Arnold Schwarzenegger
Governor

EFFECTS OF GLOBAL CLIMATE CHANGES ON BUILDING ENERGY CONSUMPTION AND ITS IMPLICATIONS ON BUILDING ENERGY CODES AND POLICY IN CALIFORNIA

PIER FINAL PROJECT REPORT

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Prepared By:
Peng Xu, Yu Joe Huang, Norman Miller, Nicole Schlegel
Lawrence Berkeley National Laboratory

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Prepared By:
Lawrence Berkeley National Laboratory

Gina Barkalow
Peng Xu, Uy Joe Huang, Norman Miller, Nicole Schlegel
Berkeley, CA 94720
Commission Contract No. 500-02-004

Prepared For:
Public Interest Energy Research (PIER)
California Energy Commission

Gina Barkalow
Contract Manager

Linda Spiegel
Program Area Lead
Energy-Related Environmental Research

Kenneth Koyama
Office Manager
Energy Generation Research Office

Martha Krebs, Ph.D.
PIER Director

Thom Kelly, Ph.D.
Deputy Director
Energy Research & Development Division

Melissa Jones
Executive Director

Preface

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Table of Contents

List of Figures

List of Tables

Abstract

Global climate change is making California's mild Mediterranean climate significantly warmer, and a substantial impact on building energy usage is anticipated. Studies to date on building cooling and energy demand have been inaccurate and insufficiently detailed regarding the climate change impacts of different building energy technologies. This study used archived General Circulation Model (GCM) projections and statistically downscaled these data to the site scale for input to building cooling and heating simulations. Building energy usage was projected to 2040, 2070, and 2010. This study found that electricity use for cooling will increase by 50 percent over the next 100 years in certain areas of California under the IPCC's worst-case carbon emission scenario, A1F1. Under the IPCC's most likely carbon scenario (A2), the cooling electricity use will increase by about 25 percent. Certain types of buildings will be more sensitive to climate change than other building types. The aggregated total building energy consumption, including both heating and cooling, will increase only slightly.

Keywords: Climate change, California weather data, prototypical building models, heat wave, building energy, building electricity, CESUS, building simulation

Executive Summary

Global climate change is making California's mild Mediterranean climate significantly warmer, and substantial building energy usage is anticipated. Recent work by Huang[1] has estimated that energy use for space cooling in Los Angeles will increase by as much as 42 percent in residential buildings and 31 percent in commercial buildings, averaged over the four global climate change scenarios developed by the Intergovernmental Panel on Climate Change, while heating will go down by 62 percent and 24 percent, respectively toward the end of this century. Electricity used for cooling will increase and gas for heating will decrease. The net energy use will increase by 25 percent to 28 percent by 2100. In addition, changing patterns of extreme weather events, such as the intensity, persistence, and extent of heat waves, will have a significant impact on peak electricity demand for cooling. The increase in extreme days was shown to result in peak energy demand that may result in shortages.

California's summertime peak energy demand "1-in-10 likelihood" currently results in energy shortages. Projected energy demand for the next 10 years indicates California will need to rely on external energy sources during peak energy demand periods due to heat extremes.

Studies to date on building cooling and energy demand have been based on simplified analyses using constant increases in annual average temperature or changes in cooling degree-days. These results may be inaccurate and insufficiently detailed regarding the climate change impacts of different building energy technologies. For example, the lack of information on changes in humidity, diurnal temperature swings, and solar radiation makes it impossible to assess the impact of climate change on the use of certain types of HVAC systems such as natural ventilation, evaporative cooling, night cooling, and so forth.

This study builds on this body of knowledge to develop more detailed hourly weather data and models to determine the California specific impact of global warming on buildings energy consumption. This study used archived General Circulation Model (GCM) projections and statistically downscaled these data to the site scale for input to building cooling and heating simulations.

Building energy usage was projected to 2040, 2070, and 2010. This study found that electricity use for cooling will increase by more than 50 percent over the next 100 years for certain areas in California under the Intergovernmental Panel on Climate Change's worst-case carbon emission scenario, A1F1. Under the Intergovernmental Panel on Climate Change's most likely carbon scenario (A2), the cooling electricity use will increase by about 25 percent. The percentage increase of the mild weather area will be greater than that of hot areas. The total energy used for cooling and heating will increase only between 2 percent and 8 percent for all three Intergovernmental Climate Change carbon scenarios evaluated in this study. The predicted overall California peak cooling electricity demand was found to not increase as much as previous studies determined For certain climate zones, the peak electricity demand will

1 Huang, Y.J. 2006. *The Impact of Climate Change on the Energy Use of the US Residential and Commercial Building Sectors.* LBNL report, Lawrence Berkeley National Laboratory, Berkeley, CA.

increase for certain types of buildings. Furthermore, certain types of buildings are more sensitive to climate change than other building types.

1.0 Introduction

Commercial buildings account for about one third of California's total electricity consumption, at a cost of about $9 billion per year. The energy consumption associated with space cooling accounts for a significant fraction of commercial building electricity use in California, and is increasing at a significant rate, particularly in the hotter inland areas. Space cooling plays a major role in determining the magnitude and timing of peak electrical demand.

Global climate change warming trends are shifting California's mild Mediterranean climate to a significantly warmer climate, and a particularly large impact on building cooling electricity usage is anticipated. It is important to estimate and predict the impacts of climate change on the statewide building energy usage, because this information may help policy-makers, utilities, and other stakeholders to respond to concerns about climate changes on energy production, distribution, and consumption in the building sector.

Title 24, the existing building code in California, is based on the old weather data and does not reflect the changes of the climate in future. As a result, in order to keep the building energy consumption per unit as the same as it is now, the building code may needs to get stricter in certain climate zones. The climate change could also change the balance between cooling and heating requirement in the code. For example, since the weather is getting warmer in winter, the insulation level could get lower. But since the cooling energy consumption plays a more important role in the overall building energy usage, the requirements for shading devices, windows, glazing materials, could get higher.

Many other national existing codes are all based on the weather data generated from observations from previous years. For example, Typical Meteorological Year (TMY) data were prepared from U.S. Weather Services hourly data files for the period 1954 through 1972. Typical months were identified by their closeness to long-term cumulative distribution functions. The current widely used TMY2 data are derived from the 1961-1990 National Solar Radiation Data Base (NSRDB).

Engineers use the TMY2 data not only for building code compliance calculation, but also for the equipment sizing and how to choose the right Heating, Ventilations, and Air Conditioning system. Some low energy cooling systems, such as natural ventilation and radiant cooling ceiling, may not work in the future when the temperature gets higher.

Because of climate change, the energy demand in various regions of California could change at different rate. In general, the gas demand for heating could decrease, and the electricity demand could increase. The cooling energy demand in coastal area of California is relatively small now because of the mild weather in summer. However, more heat waves and overall temperature increases could increase the loads more drastically in these areas than the inland areas, so that the energy distribution and needs for the grid will change in future. The study will help the state decide how to respond to the climate change in various region of the California.

The goal of this project is to better understand and predict the change of building energy usage due to global climate change. The primary objective of this project is to develop a detailed analysis of building space heating and cooling requirements based on these projected climate changes. This analysis will provide guidance for needed changes in California building codes to address global climate change impacts at the building level.

The central questions addressed in this study are:

- How will climate change affect building cooling and heating energy consumption?
- How will climate change affect the energy consumption of different types of buildings in different regions, as well as the entire state of California?

In previous researches, Huang (2006) estimated that energy use for space cooling will increase in Los Angeles by as much as 42% in residential buildings and 31% in commercial buildings, averaged over the four IPCC global climate change scenarios, while heating will go down by 62% and 24%, respectively. For more information about these scenarios, see: NCAR/DOE Parallel Climate Model (Washington et al. 2000), Hadley Centre Climate Model Version 3 (Pope et al. 2000 HadCM3/B2, as well as Section 5a.

In addition, changes in patterns of extreme weather events, such as the intensity, persistence, and extent of heat waves will have a significant impact on peak cooling electricity demand. General Circulation Model (GCM) analyses of extreme heat and energy demand by Miller et al. (2006) have shown that the number of the 10% hottest summer days in Los Angeles will increase from the present 12 days to 28-96 days toward the end of this century. This increase in extreme days was shown to correspond with peak energy demand that may result in capacity shortages.

Studies to date on building cooling and energy demand have been based on simplified analyses using constant increases in annual average temperature or changes in cooling degree-days. These results are insufficient in detail and, hence, may be inaccurate depicting climate change impacts of different building energy technologies. For example, the lack of information on changes in humidity, diurnal temperature swings, and solar radiation make it impossible to assess the impact of climate change on the use of low-energy cooling systems such as natural ventilation, evaporative cooling, nighttime cooling, etc.

Recent improvements in global and regional climate modeling can be combined with detailed building energy simulations to study the impact of climate change with much greater detail and discernment. GCMs provide the projected changes in temperature, diurnal temperature range, cloud cover fraction, and relative humidity at a 0.5 resolution, globally, for a range of Intergovernmental Panel on Climate Change (IPCC), emission scenarios extending out to 2100. Furthermore, Miller's climate modeling group at LBNL downscales GCM output both dynamically, via regional climate models (RCMs), and statistically, via regression techniques and canonical correlations, for domains, including California, with resolutions as high as 3 km. These modeling results, in conjunction with Huang's adjusted hourly weather data, provide the needed input for building energy simulations of prototypical commercial and residential buildings to analyze climate change impacts.

In this project, the following research tasks were conducted in addressing this important issue:

- Created modified hourly weather predictions for at least the 16 California climate zones under four IPCC carbon scenarios.
- Developed prototypical models of buildings in California.
- Estimated both residential and commercial building stocks in the state.
- Simulated the building heating and cooling energy using the models for both residential and commercial prototypical buildings; estimate the aggregated energy usage in future.

This report is divided into the following sections:

- One: Method. The section describes how the authors scaled down the data and generated the future weather files.
- Two: Modified hourly weather predictions. This section includes the predictions for at least the 16 California climate zones under four IPCC carbon scenarios.
- Three: Prototypical models of buildings for in California. The description of the buildings and their HVAC systems are in this section.
- Four: Commercial building stocks in the state. The authors used the California Commercial Buildings End-Use Survey (CEUS) data to generate building stocks data of each type of buildings.
- Five: Building heating and cooling energy uses the models for both residential and commercial prototypical buildings and the aggregated energy usage in future.
- Six: Conclusion and future work;
- Appendices

2.0 Literature Review

Scott et al. (2005) observed that many studies worldwide have analyzed the climate sensitivity of energy use in residential, commercial, and industrial buildings, and have used estimated relationships to explain energy consumption and to assist energy suppliers with short-term planning (Quayle and Diaz, 1979; Le Comte and Warren, 1981; Warren and LeDuc, 1981; Downton et al., 1988; Badri, 1992; Lehman, 1994; Lam, 1998; Yan, 1998; Morris, 1999; Pardo et al., 2002). The number of studies in the United States analyzing the effects of climate change on energy demand, however, is much more limited. One of the very early studies was of the electricity sector and climate projected to 2010 - 2055, indicating that climate change could increase capacity requirements by an additional 14% - 23% relative to non-climate change scenarios, requiring investments of $200 billion – $300 billion ($1990) (Linder, 1990). Following on that study, in the early and mid-1990s, there was a handful of studies that attempted an "all fuels" approach and focused on whether net energy demand would go up or down in residential and commercial buildings as a result of climate change (Loveland and Brown 1990; Scott et al. 2004; Rosenthal et al. 1995; Belzer et al. 1996), while a smaller number focused on other climate sensitive uses of energy such as agricultural crop drying and irrigation pumping (Darmstadter 1993; Scott et al. 1993).

Previous authors have taken different approaches to estimating the impact of climate change on energy use in U.S. buildings. Most of these researchers used simple uniform increases in annual average temperature as the "climate" scenario, and did not focus on transient temperature increase scenarios from General Circulation Model (GCMs), such as those analyzed by the IPCC. Previous research has used building energy simulation models to analyze the impact of climate warming on the demand for energy in individual commercial buildings (Scott et al. 1994) and on energy consumption in a variety of commercial and residential buildings in a variety of locations (Loveland and Brown 1990; Rosenthal, et al. 1995). Additionally, there has been research that used econometrics and statistical analysis techniques (most notably, the Mendelsohn papers discussed below, but also Belzer et al. 1996, Amato et al. 2005, Ruth and Amato 2002, and Franco and Sanstad 2006). Another recent study "mapped" the climate changes in four IPCC scenarios on top of existing weather files for 16 U.S. locations, and then used building energy simulations of prototypical commercial and residential buildings to analyze the impact of those climate changes on building energy use (Huang 2006).

Mendelsohn performed cross-sectional analyses to determine how energy use in the residential and commercial building stock relates to climate (Morrison and Mendelsohn 1999; Mendelsohn 2001), and he then used the relationships to estimate the impact of climate change in the year 2060 on all residential and commercial buildings. Mendelsohn (2003) used a two-step cross-sectional model of the commercial and residential building stock, which uses U.S. data and accounts for the probability that a building is being cooled (which increases with the amount of warming), and its overall energy consumption as a function of climate (matched on a county level to the Energy Information Administration (EIA) buildings in the Residential Energy Consumption Survey (RECS) (US DOE 2005) and Commercial Building Energy Consumption

Survey (CBECS)) (US DOE 2007). This was further elaborated by Mansur et al. (2005) into a complete discrete continuous choice model of energy demand in residential and commercial buildings separately. In this analysis, when natural gas is available, the marginal impact of a 1°C increase in January temperatures in their model reduces residential electricity consumption by 3% and natural gas by 2%. Scott et al. (2005b), working with end uses rather than fuels, projected about a 16% to 60% reduction in the demand for residential space heating energy by 2080, given no change in the housing stock and winter temperature increases ranging from 2°C to 10°C, or roughly a 6% and 8% decrease in space heating per degree C increase.

Thus far, studies on building cooling and energy demand have been based on simplified analyses using constant increases in annual average temperature or changes in cooling degree-days. These results may be inaccurate and insufficient in detail needed to quantify climate change impacts of different building energy technologies. Huang (2006) used results from the Hadley Centre Climate Model (HadCM3), giving the projected changes in monthly average temperature, daily temperature range, cloud cover, and relative humidity by month for 0.5º grids of the earth's surface under four IPCC carbon emission scenarios (A1FI, A2M, B1, and B2M) for the year 2080 to adjust hourly TMY2 (Typical Meteorological Year) weather files for 16 US locations. These modified weather files were then used with the DOE-2 building energy simulation program to simulate the energy demand of a set of 112 prototypical single-family houses covering 8 vintages in each of the 16 locations. For the entire U.S. residential sector, the simulations showed an increase in energy use from 0%-7%, representing up to a 10% increase in space conditioning energy use. At the regional level, the impacts varied from a 9% to 12% decrease in energy use (12% to 16% decrease in space conditioning) in Boston, to as much as a 29% to 58% increase in Miami, with a space conditioning increase ranging from 46% to 92%. Across the different building vintages, the impact was most adverse in newer houses (2% to 11% increases of total, 2% to 18% of space conditioning for 90's vintage houses) and less so in older houses (-1% to 6% increases of total, -1% to 10% of space-conditioning).

Archived General Circulation Model (GCM) projections were used and statistically downscaled to the site scale for input to building cooling and heating simulations. The GCM projections were based on the high temperature sensitivity (HadCM3) and the low temperature sensitivity (PCM) climate models for the IPCC SRES high emission scenario (A1fi) and the low emission scenario (B1). The temporal downscaling procedure was based on a series of third to fifth order regression equations that have parameters trained using the observed weather station data as predictands. The temperature and other weather variables were generated through this technique with a resulting climatological fit with fair to good replication of historical climatology. Generating sub-daily temporal resolution was based on the shift from the historical to projected probability distribution function (PDF) of each variable and mapping this on to the historical hourly observations to yield an imperfect high-resolution time series for application.

The statistically downscaled temperature is an added term, while precipitation is a multiplication factor. The minimum and maximum daily temperatures, along with daily cumulative precipitation provided the GCMs were used as predictands and fitted to third to fifth order regressions based on the daily (and finer) temperature and precipitation observations from nearest measurement sites. The resulting shifts (multiplication) in temperature (precipitation) are based on the same methods used in the TAR and AR4 reports. Variability is not captured through statistical approaches and consequently the upper limits of daily maximum temperature may be an underestimation.

The researchers that applied the statistical methods stress caution in the interpretation at such high temporal resolution. The methods show good agreement climatically (i.e. as 10-year mean values), but view hourly results with concern. Upper limits values are smoothed out, and hence the authors request that a second set of calculations be performed when the dynamically downscaled full-fields values are made available through the California Energy Commission PIER climate projections project.

3.0 Typical Year Weather Files for Future Periods

Using the procedure described in the previous section, hourly weather files were created for 63 California locations that had sufficient historical data for reliable downscaling (see Appendix I). The weather file for each location consists of hourly records of dry-bulb temperature, dewpoint temperature, pressure, and total horizontal solar radiation from 1995 through 2100, of which the data up to and including 2006 are historical, and that from 2007 on are downscaled from the GCM model. Appendix I also lists the 73 California locations included in the new TMY3 data set based on either 24 years taken from 1976-2005 or 12 years taken from 1991-2005 historical data2, the 10 included in the TMY2 data set based on 1961-1990 historical data, and the 16 California Thermal Zone (CTZ) locations based on 1941-1970 historical data. These historical "typical year" weather files are useful for determining whether and how much climate change has already occurred in California locations, and to what degree the CTZ weather files used by the Commission to analyze building energy performance may have already been outdated. Figure 1 shows the same locations on a state map of CTZ boundaries for easier identification.

Plots of the temperature and solar radiation data for four representative locations (Oakland, Sacramento, Burbank, and San Diego) are shown in Appendix II, with the historical data shown in red and the downscaled data in blue. It is apparent that in all four locations the downscaled data show a gradual rise in average dry-bulb temperatures over the period to 2100, but no evident change in solar radiation.

2 May 1982-Dec 1984, and June 1991-Dec. 1994 had atypical solar radiation due to the El Chichon and Pinatubo volcanic eruptions and were excluded in the generation of the TMY3 weather files.

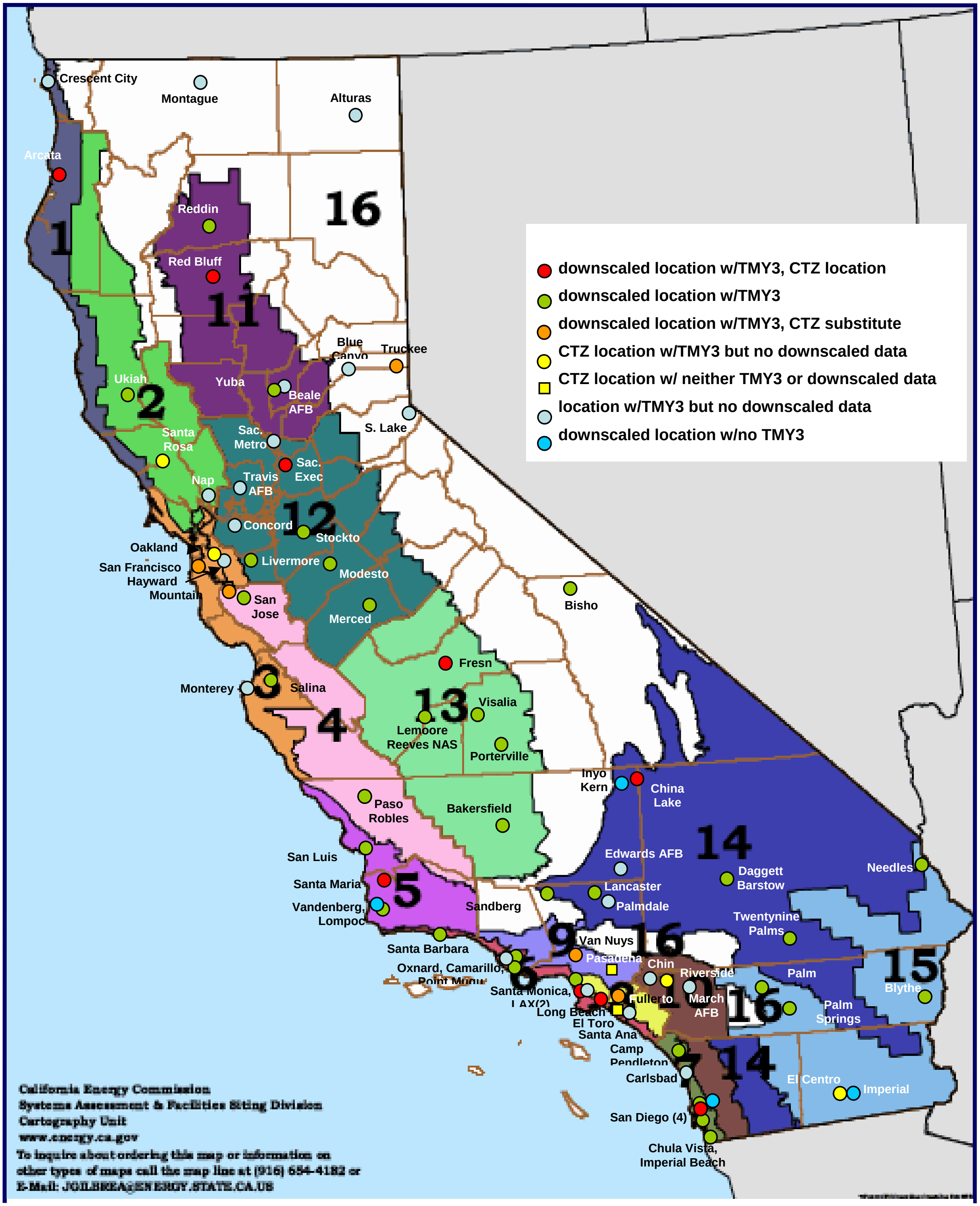

Figure 1. California weather stations

Source: Lawrence Berkeley National Laboratory

4.0 Hourly Weather Predictions

Future weather data were generated for three carbon emission scenarios using the IPCC SRES scenarios (Nakicenovic et al. 2000), namely A1F1, A2, and B1. These scenarios are described in the IPCC's Third Assessment Report (TAR) and Fourth Assessment Report (AR4). A1F1 is the worst carbon scenarios and it is characterized by a rapid economic growth and an emphasis on fossil-fuels. The A2 family of scenarios is characterized by slower and more fragmented technological changes and improvements to per capita income. B1 is the best carbon scenario. It relies on a reductions in material intensity and the introduction of clean and resource-efficient technologies.

Developing statistically downscaled input forcing requires available observations of state variables for a sufficiently long enough time period that model calibration and verification can be performed on separate time periods that capture the variability of today's climate. One potential obstacle is ensuring there are adequate data and a second is assuming that the projected climate is stationary. California has sufficient data available and did not pose a problem. Climatic stationary cannot be determined in advance. The testing that was performed to evaluate dynamic climate regimes was through an ongoing California Energy Commission (the Energy Commission)-supported project, Regional Climate Model Intercomparison and Baseline Evaluation (REBI), where statistically and dynamically downscaled climate projections were tested (Miller et al. 2008a).

Miller et al. (2007, 2008b) have produced climate analyses for the Energy Commission, as a contribution to the California Climate Assessment. Miller et al. (2008a) have simulated downscaled climate fields both through statistical and dynamic procedures using state of the art techniques. This work was representative of the current knowledge base. Site scale (buildings) downscaled at hourly intervals provided an extension of current techniques. The statistical downscaling technique applied in this study was based on statistical approaches developed by Wilby and Dawson (2002), Wilby and Dettinger (2003), and a projected variance transform based on mapping distribution functions developed by Miller and his group. The variance transform is simply an added temperature or multiplied precipitation ration based on the statistical downscaling that reflects the climate change sensitivity of each variable for each location.

The statistical downscaling approach is based on the application of third to fifth order linear equations with coefficients trained using historical observations. The predictors are the set of single-point observed temperature and precipitation observations for each location, and the predictands are the resulting high temporal resolution temperature and precipitation outcomes. Observation were only 8 -15, resulting in minimally trained regression models. The authors fitted the third to fifth order coefficients by using odd years and verified using even years as shown in the following equation.

$$\text{Predictor} = A \times \text{predictand} + B \times \text{predictand}^2 + C \times \text{predictand}^3$$

Statistical downscaling through regression is a common approach that has been well-documented in the literature (Wigley et al. 1990; Wilby et al. 1998; Huth 1999; Wilby et al. 2002; Wilby and Dawson 2004). Statistical downscaling procedures have the advantage of being computationally efficient, but as they rely on historical relationships between large-scale climate fields and local variables, partial stationarity (non-changing conditions with regard to the extreme end-members of the historical period) over time must be assumed.

Grid-cell values of each predictor and for the reference period were rescaled by simple monthly regressions. This ensured that the overall probability distributions of the simulated daily values closely approximated the observed probability distributions at selected long-term weather stations located in the urban centers studies. Observed daily maximum and minimum temperatures, cumulative precipitation, and humidity for each of the weather stations were used to develop a set of third-order regression equations in order to transform the large-scale temperature values from the GCM simulations into local-scale daily maximum temperatures, preserving the distribution of the observed mean and variance. The resulting model was then verified using a separate time period with observations. The downscaled time-series resulted in a near-exact fit to observations. The ability of this method to successfully reproduce observed daily distributions is illustrated in Figure 2, which provides a comparison between the observed and statistically downscaled annual distributions of maximum daily temperature for Sacramento and Los Angeles. Although the modeled distributions tended to be somewhat smoother than observed, in general the GFDL and PCM-based simulations captured a distribution very similar to what was observed, while HadCM3-based simulations tended to show a slightly broader distribution.

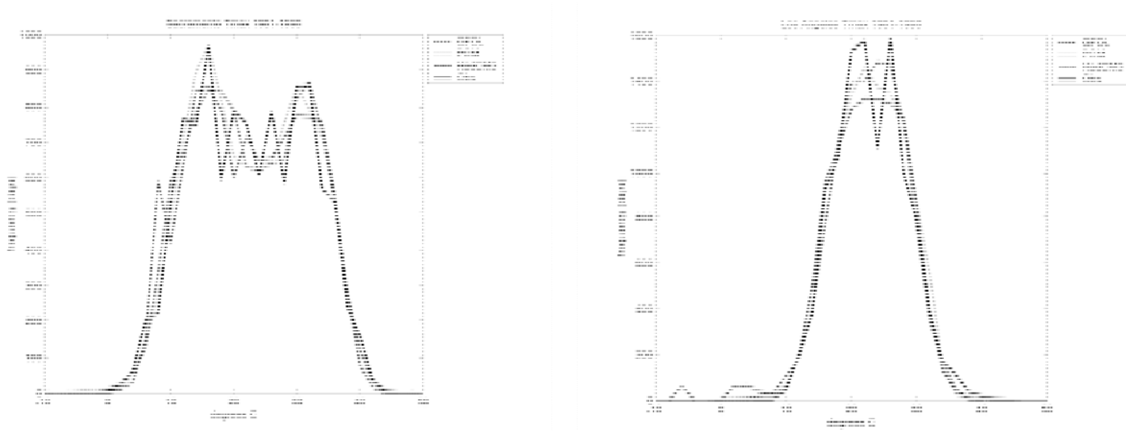

Figure 2. Comparison of observed and statistically-downscaled annual maximum-daily temperature distributions for Sacramento and Los Angeles.

Source: Lawrence Berkeley National Laboratory

The same regression relations were then applied to future simulations, such that rescaled values shared the weather statistics observed at the five stations. At the daily scales addressed by this method, the need to extrapolate beyond the range of the historically observed parts of the probability distributions was rare even in the future simulations (typically <1% of the future days, implying that stationarity is valid for this type of analysis) because most of the climate changes involve more frequent warm days than actual truly warmer-than-ever-observed days (Dettinger et al. 2004).

Future projections were then averaged for three periods (2005-2034, 2035-2064 and 2070-2099) to produce climatological near-term, mid-term, and long-term projections of daily maximum, average, and minimum temperatures for California on which to base estimates of future shifts in the timing and magnitude of electricity demand.

Because of the stochastic variations in weather from year to year, building energy simulations have generally been done using "typical year" weather data that reflect average weather characteristics over a selected period of record. For example, the CTZ (California Thermal Zone) weather files still being used by the Commission for Title-24 building energy standard calculations were created in 1976 based on the preceding 30 years of historical weather data from 1941 through 1970 (Crow 1983).3 More recent data sets developed by the National Renewable Energy Laboratory (NREL) include the 239 TMY2 weather files developed from historical weather data from 1961 through 1990 (Marion and Urban 1997), and the 1,020 TMY3 weather files developed using either 24 years taken from the 1976-2005 historical data for 226 locations or 12 years taken from the 1991-2005 for the remaining 800 or so locations (Wilcox and Marion 2008).

The method by which the above-mentioned "typical year" weather files have been created is to splice together twelve calendar months from the historical period of record judged to be the most representative using different criteria and weighting. In developing the original TMY weather files, NREL established a methodology for selecting the typical month that is straightforward and flexible (NREL 1981). In brief, the selection is made by calculating the Cumulative Distribution Function (CDF) of each climate variable (temperature, solar radiation, and wind speed) for each month of historical data, comparing these CDFs to the long-term CDF using the Finkelstein-Schafer (FS) statistic as a measure of the closeness of fit (Finkelstein and Schafer, 1971). The FS statistic is the sum of the differences between the individual and long-term CDFs. The FS statistic for each variable is multiplied by its weight, and then added to produce a cumulative FS. The month having the smallest cumulative FS is selected as the typical month.

There are at least three methods to create typical year weather files for future time periods based on the downscaled data, each with its advantages and disadvantages:

Treat the downscaled data the same as historical data to select typical months and build from them "typical year" weather files for future periods. The problems with this method are that the downscaled data do not contain all the climatic variables needed on a simulation weather file, such as wind speed and direction. Even though these variables are available in the original GCM data, they are not regarded with much credibility or relevance. Therefore, even if such weather files based completely on computer model results could be created; there would be an open question whether the differences from the historical data are due to the modeled climate change or artifacts of the synthetic weather data.

Obtain the long-term CDF from the downscaled data, but use the historical data set to select the typical months. The advantage of this method is that the future year weather file produced would still be "real" data and thus avoids the questions mentioned for the previous method. The two assumptions in this method are that (a) the long-term CDFs predicted up through 2100 would still be within the range of variability in the historical data, and (b) climate change would not affect the underlying climate patterns. The first assumption can be tested by comparing the CDFs from the downscaled data to those from the historical data, but the second assumption is impossible to test. Although this method has its appeal, it was not used in this project because it was not assured to work in all cases, and also required much more effort than the third method described in the following paragraph.

Compute the average changes in climate variables, i.e., temperature, humidity, solar, etc., in the downscaled data over time, and then map those changes onto existing "typical year" weather files such as the CTZ, TMY2, and TMY3 data sets. This method shares the same assumption as the previous one that climate change would not cause large changes in the underlying climate pattern. The advantage of this method is that it relies on the existing "typical year" weather files to get right the underlying climate patterns (occurrence of heat storms, correlation of wind and solar to other variables, etc.), and uses the downscaled data only to adjust the average monthly values for dry-bulb and dewpoint temperature, solar radiation, and pressure, as well as the diurnal temperature swing of dry-bulb and dewpoint temperatures. In other words, this method uses the downscaled data not to represent future weather, but only the expected change in weather from the historical record.

For both technical and practical reasons, the authors chose Method 3 to generate the future year "typical year" weather files. The same method was used by Huang for a previous study on the potential impact of climate change on building energy use in the United States (Huang 2006), for which software procedures had already been developed. The downscaled data for the 63 California locations consist of large (56MB) text files with 106 years of hourly records of dry-bulb and dewpoint temperature, pressure, and total solar radiation from 1995 through 2100. These were analyzed and condensed first into average daily mean and range for dry-bulb and dewpoint temperatures and temperature and average daily mean only for total solar radiation for each month of every year. These data were then further condensed into monthly means and range for each decade, starting with 1995, i.e., 1995-2004, 2005-2014, etc. Since they were obtained from historical data, the means and ranges calculated for the first decade, i.e., 1994-2005, are taken as the baseline against which the means and ranges for the subsequent decades are compared. The changes in the monthly means and ranges are then "mapped" onto the TMY3 weather file for that location, resulting in a modified weather file for each decade extending to 2100.

Although the technique has been developed to produce future "typical year" weather files for any decade up through 2100, only four snapshot decades were analyzed: TP2 (2005-2014), TP4

(2035-2044), TP6 (2055-2064), and TP9 (2085-2094). Furthermore, due to the absence of building stock data for the smaller locations, computer simulations were conducted in only 16 of the 63 available locations corresponding roughly to the locations used to develop the original 16 CTZ weather files. Appendix III shows the heating and cooling degree days for the 63 locations for the TMY3 base case, and the four snapshot decades.

The degree-day statistics in Appendix III are shown with the stations grouped by color depending on their geographical location: dark blue for mountain areas, dark green for north coastal, orange for north Central Valley, yellow for south Central Valley, light green for south coastal, and red for desert areas. Fewer lines extend to the left because there were only 16 CTZ and 11 TMY2 locations, as compared to the 53 downscaled locations with either TMY3 or NCDC weather data.

5.0 Commercial Building Prototypes

Building energy usage was estimated through a bottom-up approach by simulating prototypical commercial buildings differentiated by vintage, building use, and climate. By combining these simulation results with the building stock information and the amount of building floor area represented by each prototype, a reasonable assessment of energy use characteristics of the entire building stock in California can be produced. Sixteen commercial and residential building prototypes were used – most of these prototypical building models were developed during previous LBNL research projects (Huang 1991). These building models were used as the basis of development for future building prototypical models, referencing to the trends of building technologies and the building code. The models were developed for two building simulation models, EnergyPlus and DOE-2.1E (DOE, 1993). The simulation analysis was started using EnergyPlus, but then switched to DOE-2.1E when it became clear that using EnergyPlus would require several weeks of time for the simulations alone. The detailed descriptions of these building simulation models are given in Appendix V.

Table 1. Commercial Building Prototypes

Hotels	*Hospital*	*Offices*	*Retails*	*Schools*	*Others*
Large Hotel	Hospital	Large office	Retail	School Secondary	Sit down Restaurant
Small hotel	Outpatient Health Care	Medium office	Supermarket	School Primary	Fast-food Restaurant
		Small office	Strip mall		Warehouse

Source: Lawrence Berkeley National Laboratory

6.0 Impact on Building Energy Intensity

In the calculation, the authors assumed the building square footage to be constant. Therefore, the change of peak energy usage intensity is proportional to the change of the aggregated energy usage. Energy intensity is defined as total energy usage per square foot (KBtu/ft2).

The authors ran simulation using the hourly future weather data generated in Section 2 for each type of building. The simulation was for the years 2005-14, 2035-44, 2055-64, and 2085-94. Appendix VIII shows the change of energy usage change for each type of building.

Because of the overall temperature will increase over the next 100 years, the cooling energy consumption will increase and heating energy consumption will decrease. However, the increase and decrease of each type of buildings are different. For large office buildings, the shift will be less significant than that of warehouses and small retail stores, which rarely need air conditioning anyway. In general, cooling electricity of small buildings will increase more than that of large buildings. The impact to sit-down restaurants and small retail stores will be more than that to large offices and supermarkets.

6.1 Future Energy End Use

On each of page in the Appendix VIII, the authors plotted four types of energy intensity change for each type of buildings under different carbon scenarios.

The first one is the change of the heating energy over the next 100 years. The trend is very clear. Because of the global warming, the heating energy usage under all carbon scenarios will decrease. For example, the heating energy consumption of large office building will reduce by almost 50% in all regions. In general, the percentage reduction in Southern California will be more than that in Northern California, because buildings in Southern California barely need heating now. Heating energy percentage reductions of small buildings are generally larger than that of the big buildings. Small buildings are more sensitive to the weather changes because of their low volume to surface area ratio.

The second one is the change of the cooling energy over the next 100 years. Energy used for building cooling will increase significantly in all regions. For example, in Southern California, under A2 scenario, the cooling energy consumption of large office buildings will increase by 70% from their current level. This is assuming the internal load will be constant over the next 100 years. Cooling energy usage in Northern California will increase as well, but not as much as in the Southern California. Under A2 scenario, in Northern California, the cooling energy usage of large office buildings almost will stay until year 2044. After 2044, the energy usage will start to increase significantly. It seems that until year 2044, under A2 scenario, the weather in Northern California will still not be hot enough to trigger large cooling demand.

The third column in the figures is the change of fan energy usage. The fan energy usage in Northern California will be almost constant throughout the next 100 years. The energy usage to distribute cooling and heating to buildings will not change for large buildings in the northern areas, because of fan in these areas are used for ventilation anyway. In southern California, the upward trend of fan energy consumption is clear. However, the increase is not as much as the cooling energy itself. The fan energy of large buildings will increase by about 30% in south under A2 scenario.

The last column in the figures is the total energy usage. The total energy usage is the sum of heating, cooling, domestic hot water, and fan energy consumption. In general, the decrease of the heating energy offsets the increase of the cooling energy. However, for each region, because the changes of cooling and heating are different, the total energy consumption will either decrease or increase.

For example, under the A2 scenarios, the total energy consumption of large office buildings will stay flat in northern California. However, the total consumption will increase slightly in southern California. Under the worst scenario A1F1, the total energy usage will increase slightly in northern California, but drastically in southern California.

6.2 Building type variance

Although in general, cooling energy will increase and heating energy will decrease for all types of buildings. The magnitude of changes varies among different types of buildings. In general, small buildings are more sensitive to global warming than large buildings, because the envelop heat gain(loss) of small buildings is a larger portion of the cooling(heating) load than that of large buildings.

For example, in northern California, the total energy consumption of large and medium office buildings will increase. However, the total energy usage of small office buildings in CZ16 will actually decrease. The heating consumption of small offices in this region will decrease so much to offset the increase of cooling energy usage in the summer and so that the total energy will decrease in future.

We observed similar results for other types of small buildings, such as fast-food restaurants, primary schools, and small hotels. For small hotels, in northern California, the total energy usage will decrease in all 7 climate zones. For fast food restaurants, the total energy usage in CZ16 will in fact decrease in future. The total energy usage in other 6 northern climate zones will stay flat.

6.3 Carbon emission scenarios

A1F1. In the high carbon emission scenario, the cooling energy consumption increased drastically for nearly all building types. Large offices and supermarkets have the largest share of the energy consumption among all types of commercial buildings. The cooling energy consumption for these two types of buildings increased almost by 50% in all major climate zones. The overall building energy usage increased slightly by about 15~30%.

B1. Under the low carbon emission scenario, cooling energy consumption did not increase as much as it did in A1F1. However, the increase was still significant. For large offices and supermarkets, The overall building energy usage increase by about 15%.

A2. Scenario A2 is a scenario in between A1F1 and B1. The cooling energy consumption increases for major building types by approximately 20%. The total building energy for both heating and cooling only increases slightly. However, the change is not uniform among all climate zones. For certain climate zones such as those cold zones, the increased total energy use is higher than the others.

7.0 Impact on Aggregated Building Energy Usage

The current building stock in California was used as a base for the calculation. Forecasting the growth of each type of buildings in each climate zone is difficult. The goal of this study is not to figure out the overall energy consumption changes for each type of buildings, but the impact of the climate change alone. Therefore, the current building stock information was used as the baseline to separate out other changes, such as demographic changes and new development in Central Valley.

From the building stock data, the authors can determine which building type has the largest impact on the total energy usage. For example, large office buildings, supermarket, and retails consist of more than 60% of the total conditioned buildings square footage in California. The energy usage trend of these types of the buildings will dominate the total aggregated building energy usage. More than 70% of these large buildings locate in Climates 3, 6, 7, 8, 12. The heating load of large buildings is not as sensitive to weather change as that of small buildings. The total energy consumption will increase between 8% (zone 3) to 20% (zone 8) under the worst carbon scenario. Under the low carbon scenario, the increases of total energy consumption are between 0 (zone 3, 12) to 5% (zone 7, 8).

Appendix VII shows the aggregated energy consumption change in 2100. The total energy consumption of the all buildings in the current year (2005) has not been calibrated to the real building consumption in California. The relative term is more important here because we want to understand the trend of the energy growth. In total, the increase of total California building energy consumption is about 8% under the worst carbon scenarios and about 2% under the low carbon scenario, if the building stock stays same.

Table 2. Building total energy consumption in year 2100 relative to the year 2005

Current	*A1F1*	*A2*	*B1*
100	108	105	102

Source: Lawrence Berkeley National Laboratory

8.0 Conclusions and Future Work

In all three SRES scenarios used in this study (A1fi, A2, B1), consistent and large increases in temperature and extreme heat drive significant impacts on temperature-sensitive sectors in California. The most severe impacts occurred under the A1F1 scenario. With the rising temperature, low-energy intensity cooling systems may not work equally well in the future. For example, in future, natural ventilation may not be as applicable to buildings in the Bay Area as it is now. Increased cooling demand may require buildings with traditional HVAC system to retrofit and expand their cooling capacities. Another example is the direct and indirect evaporative cooling systems in the dry inland area. Because of rising dry-bulb and wet-bulb temperatures, the efficiency of the evaporative system may start to decrease and the systems may not be economic feasible anymore.

The change the weather will not change the energy usage of different types of buildings in the same way. For example, the total energy usage of small buildings in Northern California will actually decrease as the weather is getting warmer. The variance among different types of the buildings needs to be considered carefully in developing future building code. Code requirements of small buildings in northern regions should focus more on how to reduce cooling load rather than heating load. In the mean time, fresh air load is perhaps the number one contributor of the increasing cooling load in Southern California for large commercial buildings. Building code in these areas may need more rigorous requirements in addressing fresh air load than the codes in the other areas.

These findings do support the conclusion that climate change will have a larger effect in climate areas such as the San Francisco Bay Area more than inland regions, where space cooling (air conditioning) dominates. As such, it represents a solid starting point for assessing the detailed location effect.

This study represents one approach towards understanding how building energy consumption will change in the future. However, more fundamental issues, such as how engineering practice should change in response to the weather change, have not been addressed. For example, this study showed that the total energy in Southern California will increase by 30% over next one hundred years under the worst scenario. To keep the energy usage at the same level now, engineers in future need to develop better envelops and high efficiency HVAC system. The authors can simulate a series of these future more efficiency buildings and see at which level, the added efficiency will be enough to compensate the energy increase from the climate changes.

This study not only generated the future data files for 16 climate zones, but also virtually every weather station in California. The difference between these weather stations sometimes can be significant. For example, as it is presented in the results section above, under Climate Zone 16, the energy consumption of buildings at different weather stations may change differently. The future climate data will be helpful to reclassify the climate zones in California. The hourly data for each weather location will be useful for decision makers to make long-term city planning and assess various adaptation approaches.

This study is a preliminary step of using future hourly weather data to estimate the impact of the climate change. In a full-scale study, the authors would also like to know how climate change will affect the effectiveness of existing building codes in California. The building code in California was based on the weather files of the past. Newly constructed buildings will be used for another 50 to 100 years and the projected energy savings from the building energy code may not be accurate if only the old weather data was used.

List of Acronyms

AR4	IPCC's Fourth Assessment Report
CBECS	Commercial Building Energy Consumption Survey
CEUS	California Commercial End-Use Survey
CDF	Cumulative Distribution Function
CTZ	California Thermal Zone
EIA	Energy Information Administration
FS	Finkelstein-Schafer Statistic
GCM	General Circulation Model
HadCM3	Hadley Centre Climate Model
HVAC	Heating, Ventilation, and Air Conditioning
IPCC	Intergovernmental Panel on Climate Change
NSRDB	National Solar Radiation Data Base
NREL	National Renewable Energy Laboratory
PDF	Probability Distribution Function
RCMs	Regional Climate Models (),
RECS	Residential Energy Consumption Survey
TMY	Typical Meteorological Year
TAR	IPCC's Third Assessment Report
REBI	Regional Climate Model Intercomparison and Baseline Evaluation

9.0 References

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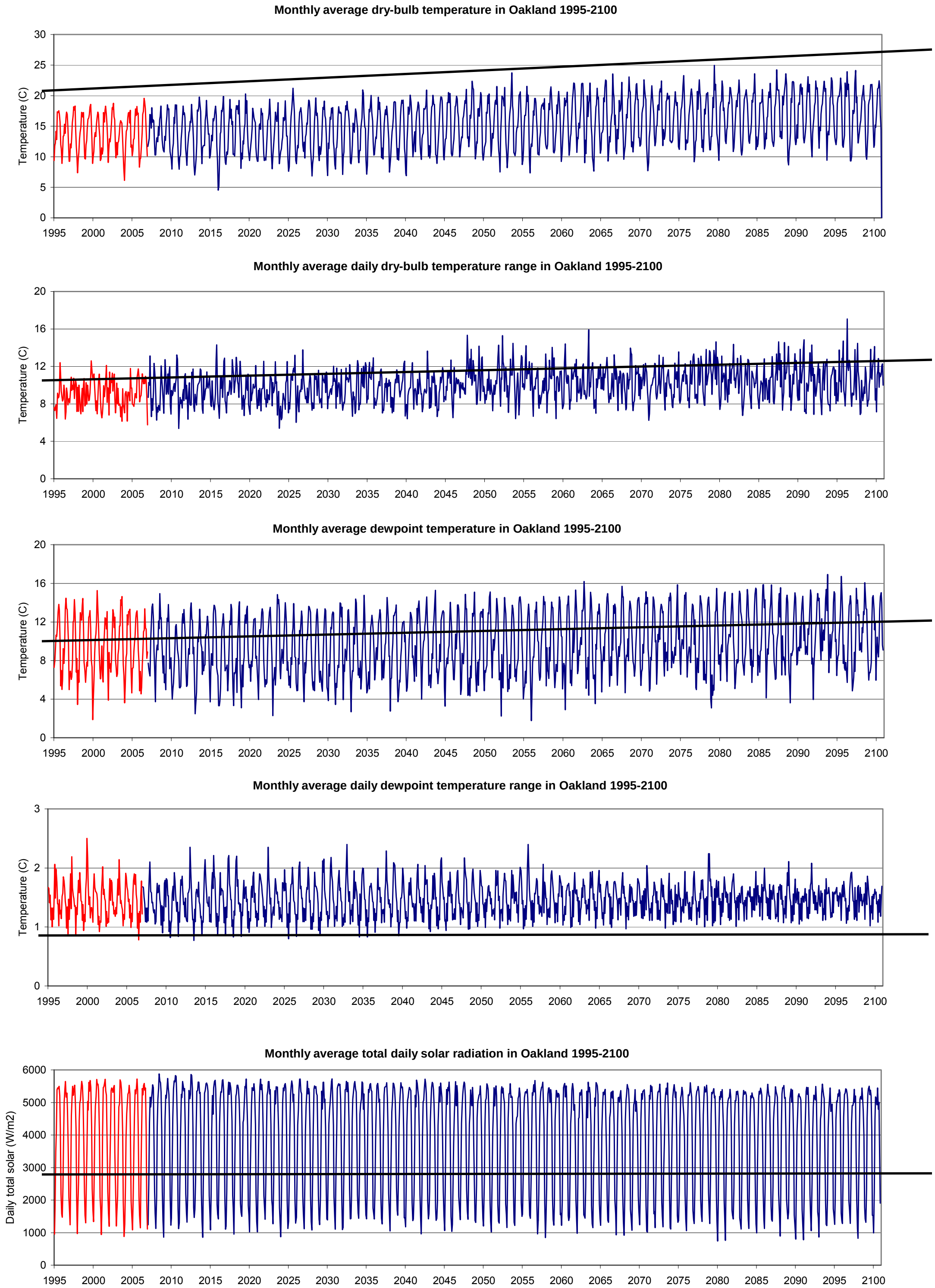
Appendix I List of Downscaled Weather Files Compared to Other Data Sets of Typical Year Weather Files for California Locations

Station Num	Station Name	Latitude North	Longitude West	Down scaled location	TMY3 (years)	TMY2 (years)	CTZ (years)
725958	Alturas	41.500	120.533		1991-2005*		
725945	Arcata AP	40.983	124.100	X	1976-2005*	1961-90	1941-70
723840	Bakersfield Meadows Fld	35.433	119.050	X	1976-2005*	1961-90	
724837	Beale AFB	39.133	121.433		1991-2005*		
724800	Bishop AP	37.367	118.350	X	1991-2005*		
725845	Blue Canyon AP	39.300	120.717		1991-2005*		
747188	Blythe Riverside Co AP	33.617	114.717	X	1991-2005*		
722880	Burbank/Glendale AP	34.200	118.350	X	1991-2005*		
723926	Camarillo (AWOS)	34.217	119.083	X	1991-2005*		
722926	Camp Pendleton MCAS	33.300	117.350	X	1991-2005*		
722927	Carlsbad/Palomar	33.133	117.283		1991-2005*		
746120	China Lake NAF	35.683	117.683	X	1991-2005*		1941-70
722899	Chino AP	33.967	117.633		1991-2005*		
722904	Chula Vista Brown Fld NAAS	32.583	116.983		1991-2005*		
724936	Concord Buchanan Fld	38.000	122.050		1991-2005*		
725946	Crescent City FAA AP	41.783	124.233		1991-2005*		
723815	Daggett Barstow AP	34.850	116.800	X	1976-2005*	1961-90	
723810	Edwards AFB	34.900	117.867		1991-2005*		
722810	El Centro NAF	32.817	115.683	X			1941-70
690140	El Toro	33.667	117.733	X			1941-70
723890	Fresno Yosemite Intl AP	36.783	119.717	X	1976-2005*	1961-90	1941-70
722976	Fullerton Muni AP	33.867	117.983	X	1991-2005*		
724935	Hayward AP	37.667	122.117		1991-2005*		
747185	Imperial	32.833	115.583	X	1991-2005*		
722909	Imperial Beach Ream Fld NAS	32.567	117.117	X			
723826	Inyokern	35.667	117.833	X			
722956	Jack Northrop Fld	33.917	118.333		1991-2005*		
723816	Lancaster Gen Wm Fox Fld	34.733	118.217	X	1991-2005*		
747020	Lemoore Reeves NAS	36.333	119.950	X	1991-2005*		
724927	Livermore Muni AP	37.700	121.817		1991-2005*		
722895	Lompoc (AWOS)	34.667	120.467	X	1991-2005*		
722970	Long Beach Daugherty Fld	33.833	118.167	X	1976-2005*	1961-90	1941-70
722950	Los Angeles Intl AP	33.933	118.400	X	1976-2005*	1961-90	
724815	Merced/MacReady Fld	37.283	120.517	X	1991-2005*		
724926	Modesto City/Co AP	37.633	120.950	X	1991-2005*		
725955	Montague Siskiyou Co. AP	41.783	122.467		1991-2005*		
724915	Monterey NAF	36.600	121.867		1991-2005*		
745090	Mountain View Moffett Fld NAS	37.400	122.050		10 years		
725957	Mt. Shasta	41.333	122.333	X			1941-70
724955	Napa Co AP	38.217	122.283		1991-2005*		
723805	Needles AP	34.767	114.617	X	1991-2005*		
724930	Oakland Metro AP	37.717	122.217	X	1991-2005*		1941-70
723927	Oxnard AP	34.200	119.200		1991-2005*		
722868	Palm Springs Intl AP	33.833	116.500	X	1991-2005*		
747187	Palm Springs Thermal AP	33.633	116.167	X	1991-2005*		

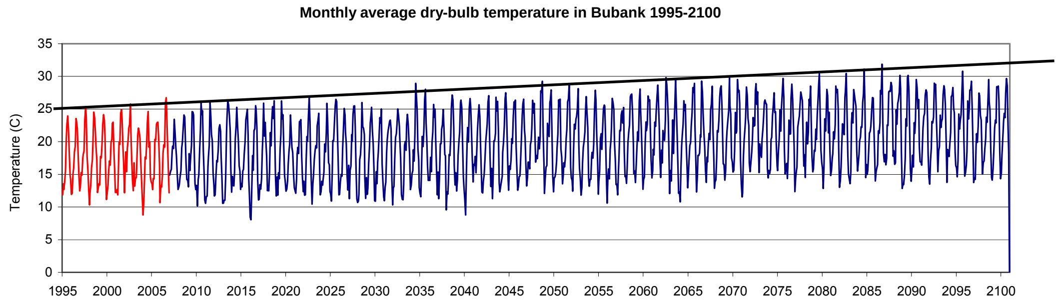
tation Num	Station Name	Latitude North	Longitude West	Down scaled location	TMY3 (years)	TMY2 (years)	CTZ (years)
724937	Palo Alto AP	37.467	122.117	X			
723820	Palmdale AP	34.633	118.083		1991-2005*		
723965	Paso Robles Muni AP	35.667	120.633	X	1991-2005*		
723910	Point Mugu NAF	34.117	119.117	X	1991-2005*		
723895	Porterville (AWOS)	36.033	119.067	X	1991-2005*		
725910	Red Bluff Muni AP	40.150	122.250	X	1991-2005*		1941-70
725920	Redding Muni AP	40.517	122.317	X	1991-2005*		
725915	Redding Muni AP-2	40.517	122.317	X			
722869	Riverside Muni	33.950	117.450	X	1991-2005*		1941-70
722860	Riverside March AFB	33.900	117.250	X	1991-2005*		
724830	Sacramento Exec AP	38.500	121.500	X	1976-2005*	1961-90	1941-70
724839	Sacramento Metro AP	38.700	121.583		1991-2005*		
724917	Salinas Muni AP	36.667	121.600	X	1991-2005*		
724938	San Carlos AP	37.517	122.250	X			
723830	Sandberg	34.750	118.717	X	1991-2005*		
722907	San Diego Gillespie	32.833	116.967	X			
722900	San Diego Lindbergh Fld	32.733	117.167	X	1976-2005*	1961-90	1941-70
722930	San Diego Miramar NAS	32.867	117.133		1991-2005*		
722903	San Diego Montgomery	32.817	117.133	X	1991-2005*		
722903	San Diego Montgomery2	32.817	117.133	X			
722906	San Diego North Is.NAS	32.700	117.200	X	1991-2005*		
724940	San Francisco Intl AP	37.617	122.400	X	1976-2005*	1961-90	
724946	San Jose Reid Hillv	37.333	121.817	X			
724945	San Jose Intl AP	37.367	121.933	X	1991-2005*		1941-70
722897	San Luis Obispo Co Rgnl	35.233	120.633	X	1991-2005*		
722977	Santa Ana John Wayne AP	33.683	117.867		1991-2005*		
723925	Santa Barbara Muni AP	34.433	119.850	X	1991-2005*		
723940	Santa Maria Public AP	34.917	120.467	X	1976-2005*	1961-90	1941-70
722885	Santa Monica Muni	34.017	118.450	X	1991-2005*		
724957	Santa Rosa (AWOS)	38.517	122.817	X	1991-2005*		1941-70
725847	South Lake Tahoe	38.900	120.000		1991-2005*		
724920	Stockton Metro AP	37.900	121.233	X	1991-2005*		
745160	Travis Fld AFB	38.267	121.933		1991-2005*		
725846	Truckee-Tahoe	39.317	120.133	X	1991-2005*		
690150	Twentynine Palms	34.300	116.167	X	1991-2005*		
725905	Ukiah Muni AWOS	39.133	123.200	X			
725905	Ukiah Muni AP	39.133	123.200	X	1991-2005*		
723930	Vandenberg AFB	34.750	120.567	X			
722886	Van Nuys AP	34.217	118.483	X	1991-2005*		1941-70
723896	Visalia Muni (AWOS)	36.317	119.400	X	1991-2005*		
724838	Yuba Co	39.100	121.567	X	1991-2005*		
	Total number of weather files			63	73	10	16

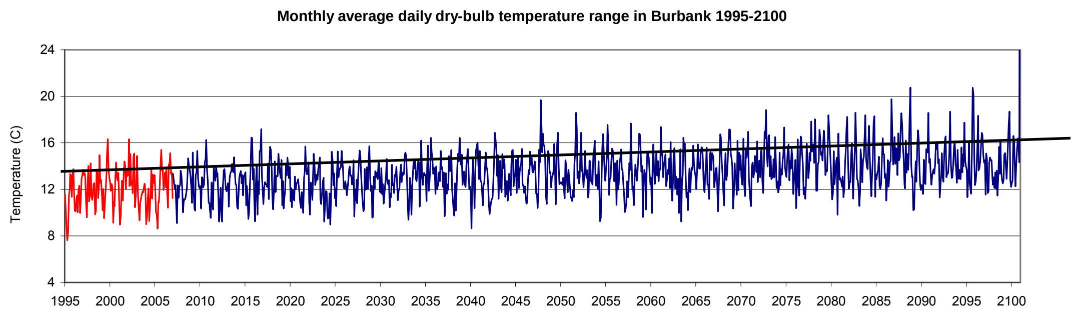
- May 1982-Dec 1984, and June 1991-Dec. 1994 had atypical solar radiation due to the El Chichon and Pinatubo volcanic eruptions and excluded from the data set.

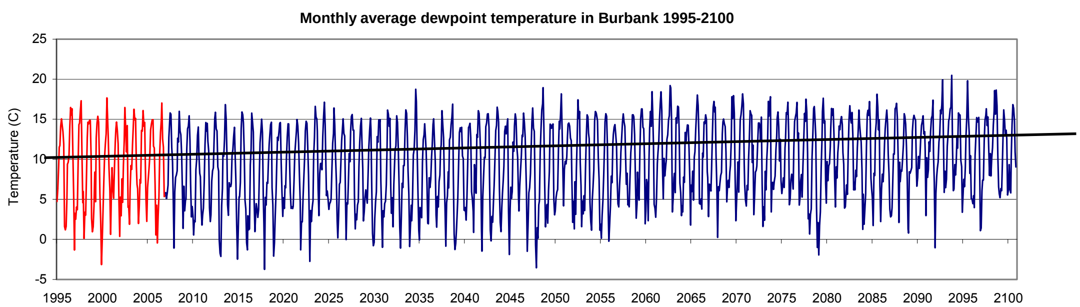
Appendix II: Future Climate Data of Four Cities in California

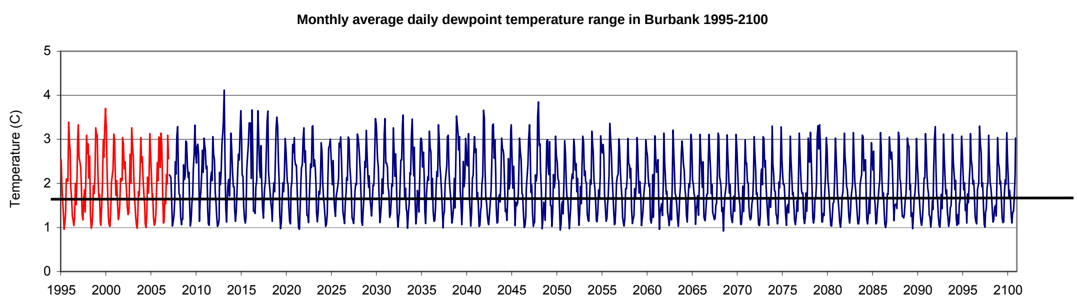


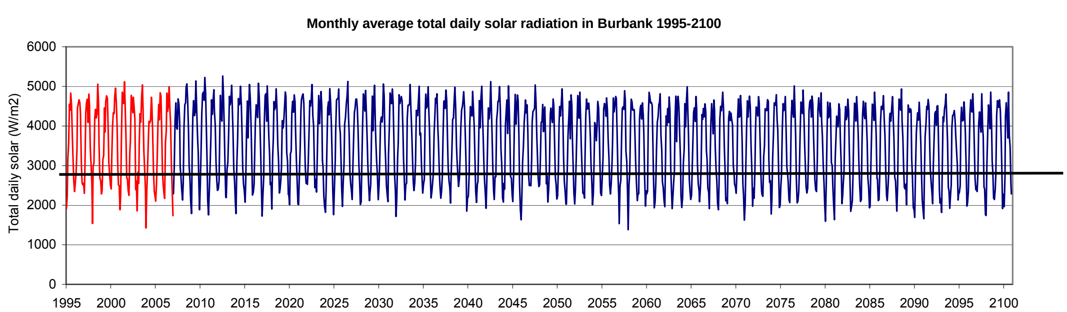
Climatic data for Oakland 1995-2100



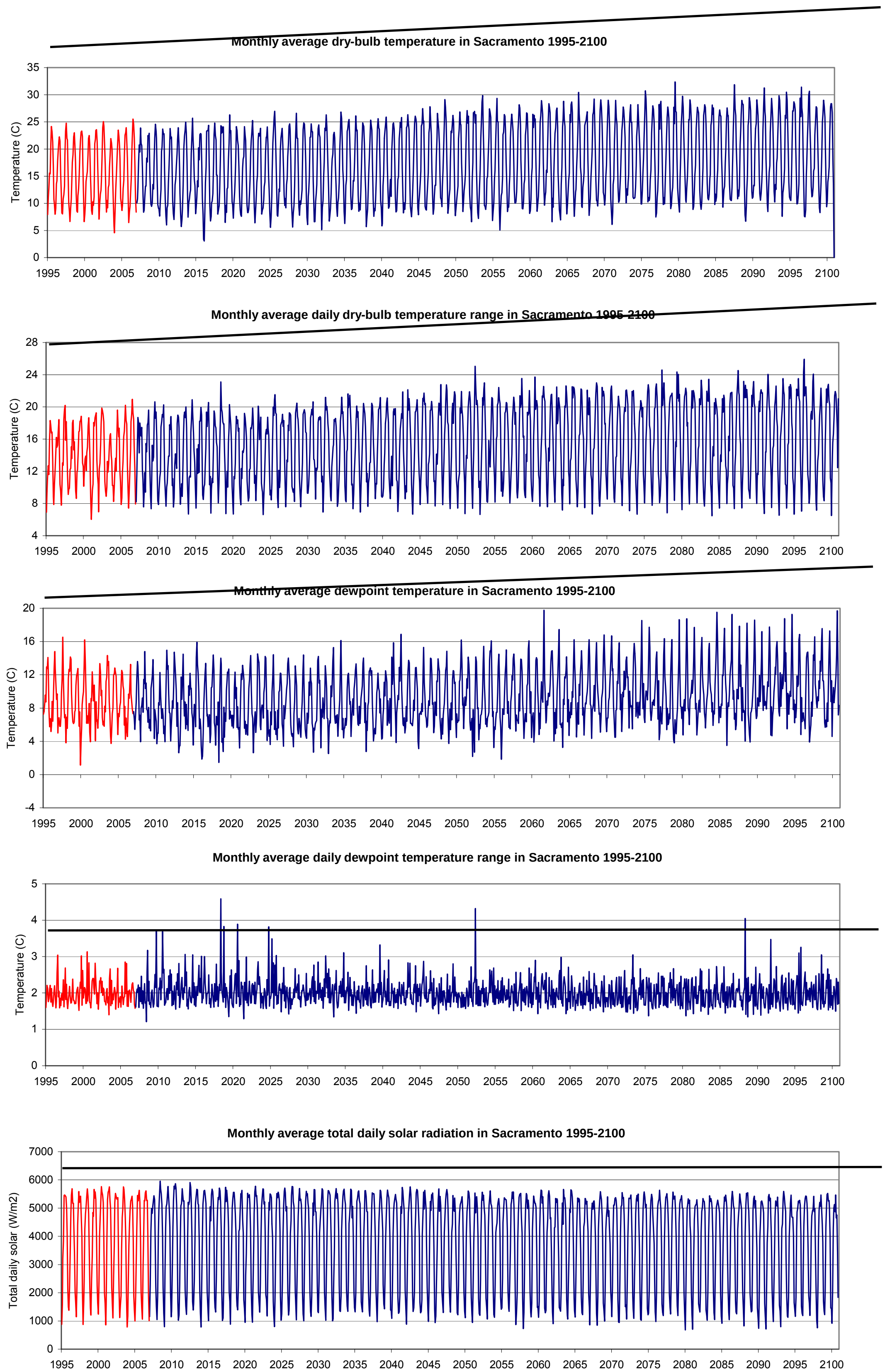




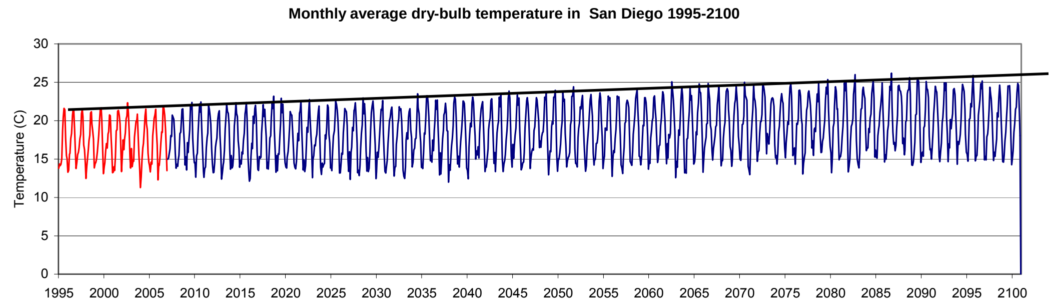


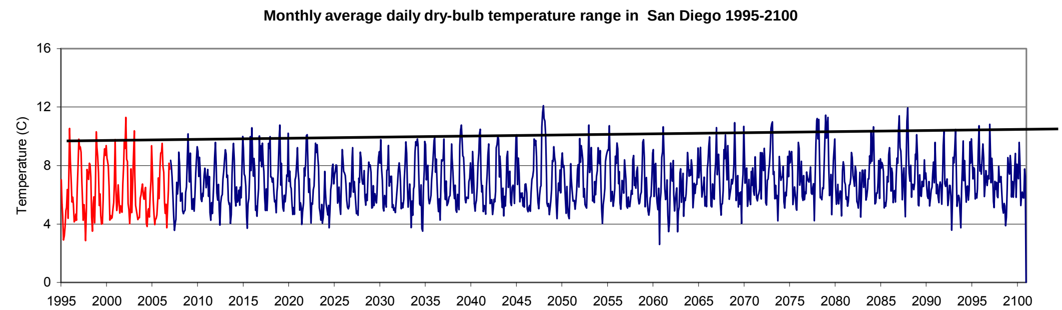


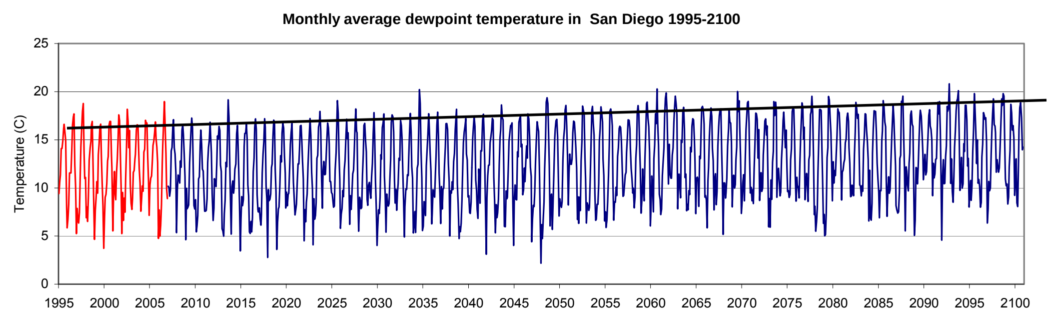
Climatic data for Burbank 1995-2100

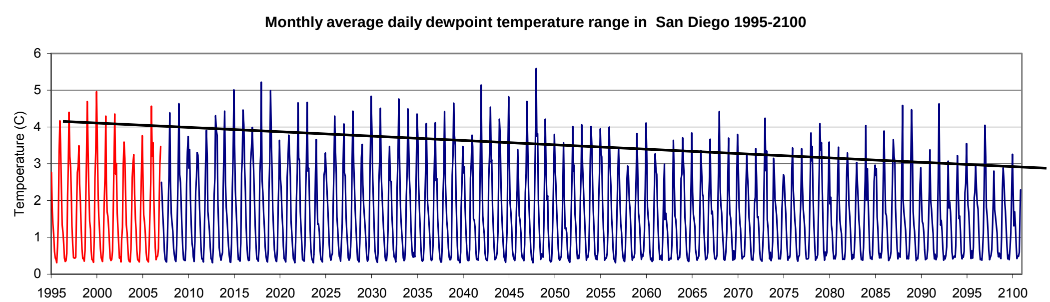


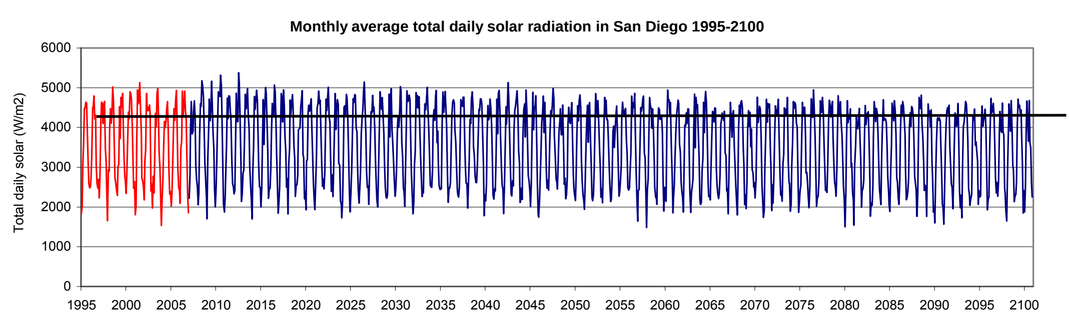
Climatic data for Sacramento 1995-2100











Climatic data for San Diego 1995-2100

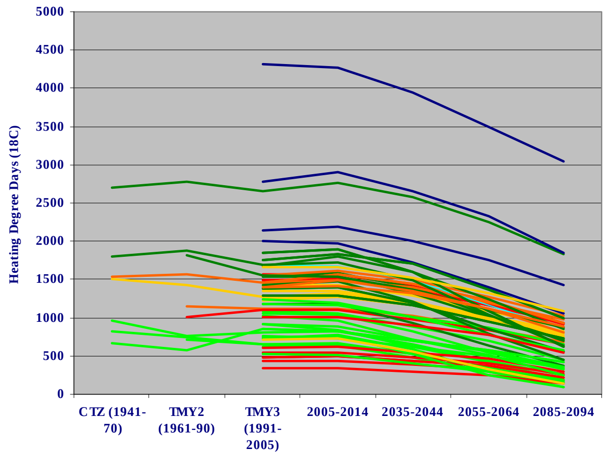
Appendix III: Heating and Cooling Degrees for Downscaled Locations for Three Climate Change Scenarios in Four Future Time Periods

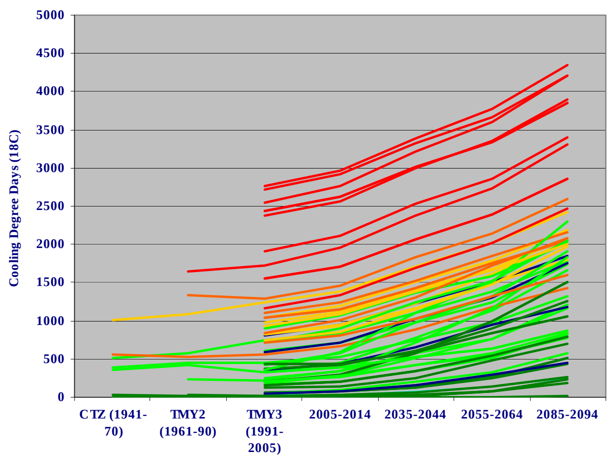
Location	CC Scenario	Heating Degree Days 18C							Cooling Degree Days 18C							(Cooling Degree Hours)/24 26C						
		CTZ	TM2	TM3	2005-2014	2035-2044	2055-2064	2085-2094	CTZ	TM2	TM3	2005-2014	2035-2044	2055-2064	2085-2094	CTZ	TM2	TM3	2005-2014	2035-2044	2055-2064	2085-2094
	A1FI				2759	2577	2244	1827				0	1	3	10				0	0	0	0
Arcata (CTZ01)	A2	2700 (2184)	2779	2650	2633	2792	2394	1994	0 (0)	1	1	0	0	1	6	0 (0)	0	0	0	0	0	0
	B1				2623	2426	2478	2346				1	2	1	2				0	0	0	0
	A1FI				1124	1027	858	682				1467	1825	2142	2586				506	704	889	1181
Bakersfield	A2		1152	1111	1102	1116	939	752		1335	1295	1461	1590	1738	2273		411	405	487	580	646	960
	B1				1105	1003	974	963				1442	1564	1558	1726				492	545	541	624
	A1FI				2189	2009	1750	1434				943	1223	1504	1850				425	579	742	954
Bishop	A2			2139	2159	2167	1875	1610			806	960	1050	1196	1595			346	425	498	561	791
	B1				2139	1957	1942	1906				920	1025	1041	1156				417	464	472	538
	A1FI				819	655	434	249				843	1103	1376	1793				217	315	400	580
Burbank/ Glendale (CTZ09)	A2	966 (755)	755	808	752	825	571	313	510 (575)	575	746	839	868	1039	1503	116 (166)	166	167	198	219	277	453
	B1				754	613	579	532				828	928	896	1071				206	240	225	279
	A1FI				1034	827	549	325				196	344	507	817				22	38	55	91
Camarillo	A2			1055	973	1054	744	415			171	213	230	309	592			20	21	24	34	62
	B1				991	804	801	706				212	239	229	325				26	26	27	38
	A1FI				1508	1371	1162	933				1713	2062	2395	2856				751	968	1177	1483
China Lake (CTZ14)	A2	1316 (1655)		1489	1474	1493	1274	1040	1694 (1032)		1546	1710	1830	1988	2547	686 (377)		633	734	835	908	1260
	B1				1481	1338	1318	1286				1686	1805	1807	1969				733	793	792	883
	A1FI				1098	978	836	647				1949	2374	2739	3309				820	1098	1333	1757
Daggett Barstow	A2		1013	1100	1093	1090	936	714		1651	1717	1946	2130	2283	2940		605	668	802	946	1026	1471
	B1				1061	974	923	922				1928	2054	2084	2214				811	874	892	968
	A1FI				491	437	367	225				2627	3018	3343	3849				1202	1474	1679	2082
El Centro (CTZ15)	A2	606 (486)		476	496	500	397	233	2487 (2308)		2436	2616	2753	2914	3530	1116 (1010)		1046	1168	1290	1372	1829
	B1				448	410	369	382				2594	2732	2766	2888				1174	1245	1267	1346
	A1FI				631	480	298	154				447	783	1135	1667				23	60	108	259
El Toro (CTZ08)	A2	933 (755)		615	563	635	403	204	375 (448)		326	460	478	690	1296	70 (83)		10	16	21	40	143
	B1				556	425	406	361				434	557	517	775				19	29	24	44
	A1FI				1317	1203	1023	821				1383	1704	2016	2422				515	697	888	1153
Fresno (CTZ13)	A2	1504 (1243)	1435	1274	1300	1311	1097	943	1017 (1127)	1092	1238	1409	1507	1677	2136	346 (386)	380	419	514	594	670	954
	B1				1292	1162	1138	1128				1370	1500	1500	1636				505	564	568	644
	A1FI				774	590	299	89				712	980	1245	1740				120	189	251	421
Fullerton	A2			736	676	778	447	161			607	720	717	900	1424			89	107	121	158	300
	B1				673	509	482	431				686	792	754	949				114	134	121	160
	A1FI				1508	1371	1162	933				1713	2062	2395	2856				751	968	1177	1483
Inyokern	A2			1489	1474	1493	1274	1040			1546	1710	1830	1988	2547			633	734	835	908	1260
	B1				1481	1338	1318	1286				1686	1805	1807	1969				733	793	792	883
	A1FI				1571	1418	1179	914				1334	1692	2013	2468				489	693	888	1193
Lancaster	A2			1574	1538	1555	1322	1032			1165	1328	1462	1610	2145			386	470	565	635	957
	B1				1540	1396	1372	1331				1306	1423	1419	1585				477	525	524	612
	A1FI				1424	1296	1094	870				1195	1511	1792	2190				467	634	789	1024
Lemoore	A2			1427	1402	1413	1212	967			1041	1187	1310	1434	1904			375	450	535	583	844
	B1				1396	1277	1258	1225				1168	1269	1270	1413				454	495	495	563
	A1FI				1891	1607	1084	616				8	22	85	240				4	7	15	30
Lompoc	A2			1849	1738	1953	1381	858			5	8	7	27	107			4	4	3	7	17
	B1				1743	1471	1575	1311				9	20	10	27				7	8	6	10
	A1FI				666	535	344	177				535	752	976	1320				53	92	130	231
Long Beach (CTZ06)	A2	827 (844)	744	647	603	671	446	238	392 (216)	443	458	533	553	692	1080	49 (7)	39	35	42	49	74	158
	B1				606	495	463	433				527	612	580	731				48	63	55	75
	A1FI				656	530	345	182				270	419	577	833				3	7	12	32
Los Angeles	A2		720	648	596	655	452	241		232	223	262	275	369	650		6	2	2	2	4	18
	B1				601	504	469	438				263	329	295	404				3	4	4	5
	A1FI				1289	1194	982	755				934	1166	1484	1801				351	467	630	794
Merced	A2			1247	1227	1305	1059	867			828	951	991	1177	1567			293	354	397	464	653
	B1				1228	1100	1118	1063				914	1025	1016	1157				347	389	390	455
	A1FI				1269	1169	961	753				940	1220	1614	2030				303	422	608	824
Modesto	A2			1220	1200	1280	1021	852			821	970	1021	1228	1727			248	307	353	416	639
	B1				1202	1080	1092	1042				919	1075	1042	1230				300	344	342	412
	A1FI				2905	2654	2326	1848				431	657	941	1181				165	265	395	518
Mt. Shasta (CTZ16)	A2	3032 (3007)		2777	2736	2891	2467	2113	339 (162)		353	527	534	677	1058	61 (68)		132	206	215	269	443
	B1				2763	2509	2548	2434				453	523	553	659				181	199	210	269
	A1FI				539	476	396	257				2964	3382	3778	4341				1453	1783	2064	2524
Needles	A2			540	554	534	428	293			2764	2985	3156	3359	4014			1274	1462	1609	1740	2252
	B1				492	457	420	426				2935	3087	3144	3240				1439	1532	1564	1635
	A1FI				1530	1317	1005	715				71	122	245	436				16	23	36	56
Oakland (CTZ03)	A2	1599 (1437)		1535	1457	1510	1177	854	29 (28)		53	70	74	118	283	1 (10)		11	15	16	22	38
	B1				1471	1274	1316	1178				66	85	82	112				14	17	18	21
	A1FI				344	300	252	138				2763	3222	3605	4205				1242	1562	1806	2275
Palm Springs	A2			337	355	357	267	144			2551	2748	2905	3101	3856			1070	1215	1351	1455	1984
	B1				319	278	238	254				2742	2894	2949	3079				1220	1297	1326	1421
	A1FI				1577	1400	1026	697				416	603	895	1251				240	324	456	614
Paso Robles	A2			1537	1445	1640	1198	866			374	439	430	625	990			212	242	250	328	486
	B1				1457	1250	1311	1150				445	533	478	652				253	285	266	339

Location	CC Scenario	Heating Degree Days 18C							Cooling Degree Days 18C							(Cooling Degree Hours)/24 26C						
		CTZ	TM2	TMY3	2005-2014	2035-2044	2055-2064	2085-2094	CTZ	TM2	TMY3	2005-2014	2035-2044	2055-2064	2085-2094	CTZ	TM2	TMY3	2005-2014	2035-2044	2055-2064	2085-2094
	A1FI				1183	938	629	368				70	157	266	512				0	1	2	9
Point Mugu	A2			1185	1086	1157	847	484			41	55	60	122	330			0	0	0	0	4
	B1				1097	949	926	808				54	103	72	132				0	0	0	1
	A1FI				1348	1206	997	799				1124	1420	1674	2079				418	582	724	957
Porterville	A2			1354	1323	1327	1126	880			972	1112	1230	1336	1785			336	403	485	532	773
	B1				1327	1205	1177	1143				1099	1190	1179	1319				411	446	442	513
	A1FI				1618	1496	1269	1026				1249	1517	1852	2153				462	624	837	1027
Red Bluff (CTZ11)	A2			1551	1554	1654	1350	1157			1110	1308	1350	1495	1909			381	491	533	603	865
	B1				1565	1412	1421	1382				1253	1351	1358	1497				468	516	522	608
	A1FI				1575	1440	1230	934				1153	1432	1753	2044				441	601	798	967
Redding	A2			1458	1481	1590	1278	1090			1043	1284	1274	1437	1882			375	517	518	599	866
	B1				1492	1309	1334	1284				1191	1262	1308	1445				467	487	515	604
	A1FI				878	719	558	359				900	1249	1516	2052				325	484	601	896
Riverside March AFB (CTZ 10)	A2			909	883	870	701	386			710	848	1020	1135	1698			229	279	376	415	702
	B1				852	737	658	677				887	958	967	1099				318	339	345	392
	A1FI				1496	1390	1200	972				664	891	1182	1428				251	359	504	631
Sacramento (CTZ12)	A2	1531 (1485)	1570	1453	1441	1526	1269	1099	557 (484)	530	557	710	751	879	1229	196 (187)	183	200	267	299	347	519
	B1				1445	1318	1328	1294				663	752	762	877				256	286	294	350
	A1FI				1684	1491	1163	852				37	71	139	256				9	14	23	39
Salinas	A2			1696	1617	1671	1346	1015			24	34	34	60	161			6	9	9	13	26
	B1				1634	1461	1483	1359				32	46	41	55				9	11	11	13
	A1FI				1394	1195	858	566				299	578	995	1507				41	62	117	279
San Carlos	A2			1388	1289	1369	998	697			207	294	335	583	1145			23	32	40	54	135
	B1				1302	1117	1107	998				271	430	377	554				38	45	42	48
	A1FI				1965	1731	1401	1050				716	1031	1310	1749				145	269	395	645
Sandberg	A2			2001	1910	1923	1629	1205			595	705	825	956	1425			99	128	186	234	442
	B1				1930	1743	1708	1631				693	803	776	938				140	169	160	218
	A1FI				827	701	582	417				393	530	637	868				34	48	59	108
San Diego Lindbergh (CTZ07)	A2	669 (718)	572	856	819	810	695	446	351 (304)	420	321	359	431	481	707	11 (17)	13	21	23	35	38	71
	B1				804	737	681	682				380	416	412	469				30	32	32	34
	A1FI				1530	1359	1100	864				34	66	143	258				6	11	19	32
San Francisco	A2		1824	1557	1482	1514	1254	989		31	21	34	37	63	166		7	4	6	7	10	20
	B1				1503	1359	1376	1274				32	42	42	61				7	7	8	11
	A1FI				1290	1170	940	729				199	340	545	790				34	62	107	172
San Jose Intl (CTZ04)	A2	1451 (1314)		1296	1231	1303	1028	837	104 (194)		158	209	242	333	617	12 (49)		24	33	42	57	116
	B1				1251	1113	1116	1048				197	260	238	328				35	43	41	57
	A1FI				1472	1217	794	454				82	118	264	515				35	46	74	121
San Luis Obispo	A2			1432	1324	1513	1019	625			63	81	69	132	332			26	35	30	48	88
	B1				1333	1104	1178	958				76	112	87	143				34	41	38	49
	A1FI				1195	1005	780	568				98	209	332	572				6	11	18	46
Santa Barbara	A2			1242	1152	1139	949	661			52	70	117	174	393			2	4	5	8	25
	B1				1171	1050	1021	955				79	124	104	162				5	6	6	7
	A1FI				1731	1494	1041	634				17	29	77	190				9	13	24	47
Santa Maria (CTZ05)	A2	1808 (1391)	1873	1700	1599	1786	1299	850	38 (27)	21	12	18	21	31	100	14 (11)	8	6	9	9	12	31
	B1				1611	1385	1463	1244				17	27	20	36				9	12	11	16
	A1FI				758	521	255	86				345	721	1167	1837				5	19	66	342
Santa Monica	A2			747	645	747	383	140			248	343	343	622	1380			3	3	6	11	116
	B1				684	480	448	377				321	486	394	711				7	8	7	13
	A1FI				1801	1604	1249	853				142	243	483	705				82	120	197	268
Santa Rosa (CTZ02)	A2	1836 (1707)		1684	1651	1845	1365	1043	459 (267)		127	166	151	277	549	196 (121)		73	91	89	128	211
	B1				1615	1390	1491	1313				182	228	206	302				99	109	102	140
	A1FI				1417	1327	1119	890				806	1024	1313	1600				302	404	543	687
Stockton	A2			1390	1362	1434	1193	1007			714	825	870	1027	1386			252	305	341	397	563
	B1				1367	1249	1256	1202				799	899	881	1013				302	335	333	391
	A1FI				4274	3944	3492	3047				70	148	295	455				67	117	188	268
Truckee	A2			4314	4161	4277	3803	3337			53	91	124	157	335			48	74	93	113	202
	B1				4210	3966	3969	3841				72	113	108	157				68	87	86	113
	A1FI				1008	896	778	548				2112	2531	2861	3398				892	1171	1386	1805
Twentynine Palms	A2			1012	1027	1017	872	591			1909	2108	2258	2427	3070			747	867	996	1085	1537
	B1				954	892	830	837				2071	2209	2246	2374				878	935	952	1045
	A1FI				1837	1709	1374	997				441	583	840	1053				191	253	379	474
Ukiah Muni	A2			1757	1726	1930	1481	1166			433	492	482	640	901			182	213	211	277	400
	B1				1716	1526	1588	1446				513	567	539	662				224	241	231	294
	A1FI				731	558	326	137				848	1147	1471	1977				263	377	484	695
Van Nuys	A2			709	650	734	464	206			740	850	886	1091	1638			211	250	278	341	549
	B1				652	515	487	437				837	956	921	1121				258	294	279	345
	A1FI				1664	1529	1319	1092				1090	1388	1654	2010				380	533	681	894
Visalia	A2			1655	1636	1647	1441	1196			936	1080	1198	1313	1756			301	365	446	488	729
	B1				1640	1514	1490	1460				1063	1156	1161	1293				371	409	406	469
	A1FI				1484	1348	1118	809				1002	1311	1731	2087				372	526	753	963
Yuba County	A2			1396	1414	1529	1187	974			835	1058	1110	1309	1810			294	394	438	514	788
	B1				1403	1229	1258	1222				980	1131	1148	1300				375	428	439	520

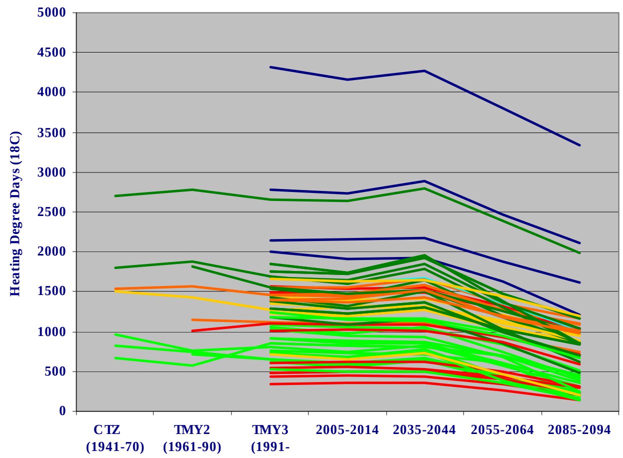
Appendix IV: Heating and Cooling Degree-Days for 53 Downscaled 16 CTZ and 11 TM2 Locations

Color of lines indicate their general location: dark blue for mountain areas, dark green for north coastal, orange for north Central Valley, yellow for south Central Valley, light green for south coastal, and red for desert areas.

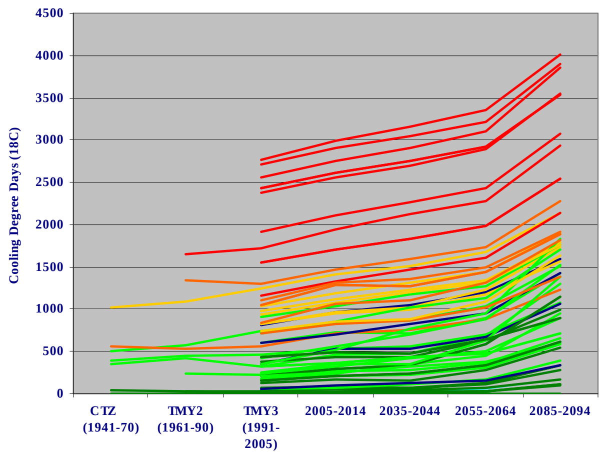




Scenario A1FI

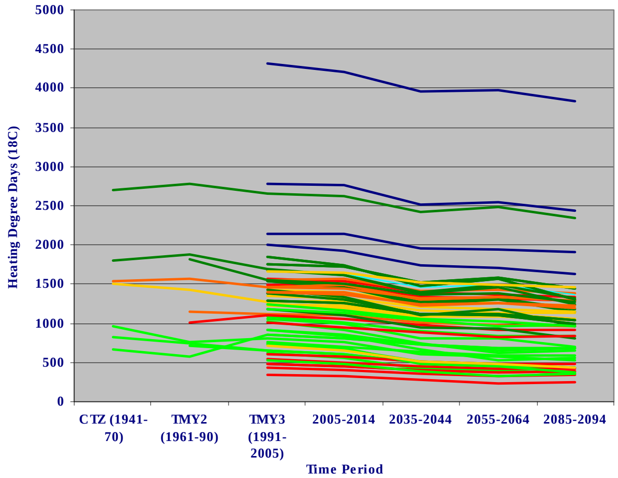


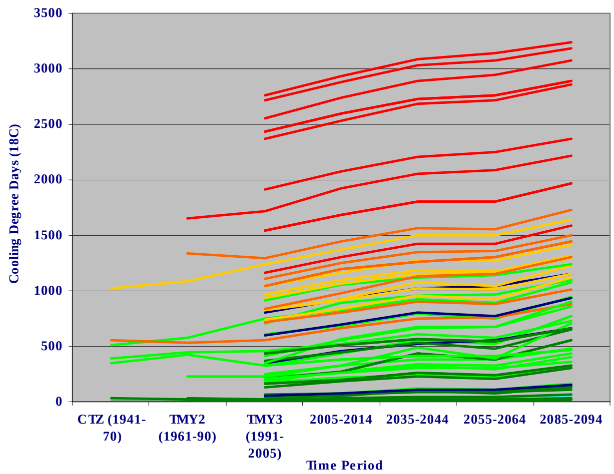
Heating Degree Days (18C)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
CTZ (1941-70)
TMY2 (1961-90)
TMY3 (1991-
2005-2014
2035-2044
2055-2064
2085-2094



Cooling Degree Days (18C)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
CTZ (1941-70)
TMY2 (1961-90)
TMY3 (1991-2005)
2005-2014
2035-2044
2055-2064
2085-2094

Scenario A2


5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Heating Degree Days (18C)
CTZ (1941-70)
TMY2 (1961-90)
TMY3 (1991-2005)
2005-2014
2035-2044
2055-2064
2085-2094
Time Period


3500
3000
2500
2000
1500
1000
500
0
Cooling Degree Days (18C)
CTZ (1941-70)
TMY2 (1961-90)
TMY3 (1991-2005)
2005-2014
2035-2044
2055-2064
2085-2094
Time Period

Scenario B1

Appendix V: Prototypical Model Detailed Descriptions

Fast Food Restaurant, new construction

```
 Description:  Single story, Two zone building.
 Form:         Area = 232 m2 (2,500 ft2); Number of Stories = 1; Shape =
rectangle, Aspect ratio = 1.5
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade
floor
               Windows: window-to-wall ratio = 14%
               Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
 HVAC:         ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 -
PSZ-AC, gas furnace
               No economizer

 Int. gains:   W/m2 (W/ft2)   lights            elec plug         gas plug
               Kitchen         12.9 (1.2)          53.8 (5.0)       53.8
(5.0)
               Dining         22.6 (2.1)          0.0 (0.0)            0

 Detached Shading:                None
 Daylight:                        None
 Natural Ventilation:             None
 Zonal Equipment:                 None
 Air Primary Loops:               PSZ-AC:1; PSZ-AC:2
 Plant Loops:                     SHWSys1
 System Equipment Autosize:       No
 Purchased Cooling:               None
 Purchased Heating:               None
 Coils:                           COIL:DX:COOLINGBYPASSFACTOREMPIRICAL;
COIL:GAS:HEATING
 Pumps:                           None
 Boilers:                         None
 Chillers:                        None
```

Hospital, new construction

```
 Description:  Five story motel
 Form:         Area = 18,697 m2 (201,250 ft2); Number of Stories = 5 +
Basement; Aspect ratio = 1.33
               Opaque constructions: steel frame walls; built up flat roof;
basement
               Windows: window-to-wall ratio = 11.2% (N), 12.1% (E), 13.4%
(S), 23.2%(W)
               Infiltration = 0.3 ACH with fans off, 0.15 ACH with fans on
 HVAC:         Water cooled electric chiller, natural gas boiler, 2 VAV
systems
               Economizer

 Int. gains:   W/m2 (W/ft2)   lights            elec plug         gas plug
               Basement      10.76 (1.0)          2.7 (0.25)          0
               ER Rooms      29.2 (2.7)           21.5 (2.0)          0
               OR Rooms      26.0 (2.2)          53.8 (5.0)          0
               Nurse Stat.   10.76 (1.0)          8.07 (0.75)          0
               ICU Rooms     8.61 (0.8)           32.3 (3.0)          0
               Pat. Rooms    7.53 (0.7)           8.07 (0.75)          0
               Lobby         14.0 (1.3)          8.07 (0.75)          0
```

	lights	elec plug	gas plug
Corridor	10.76 (1.0)	0.0 (0.0)	0
Office	10.76 (1.0)	8.07 (0.75)	0
Lab	15.06 (1.4)	32.3 (3.0)	
Kitchen	12.9 (1.2)	43.0 (4.0)	43.0 (4.0)
Dining areas	9.68 (0.9)	2.69 (0.25)	

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	SINGLE DUCT:VAV:REHEAT
Air Primary Loops:	VAV with Reheat
Plant Loops:	SWH, HHW, CHW
System Equipment Autosize:	yes
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:WATER:SIMPLEHEATING,
Pumps:	PUMP:VARIABLE SPEED (3)
Boilers:	BOILER:SIMPLE
Chillers:	CHILLER:ELECTRIC - Water cooled

Large Hotel, new construction

Description: Six story motel, 179 rooms plus laundry facility

Form: Area = 9,366 m2 (100,816 ft2); Number of Stories = 6; Aspect ratio = 3.79 (ground floor and basement), 5.07 (all other floors)

Opaque constructions: steel frame walls; built up flat roof; basement

Windows: window-to-wall ratio = 22%,

Infiltration = 0.3 ACH with fans off, 0.15 ACH with fans on

HVAC: Air cooled electric chiller, natural gas boiler, VAV Economizer

Int. gains:

W/m2 (W/ft2)	lights	elec plug	gas plug
Rooms	11.8 (1.1)	6.45 (0.6)	0
Lobby	11.8 (1.1)	8.07 (0.75)	0
Corridor	5.38 (0.5)	0.0 (0.0)	0
Laundry	6.46 (0.6)	32.3 (3.0)	
Kitchen	12.9 (1.2)	43.0 (4.0)	43.0 (4.0)
Dining areas	22.6 (2.1)	2.69 (0.25)	

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	SINGLE DUCT:VAV:REHEAT
Air Primary Loops:	VAV with Reheat
Plant Loops:	SWH, HHW, CHW
System Equipment Autosize:	yes
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:WATER:SIMPLEHEATING,
Pumps:	PUMP:VARIABLE SPEED (3)
Boilers:	BOILER:SIMPLE
Chillers:	CHILLER:ELECTRIC

Large Office, new construction

Description: 12 story plus basement, office building.
Form: Area = 42,757 m2 (460,235 ft2); Number of Stories = 12; Shape = rectangle, Aspect ratio = 1.5
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 40%, equal distribution of windows
Infiltration = Perimeter zones: 0.3 ACH (fans off), 0.15 ACH (fans on)
Core zones: 0.15 ACH (fans off), 0.075 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 7 - VAV with reheat
with economizer

Int. gains: lights = 10.76 W/m2 (1.0 W/ft2);
elec. plug loads = 8.07 W/m2 (0.75 W/ft2)
gas plug load = 0 W/m2 (0 W/ft2)
people = 195 total; 3.91/100 m2 (3.63/1000 ft2)

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	None
Air Primary Loops:	VAV WITH REHEAT
Plant Loops:	SHWSys1, HeatSys1, CoolSys1
System Equipment Autosize:	No
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps:	Yes
Boilers:	BOILER:SIMPLE - natural gas
Chillers:	CHILLER:ELECTRIC - Water cooled

Medium Office, new construction

Description: Three story, 15 zone office building.
Form: Area = 4,952 m2 (53,627 ft2); Number of Stories = 3; Shape = rectangle, Aspect ratio = 1.5
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 33%, equal distribution of windows
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains: lights = 10.76 W/m2 (1.0 W/ft2);
elec. plug loads = 8.07 W/m2 (0.75 W/ft2)
gas plug load = 0 W/m2 (0 W/ft2)
people = 195 total; 3.91/100 m2 (3.63/1000 ft2)

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	None
Air Primary Loops:	PSZ-AC:1 - PSZ-AC:15
Plant Loops:	SHWSys1
System Equipment Autosize:	No
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps:	None
Boilers:	None
Chillers:	None

Out Patient Health Care, new construction

Description: Two story, two zone office building.

Form: Area = 930 m2 (10,005 ft2); Number of Stories = 2; Shape = rectangle, Aspect ratio = 1.5

Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor

Windows: window-to-wall ratio = 15%, equal distribution of windows

Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)

HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace

No economizer

Int. gains: lights = 10.76 W/m2 (1.0 W/ft2);
elec. plug loads = 8.07 W/m2 (0.75 W/ft2)
gas plug load = 0 W/m2 (0 W/ft2)
people = 50 total; 3.91/100 m2 (3.63/1000 ft2)

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	None
Air Primary Loops:	PSZ-AC:1; PSZ-AC:1
Plant Loops:	SHWSys1
System Equipment Autosize:	No
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps:	None
Boilers:	None
Chillers:	None

Retail, new construction

Description: Two story, Two zone building.

Form: Area = 5,576 m2 (60,022 ft2); Number of Stories = 2; Shape = rectangle, Aspect ratio = 1.0

Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor

Windows: window-to-wall ratio = 28%, first floor south wall

only (0.07% total)
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains: lights = 16.5 W/m2 (1.5 W/ft2);
elec. plug loads = 3.23 W/m2 (0.30 W/ft2)
gas plug load = 0 W/m2 (0 W/ft2)
people = 200 total; 3.59/100 m2 (3.34/1000 ft2)

Detached Shading: None
Daylight: None
Natural Ventilation: None
Zonal Equipment: None
Air Primary Loops: PSZ-AC:1; PSZ-AC:2
Plant Loops: SHWSys1
System Equipment Autosize: No
Purchased Cooling: None
Purchased Heating: None
Coils: COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps: None
Boilers: None
Chillers: None

Sit Down Restaurant, new construction

Description: Single story, Two zone building.
Form: Area = 511 m2 (5,500 ft2); Number of Stories = 1; Shape = rectangle, Aspect ratio = 1.0
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 14%
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains:

W/m2 (W/ft2)	lights	elec plug	gas plug
Kitchen	12.9 (1.2)	53.8 (5.0)	53.8 (5.0)
Dining	22.6 (2.1)	0.0 (0.0)	0

Detached Shading: None
Daylight: None
Natural Ventilation: None
Zonal Equipment: None
Air Primary Loops: PSZ-AC:1; PSZ-AC:2
Plant Loops: SHWSys1
System Equipment Autosize: No
Purchased Cooling: None
Purchased Heating: None
Coils: COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps: None

Boilers:	None
Chillers:	None

Supermarket, new construction

Description: Single story, six zone building.
Form: Area = 1,766 m2 (19,007 ft2); Number of Stories = 1; Shape = rectangle, Aspect ratio = 1.0
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 14%
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains: W/m2 (W/ft2)	lights	elec plug	gas plug
Office	11.8 (1.1)	8.07 (0.75)	0
DryStorage	8.6 (0.8)	8.07 (0.75)	0
Deli	18.3 (1.7)	26.9(2.5)	0
Sales	18.3 (1.7)	5.38 (0.5)	0
Produce	18.3 (1.7)	5.38 (0.5)	0
Bakery	18.3 (1.7)	26.9 (2.5)	26.9 (2.5)

Refrigeration 28 (2.6) applied as external equipment based on the building floor area

Detached Shading:	None
Daylight:	None
Natural Ventilation:	None
Zonal Equipment:	None
Air Primary Loops:	PSZ-AC:1; PSZ-AC:2
Plant Loops:	SHWSys1
System Equipment Autosize:	No
Purchased Cooling:	None
Purchased Heating:	None
Coils:	COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps:	None
Boilers:	None
Chillers:	None

Primary school, new construction

Description: Single story, primary school, 25 zones
Form: Area = 6,871 m2 (73,959 ft2); Number of Stories = 1; Shape = Main corridor with three wings for class rooms
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 35%,
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains: W/m2 (W/ft2)	lights	elec plug	gas plug

	Classroom:	15 (1.4)	15 (1.4)	0
	corridor	5.38 (0.5)	4.0 (0.37)	0
	offices	11.8(1.1)	10.8(1.0)	
	Gym	15 (1.4)	5.0 (0.46)	
	Kitchen	12.9 (1.2)	20 (1.86)	20 (1.86)
	Cafeteria	15 (1.4)	10.76 (1.0)	
	Library	14 (1.3)	15 (1.4)	

Detached Shading: None
Daylight: None
Natural Ventilation: None
Zonal Equipment: None
Air Primary Loops: PSZ-AC air loop for each zone
Plant Loops: SHWSys1
System Equipment Autosize: yes
Purchased Cooling: None
Purchased Heating: None
Coils: COIL:DX:COOLINGBYPASSFACTOREMPIRICAL; COIL:GAS:HEATING
Pumps: None
Boilers: None
Chillers: None

Secondary school, new construction

Description: Two story, secondary (high) school, 47 zones
Form: Area = 23,804 m2 (210,886 ft2); Number of Stories = 2; Shape = Main corridor with three wings for class rooms
Opaque constructions: steel frame walls; built up flat roof; slab-on-grade floor
Windows: window-to-wall ratio = 35%,
Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
HVAC: ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 - PSZ-AC, gas furnace
No economizer

Int. gains:	W/m2 (W/ft2)	lights	elec plug	gas plug
	Classroom:	15 (1.4)	15 (1.4)	0
	corridor	5.38 (0.5)	4.0 (0.37)	0
	offices	11.8(1.1)	10.8(1.0)	
	Gym	15 (1.4)	5.0 (0.46)	
	Kitchen	12.9 (1.2)	20 (1.86)	20 (1.86)
	Cafeteria	15 (1.4)	10.76 (1.0)	
	Library	14 (1.3)	15 (1.4)	

Detached Shading: None
Daylight: None
Natural Ventilation: None
Zonal Equipment: None
Air Primary Loops: PSZ-AC air loop for each zone
Plant Loops: SHWSys1
System Equipment Autosize: yes
Purchased Cooling: None
Purchased Heating: None

```
 Coils:                          COIL:DX:COOLINGBYPASSFACTOREMPIRICAL;
COIL:GAS:HEATING
 Pumps:                          None
 Boilers:                        None
 Chillers:                       None
```

Small Motel, new construction

```
Description:  Two story motel, 74 rooms plus laundry facility
 Form:          Area = 1,958 m2 (21,080 ft2); Number of Stories = 2; Shape =
"L"
               Opaque constructions: steel frame walls; built up flat roof;
slab-on-grade floor
               Windows: window-to-wall ratio = 28%,
               Infiltration = 0.15 ACH continuous
 HVAC:         ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 1 -
PTAC with HHW coil
               No economizer

 Int. gains:   W/m2 (W/ft2)   lights           elec plug          gas plug
               Rooms         11.8 (1.1)           6.45 (0.6)           0
               corridor      5.38 (0.5)          0.0 (0.0)            0
               Laundry       6.46 (0.6)           32.3 (3.0)

 Detached Shading:               None
 Daylight:                       None
 Natural Ventilation:            None
 Zonal Equipment:                None
 Air Primary Loops:              None
 Plant Loops:                    SHWSys1, HHW
 System Equipment Autosize:      yes
 Purchased Cooling:              None
 Purchased Heating:              None
 Coils:                          COIL:WATER:SIMPLEHEATING,
Coil:DX:CoolingBypassFactorEmpirical
 Pumps:                          None
 Boilers:                        None
 Chillers:                       None
```

Small Office, new construction

```
 Description:  Single story, one zone office building.
 Form:         Area = 511 m2 (5,503 ft2); Number of Stories = 1; Shape =
rectangle, Aspect ratio = 1.5
               Opaque constructions: steel frame walls; built up flat roof;
slab-on-grade floor
               Windows: window-to-wall ratio = 18%, equal distribution of
windows
               Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
 HVAC:         ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 -
PSZ-AC, gas furnace
               No economizer

 Int. gains:   lights = 10.76 W/m2 (1.0 W/ft2);
               elec. plug loads = 8.07 W/m2 (0.75 W/ft2)
               gas plug load = 0 W/m2 (0 W/ft2)
```

```
               people = 20 total; 3.91/100 m2 (3.63/1000 ft2)

 Detached Shading:                None
 Daylight:                        None
 Natural Ventilation:             None
 Zonal Equipment:                 None
 Air Primary Loops:               PSZ-AC:1
 Plant Loops:                     SHWSys1
 System Equipment Autosize:       No
 Purchased Cooling:               None
 Purchased Heating:               None
 Coils:                           COIL:DX:COOLINGBYPASSFACTOREMPIRICAL;
COIL:GAS:HEATING
 Pumps:                           None
 Boilers:                         None
 Chillers:                        None
```

Strip Mall, new construction

```
 Description:  Single story, two zone stores, double size on end and middle
store repeated 16 times.
 Form:         Area = 2230 m2 (24,000 ft2); 20 111.5 m2 (1,200 ft2) stores;
               Number of Stories = 1; Shape = rectangle
               Opaque constructions: steel frame walls; built up flat roof;
slab-on-grade floor
               Windows: window-to-wall ratio = 45%, south wall only
               Infiltration = 0.3 ACH (fans off), 0.15 ACH (fans on)
 HVAC:         ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 -
PSZ-AC, gas furnace
               No economizer

 Int. gains:   W/m2 (W/ft2)   lights          elec plug        gas plug
               Sales:        18.3 (1.7)         3.23 (0.3)         0
               Storage        8.6 (0.8)         3.23 (0.3)          0

 Detached Shading:                None
 Daylight:                        None
 Natural Ventilation:             None
 Zonal Equipment:                 None
 Air Primary Loops:               PSZ-AC:1
 Plant Loops:                     None
 System Equipment Autosize:       No
 Purchased Cooling:               None
 Purchased Heating:               None
 Coils:                           COIL:DX:COOLINGBYPASSFACTOREMPIRICAL;
COIL:GAS:HEATING
 Pumps:                           None
 Boilers:                         None
 Chillers:                        None
```

Warehouse, new construction

```
 Description:  Single story, three zones
 Form:         Area = 4,835 m2 (52,045 ft2); Number of Stories = 1; Shape =
rectangle
               Opaque constructions: steel frame walls; built up flat roof;
```

```
slab-on-grade floor
               Windows: window-to-wall ratio = %, south wall only
               Infiltration = 0.3 ACH Continuous
 HVAC:         ASHRAE 90.1-2004 Appendix G Table G3.1.1B System Number 3 -
PSZ-AC, gas furnace
               No economizer

 Int. gains:   W/m2 (W/ft2)   lights            elec plug         gas plug
               Office        11.8 (1.1)           8.1 (0.75)           0
               Fine Storage   15.1 (1.4)           0.0 (0.0)            0
               Bulk Storage   9.7 (0.9)           2.56 (0.24)           0

 Detached Shading:                 None
 Daylight:                         None
 Natural Ventilation:              None
 Zonal Equipment:                  None
 Air Primary Loops:                PSZ-AC:1
 Plant Loops:                      None
 System Equipment Autosize:        No
 Purchased Cooling:                None
 Purchased Heating:                None
 Coils:                            COIL:DX:COOLINGBYPASSFACTOREMPIRICAL;
COIL:GAS:HEATING
 Pumps:                            None
 Boilers:                          None
 Chillers:                         None
```

Appendix VI: Building Stock Data for 16 California Climate Zones

	Climate Zones								
	1	2	3	4	5	6	7	8	9
Hospital	0	3,000,699	12,488,500	4,830,786	1,055,593	7,552,598	2,047,782	15,542,890	8,666,046
Outpatient Health Care	1,285,861	1,197,305	8,051,286	6,748,872	0	19,107,961	4,142,465	13,454,486	20,181,951
Large office	1,732,189	16,229,354	244,650,087	61,988,631	4,450,674	145,279,438	149,360,777	110,272,120	71,797,821
Medium office	3,509,570	3,329,391	14,926,705	13,335,355	0	7,104,053	4,819,392	9,306,390	7,047,332
Small office	3,509,570	3,329,391	14,926,705	13,335,355	0	7,104,053	4,819,392	10,872,153	7,047,332
Retail	441,074	11,364,805	43,276,753	17,767,449	4,803,712	30,720,203	25,238,781	43,931,049	24,243,860
Sit down restaurant	0	0	16,513,710	6,637,335	1,097,861	18,689,375	5,339,453	11,715,730	2,335,247
Super market	0	22,650,283	66,250,620	18,938,092	7,141,746	57,702,582	42,053,988	90,983,478	33,729,581
Strip mall	354,236	5,903,310	18,578,226	3,383,193	918,125	11,192,609	11,191,713	27,822,002	23,757,940
Small hotel	0	0	11,048,636	6,728,910	0	21,422,839	23,746,889	7,426,226	2,785,507
Large Hotel	3,563,986	3,921,764	54,201,798	15,533,783	5,425,116	37,166,970	22,657,872	24,679,761	12,138,241
School Primary	0	17,828,925	23,392,962	22,076,822	723,548	13,775,687	16,214,743	24,610,333	22,177,461
School Secondary	0	21,031,772	20,956,649	8,429,072	0	21,364,167	19,271,195	21,915,672	28,898,854
Warehouse	0	28,027,351	95,714,449	52,312,642	9,802,201	81,003,878	36,032,075	177,346,551	95,897,449
Others	0	3,603,312	43,693,765	29,564,872	4,696,276	34,349,701	28,204,330	7,090,648	10,482,559

	Climate zones								
	9	10	11	12	13	14	15	16	Total
Hospital	8,666,046	6,391,358	389,257	13,590,550	5,599,612	312,788	1,000,267	5,313,652	87,782,378
Outpatient Health Care	20,181,951	13,711,010	3,160,240	12,454,345	1,705,524	467,300	0	8,692,736	114,361,341
Large office	71,797,821	35,071,375	12,780,727	155,972,053	36,326,353	9,467,422	3,651,085	7,722,556	1,066,752,661
Medium office	7,047,332	10,891,124	18,360,298	11,264,943	25,473,263	1,973,394	1,036,139	7,942,811	140,320,162
Small office	7,047,332	10,891,124	18,360,298	11,264,943	27,295,696	1,973,394	1,036,139	7,942,811	143,708,357
Retail	24,243,860	38,750,637	12,979,613	32,722,249	111,319,245	10,614,016	322,968	1,511,036	410,007,449
Sit down restaurant	2,335,247	5,812,467	0	9,424,750	6,671,956	1,684,784	0	2,828,443	88,751,111
Super market	33,729,581	37,290,733	11,787,062	96,513,013	44,952,815	18,220,444	6,728,280	0	554,942,717
Strip mall	23,757,940	29,476,205	5,476,502	20,741,423	18,624,593	1,667,727	146,461	342,416	179,576,682
Small hotel	2,785,507	26,378,929	0	8,805,676	10,044,801	1,161,278	5,617,951	684,945	125,852,587
Large Hotel	12,138,241	7,522,690	0	21,067,705	10,018,785	0	4,430,811	6,651,383	228,980,666
School Primary	22,177,461	18,085,831	9,178,591	33,533,034	8,128,647	2,928,227	0	4,348,790	217,003,601
School Secondary	28,898,854	19,757,057	5,127,372	26,401,787	26,981,384	2,820,527	5,147,274	0	228,102,783
Warehouse	95,897,449	151,477,025	14,784,608	123,315,895	29,628,583	11,206,392	13,966,594	3,084,490	923,600,183
Others	10,482,559	45,992,588	39,087,067	15,726,336	11,494,128	10,446,396	2,405,493	2,721,714	289,559,185
								Grand Total	4,799,301,862

Appendix VII Aggregated Building Energy Consumption for 16 California Climate Zones

Year 2005, Total Energy Consumption for 16 California climate zones (MMBtu)								
	Climate Zones							
	1	2	3	4	5	6	7	8
Hospital	0	558,355	2,307,667	903,792	197,093	1,414,375	382,526	2,911,883
Outpatient Health Care	184,367	176,573	1,165,585	984,762	0	2,899,442	638,520	2,063,851
Large office	215,571	2,138,055	30,458,120	7,844,661	549,762	18,323,369	18,804,522	14,056,387
Medium office	348,570	346,690	1,461,872	1,347,804	0	724,140	497,506	965,491
Small office	309,509	318,872	1,287,677	1,253,857	0	636,559	455,770	1,066,504
Retail	39,617	1,098,693	4,088,788	1,733,481	459,347	3,092,910	2,588,237	4,503,592
Sit down restaurant	0	0	3,076,339	1,365,001	205,981	3,771,734	1,142,910	2,552,740
Super market	0	8,194,193	22,629,666	6,942,136	2,467,759	21,258,689	16,205,504	35,564,077
Strip mall	2,653	51,182	143,857	29,671	7,250	96,797	100,390	258,606
Small hotel	0	0	1,861,179	1,190,815	0	3,645,632	4,104,175	1,303,934
Large hotel	381,525	438,983	5,944,673	1,765,259	603,490	4,251,654	2,605,429	2,854,091
School Primary	0	3,964,618	4,490,435	4,557,649	138,244	2,610,148	3,094,421	4,925,881
School Secondary	0	1,805,893	1,523,618	661,724	0	1,520,310	1,384,250	1,659,236
Warehouse	0	2,585,383	8,809,877	4,828,457	901,770	7,464,507	3,318,914	16,363,766
Others	0	1,326,577	13,722,901	10,293,158	1,484,978	10,568,716	8,883,518	2,333,603
	Climate Zones							
	9	10	11	12	13	14	15	16
Hospital	1,620,204	1,196,654	71,831	2,526,721	1,037,314	57,703	183,044	994,171
Outpatient Health Care	3,078,353	2,107,794	481,768	1,886,896	263,009	74,989	0	1,334,639
Large office	9,383,975	4,811,442	1,767,021	21,327,229	4,997,598	1,366,906	535,578	1,093,031
Medium office	734,614	1,164,915	1,989,155	1,208,954	2,770,536	222,862	118,115	887,510
Small office	714,459	1,072,449	1,943,866	1,143,223	2,879,355	223,661	125,539	845,194
Retail	2,462,449	3,948,690	1,298,221	3,267,889	11,274,135	1,101,947	34,596	150,726
Sit down restaurant	527,556	1,288,159	0	2,113,241	1,564,824	421,249	0	641,986
Super market	13,395,028	14,581,795	4,592,829	36,803,307	17,682,977	7,606,337	3,055,951	0
Strip mall	229,264	284,445	54,601	197,873	187,363	18,548	1,875	3,384
Small hotel	505,959	4,768,783	0	1,616,854	1,901,029	231,118	1,176,989	132,312
Large hotel	1,407,065	863,981	0	2,414,728	1,161,328	0	532,783	773,622
School Primary	4,781,682	3,830,941	2,232,386	7,619,124	1,954,045	772,100	0	1,161,312
School Secondary	2,378,376	1,610,398	489,937	2,334,050	2,523,839	291,351	586,403	0
Warehouse	8,859,006	14,031,317	1,368,759	11,406,720	2,743,385	1,041,111	1,303,502	283,950
Others	3,739,234	16,387,619	15,878,991	5,994,801	4,617,162	4,462,143	1,095,618	1,202,270
Total					773,546,850			

A1F1, Year 2100, Total Energy Consumption for 16 California climate zones (MMBtu)

	Climate Zones							
	1	2	3	4	5	6	7	8
Hospital	0	559,630	2,330,562	899,082	199,039	1,415,256	383,263	2,899,371
Outpatient Health Care	191,709	183,673	1,211,021	1,047,222	0	2,990,555	652,024	2,168,594
Large office	218,568	2,220,906	31,422,857	8,304,927	571,259	19,127,007	19,530,415	14,969,992
Medium office	351,940	350,618	1,511,528	1,426,950	0	763,934	520,639	1,036,220
Small office	297,752	333,605	1,360,917	1,406,747	0	711,613	495,867	1,243,394
Retail	40,870	1,146,084	4,305,027	1,837,598	488,794	3,259,362	2,690,706	4,783,872
Sit down restaurant	0	0	3,340,613	1,574,542	227,791	4,299,086	1,264,756	3,030,391
Super market	0	8,910,395	24,355,715	7,793,688	2,702,318	23,544,769	17,495,721	40,413,951
Strip mall	2,614	57,675	162,188	36,065	8,334	113,512	113,932	320,231
Small hotel	0	0	1,895,467	1,277,113	0	3,856,718	4,338,794	1,437,123
Large hotel	386,015	450,395	6,154,434	1,836,171	627,903	4,396,729	2,671,590	2,970,703
School Primary	0	3,977,811	4,546,656	5,109,570	141,087	2,894,662	3,337,643	5,896,636
School Secondary	0	1,822,193	1,538,777	748,249	0	1,695,674	1,509,320	2,013,283
Warehouse	0	2,596,594	8,834,763	4,853,305	904,645	7,492,589	3,328,283	16,451,553
Others	0	1,329,856	13,730,038	11,268,060	1,482,129	11,867,879	9,944,283	2,776,201
	Climate Zones							
	9	10	11	12	13	14	15	16
Hospital	1,615,004	1,187,323	71,357	2,510,208	1,028,257	56,970	180,528	986,294
Outpatient Health Care	3,255,550	2,249,154	507,650	1,971,710	278,009	81,017	0	1,368,280
Large office	9,918,151	5,155,843	1,836,846	22,244,734	5,229,542	1,441,163	577,437	1,108,901
Medium office	777,744	1,223,182	2,030,098	1,236,074	2,847,911	227,970	121,223	889,615
Small office	813,051	1,272,192	2,114,372	1,249,536	3,191,754	255,423	147,505	879,170
Retail	2,597,487	4,169,956	1,343,996	3,394,442	11,692,417	1,141,272	35,333	153,733
Sit down restaurant	613,446	1,563,554	0	2,366,885	1,780,278	492,830	0	686,597
Super market	15,043,056	16,761,439	5,074,762	40,389,490	19,638,649	8,600,961	3,454,467	0
Strip mall	280,344	369,632	64,294	231,267	225,078	23,176	2,379	3,706
Small hotel	549,636	5,368,903	0	1,727,497	2,063,855	256,077	1,335,864	135,991
Large hotel	1,457,681	899,563	0	2,473,401	1,189,606	0	550,661	783,550
School Primary	5,623,982	4,870,153	2,524,633	8,487,798	2,287,096	952,186	0	1,171,379
School Secondary	2,840,757	2,054,141	552,833	2,604,008	2,948,863	361,925	774,871	0
Warehouse	8,903,119	14,138,866	1,377,038	11,467,145	2,760,421	1,049,086	1,312,511	285,554
Others	4,259,588	19,709,204	17,172,252	6,497,886	5,118,048	5,156,254	1,290,884	1,192,553
Total	832.889,140							

A2, Year 2100, Total Energy Consumption for 16 California climate zones (MMBtu)								
	Climate Zones							
	1 2 3			4 5 6 7				8
Hospital	0	559,675	2,324,360	901,642	198,543	1,414,551	382,689	2,908,929
Outpatient Health Care	190,783	181,937	1,201,735	1,028,461	0	2,965,205	647,674	2,137,380
Large office	218,949	2,199,321	31,112,152	8,171,651	566,808	18,931,121	19,336,246	14,721,328
Medium office	351,273	349,070	1,498,193	1,407,547	0	752,059	514,422	1,017,468
Small office	300,138	328,328	1,336,338	1,359,073	0	692,835	487,963	1,197,133
Retail	40,632	1,134,605	4,248,190	1,812,191	480,964	3,212,770	2,665,720	4,713,582
Sit down restaurant	0	0	3,265,696	1,515,569	221,761	4,159,757	1,239,714	2,895,601
Super market	0	8,715,829	23,925,528	7,590,198	2,642,898	23,024,292	17,241,294	39,189,314
Strip mall	2,628	55,757	157,172	34,187	8,061	108,867	110,015	302,008
Small hotel	0	0	1,881,509	1,250,568	0	3,791,664	4,277,527	1,399,138
Large hotel	385,231	447,944	6,107,097	1,820,870	622,442	4,362,783	2,658,222	2,944,296
School Primary	0	3,934,933	4,498,155	4,898,516	139,505	2,798,875	3,285,755	5,546,800
School Secondary	0	1,801,687	1,521,173	715,417	0	1,635,712	1,485,231	1,894,172
Warehouse	0	2,593,511	8,828,063	4,845,720	904,024	7,484,353	3,325,760	16,425,838
Others	0	1,321,533	13,584,974	10,907,368	1,465,911	11,413,146	9,659,701	2,637,402
	Climate Zones							
	9	10 11		12 13 14 15				16
Hospital	1,619,077	1,192,947	71,481	2,516,188	1,032,163	57,249	181,333	988,897
Outpatient Health Care	3,204,894	2,201,303	501,446	1,946,272	273,400	79,180	0	1,355,111
Large office	9,763,068	5,041,510	1,822,063	21,938,249	5,160,703	1,419,293	564,823	1,101,893
Medium office	765,975	1,208,152	2,020,673	1,228,160	2,831,799	227,444	120,897	888,503
Small office	790,429	1,214,143	2,073,122	1,217,374	3,094,786	245,651	141,122	865,707
Retail	2,562,334	4,128,105	1,333,179	3,365,729	11,602,527	1,134,161	35,289	152,894
Sit down restaurant	589,159	1,487,585	0	2,293,796	1,716,611	471,108	0	671,755
Super market	14,624,134	16,209,536	4,952,766	39,407,711	19,124,501	8,336,916	3,357,176	0
Strip mall	266,089	343,987	61,738	221,259	213,205	21,747	2,240	3,590
Small hotel	536,767	5,160,774	0	1,692,363	2,012,375	248,157	1,289,432	134,528
Large hotel	1,447,849	891,288	0	2,459,549	1,183,494	0	546,828	780,939
School Primary	5,344,325	4,469,190	2,445,850	8,166,719	2,172,340	892,206	0	1,153,897
School Secondary	2,687,882	1,889,170	534,529	2,509,160	2,798,374	338,548	719,409	0
Warehouse	8,886,817	14,107,055	1,375,018	11,449,881	2,755,606	1,046,845	1,309,787	285,169
Others	4,086,311	18,568,587	16,825,419	6,332,602	4,946,038	4,933,990	1,238,661	1,186,783
Total	815,608,124							

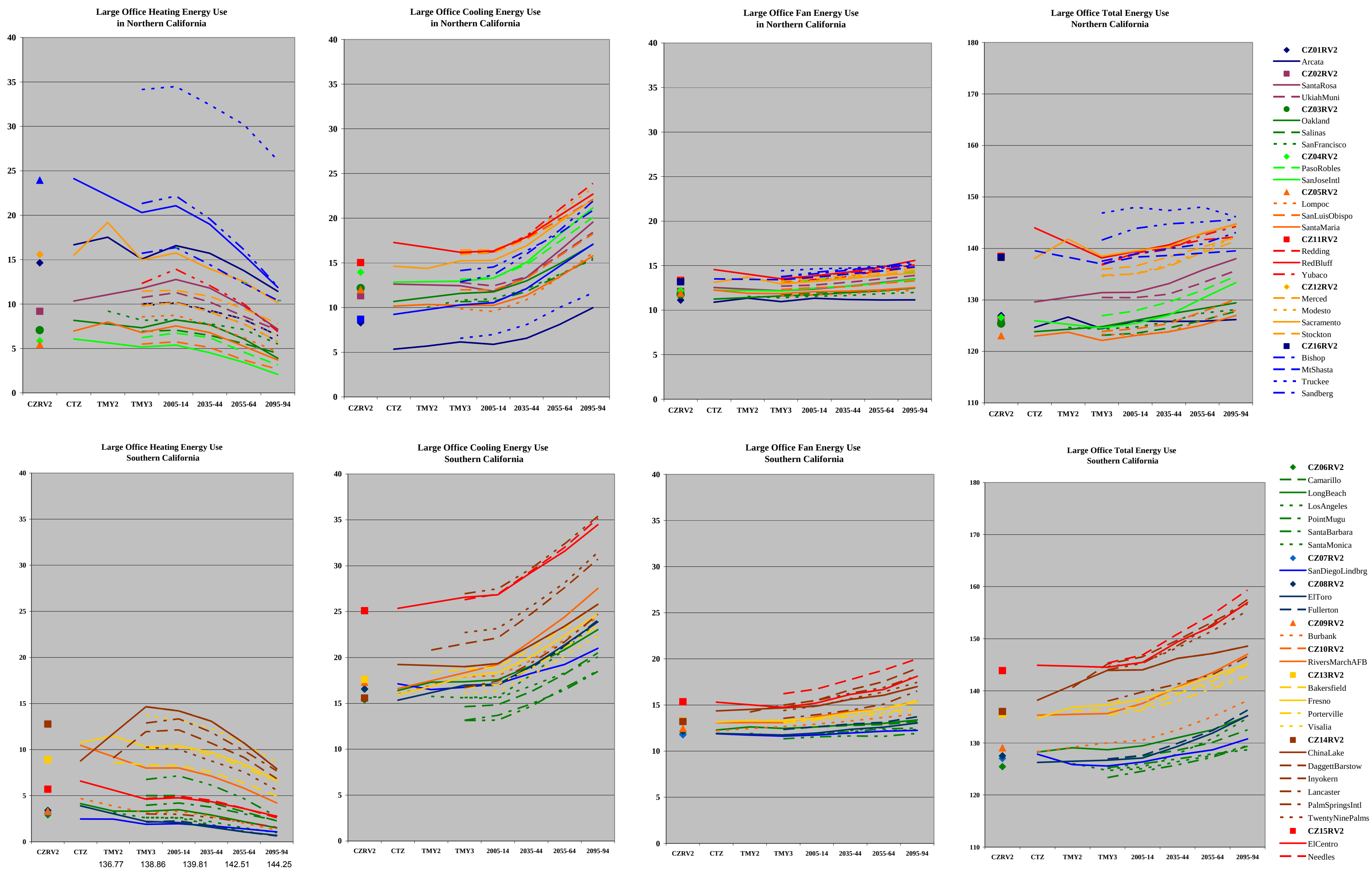
B1, Year 2100, Total Energy Consumption for 16 California climate zones (MMBtu)

	Climate Zones							
	1	2	3	4	5	6	7	8
Hospital	0	559,180	2,314,785	903,912	197,857	1,415,508	382,771	2,913,048
Outpatient Health Care	187,710	179,021	1,181,929	1,003,085	0	2,933,486	642,703	2,098,631
Large office	217,684	2,161,425	30,803,892	7,989,095	557,773	18,570,344	19,031,550	14,318,835
Medium office	349,307	346,706	1,477,893	1,369,808	0	736,146	503,723	988,804
Small office	303,894	321,886	1,304,295	1,294,530	0	656,959	466,951	1,115,918
Retail	39,930	1,113,353	4,154,857	1,766,884	469,467	3,148,360	2,619,028	4,601,777
Sit down restaurant	0	0	3,143,109	1,423,642	212,385	3,929,908	1,180,393	2,697,371
Super market	0	8,409,484	23,116,608	7,193,634	2,541,152	21,972,470	16,599,129	37,054,386
Strip mall	2,618	52,805	148,440	31,481	7,575	101,610	104,419	276,412
Small hotel	0	0	1,863,831	1,207,873	0	3,696,190	4,160,692	1,339,357
Large hotel	382,950	442,767	6,007,908	1,789,103	612,224	4,301,086	2,626,727	2,893,579
School Primary	0	3,916,391	4,461,428	4,629,289	137,532	2,662,542	3,153,767	5,115,996
School Secondary	0	1,786,544	1,512,441	673,146	0	1,550,326	1,417,204	1,733,858
Warehouse	0	2,588,886	8,817,534	4,835,781	902,685	7,473,283	3,321,437	16,387,708
Others	0	1,316,092	13,574,779	10,430,487	1,460,917	10,819,641	9,140,741	2,447,656
	Climate Zones							
	9	10	11	12	13	14	15	16
Hospital	1,621,591	1,196,398	71,788	2,523,969	1,035,676	57,588	182,789	992,364
Outpatient Health Care	3,135,064	2,143,991	489,047	1,908,753	266,441	76,218	0	1,340,659
Large office	9,541,930	4,915,955	1,790,452	21,611,878	5,057,991	1,381,723	545,071	1,093,958
Medium office	748,427	1,180,707	2,002,803	1,216,191	2,791,233	223,711	119,161	885,802
Small office	746,453	1,119,934	1,983,463	1,168,231	2,946,297	230,246	130,134	846,962
Retail	2,509,482	4,017,278	1,311,936	3,306,829	11,392,133	1,113,180	34,879	151,066
Sit down restaurant	551,585	1,354,014	0	2,175,774	1,614,847	436,839	0	647,791
Super market	13,879,385	15,100,882	4,716,239	37,702,326	18,157,116	7,851,857	3,159,600	0
Strip mall	243,519	304,194	56,937	205,962	195,186	19,537	2,001	3,418
Small hotel	517,491	4,882,476	0	1,639,683	1,933,900	235,993	1,208,197	132,398
Large hotel	1,425,029	873,159	0	2,431,898	1,168,015	0	537,457	774,736
School Primary	4,969,969	3,953,744	2,284,766	7,735,987	2,007,654	802,608	0	1,140,981
School Secondary	2,481,834	1,671,447	499,731	2,375,831	2,587,852	302,798	619,114	0
Warehouse	8,867,637	14,058,583	1,371,322	11,422,751	2,748,421	1,043,035	1,305,458	284,398
Others	3,874,773	16,953,788	16,082,895	6,087,153	4,694,288	4,580,814	1,136,884	1,182,619
Total	787,932,522							

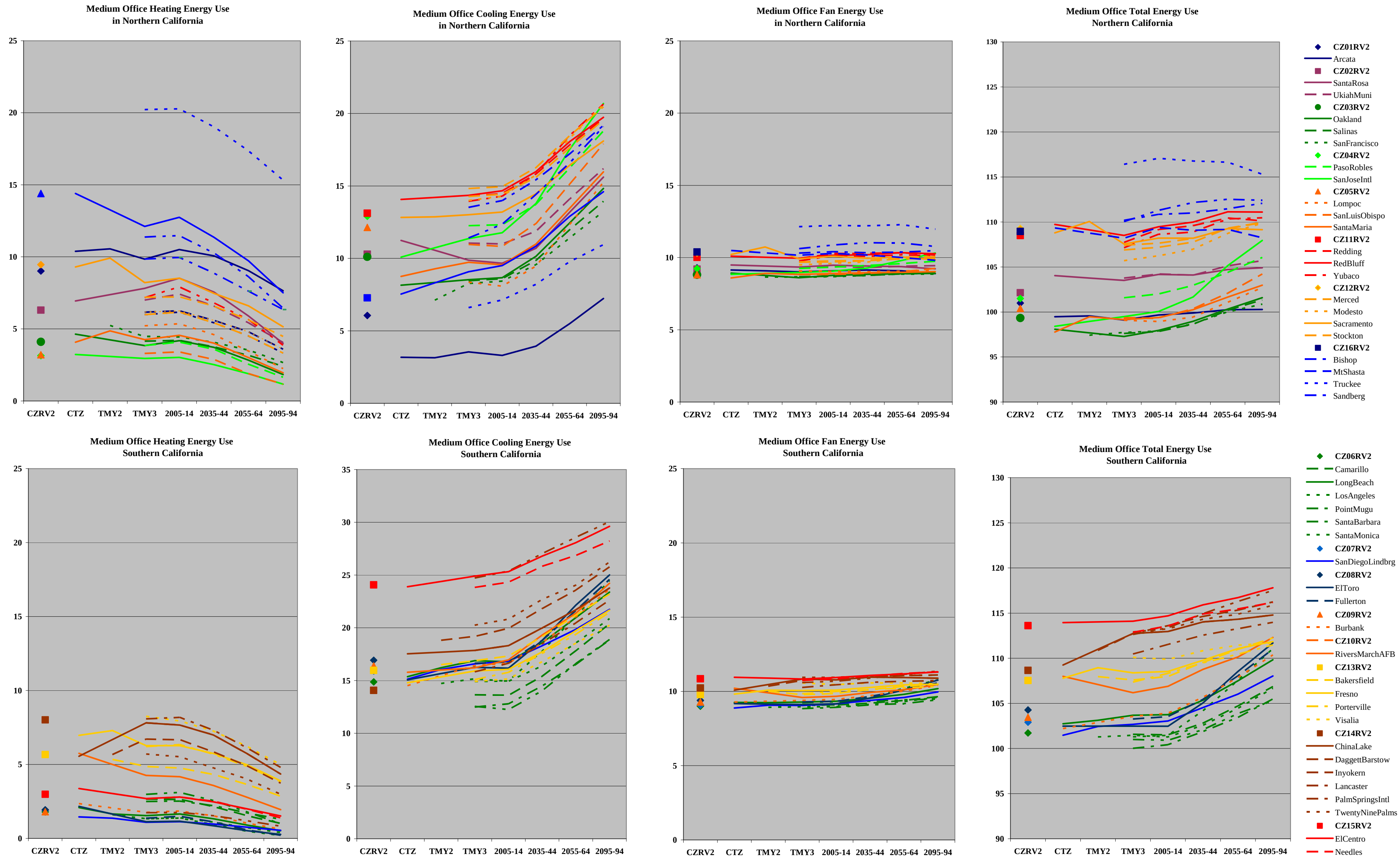
Appendix VIII: Plots of Building Energy Use for 15 Building Types in California Climates Under Three Climate Change Scenarios

Symbols on left side of each plot show the calculated energy usages (kBtu/ft^2) with the current CTZ (CZXXRV2) weather files, which have been averaged for each California Thermal Zone (CTZ) and thus are not tied to any particular location. The following points are, from left to right, with the original CTZ weather files (CTZ), the TMY2 and TMY3 weather files, and finally with four future time periods. The top four plots are for northern California locations, i.e., CTZ 1, 2, 3, 4 5, 11, 12, and 16. The bottom four plots are for southern California locations, i.e., CTZ 6 through 15.

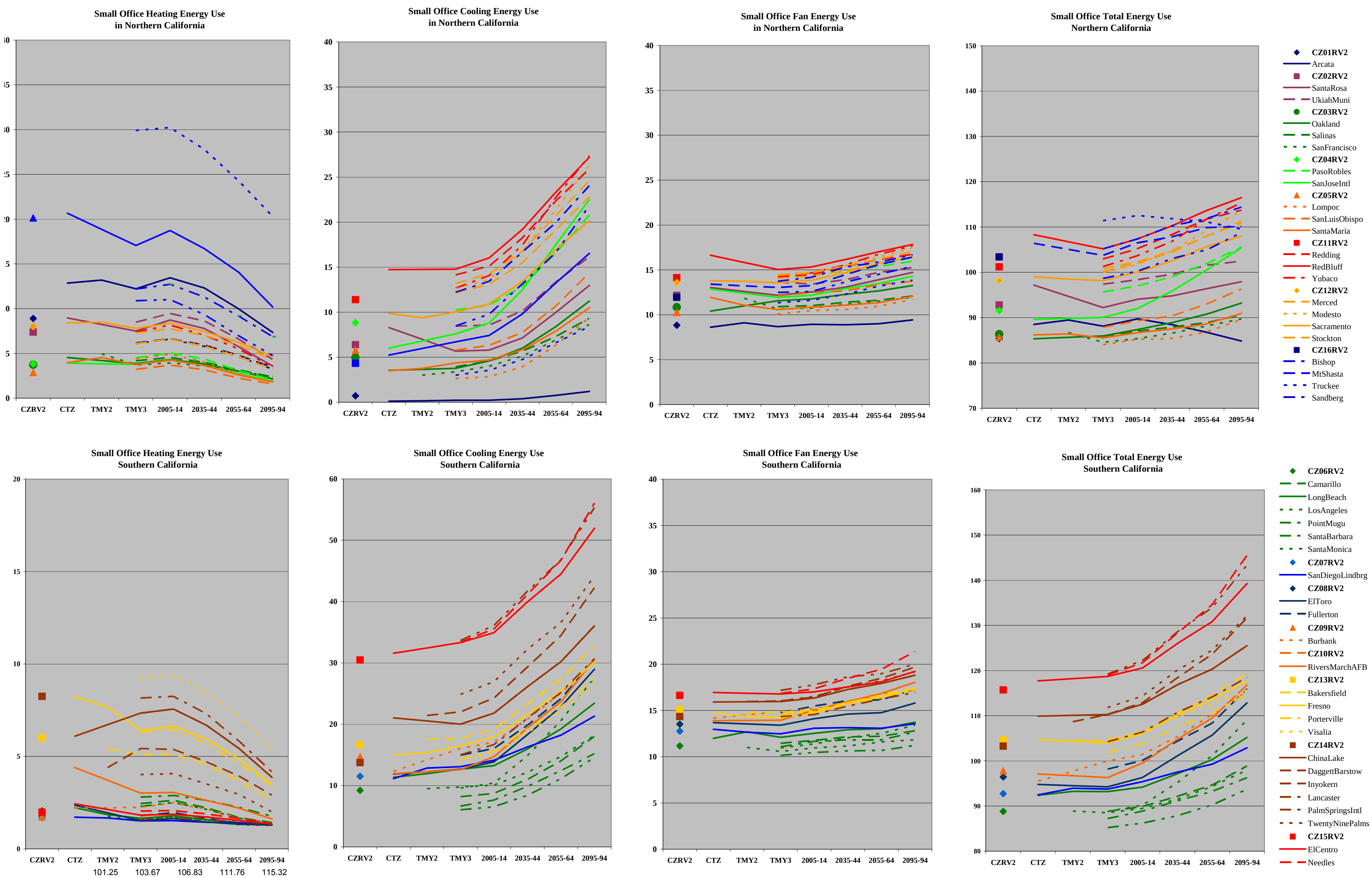
Large Office Energy Use Under the A1FI Scenario



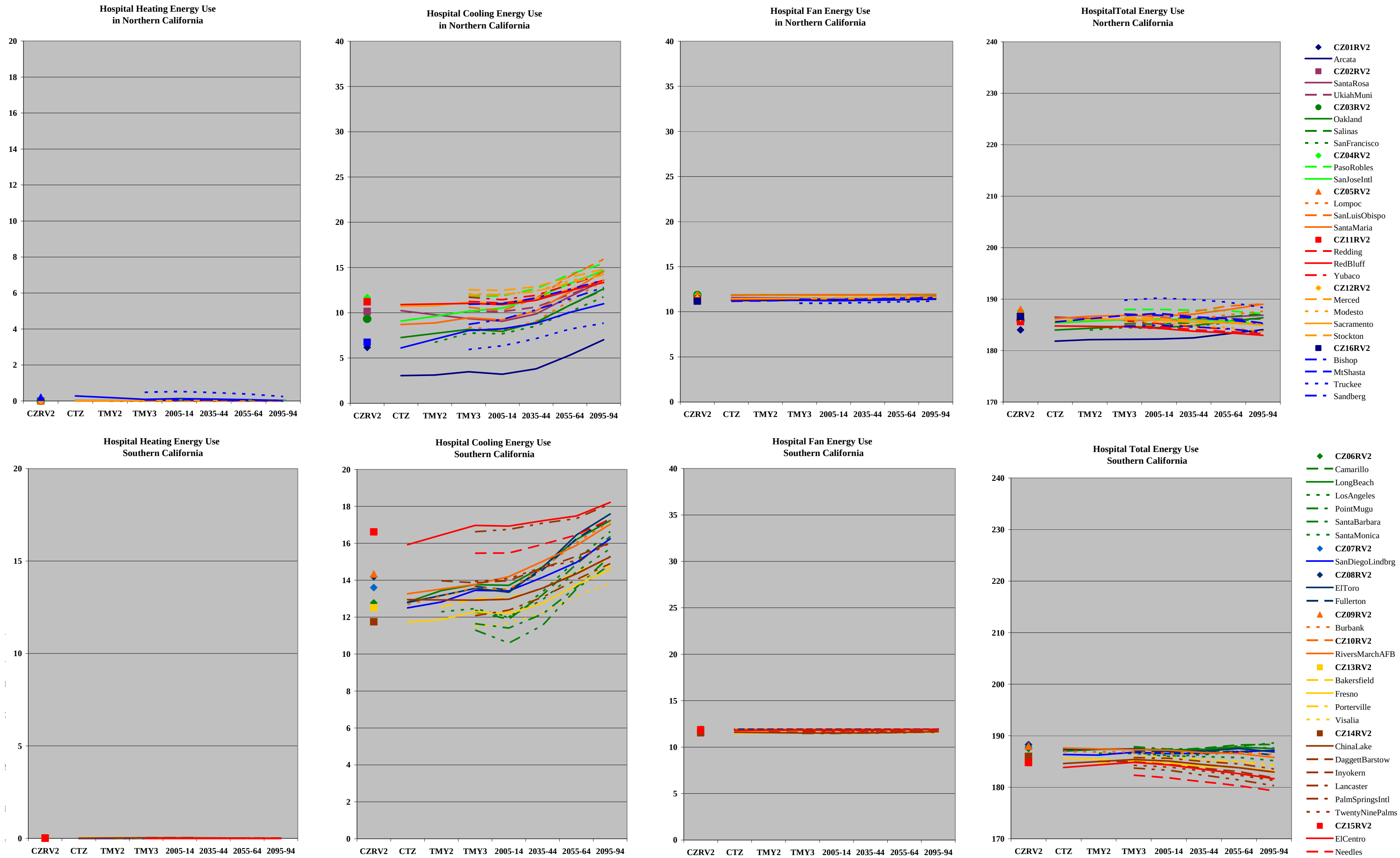
Medium Office Energy Use under the A1FI Scenario



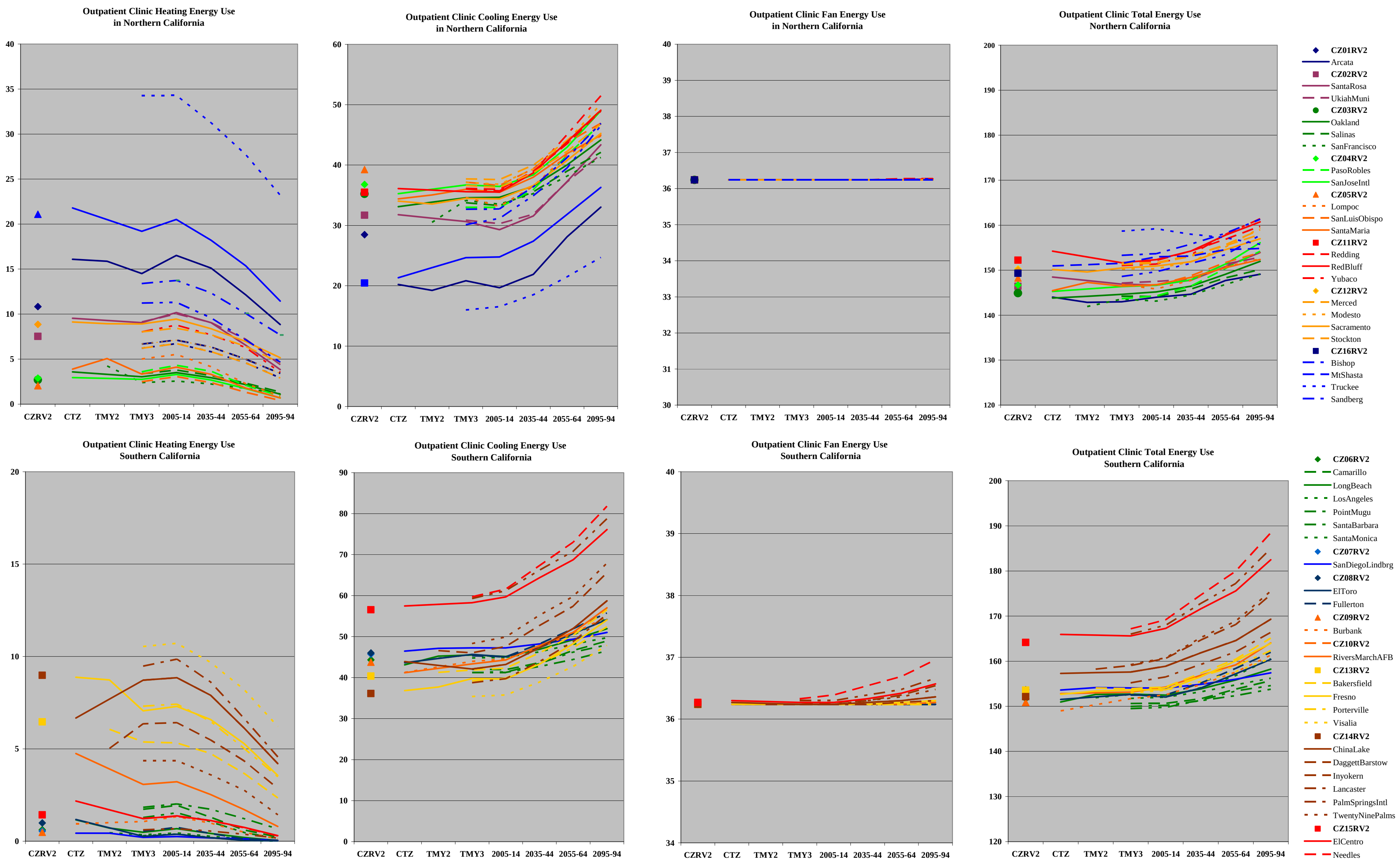
Small Office Energy Use Under the A1FI Scenario



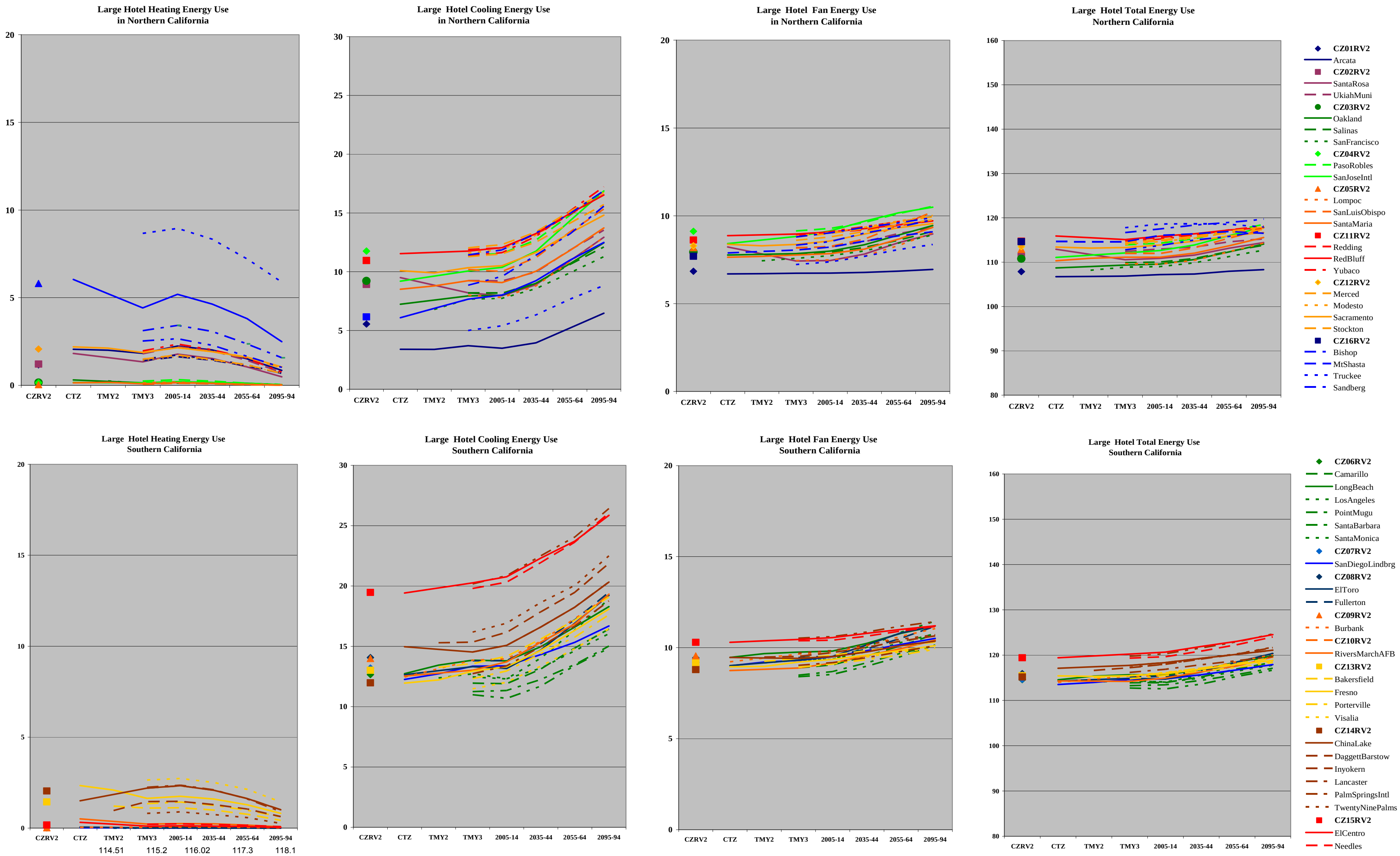
Hospital Energy Use Under the A1FI Scenario



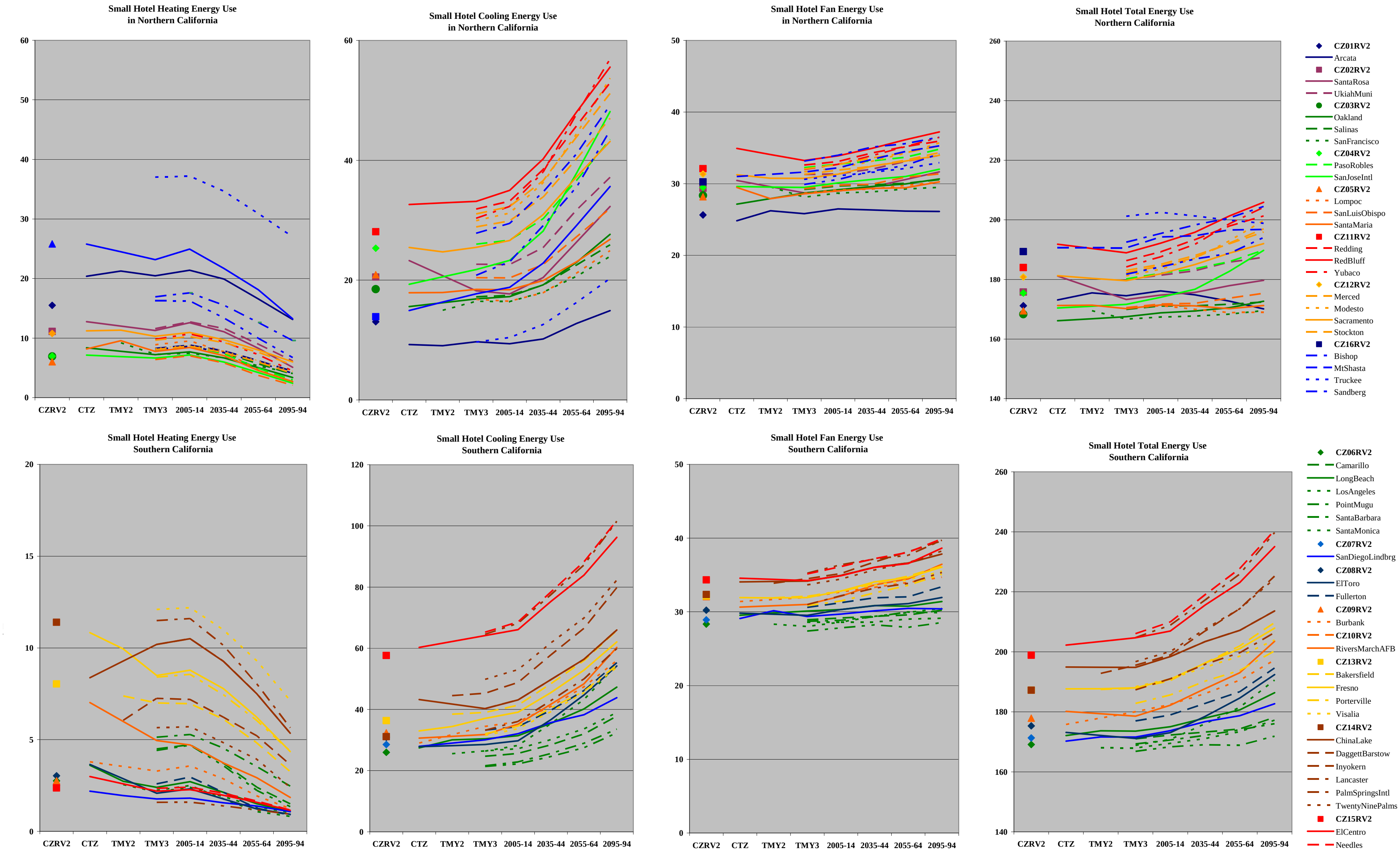
Outpatient Clinic Energy Use Under the A1FI Scenario



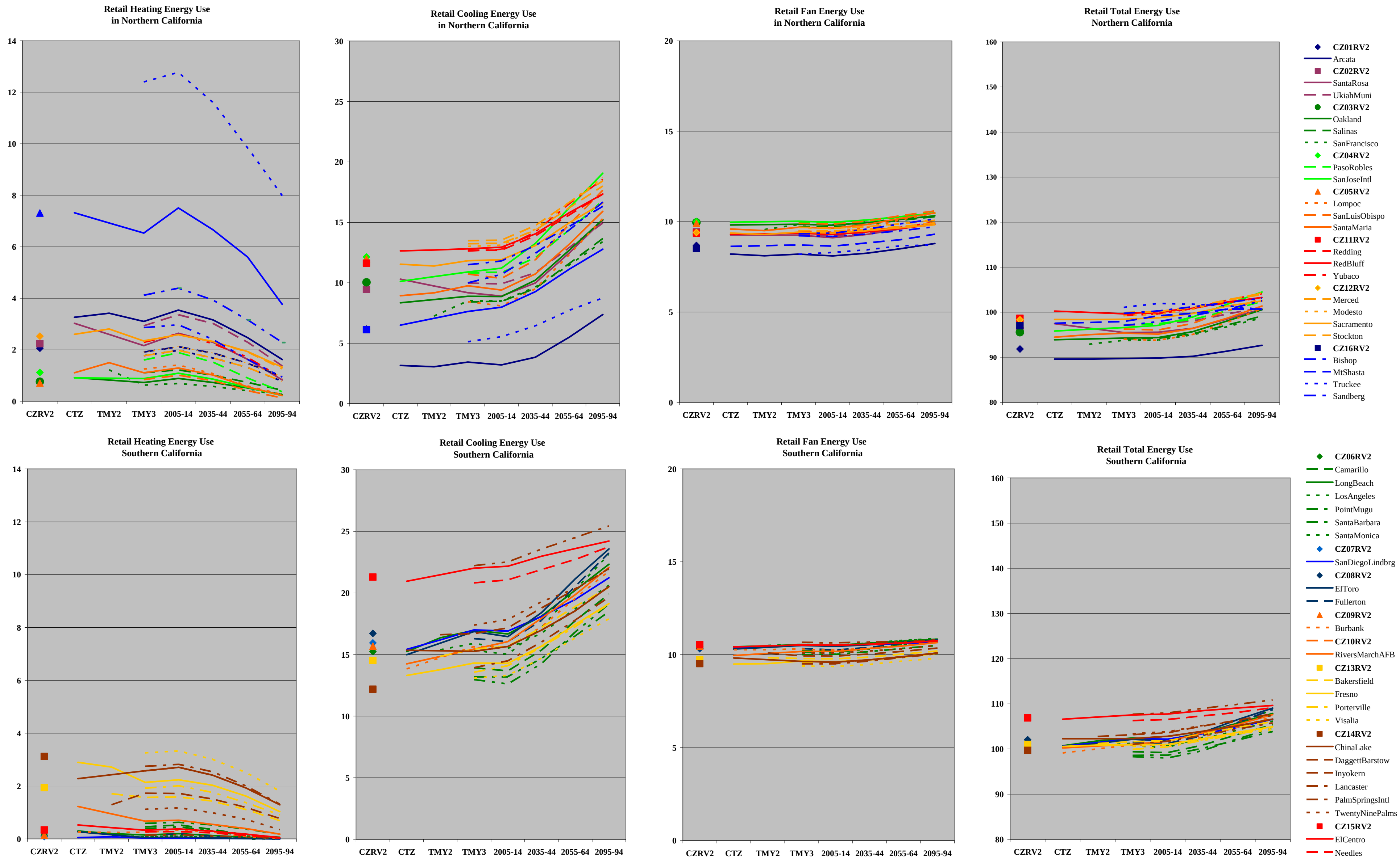
Large Hotel Energy Use Under the A1FI Scenario



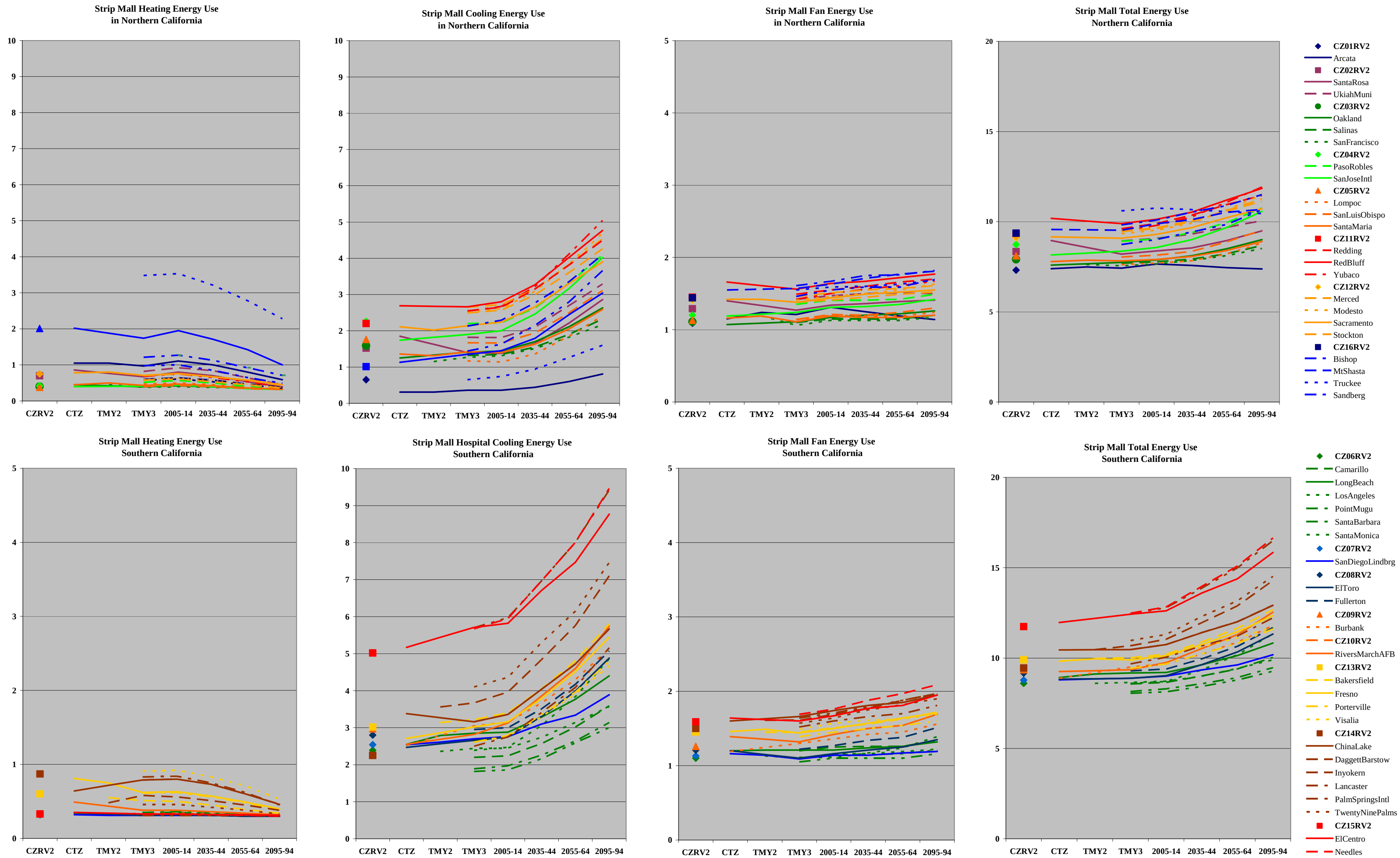
Small Hotel Energy Use Under A1FI Scenario



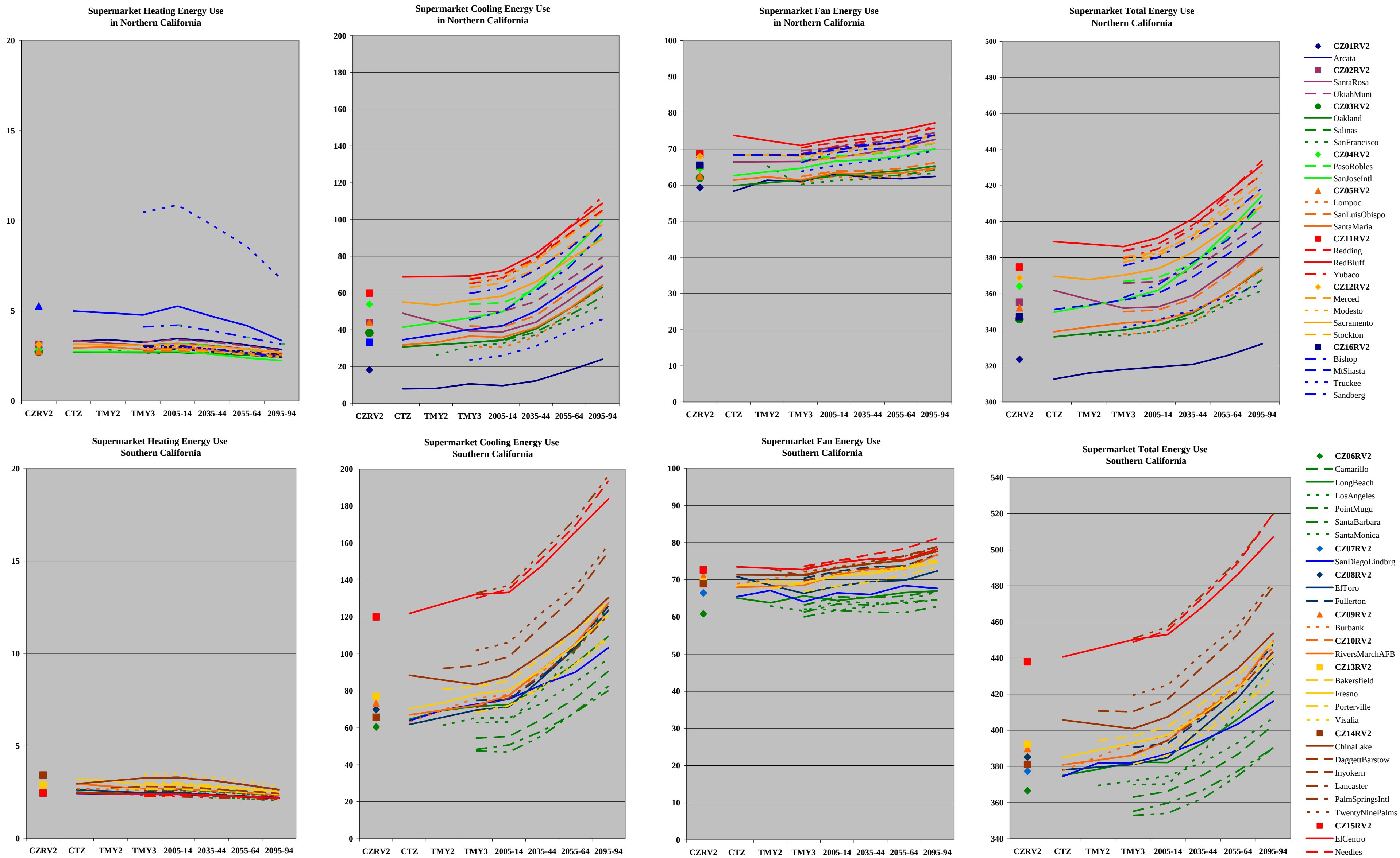
Retail Energy Use Under A1FI Scenario



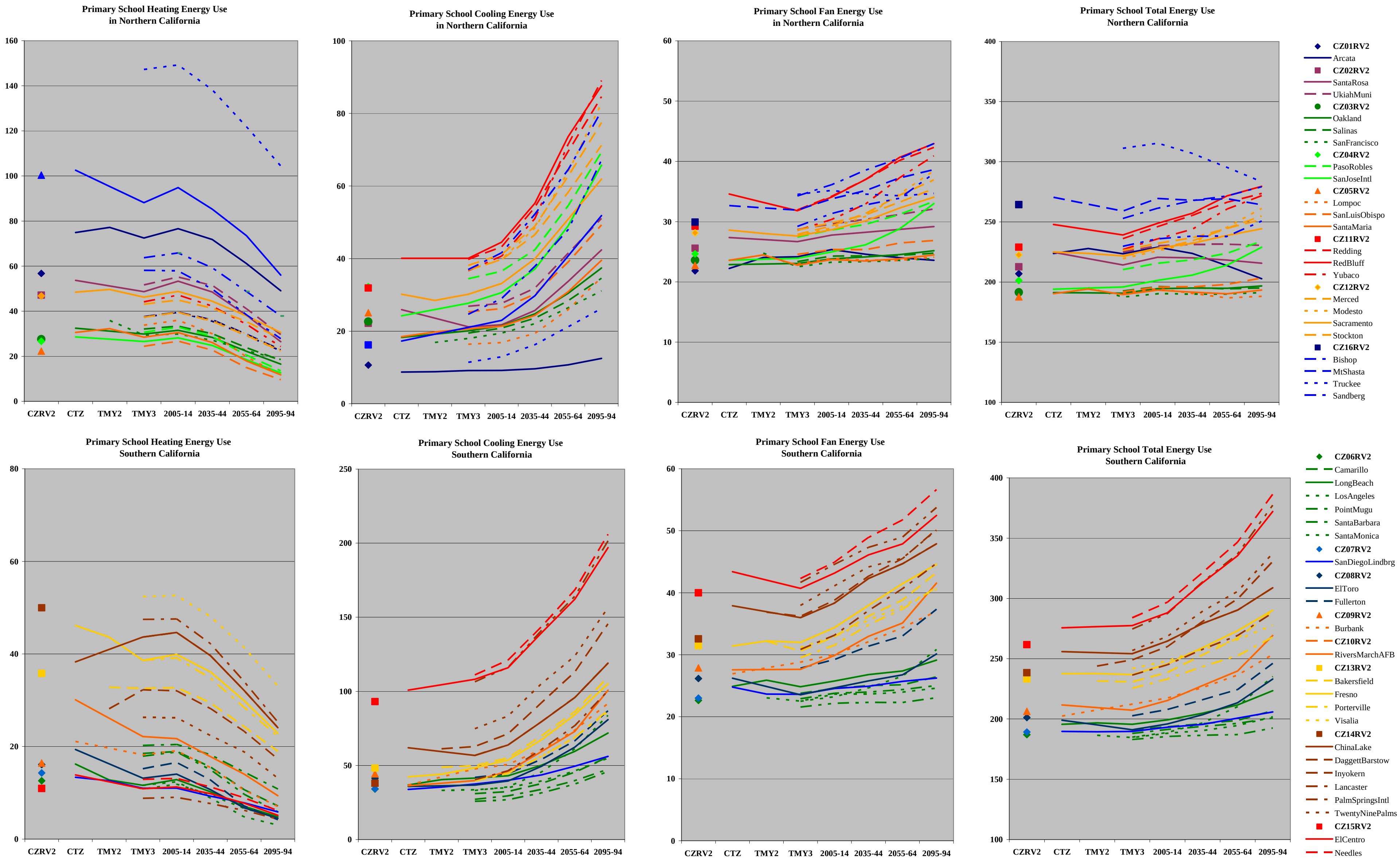
Strip Mall Energy Use Under A1FI Scenario



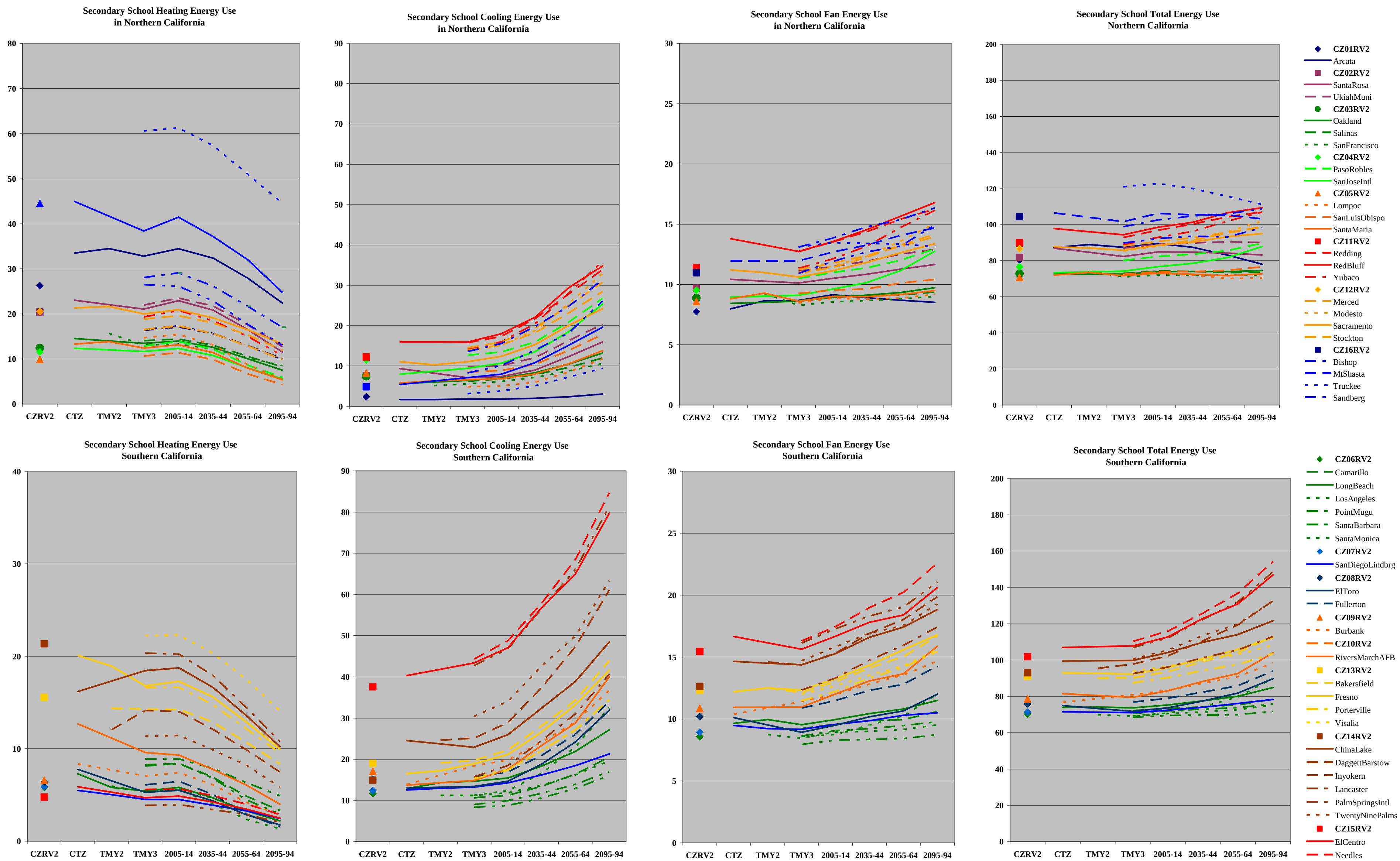
Supermarket Energy Use Under A1FI Scenario



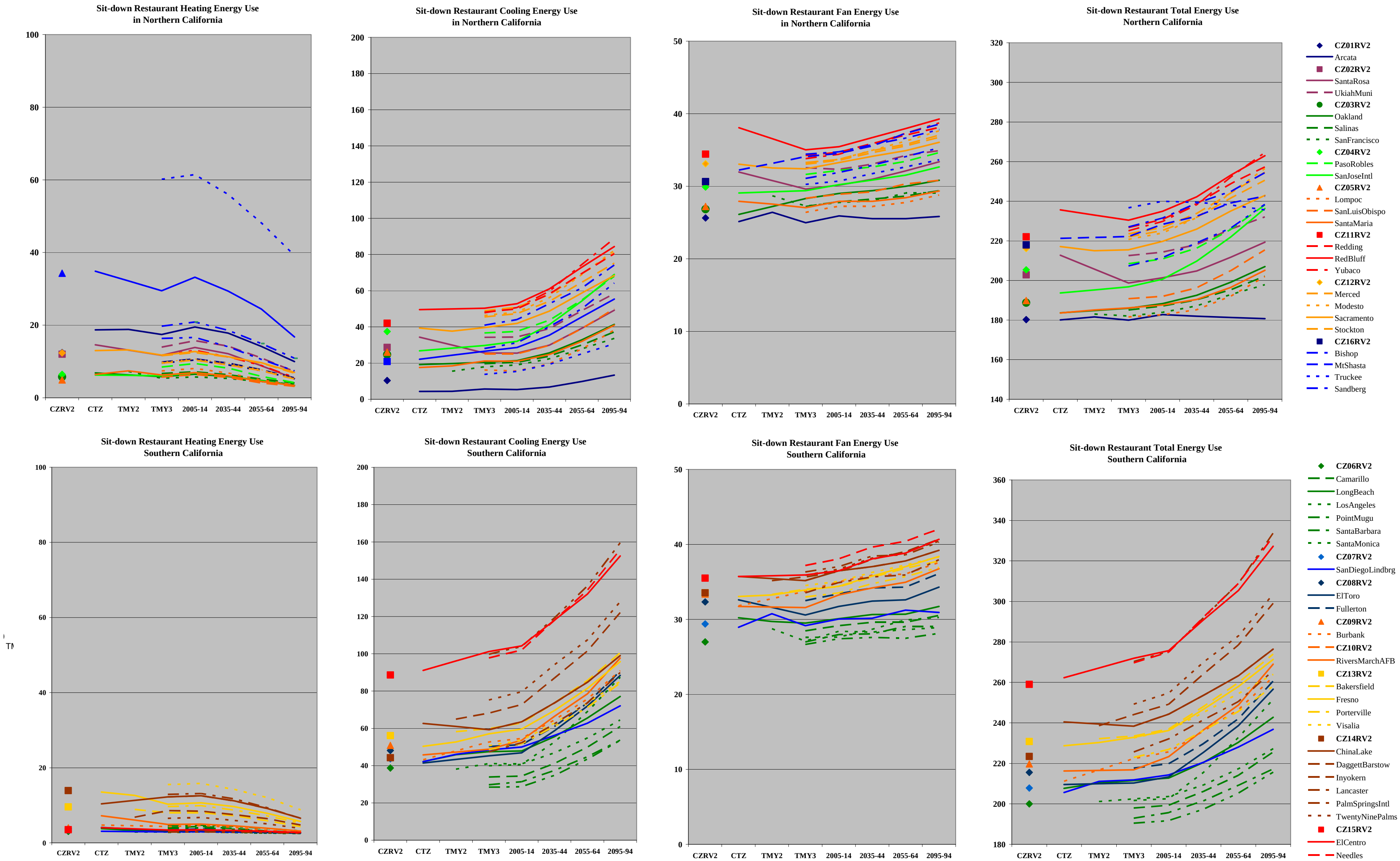
Primary School Energy Use Under A1FI Scenario



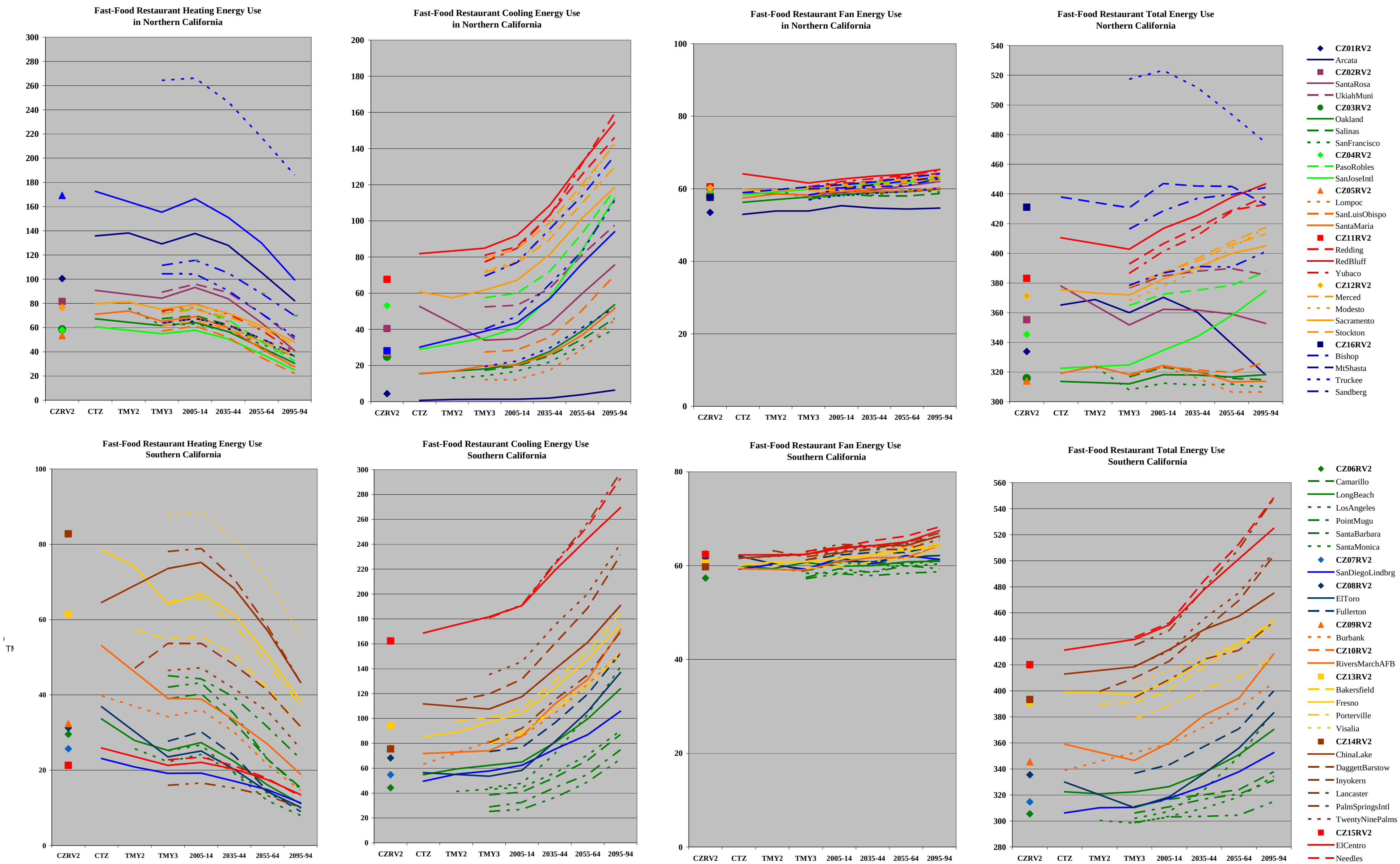
Secondary School Energy Use Under A1FI Scenario



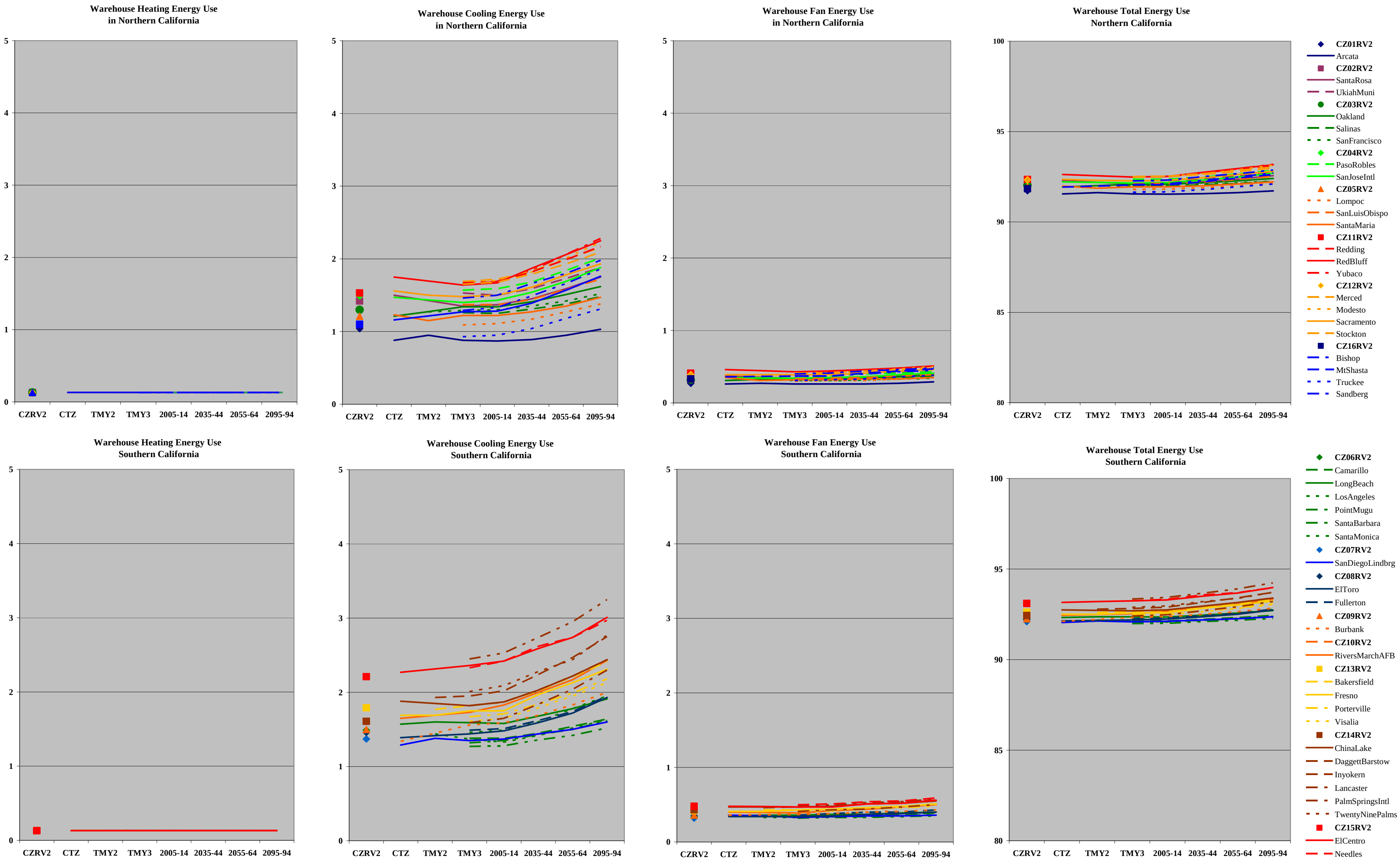
Sit-down Restaurant Energy Use Under A1FI Scenario



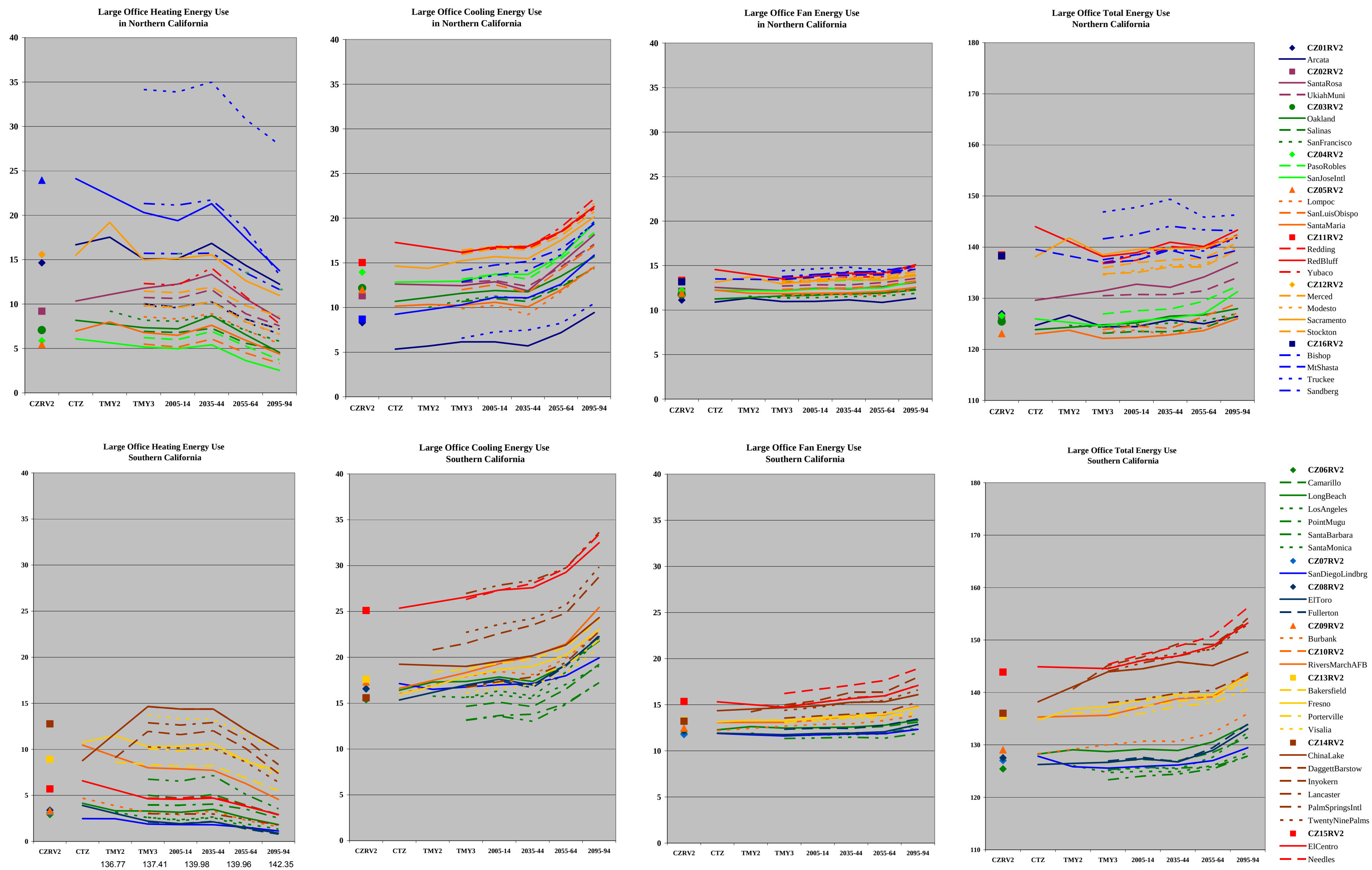
Fast-Food Restaurant Energy Use Under A1FI Scenario



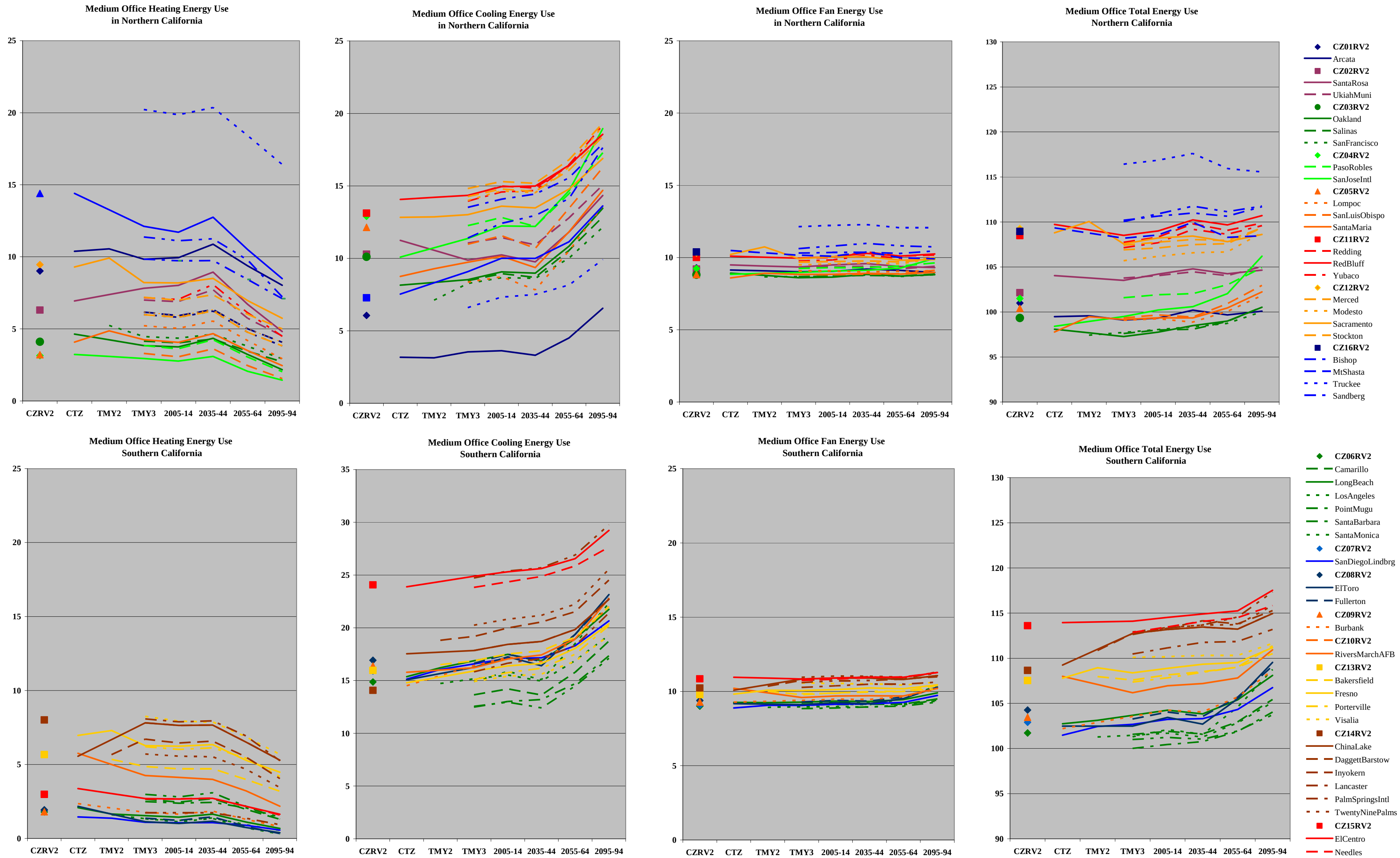
Warehouse Energy Use Under A1FI Scenario



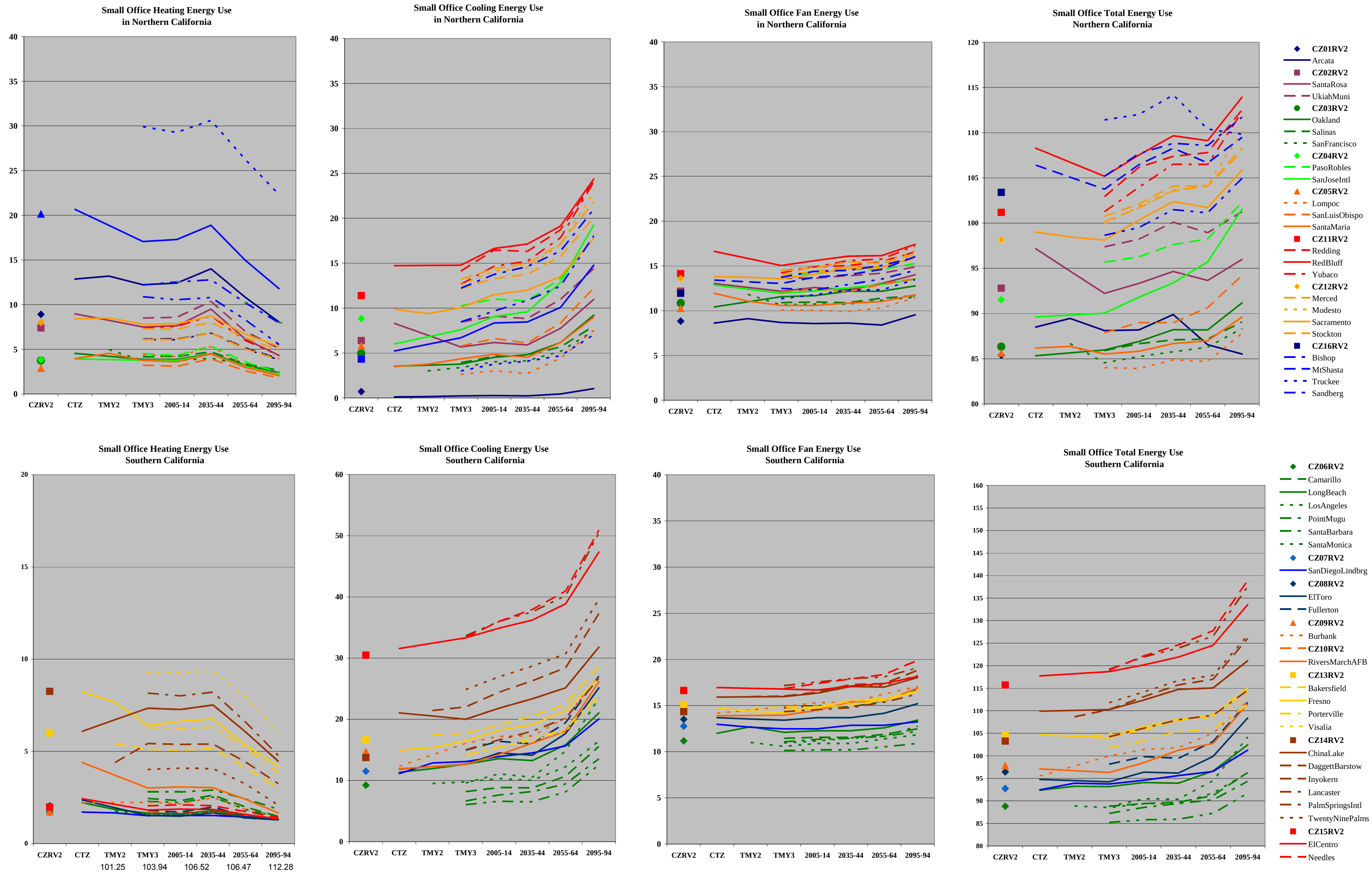
Large Office Energy Use Under the A2 Scenario



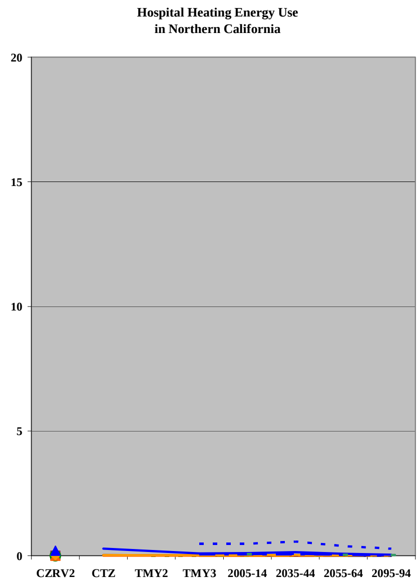
Medium Office Energy Use Under the A2 Scenario

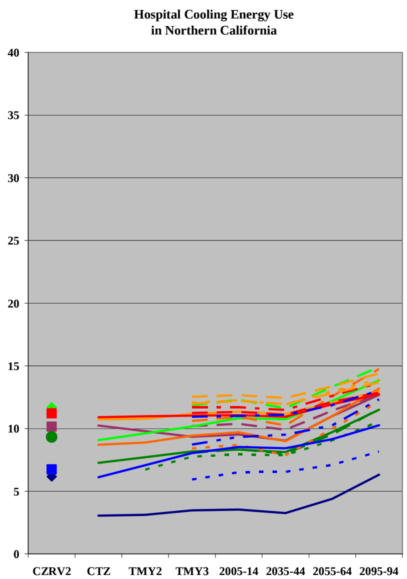


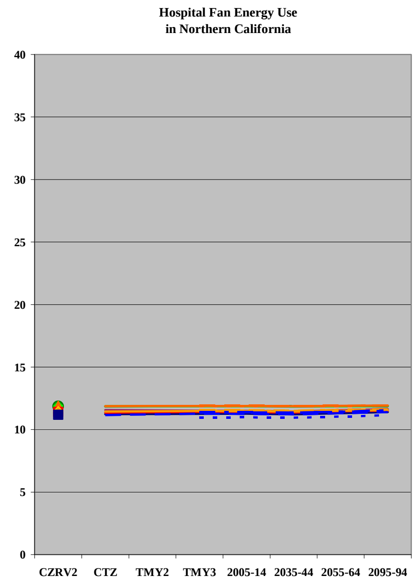
Small Office Energy Use Under the A2 Scenario

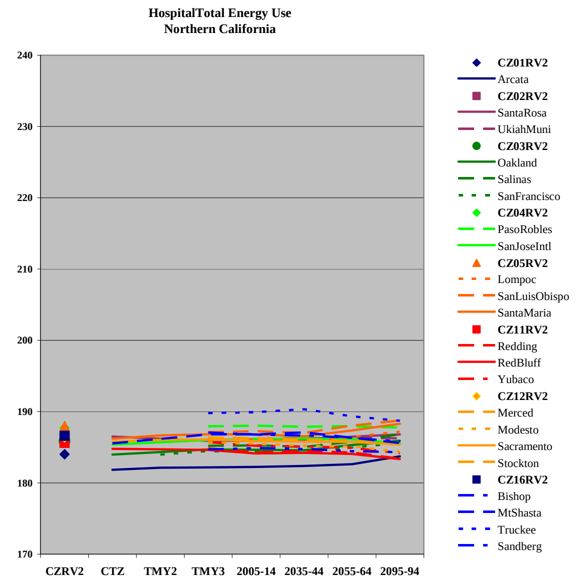


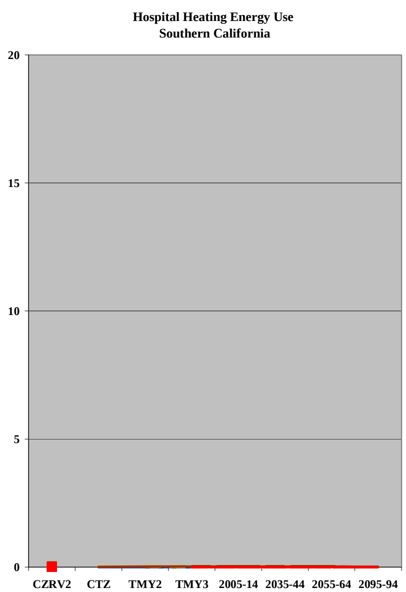
Hospital Energy Use Under the A2 Scenario

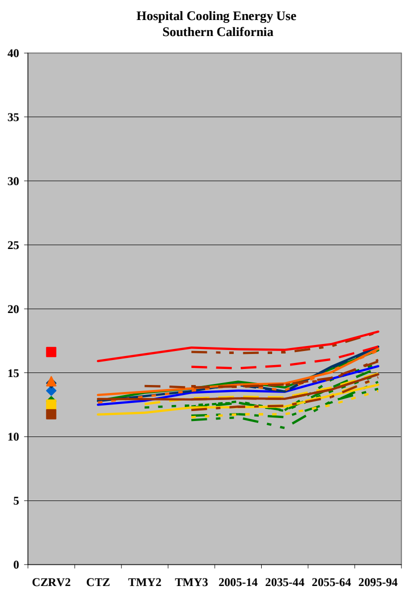


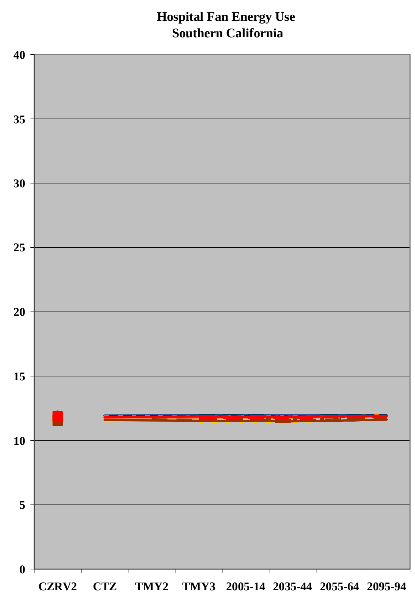


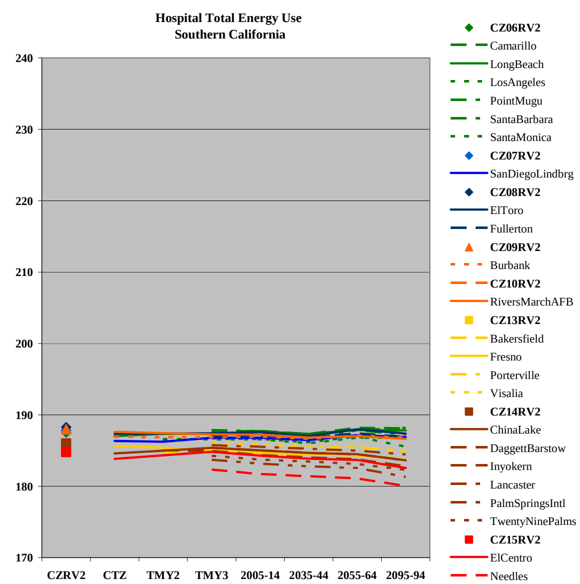




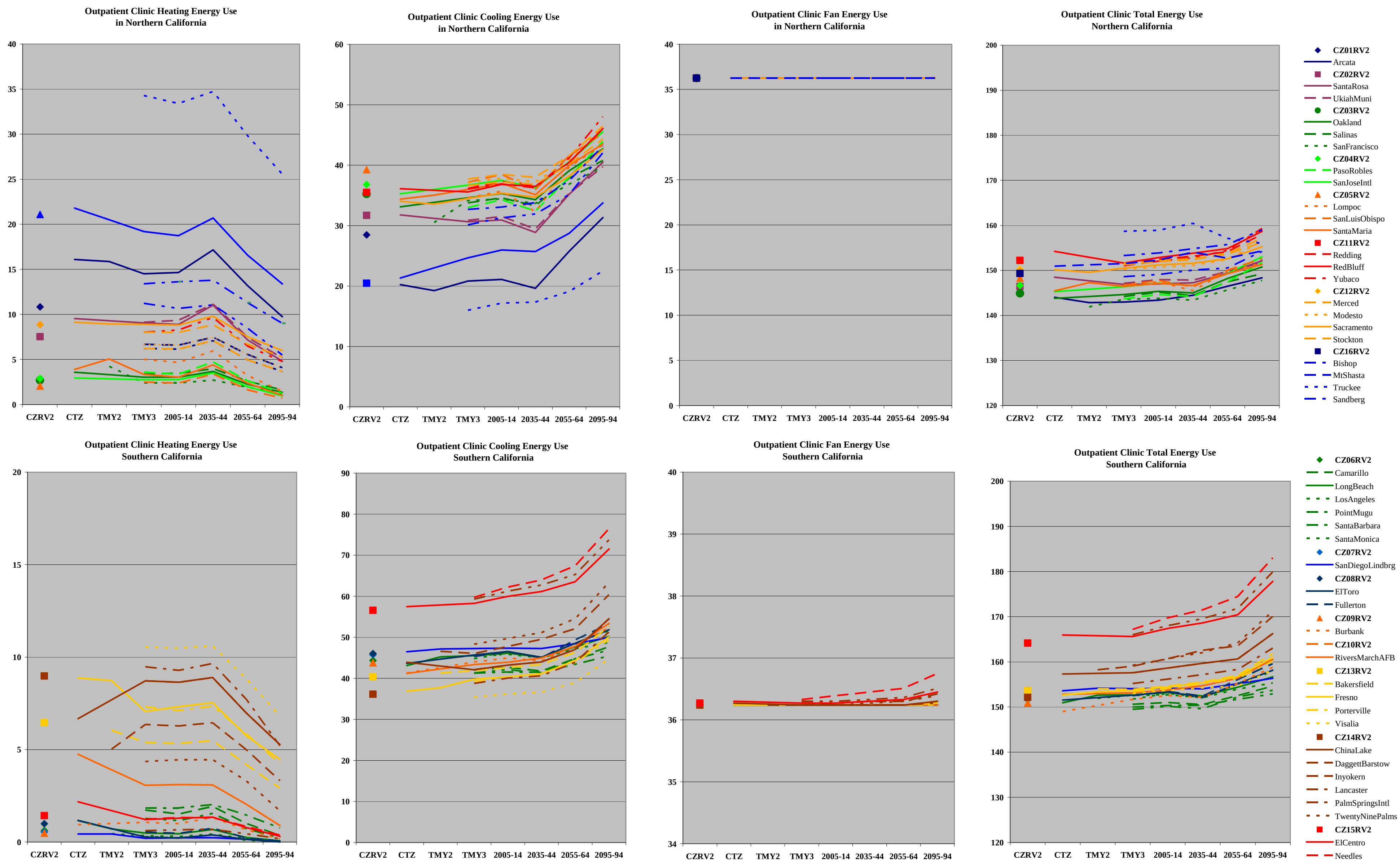




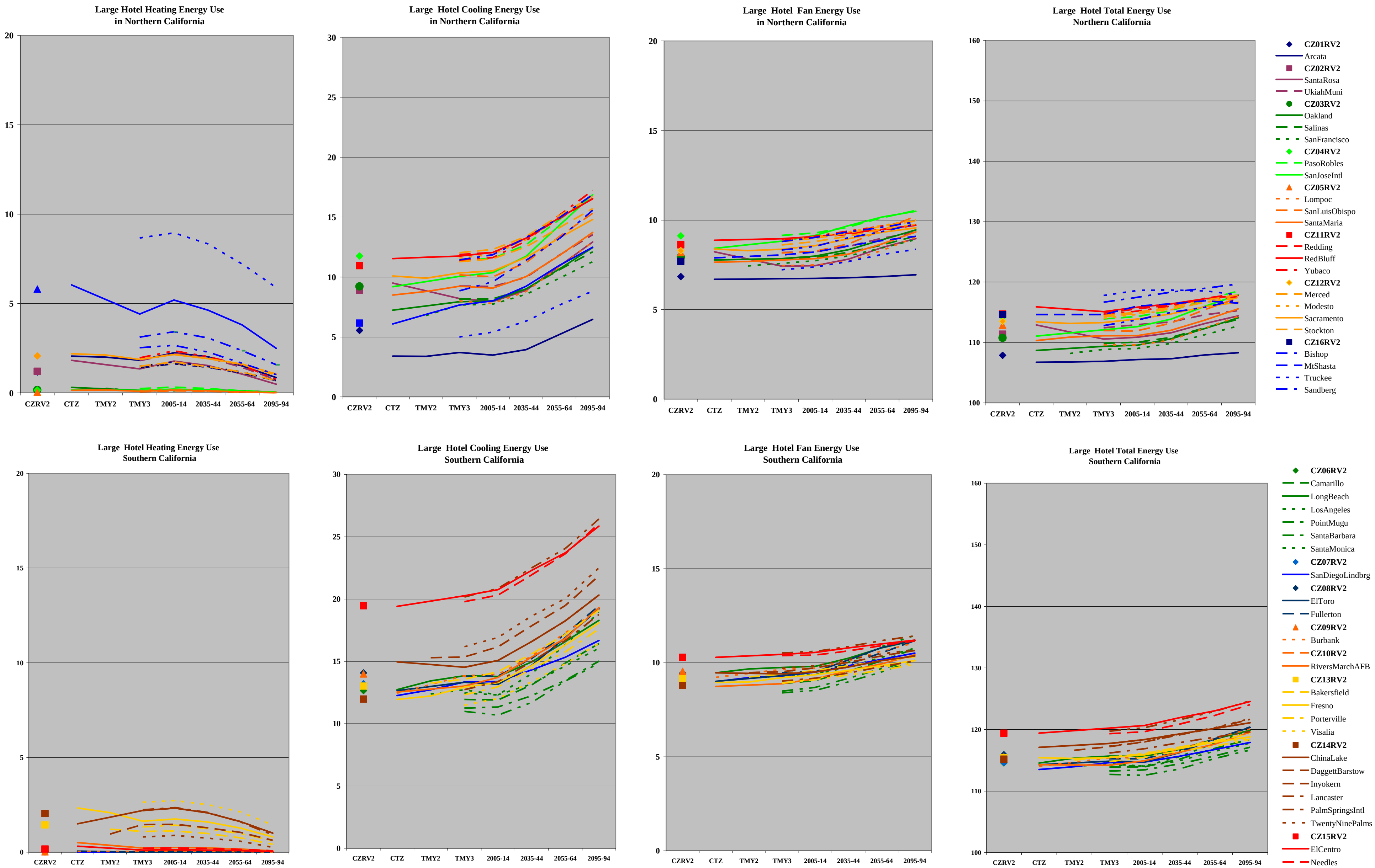




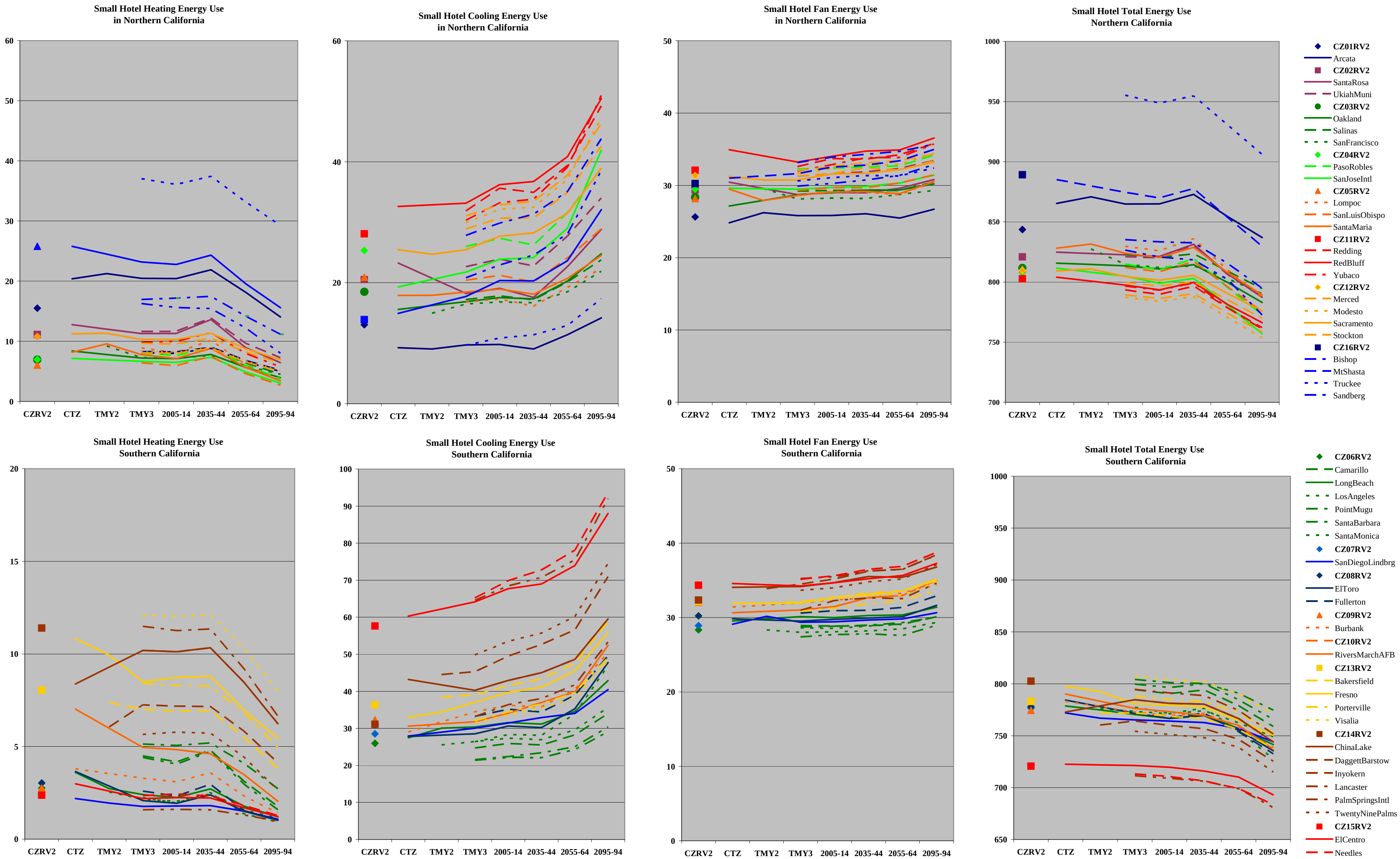
Outpatient Clinic Energy Use Under the A2 Scenario



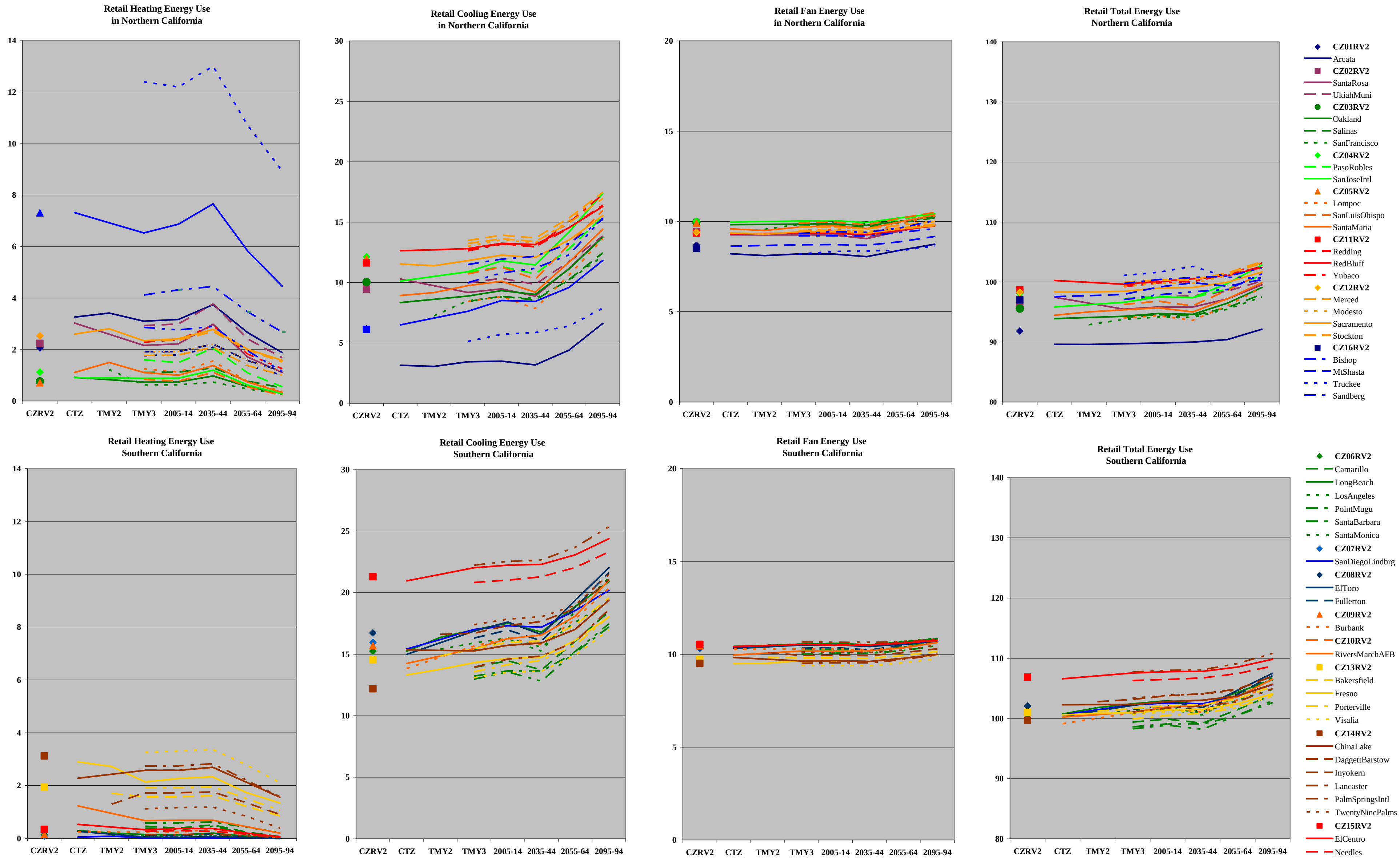
Large Hotel Energy Use Under the A2 Scenario



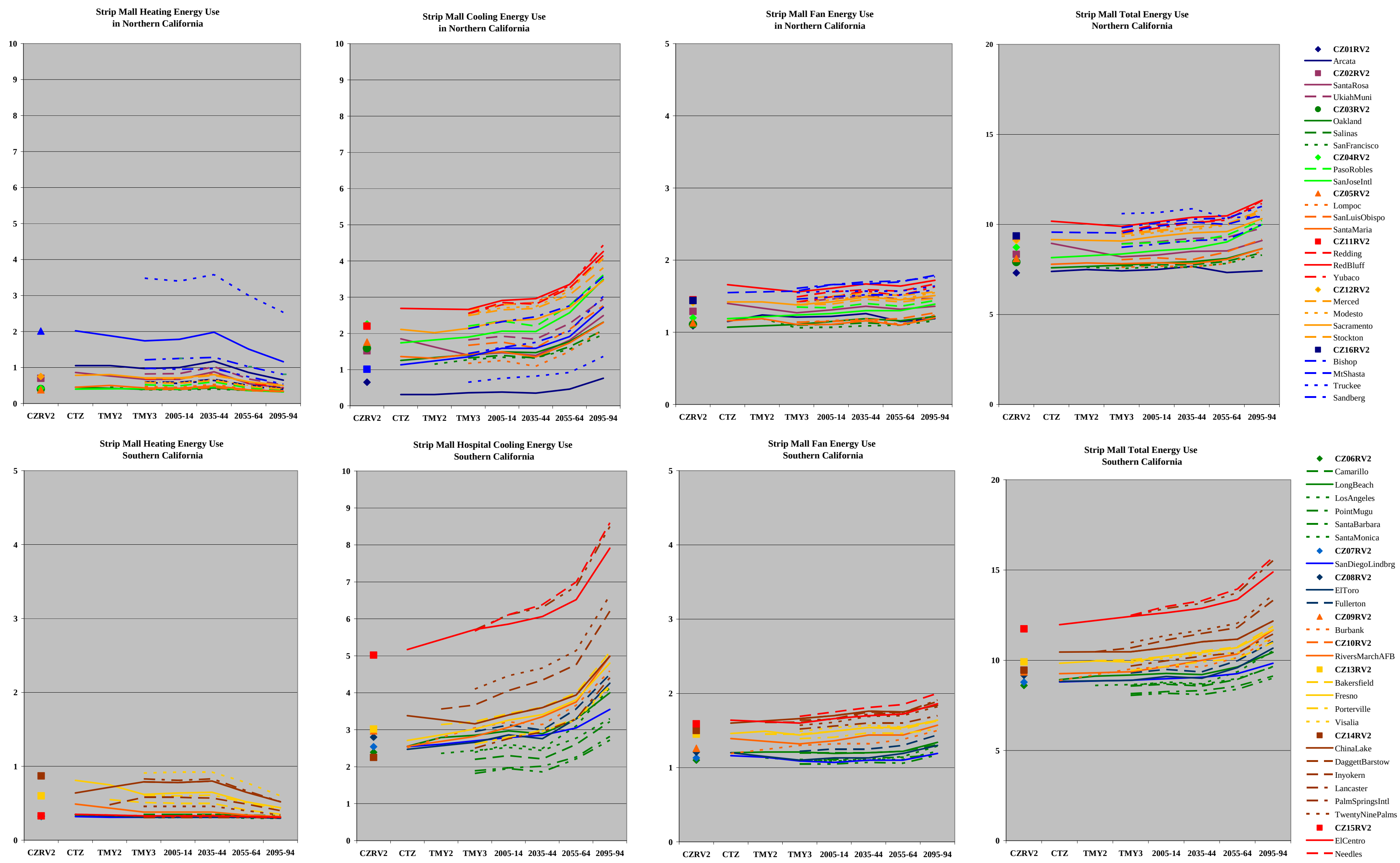
Small Hotel Energy Use Under A2 Scenario



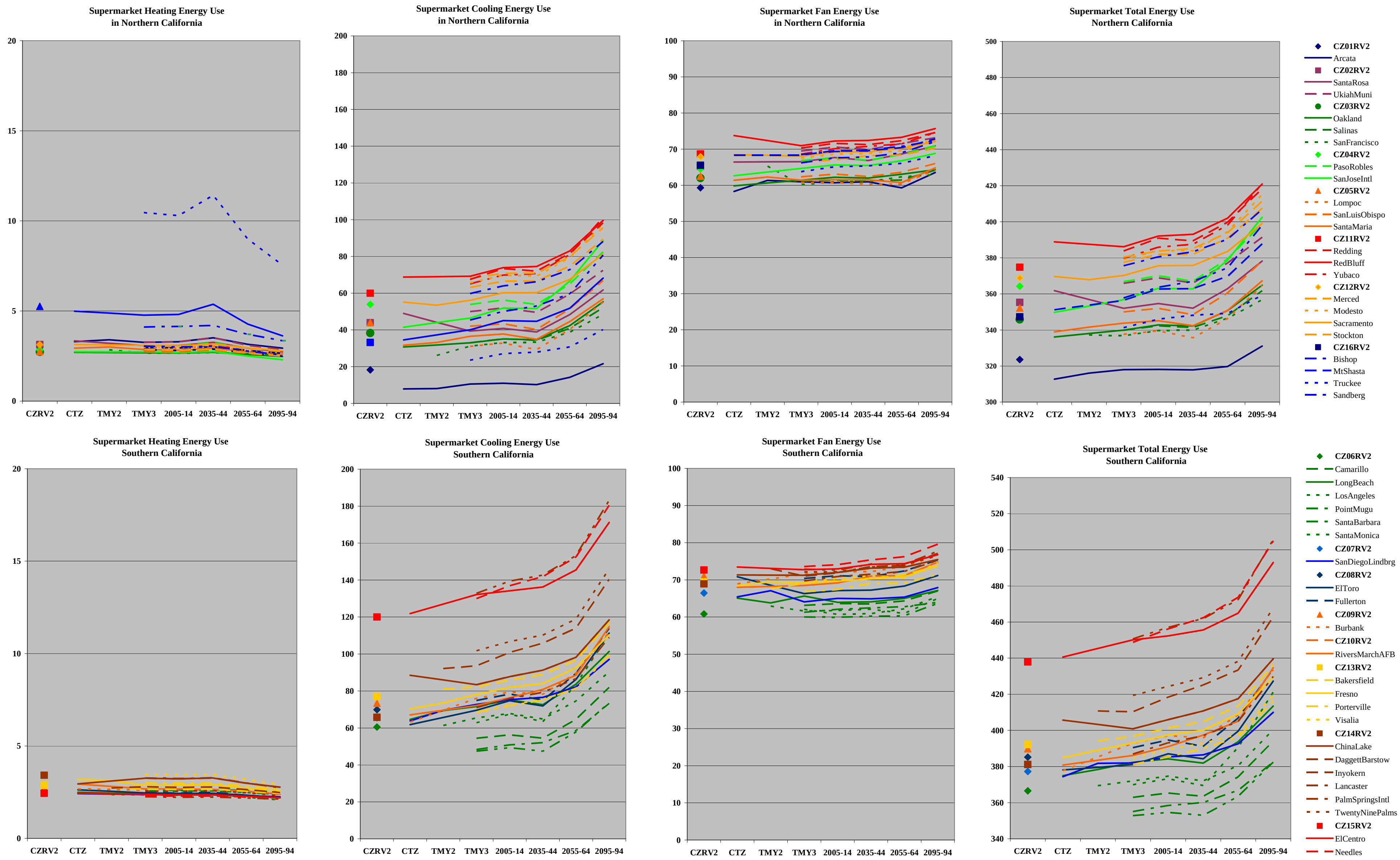
Retail Energy Use Under A2 Scenario



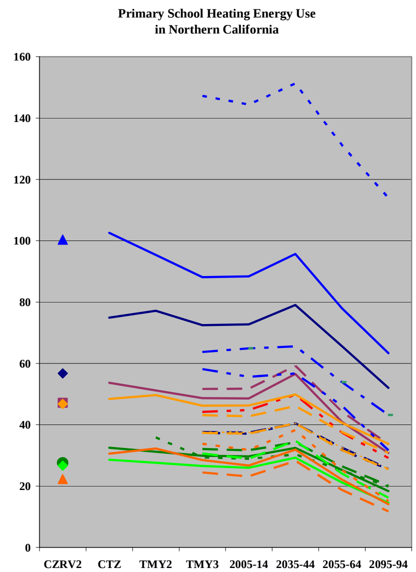
Strip Mall Energy Use Under A2 Scenario

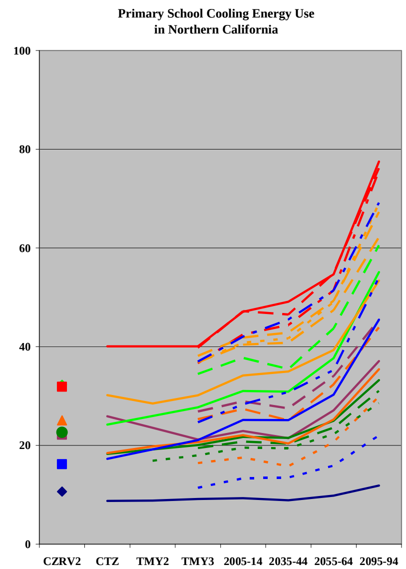


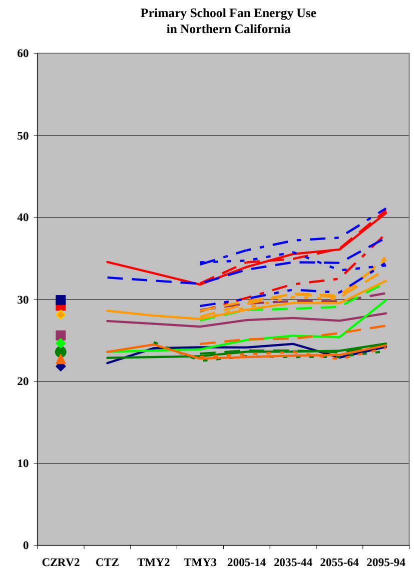
Supermarket Energy Use Under A2 Scenario

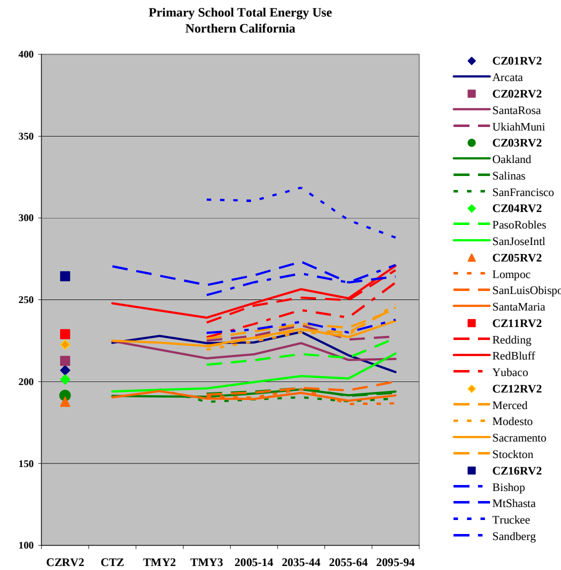


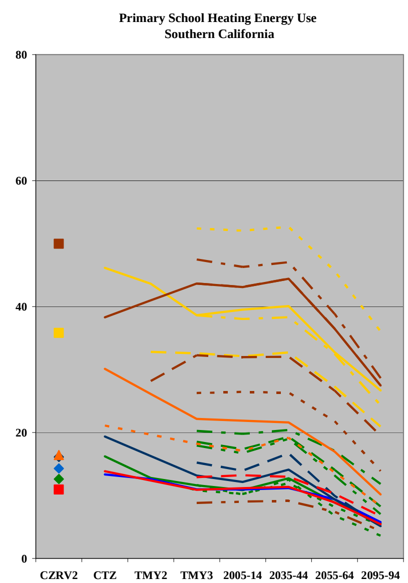
Primary School Energy Use Under A2 Scenario

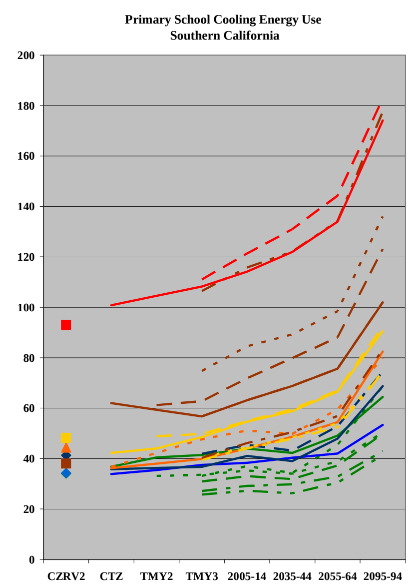


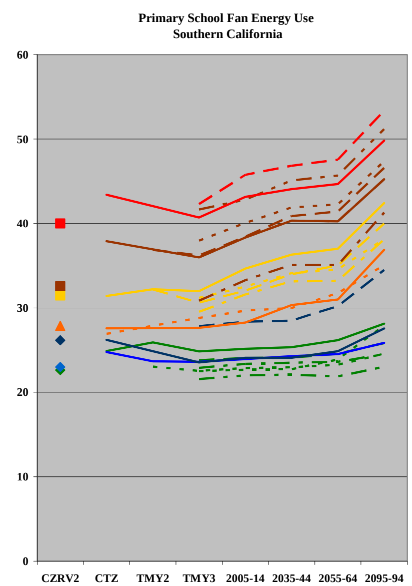


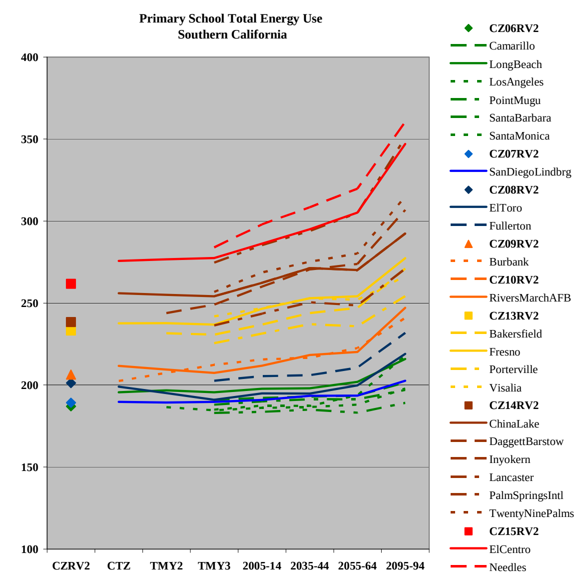




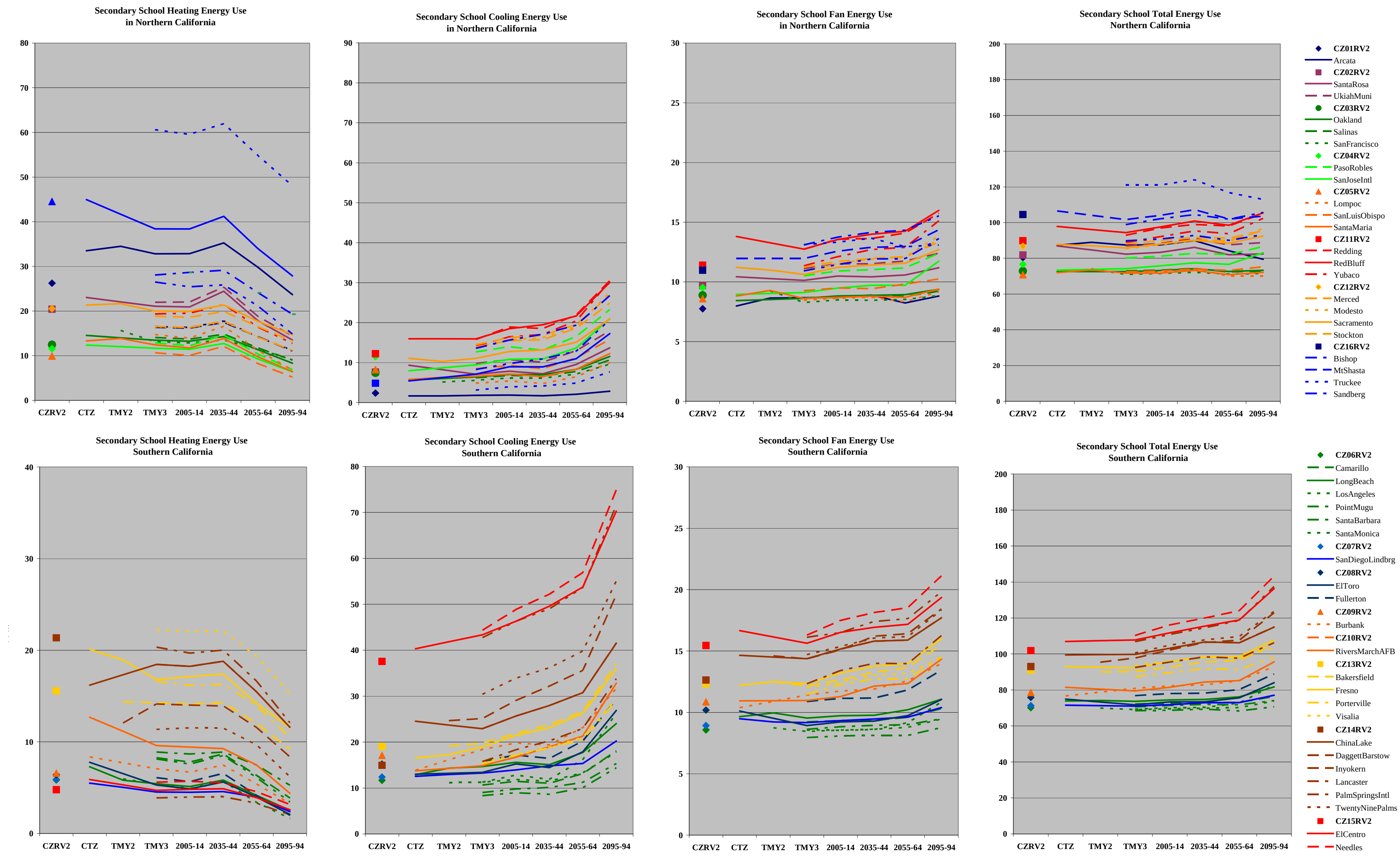




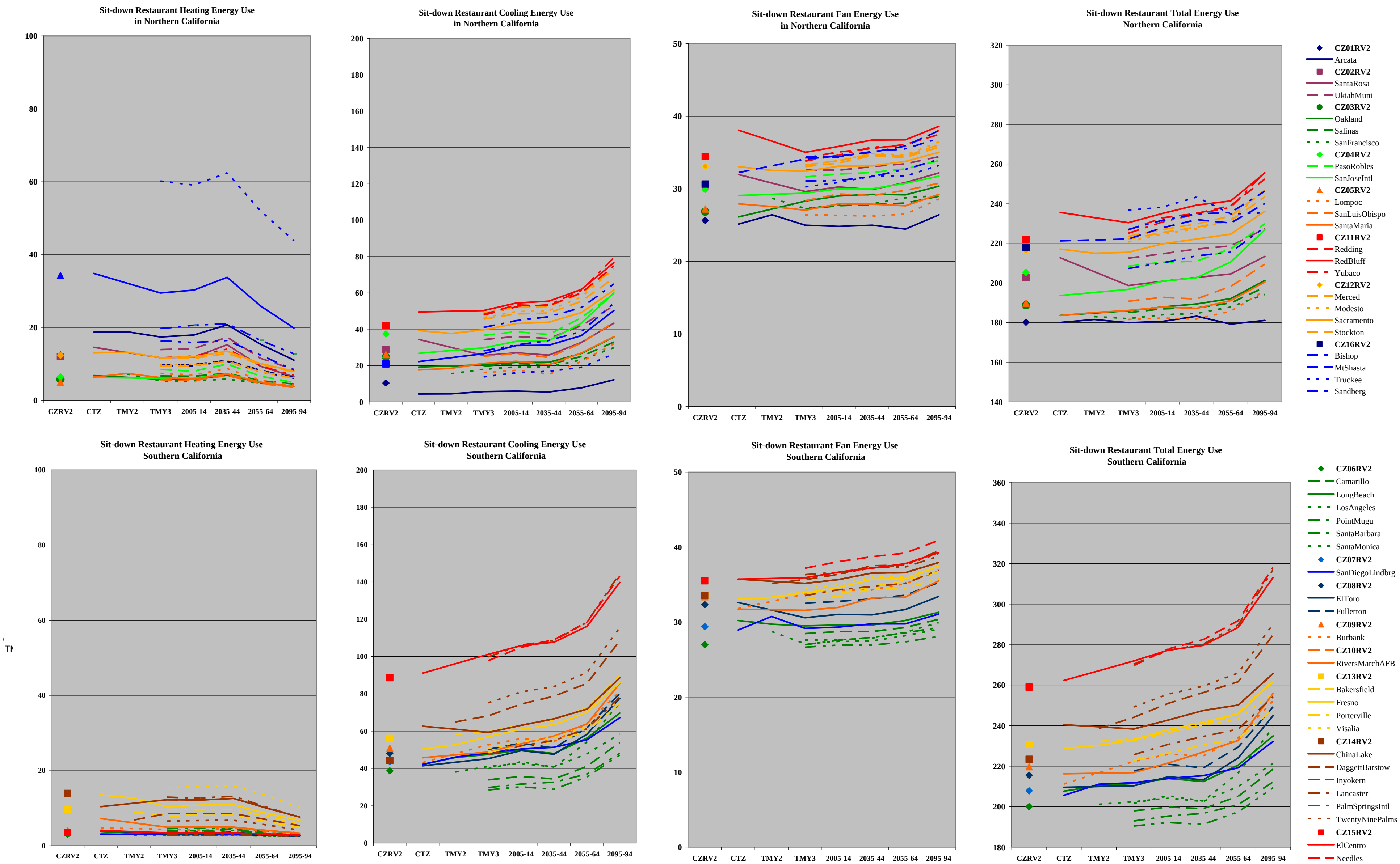




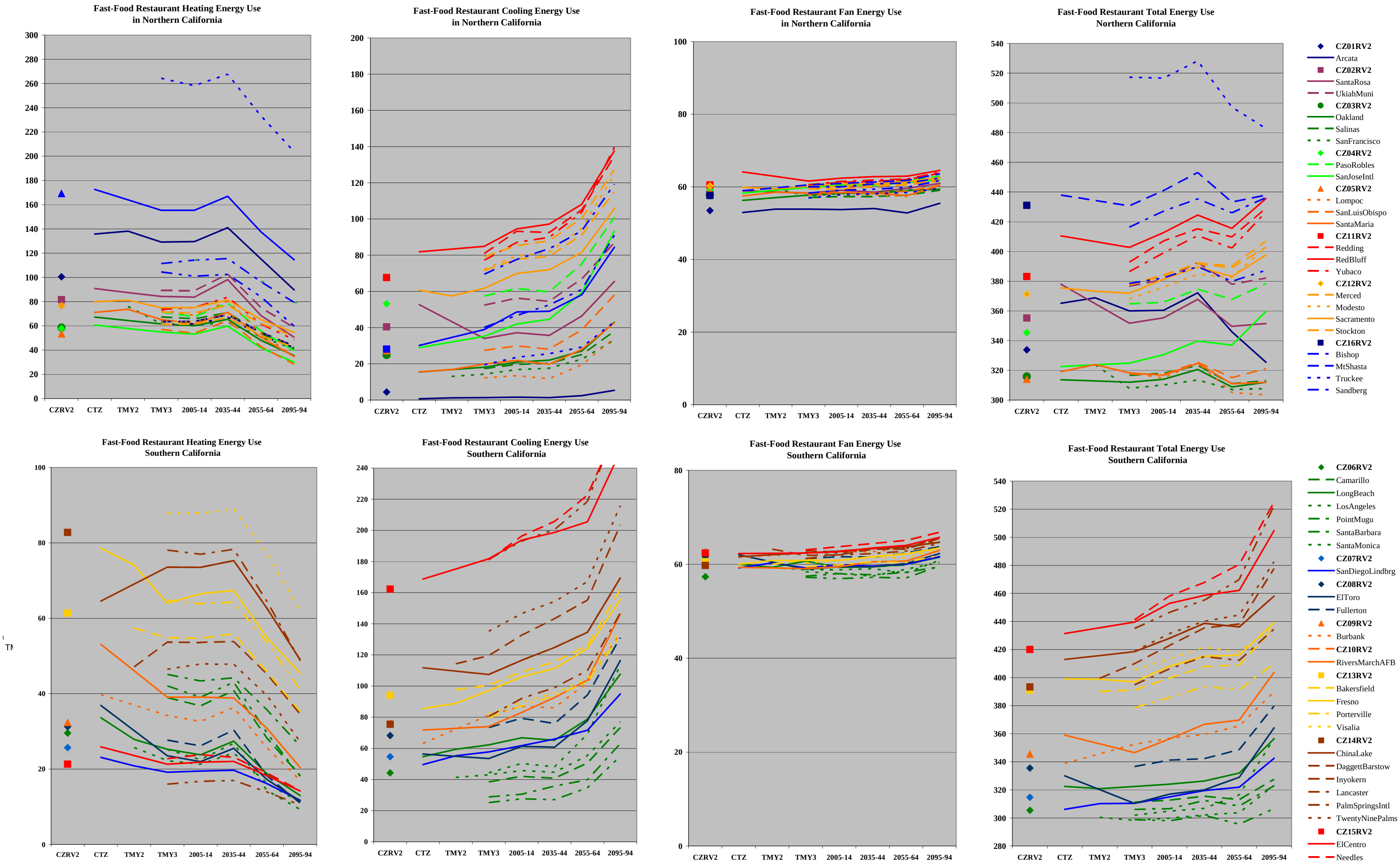
Secondary School Energy Use Under A2 Scenario



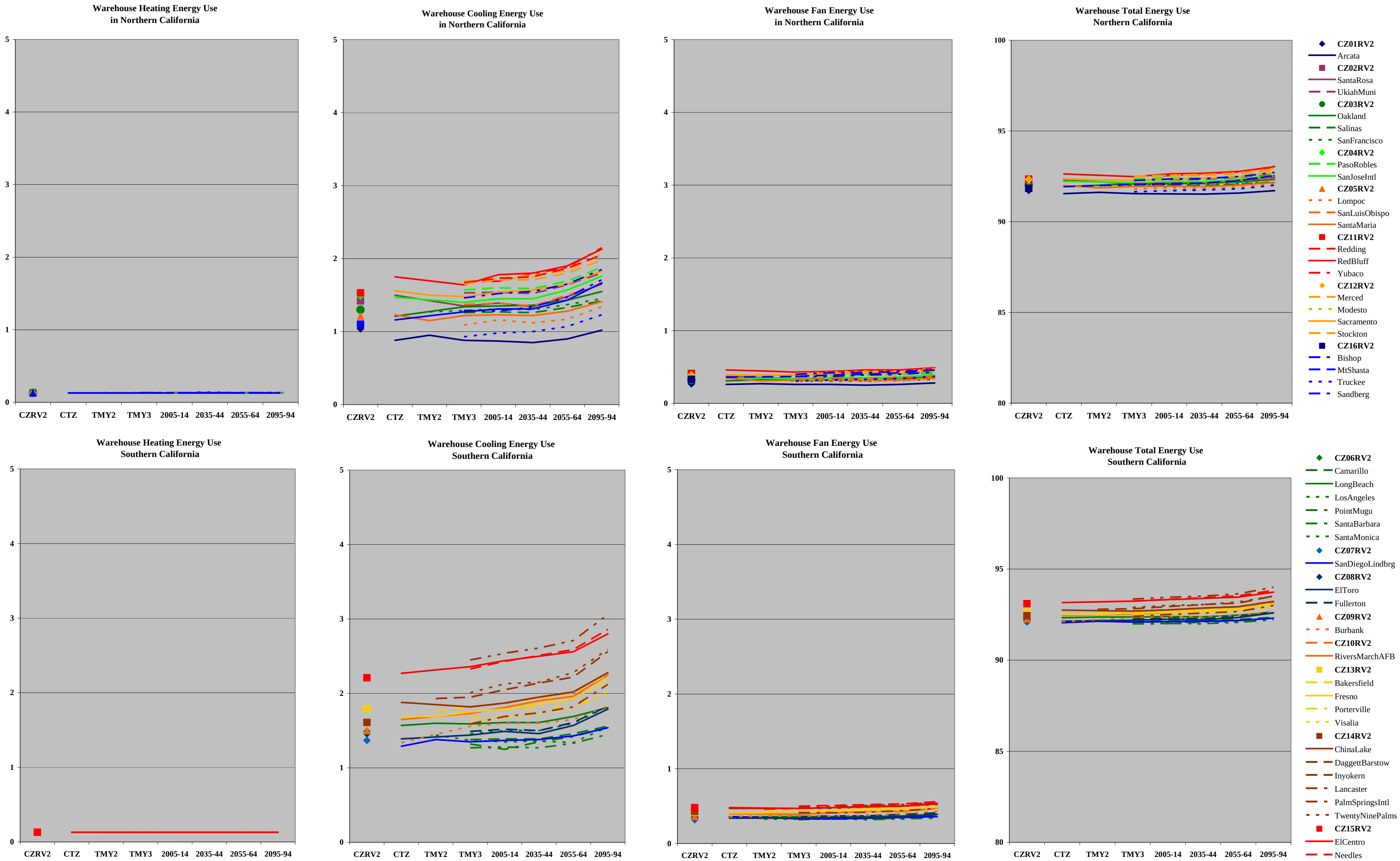
Sit-down Restaurant Energy Use Under A2 Scenario



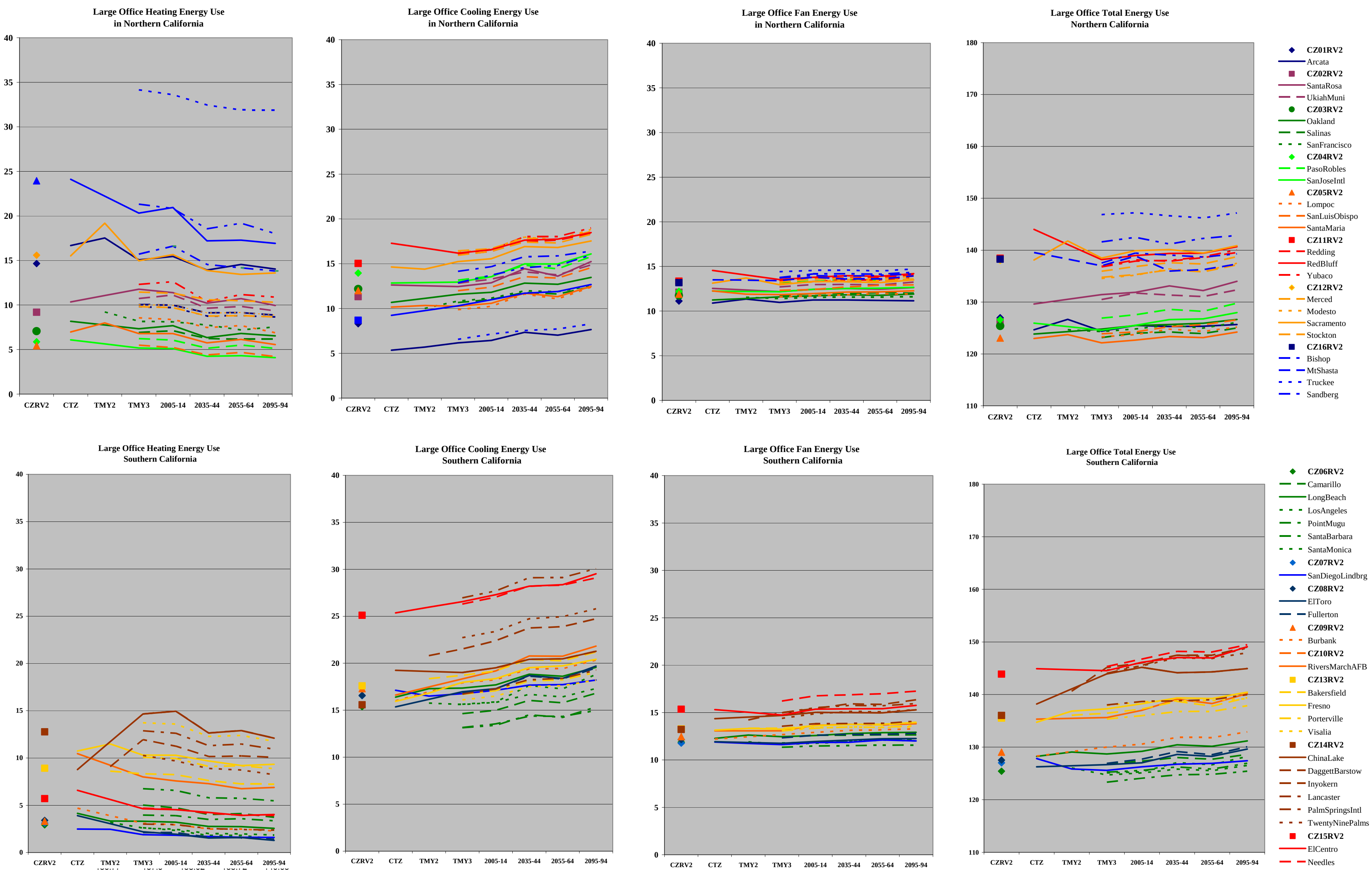
Fast-Food Restaurant Energy Use Under A2 Scenario



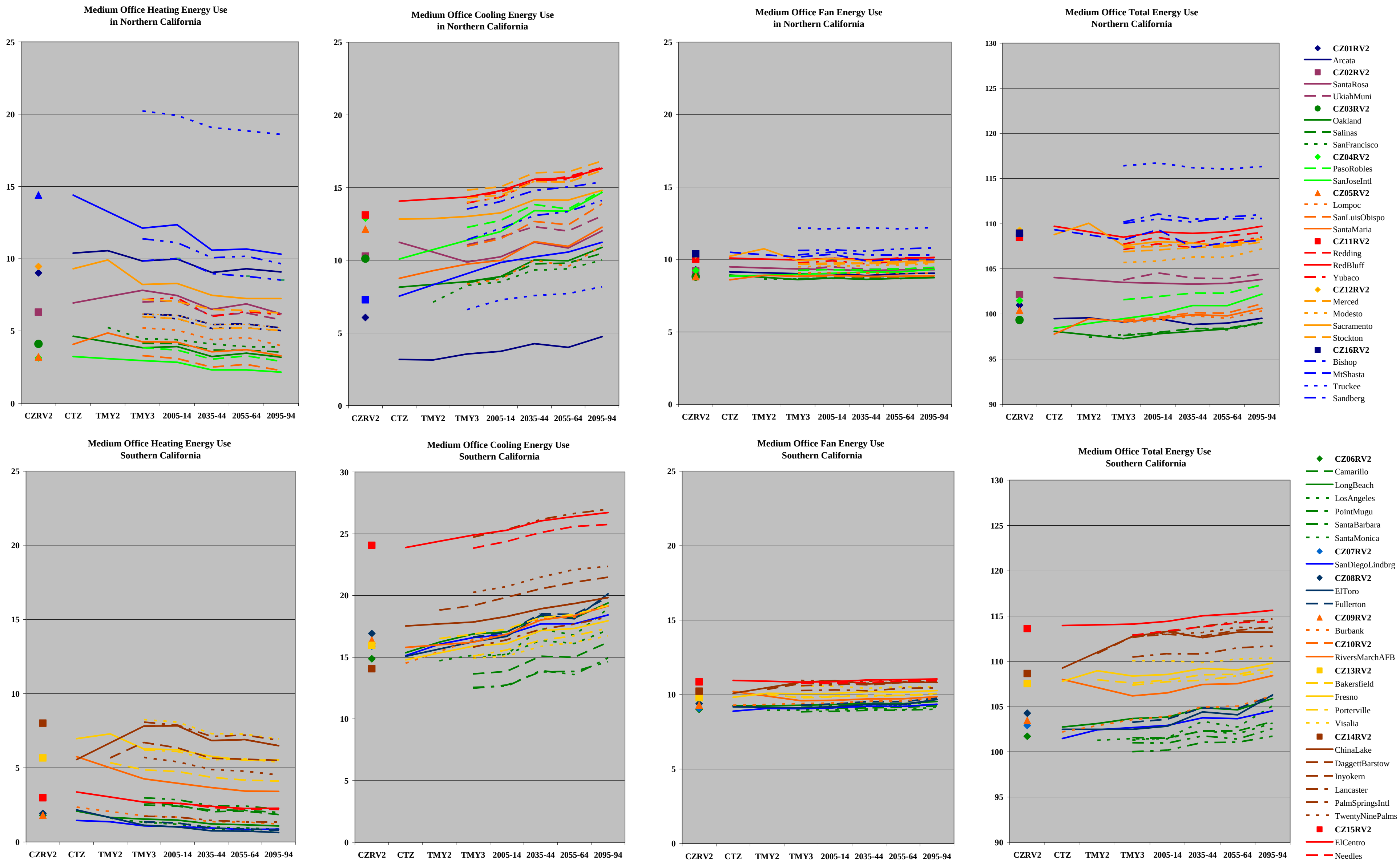
Warehouse Energy Use Under A2 Scenario



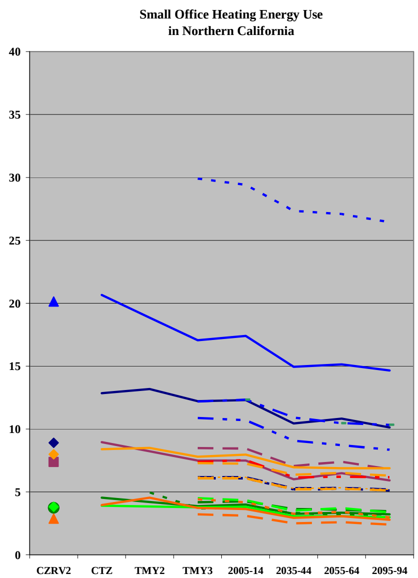
Large Office Energy Use Under the B1 Scenario

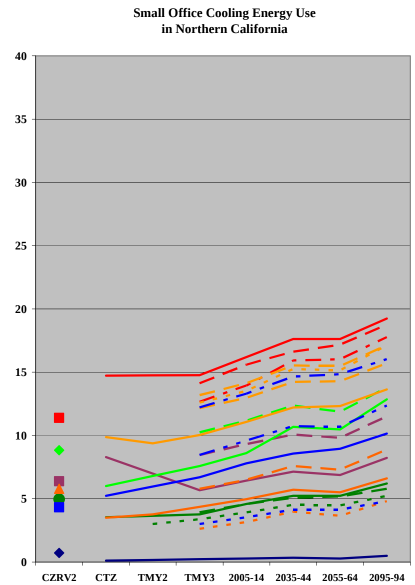


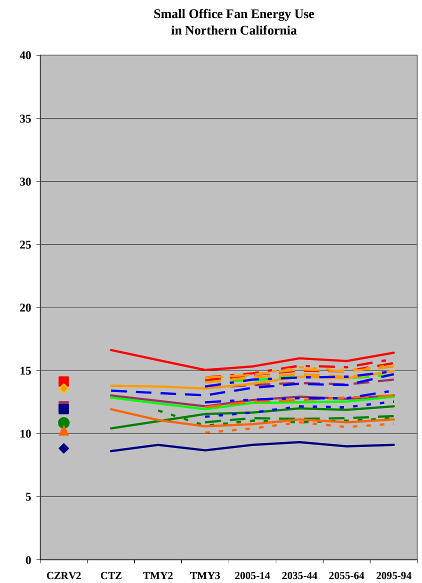
Medium Office Energy Use Under the B1 Scenario

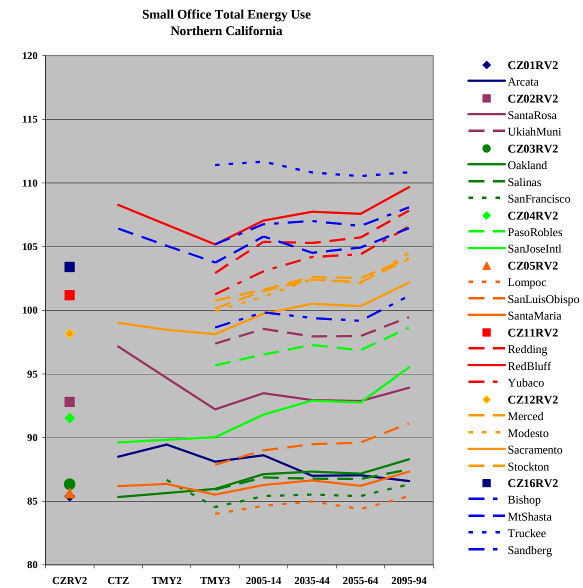


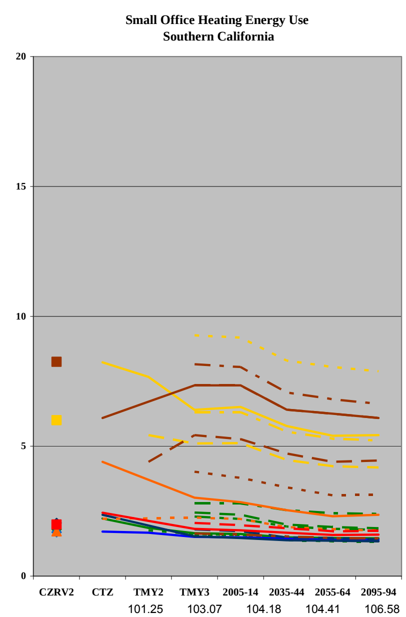
Small Office Energy Use Under the B1 Scenario

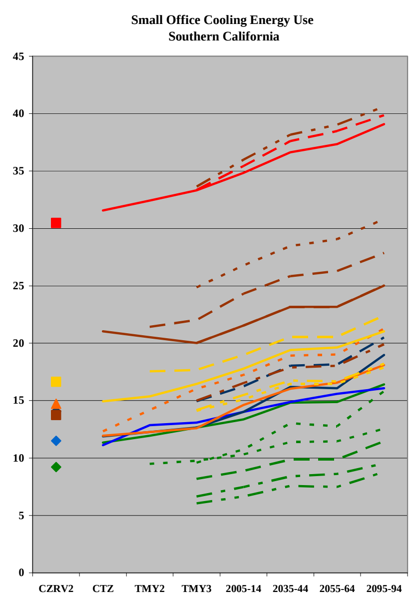


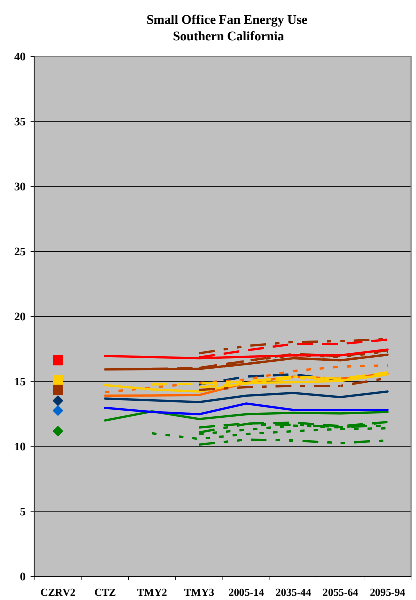


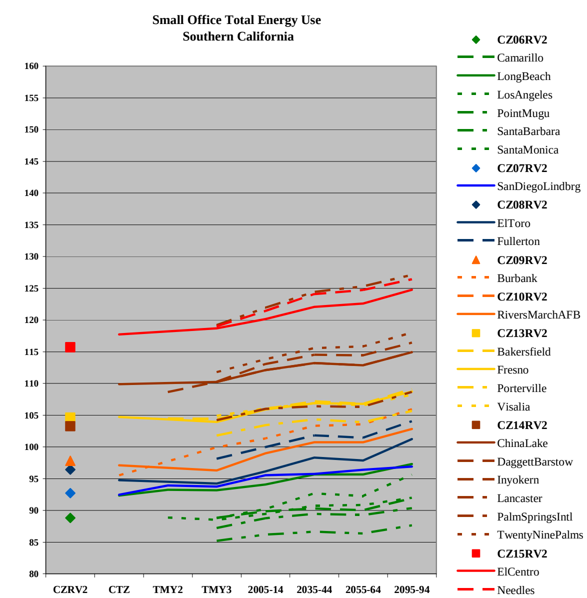




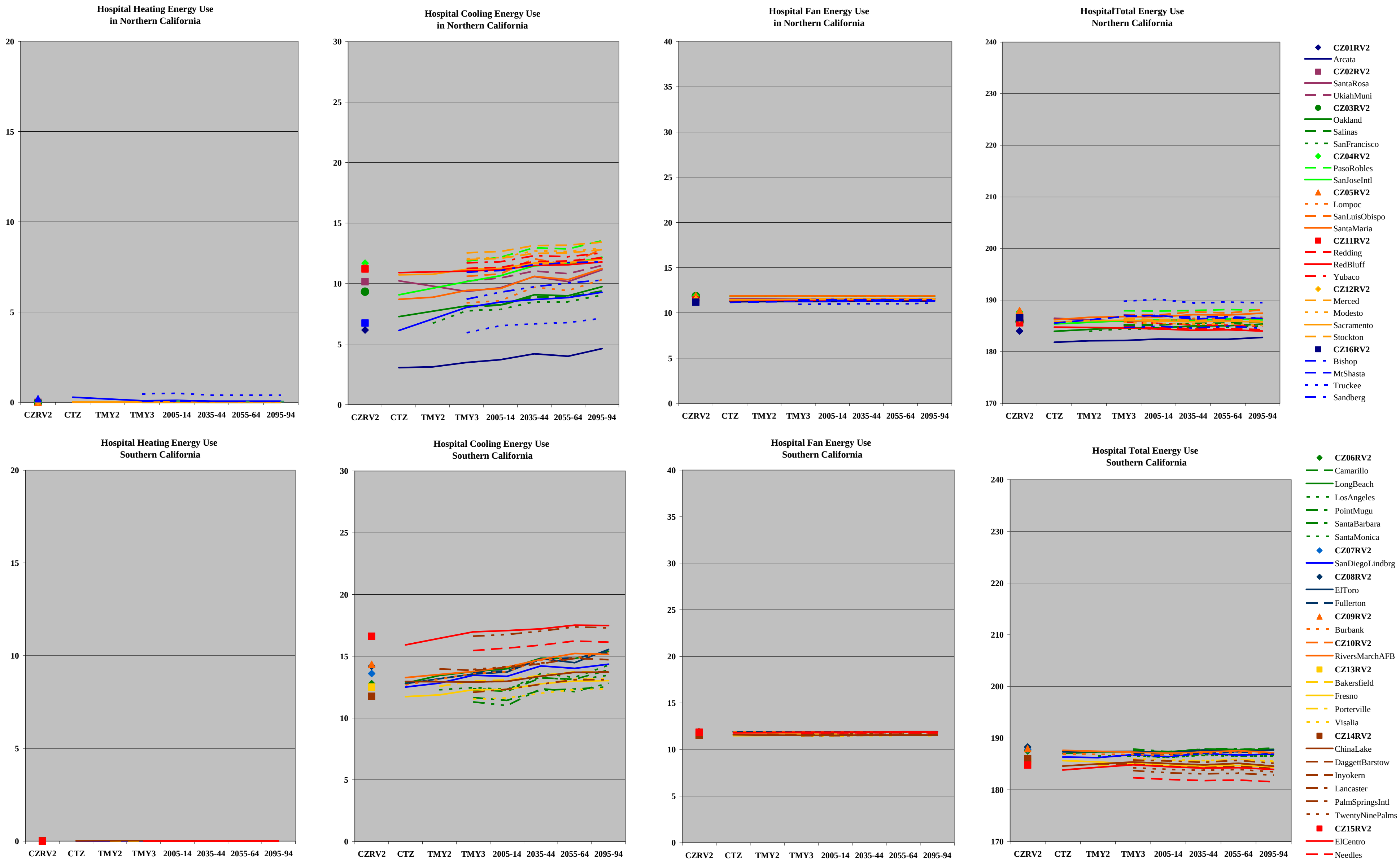




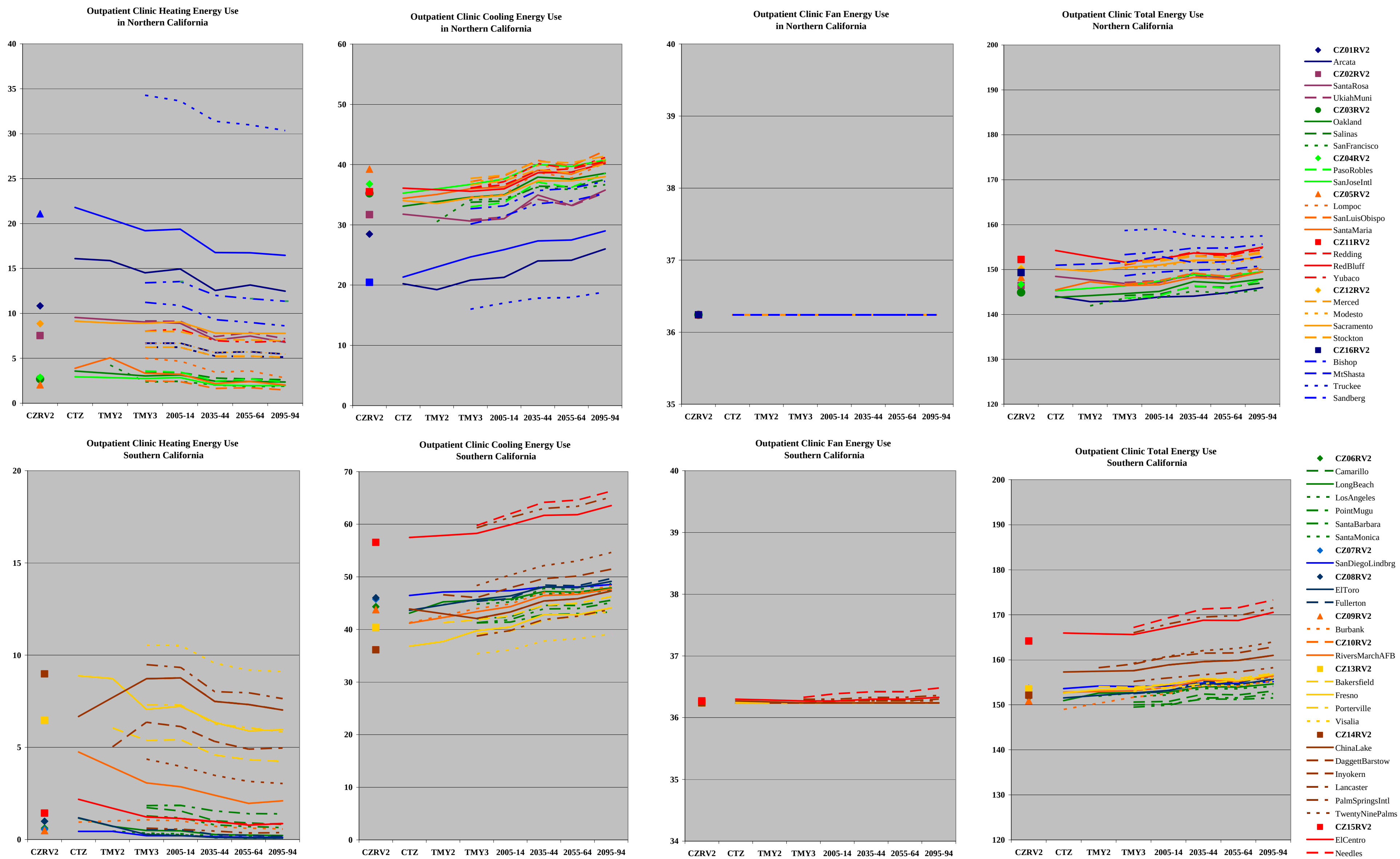




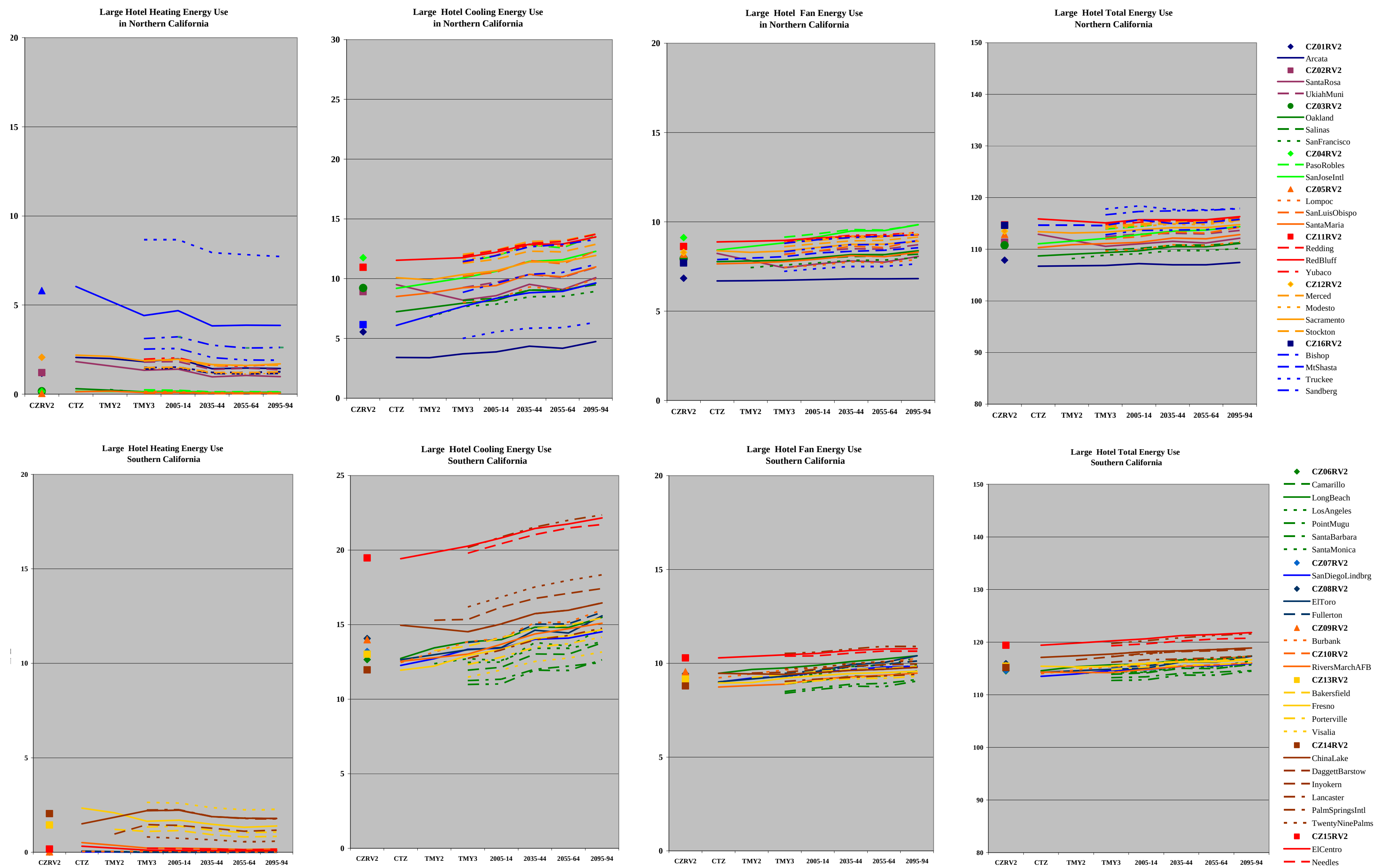
Hospital Energy Use Under the B1 Scenario



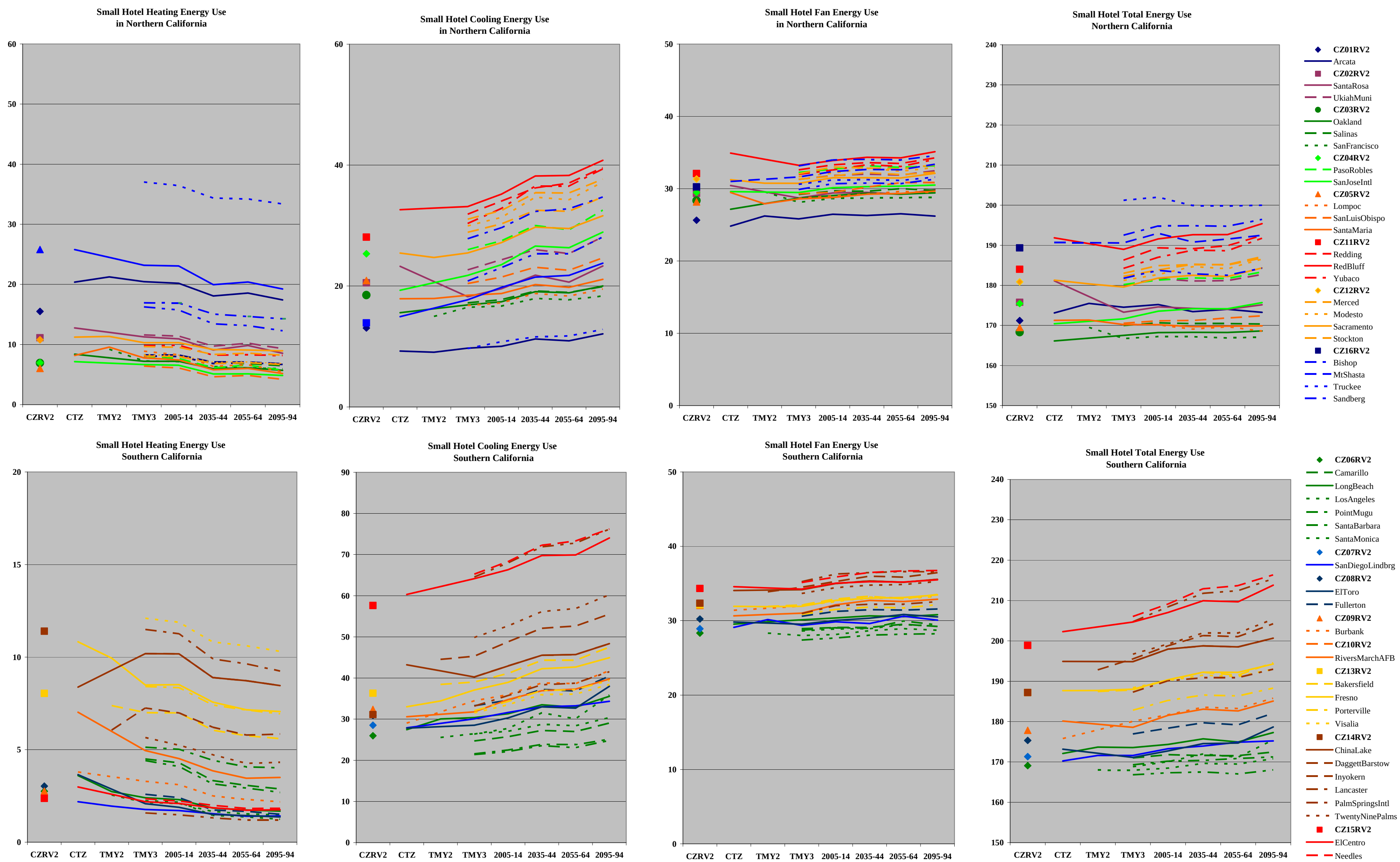
Outpatient Clinic Energy Use Under the B1 Scenario



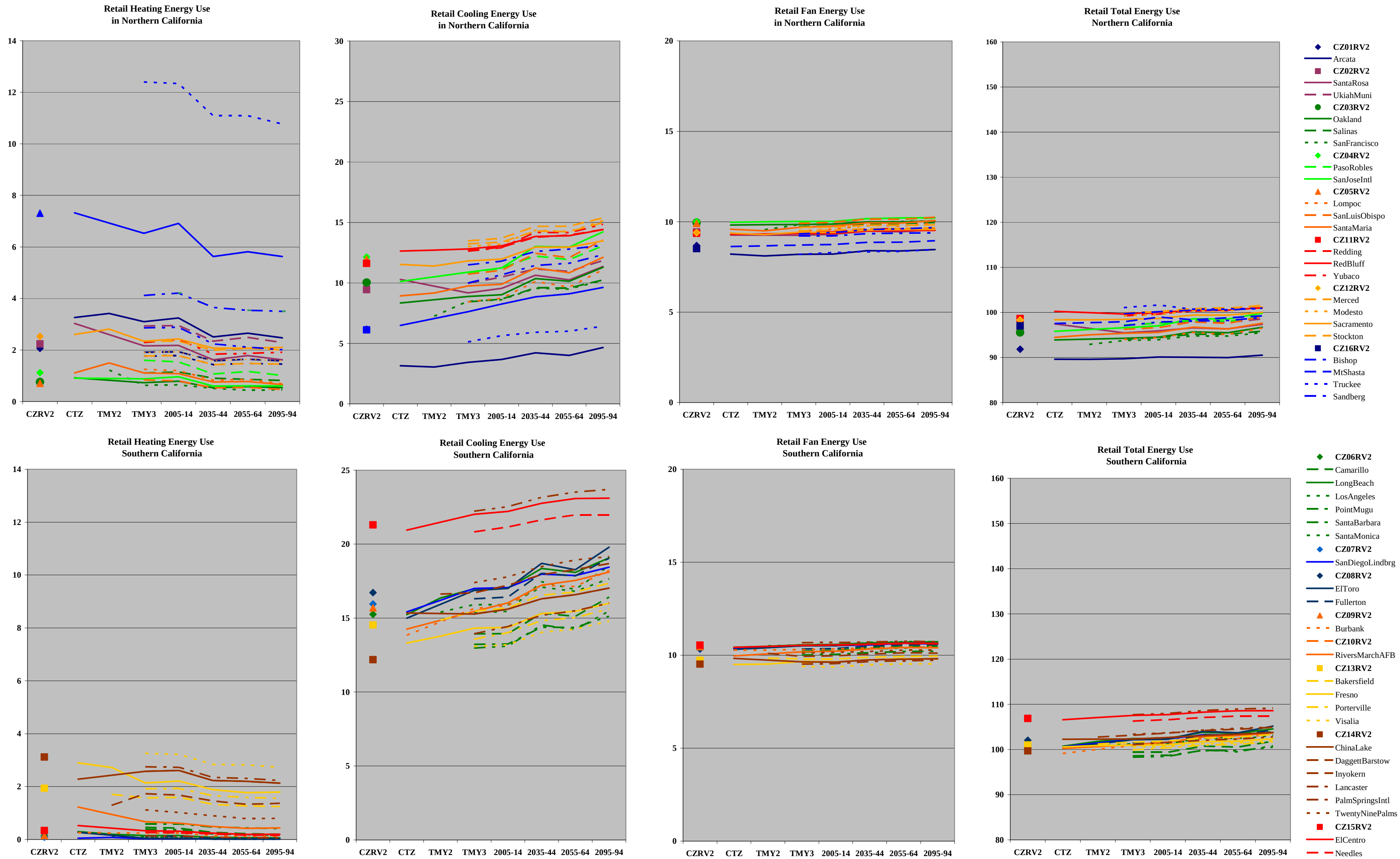
Large Hotel Energy Use Under the B1 Scenario



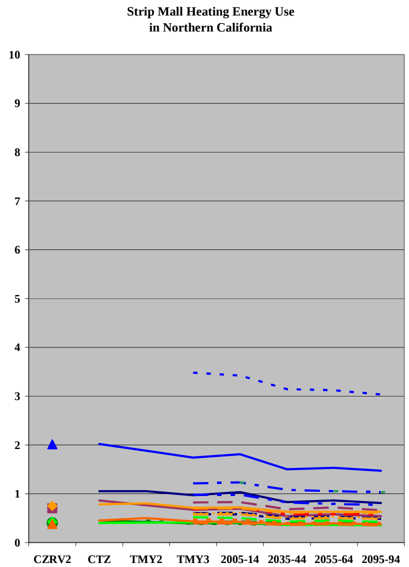
Small Hotel Energy Use Under B1 Scenario

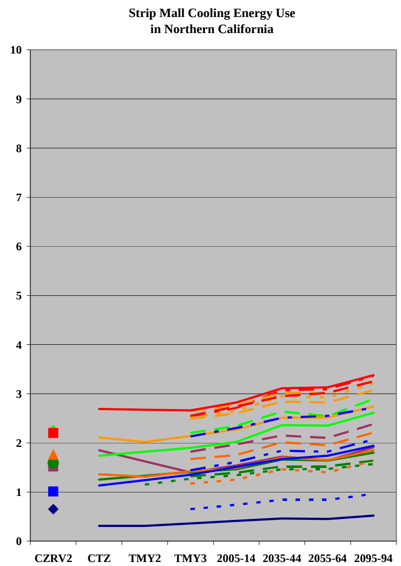


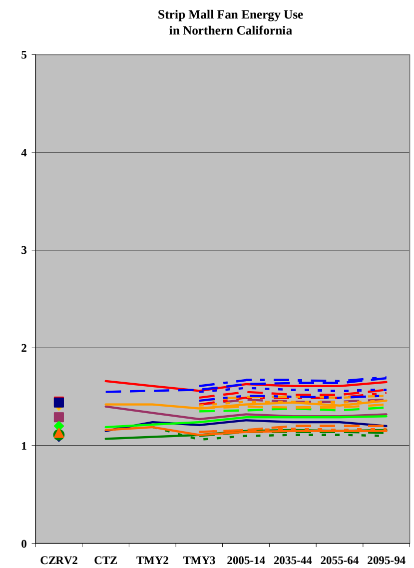
Retail Energy Use Under B1 Scenario

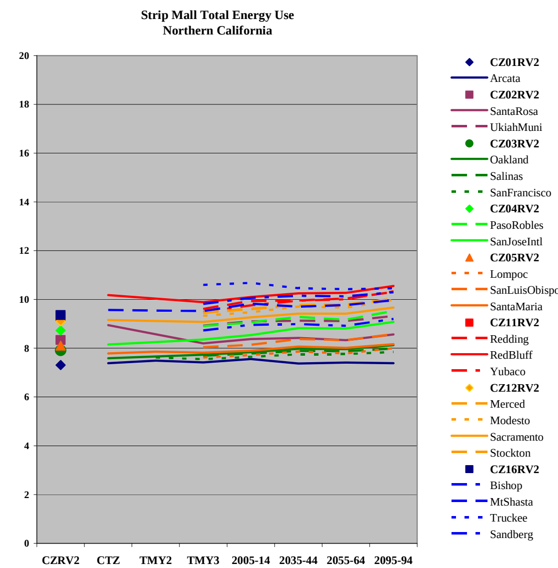


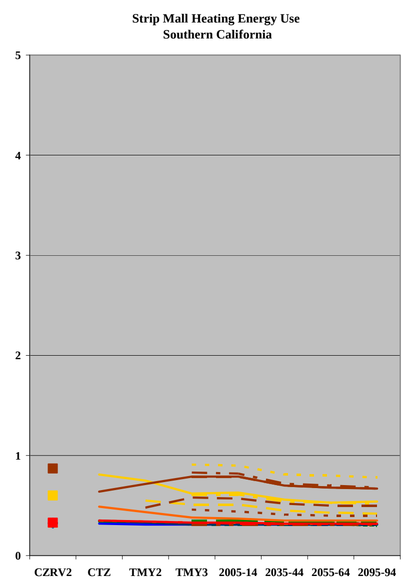
Strip Mall Energy Use Under B1 Scenario

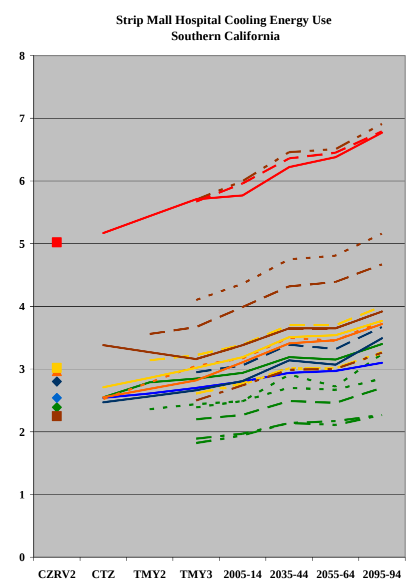


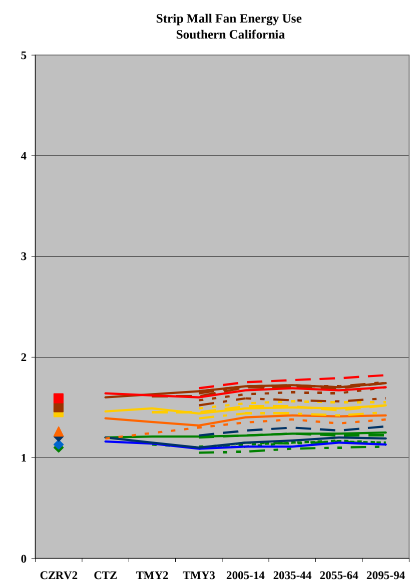


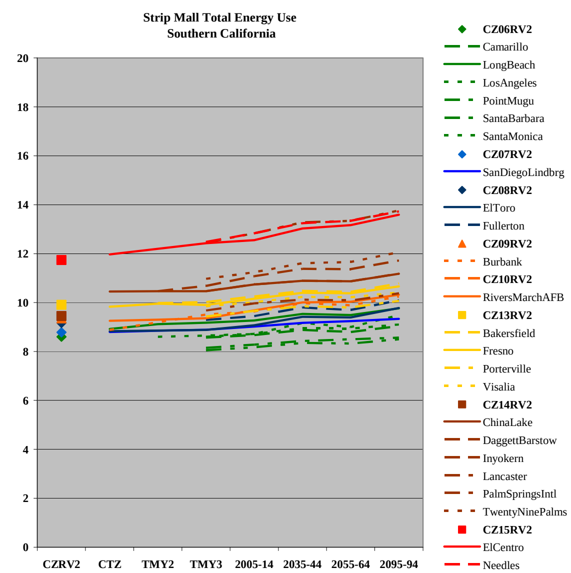




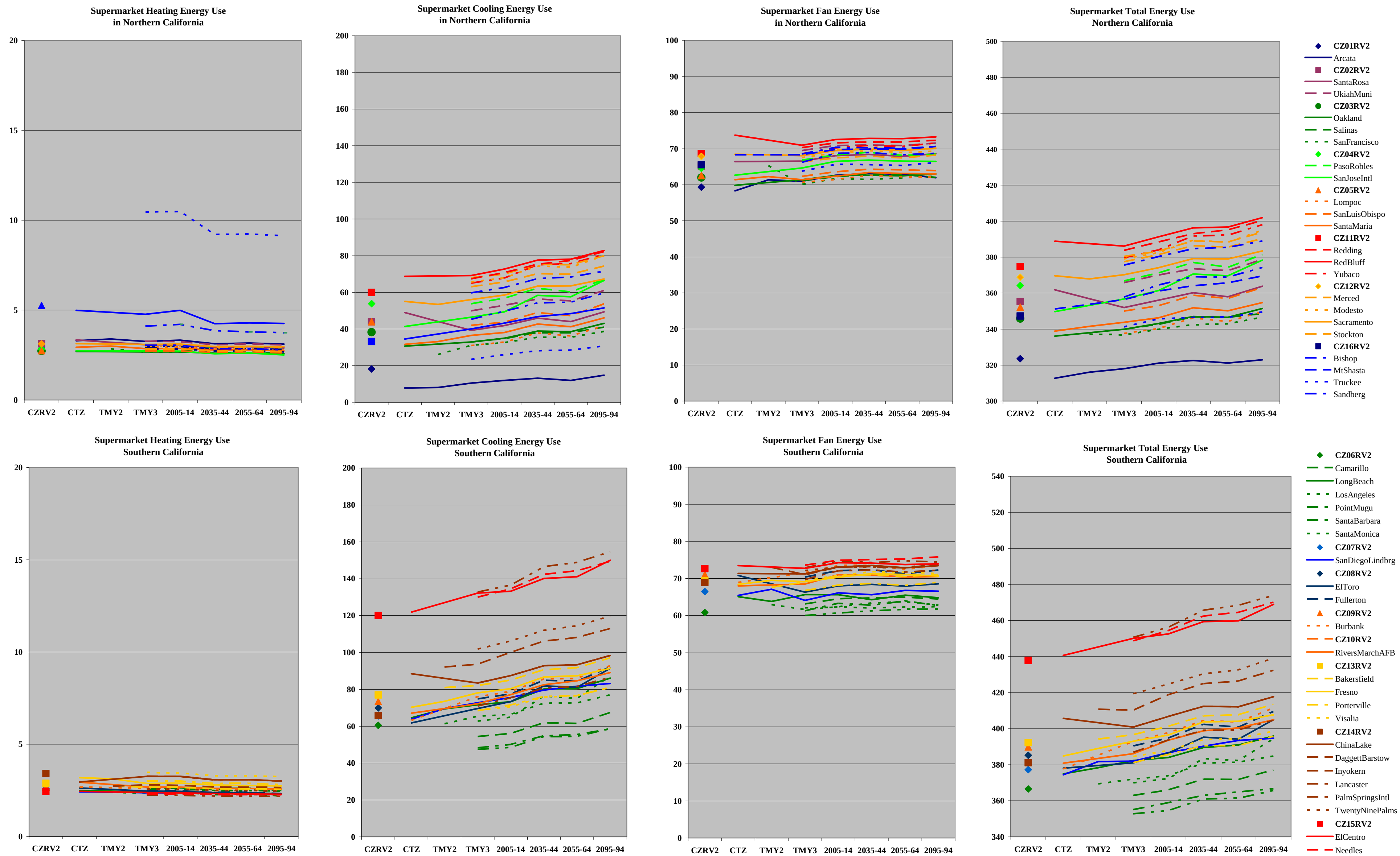




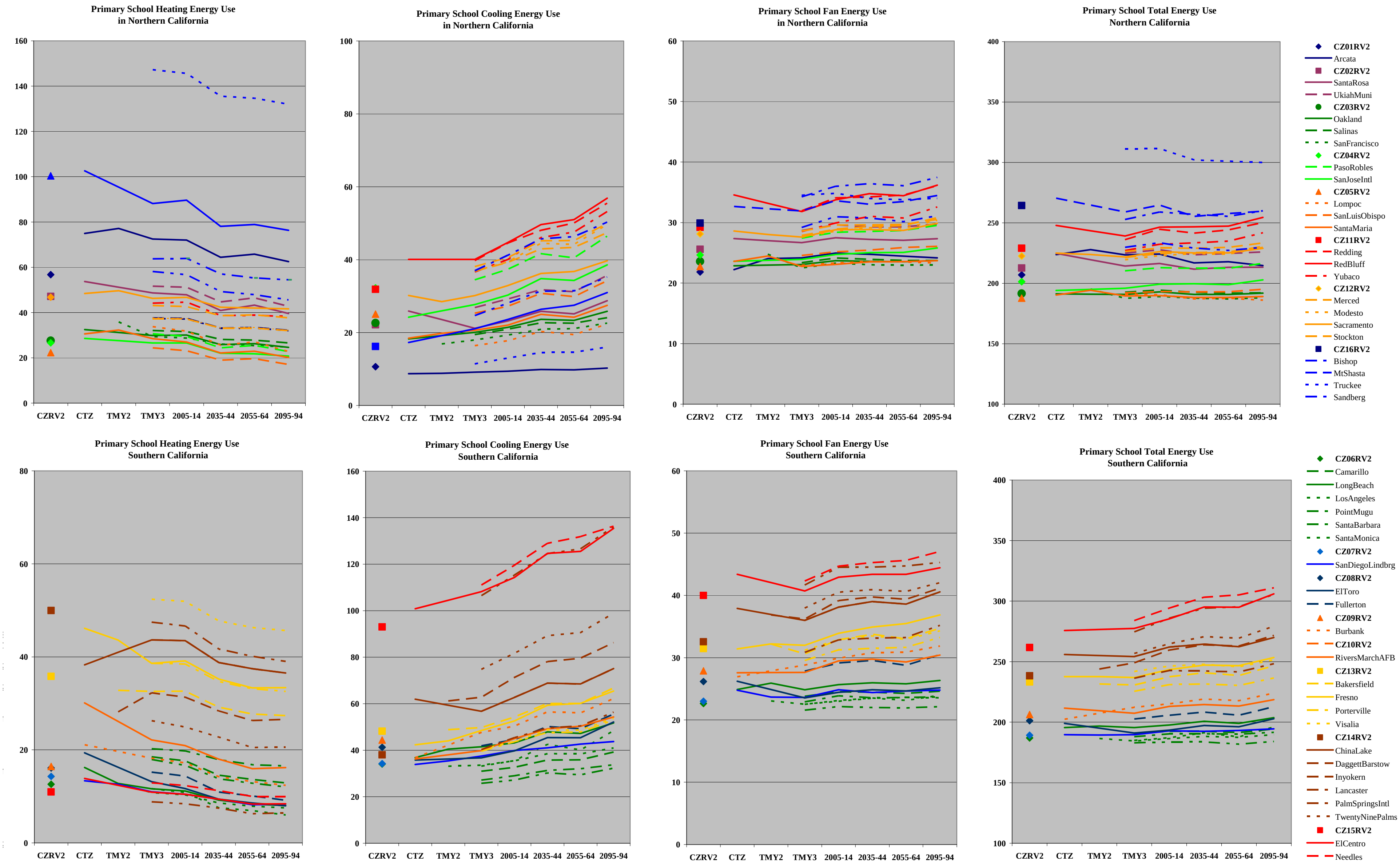




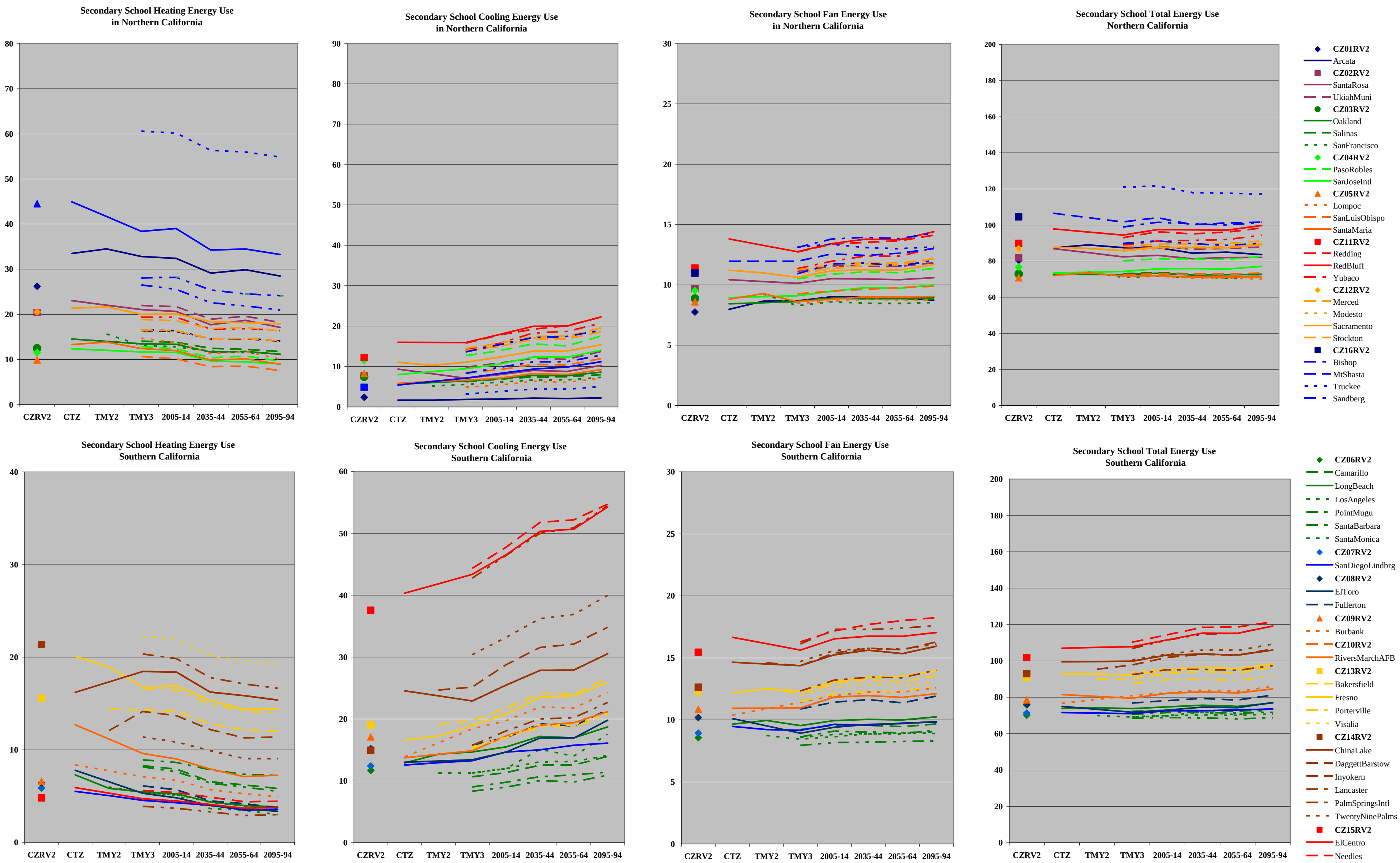
Supermarket Energy Use Under B1 Scenario



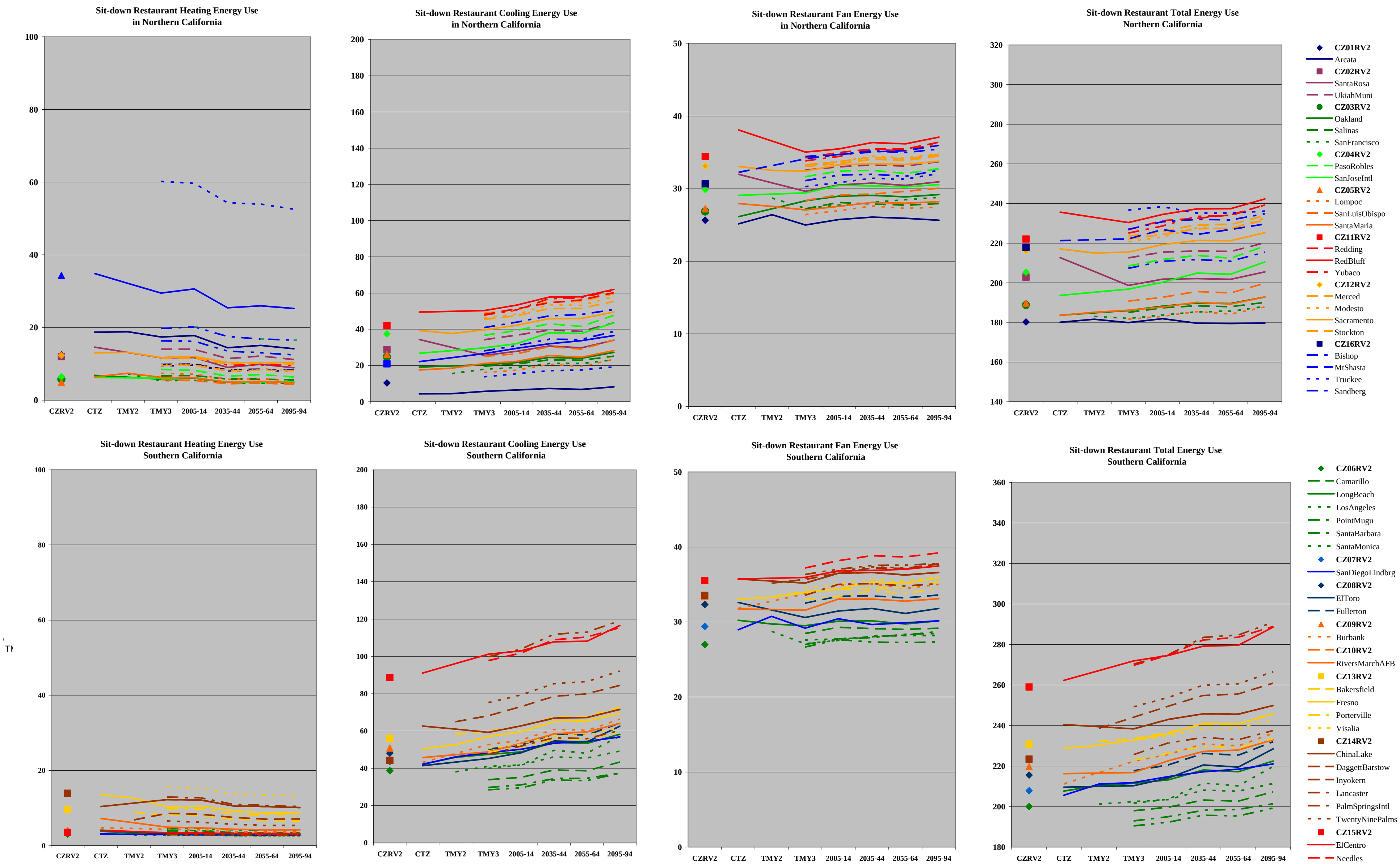
Primary School Energy Use Under B1 Scenario



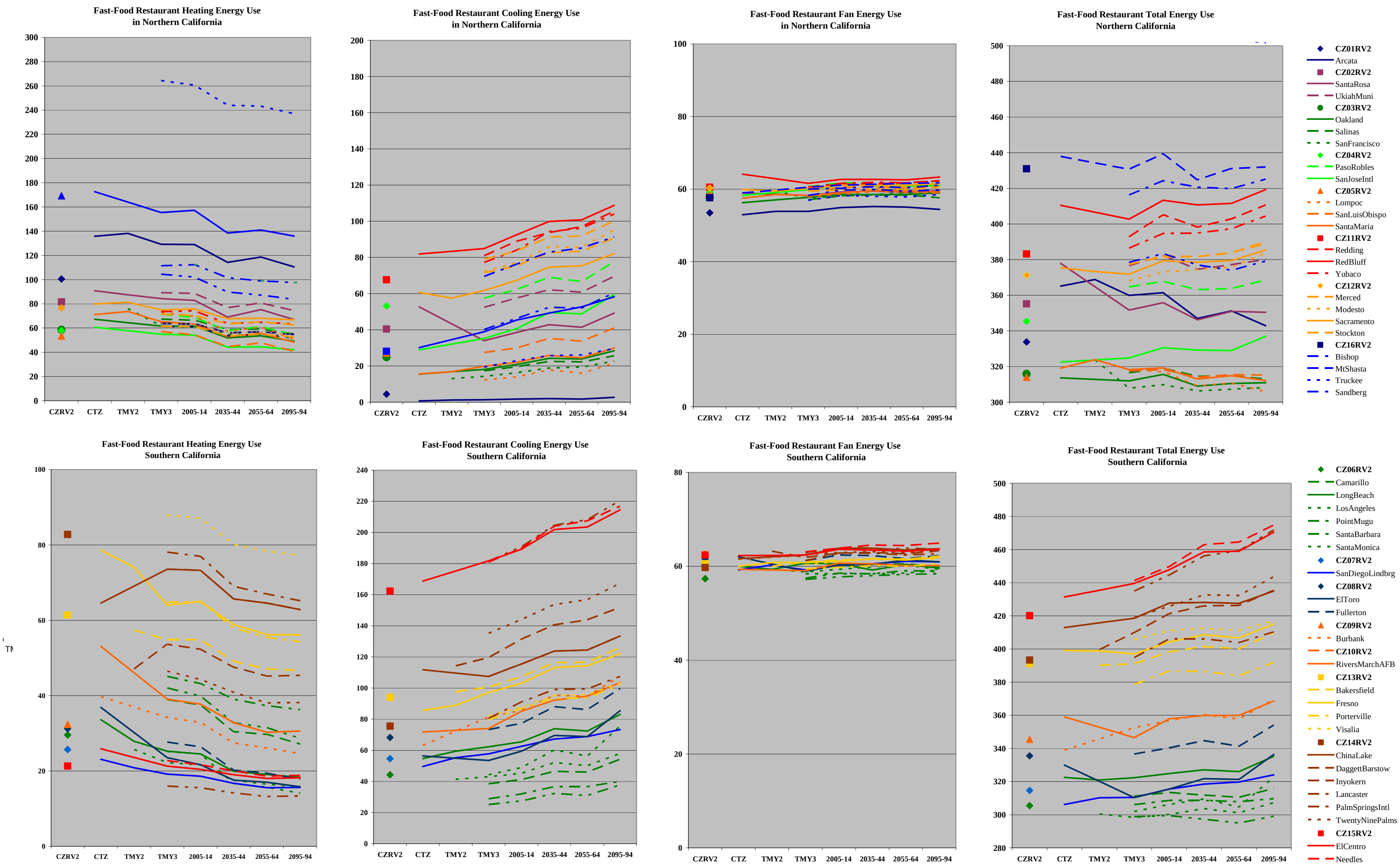
Secondary School Energy Use Under B1 Scenario



Sit-down Restaurant Energy Use Under B1 Scenario



Fast-Food Restaurant Energy Use Under B1 Scenario



Warehouse Energy Use Under B1 Scenario