

Deconstructing the Rosenfeld Curve: Understanding California's Low Per Capita Electricity Consumption

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Abstract

Since the early 1970s, electricity consumption per capita in California has stayed nearly constant, while rising steadily for the United States as a whole. In the context of global energy policy making today, where both climate and energy security concerns play an increasingly large role, it is important to understand the factors behind California's success in stabilizing electricity consumption. In this paper we use empirical data to estimate the fraction of the difference between California and the United States owing to policy independent characteristics such as climate or demographics, and the fraction that may be due to policy measures aimed at saving energy. We analyze both recent and historical data. For 2001, we find that up to about 23% of the overall difference between California and the United States could be due to policy measures, the remainder being explained by various structural factors.

1 Introduction

California's energy policies and energy use patterns have garnered much interest in recent years, partially because of the state's relatively low per capita electricity consumption. Since the early

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1970s, electricity consumption per capita in California has stayed nearly constant, while rising steadily for the US as a whole. Consequently today, the state consumes 40% less electricity per person than the national average. California’s energy policies have consistently encouraged energy efficiency programs and appliance and building standards. Many people have sought to draw a causal link between California policies and the differential between state and national electricity per-capita consumption levels. Indeed a graph comparing retail sales of electricity per capita for California and the United States is often casually referred to as the ‘Rosenfeld Curve’, after Arthur Rosenfeld, the influential member of California’s Energy Commission (See Figure 1).

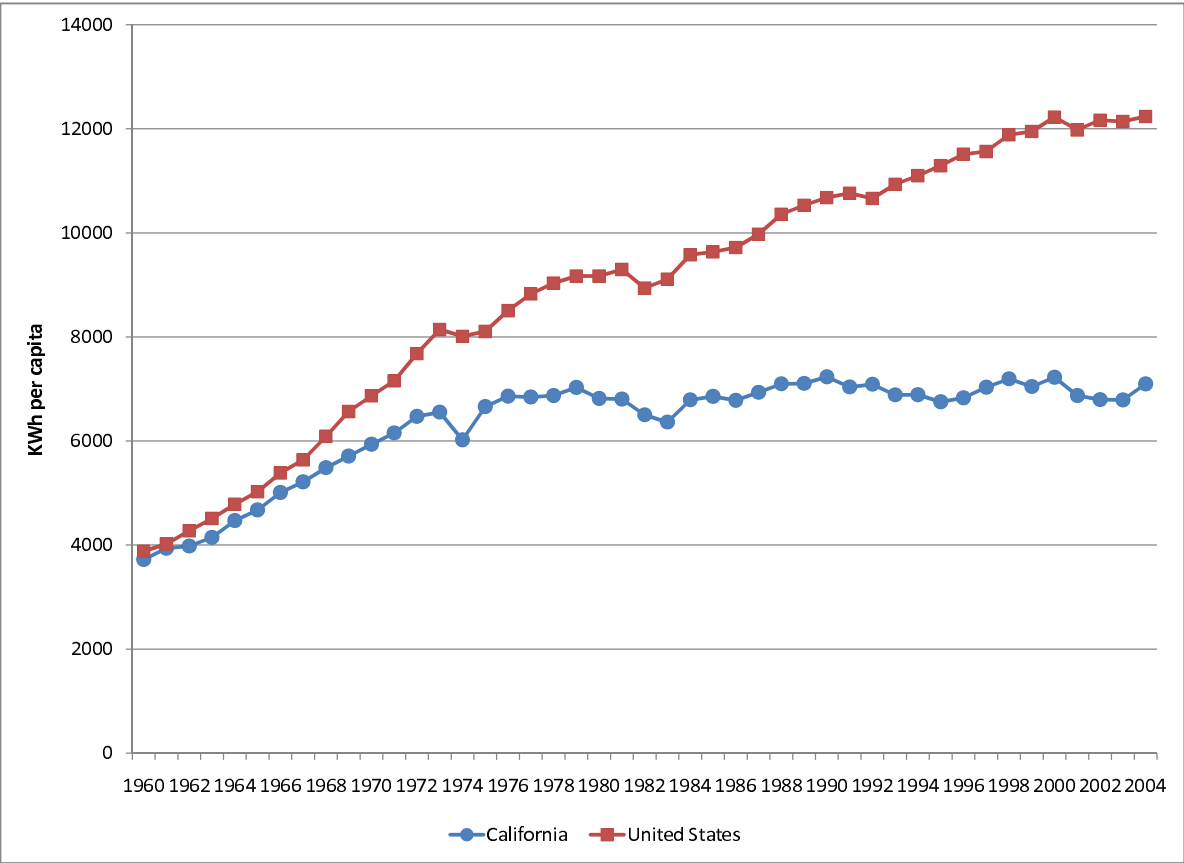


Figure 1: California and US per capita electricity consumption (the ‘Rosenfeld Curve’). Notice the flat-lining of California numbers since the early 1970s. Source: Energy Information Administration (2006)

In the context of energy policy making today, where climate and energy security concerns provide strong motivations for reducing energy use, it is important to understand the underlying causes

of California’s stabilization of per capita electricity consumption. California occupies a position at the forefront of US policy encouraging efficient and environmentally sustainable energy use. Consequently, separating the impacts of California policy from the impacts of policy independent structural factors influencing per capita electricity use could have important implications for the United States as a whole. Most attempts to estimate efficiency savings have concentrated on the US as a whole and have come to mixed conclusions on the effects of utility programs (See for example Loughran and Kulick (2004); Auffhammer et al. (2008)). There have been very few studies seeking to directly quantify the role of various policies and programs in California. Bernstein et al. (2000) studied the public benefits of energy use changes and improved efficiencies in California without looking at the causes in detail. The California Energy Commission does publish savings estimates (see California Energy Commission (2003)) that are obtained ‘bottom up’ using a combination of model runs and exogenous inputs. However, the only work we are aware of looking specifically at California and relying on empirical data is that of Schipper and McMahon (1995).¹

The purpose of this paper therefore is to estimate what fraction of the difference between California and the United States is the result of policy independent characteristics such as climate or demographics, and what fraction is the result of proactive policy measures aimed at saving energy.

In order to accomplish this end, we estimate the effects of various policy independent factors and successively subtract their contribution to the overall difference between the state and nation. The remaining ‘unexplained’ difference forms an estimate of the role of state policy. We view this estimate as an upper bound on the role of state policy because we have not been able to completely rule out the possibility of other factors. We compare this bound with California Energy Commission (CEC) savings estimates, and find that our upper bound (obtained ‘top-down’ by correcting for other factors), is close to the CEC direct savings estimate.

¹The authors concentrate on overall energy use per unit economic output (as opposed to electricity in this paper) across a variety of sectors. While not providing a complete breakdown of structural effects, they do correct for a number of factors and identify the role of state policies. They also identify a number of areas needing further work and more data, many of which remain important today.

2 Residential Sector Electricity Consumption

The largest and fastest growing electricity consuming sector in California is the residential sector. It is both complicated and interesting because a variety of factors affect use of electricity and because many of these factors can be influenced to change consumption.

The basic consuming unit within this sector is the household; consequently our interest is in factors that influence the electricity consumption of households. In keeping with the goal of this paper, we quantify factors such as demographics or climate that are independent from energy efficiency policies, and distinguish these from other forces, such as prices and technology characteristics, that are directly influenced by energy efficiency policies. We examine the effects of the following sectoral characteristics:

1. Household distribution by income
2. Household distribution by size
3. Householder age profile
4. Climate characteristics
5. Urbanization
6. Housing unit floor space
7. Housing unit age
8. Fuel choices (for space conditioning and water heating)
9. Appliance use patterns ('lifestyles')

In attempting to quantify the role of each of these factors on residential sector electricity consumption, we employ the following general methodology. Beginning with empirical consumption and household data², we define test statistics that are measures of the expected household electricity consumption in California and the US, *corrected for state-nation differences in one factor*

²Data are primarily from the decennial US Census reports, the American Community Surveys and from sample surveys such as the EIA Residential Electricity Consumption Survey (Energy Information Administration (2001)).

alone³. We test for statistically significant differences between the US and CA values. A significant difference between the two values is then attributed to state-nation differences in the particular characteristic in question.

2.1 Demographics

Demographic factors such as household income, or household size can strongly influence electricity consumption by driving greater demand or creating significant economies of scale (see O'Neill and Chen (2002)). For that reason, differences between California and the US as a whole with regards to household income distributions and household sizes, would naturally be expected to lead to differences in residential electricity consumption. It is sometimes informally argued that Californias average household energy use is depressed by income inequalities and the presence of large numbers of poorly paid immigrants, resulting in more households at lower income groups. Similarly, Census data indicates that the average household size in 2001 in California was as high as 2.92 members as compared to 2.60 for the United States.

We therefore carry out a set of simple statistical tests to determine the effect of these demographic differences on household electricity consumption (and whether we can assign statistical significance to any implied effect). For example, in testing for the effect of household income we define two quantities

$$E_{ca}^{in} = \sum_i \frac{H_{ca}^i E_{us}^i}{T_{ca}} \text{ and } \bar{E}_{us} = \sum_i \frac{H_{us}^i E_{us}^i}{T_{us}}$$

where

H_{ca}^i and H_{us}^i are the numbers of CA and US households in income group i , respectively,

T_{ca} and T_{us} are the total number of households in California and the US, respectively,

E_{us}^i is the national average household electricity consumption (annually) for a household in income group i .

³In forming these test statistics we use national averages for our energy consumption data (for example, national average household electricity consumption within a particular income group). State figures are used only for the factor being tested. The use of energy figures that are at the national level eliminates the effect of inherent efficiencies unique to California.

\bar{E}_{us} is the average household electricity consumption in the United States. E_{ca}^{in} estimates what the average household electricity consumption in California would be, if the state differed from the nation only in the distribution of households by income. Differences between \bar{E}_{us} and E_{ca}^{in} can then be interpreted as differences in average per capita consumption that result purely from differences in the distributions of households by income group. Formally we test the hypothesis $H_0 : E_{ca}^{in} = \bar{E}_{US}$ versus the alternative $H_1 : E_{ca}^{in} \neq \bar{E}_{US}$ ⁴.

In the case of household size we use a similar test (with size groups instead of income groups). The results are interesting. We find that state-nation differences in household income distribution alone, would cause Californias household electricity consumption to exceed the national figure by about 3.9% of the US average. This difference turns out to be just significant (at a 95% confidence level). In the case of household size, the effect is more marked. Californias greater household size was found to explain an approximately 11% reduction ($\pm 4.40\%$) from the national average figures. Note that these two forces act in opposite directions but the overall effect is to depress electricity consumption measured on a per capita basis. We also tested for the effect of state-nation differences in householder age, but found no evidence of a significant effect.

2.2 Climate and Location

Demographics apart, climate characteristics and household location have a large part to play in influencing electricity consumption patterns. In order to estimate the effect of climate on household electricity use, two distinct end uses were considered - space heating and air conditioning. For space heating, two factors need to be taken into account. The first is the difference in (population weighted) heating degree days between California and the United States. The second is the choice of heating fuel - the popularity of natural gas over electricity for heating in California households reduces observed electricity consumption. We separately estimate the role that the climate plays in creating differences in the average cooling and heating loads between the state, and nation.

⁴We assume a Gaussian distribution for the t-statistic in this test using the fact that sample sizes involved are large, and treating the denominator (which is a complete population count from the census) as constant. The latter assumption allows the use of a standard Gaussian test as opposed to the much more complicated test for a normal ratio distribution.

In analyzing cooling, we distinguish between central and room air-conditioning. Electricity demand for air conditioning purposes is estimated as follows:

$$E_{ca}^{cool} = \alpha_{ca}^{cac} \frac{E_{us}^{cac}}{CDD_{us}} CDD_{ca} + \alpha_{ca}^{rac} \frac{E_{us}^{rac}}{CDD_{us}} CDD_{ca}$$

Here CDD refers to population weighted cooling degree days (climate effect) and α_{ca}^{cac} and α_{ca}^{rac} are the fraction of households using central AC equipment (cac) or room AC equipment (rac) respectively. E_{us}^{cac} and E_{us}^{rac} is the national average electricity consumption on air-conditioning for households using equipment type cac or rac respectively.

A similar process is carried out to estimate the heating load (corrected only for climate differences) and as before we test for statistically significant differences between the corrected statistics for the state (as determined above) and the national average figure. The milder climate in the state of California and fuel substitution possibilities in space heating, are reflected in a statistically significant difference in the expected electricity consumption for space heating and cooling, independent of any other efficiency effects. We find that point estimates suggest about a 7.8% ($\pm 1.3\%$) reduction in electricity consumption in California due to reduced cooling needs, and a 8.0% ($\pm 1.36\%$) reduction due to differences in space heating demand (both as a percentage of total US household electricity consumption).

Similarly, the location of a household in a city, a suburb, or a rural area has a marked effect on energy use patterns. A number of factors could be responsible for this, including larger floor space outside cities and differences in lifestyles due to variations in living costs. Since the floorspace of households, across income groups, tends to be larger outside cities it is not surprising therefore that electricity consumption also differs by location. In order to obtain an estimate of the effect of urbanization, we begin by obtaining the distribution of households by location type from the 2000 US Census. Empirical data on electricity consumption as a function of location is available from the 2001 RECS. Carrying out a hypothesis test analogous to those described earlier suggests that urbanization can explain a statistically significant reduction in electricity consumption in California of about 10.4% ($\pm 4.04\%$) of the national average.

2.3 Housing Unit Floorspace and Age

For a given household size, larger housing units tend to use more energy, with higher heating and cooling loads as well as a greater lighting load. Comparing the distribution of households by size between California and the United States reveals that within the state, while household sizes are larger than the national average, the size of housing units tends to be smaller. Consequently we find that floorspace differences could account for a statistically significant reduction in California household electricity consumption of about 11% of the national average. However since housing unit size is known to be strongly correlated with location, we do not incorporate both these effects when assessing the contribution of structural factors. As far as differences in housing unit age is concerned, no significant effect was detected.

2.4 Fuel Choices for Water Heating

Household fuel-mix differences expectedly translate to variations in electricity demand. The RECS 2001 reveals that on a national level electricity makes up 39.48% of the total energy consumed, while in California the same figure is 32.58%. We have already accounted for electricity demand differences due to the greater use of natural gas for heating in California. A similar analysis of electricity consumption for water heating applications, reveals that California's greater reliance on fuels other than electricity for water heating⁵, would account for a statistically significant reduction in electricity demand of about 5.6% of the national average household electricity consumption.

Before closing this discussion, we should acknowledge that it could be argued that state policy does have an influence on fuel-mix decisions. For example, Title-24 building standards may have made it harder to construct all electric homes. Similarly, high electricity prices (influenced in part by regulations and various legislative measures), do make fuels such as natural gas attractive. However, simple switches in the form of energy used lead to only small reductions in energy use and carbon emissions. For this reason we separately quantify reductions in electricity consumption due to fuel mix differences. This ensures that the 'unexplained' difference that remains credits

⁵Nationwide, over 38% of households use electricity as the primary fuel for water heating, while in California this fraction is just under 15% (based on the 2001 RECS).

policy only for those reductions in electricity energy use that do not simply shift the form of energy consumed.

2.5 Lifestyles

Apart from these factors, it is also interesting to look at the role of ‘lifestyles’ in influencing electricity use. We have not attempted to quantify such differences and it would be necessary to obtain more data to do so accurately. However the RECS datasets do reveal some evidence of differences in the way Californians live when compared with the rest of the nation. These include significantly more energy conserving behavior with regards to space heating, lower ownership of appliances such as washing machines and so on. It is true that factors such as prices and climate may influence these numbers but they are interesting nonetheless.

2.6 A Note on Electricity Prices

Thus far we have not addressed the role of electricity prices in influencing electricity demand. California’s electricity tariffs are high in comparison with the rest of the state. But electricity bills are often lower than the national average (in part thanks to lower consumption aided by greater efficiency of use). In this paper we do not attempt to directly estimate electricity demand reductions due to California’s higher tariffs. This is partly because electricity prices are strongly influenced by state policy, including regulations on utilities and the supply sources they are allowed to use. As such, we regard any reductions due to higher tariffs as being heavily policy dependent. These effects would thus form a part of the component of California-US consumption differences that remains after we account for structural causes⁶. This remaining share should thus be viewed as an aggregation of the effect of policies aimed at increasing efficiencies, price effects that are influenced by state policy, and other factors that we may not have accounted for in our analysis.

The response of consumers to price changes in California is difficult to estimate. Estimates of consumer price and substitution elasticity for energy sources and electricity have been derived in the past (see for example, Roy et al. (2006); Branch (1993)). Even so, there remains considerable debate

⁶See section 2.4 for a little more detail on the difference between real savings in electricity consumption and apparent savings due to fuel mix differences.

about how consumers respond to price changes and how much lag exists in demand shifts. Short-run and long-run elasticities are likely to be quite different, further complicating such an analysis. Thus it is difficult to compare California, with higher tariffs but lower baseline consumption, with states that may have lower tariffs but higher baseline consumption.

Some issues to be considered in evaluating the role of price changes are discussed in Reiss and White (2005). They build a model to evaluate the effect of alternative tariff schemes on demand, for California, based on RECS survey data. They find that electricity demand can be broken down into an inelastic baseline component, and incremental use (for appliances such as pumps, air conditioners, swimming pools, refrigerators) that is elastic. The price elasticity for the elastic component varies depending on the end use category (the authors set up eight appliance categories including baseline use). In addition, the authors find that the demand response of consumers is highly heterogeneous, with a small proportion accounting for most of the demand response, and with most consumers exhibiting very low price elasticity. A mean value for price elasticity was estimated to be -0.4, but as the authors point out, other studies in the residential sector have shown widely varying estimates.

3 Industrial Sector Electricity Consumption

Measured on a per capita basis, in 2001 about 20.50% of California's electricity sales were reported to the industrial sector. This was a lower percentage than the corresponding figure for the United States in the same year, where industrial sales made up about 28.5% of the total. In absolute terms also, per capita industrial electricity consumption in California is significantly lower than for the nation as a whole. State per capita electricity sales to industry were 1393 KWh in 2002, 60% smaller than the national average of 3475 KWh (all figures computed using EIA retail sales figures).

Part of the difference between the state of California and the US could be due to smaller, lighter industry, relative to the national industry profile. There are two important aspects of the industrial sector that influence energy use. The first is obviously the type of industry - refineries and chemical industry units for example, are far more energy intensive than firms manufacturing

microprocessors. Apart from the type of industry, the size of units makes a substantial difference to energy intensities - partly due to economies of scale, and partly because the product mix of smaller and larger manufacturing units may differ.

The first stage in our analysis of this sector is therefore to account for differences due to the nature of industry. We disaggregate the sector first by industry type (based on NAICS codes) and secondly by size, as measured by the number of employees. We use the latter metric of size because our eventual interest is in comparing per capita values of electricity consumption. Corresponding to this choice we form the following expression for per capita industrial electricity consumption:

$$E_{ca}^{ind} = \frac{\sum_i \sum_j \alpha_{ij} \eta_i p_{ij}}{P}$$

where

E_{ca}^{ind} is the California industrial electricity consumption per capita correcting for industry size and type only,

α_{ij} is the national average energy use per employee in industry type i , belonging to size group j ,

η_i is electricity as a fraction of total energy consumption in industry type i ,

p_{ij} is the number of employees working in units of type i and size group j ,

P is the total population.

Data on industry distribution is obtained principally from the 2002 United States Economic Census and the 2002 Statistics of US Business survey. We use the 2002 Manufacturing Energy Consumption Survey (Energy Information Administration (2002)) as well as US Department of Energy figures to obtain data on energy intensities (energy use per employee) for different unit sizes and NAICS codes.

It was found that a significant fraction of the observed difference in industrial electricity consumption between the nation and the state may be explained simply by which industries make up the largest share of the industrial sector, and the unit sizes most prevalent. Based on these factors alone, California's per capita industrial electricity sales are predicted to be about 62% of the na-

tionwide figure (or about 2154 KWh). For the 2002 US figure of 3,475 KWh, California's industrial sector makeup and the scale of industry units would be broadly consistent with a reduction by about 38% of the national average.

3.1 Industry Self Generation

Aside from the structural makeup of the industrial sector, an additional factor influencing retail electricity sales is the percentage of electricity generated on-site, since electricity generated on-site is not included in data on electricity sales, even though it represents electricity use. There is a greater fraction of on-site generation in California than in the United States. While the total national on-site generation stood at 152,600 KWh in 2002 (15.54% of total industrial sales), in California the corresponding figure was 17,142 KWh (35.45% of state industrial electricity sales). This difference would explain a decrease in state retail electricity sales to the industrial sector by about 7.4% of the national per capita industrial electricity consumption.

4 Commercial Sector Electricity Consumption

As a primarily services oriented economy, most of California's economic output comes from activities in this sector and on a per capita basis nearly half of electricity sales are to the commercial sector. In analyzing the commercial sector, energy intensities are expressed in KWh per sq.ft, and the size of the sector is measured in terms of the floor space occupied.

The energy intensities of different parts of the commercial sector differ widely. For example, food sales and food service (restaurants, cafeterias, food stores, etc.) uses about 50 KWh of electricity per square foot, significantly more than the educational sector, where energy intensities are about 11 KWh per sq ft (national average figures, from the 2003 Commercial Buildings Energy Consumption Survey). Thus differences in the composition of the commercial sector can potentially have a significant impact on electricity consumed. Additionally, there are significant differences in the per capita density of commercial floorspace between California and the US. The US as a whole uses more commercial floorspace per capita, across all end uses, than does California. Consequently even though the nature of end uses is similar, the state electricity consumption is lowered.

Testing for these factors indicates that state-nation differences in per capita commercial floorspace density and slight differences in the sectoral makeup, would together account for a reduction in California’s per capita consumption by about 27% of the national figure. The actual difference in 2003, based on a comparison of CEC sales figures for the state and EIA statistics for the nation, was somewhat greater (33% of the US figure). It therefore seems to be the case that a significant amount of the variation between state and national level commercial electricity sales can be explained by differences in floor space intensity (floor space per capita), with a small contribution from differences in usage shares. The unexplained residual could be due to efficiency measures, utility programs, and appliance and building standards.

5 Historical Trends in Electricity Consumption

The preceding discussion has focused on deconstructing the contributing factors to low electricity consumption in California, for a snapshot of time in the recent past. We focus on a recent year in part because of the relative ease of obtaining data⁷. As we go further back in time it becomes progressively more difficult to obtain state disaggregated data of the kind used in this analysis. That said, given that the difference between California’s electricity consumption levels and the national average has gradually increased over the last four decades, it is important to examine years before 2001 in order to test whether the time trend in Figure 1 can be explained by similar factors.

We analyzed data for previous years, using the same methods described earlier in this paper. Due to data constraints, in some cases, we were forced to use CEC Demand Forecast model outputs (e.g. California Energy Commission (2003)) instead of the sample surveys used for the 2001 analysis.⁸ Data constraints are most severe for the industrial sector as a result of the switch from the SIC to NAICS classification in 1997. This reclassification has made it difficult to obtain comparable employee data for years before 1997. Fortunately however, the difference in electricity consump-

⁷The choice of years is also constrained by the release schedules of the EIA surveys used as our primary data source. The latest survey data for commercial buildings for example, is for 2002.

⁸However since we use only historical output figures (which would have been appropriately calibrated) from the model runs, we believe that the point estimates involved should be ‘reasonably’ close to reality. We cannot of course, associate standard errors with such numbers.

tion levels between the state and nation in the industrial sector has changed very slowly over the past twenty years. Both the United States and California display relatively flat levels of industrial electricity consumption (per capita) in recent years. This trend is not surprising since energy costs are an important part of total costs in some industries. Economically beneficial energy savings are likely to spread faster nationwide in the industrial sector than in the residential sector. Thus it is possible that the relatively stable difference is largely a consequence of consistent differences in industrial sector composition and on-site generation differences⁹. For the industrial sector therefore, we do not perform a disaggregation in previous years, instead we scale our estimate for 2001 by the modest trend over the past 20 years to compute an estimate of the difference for 1990 and 1980.

6 Results

Our analysis uses the latest data available to us, but the year of analysis differs across the three sectors (because the EIA surveys used do not follow identical time schedules). Our initial disaggregation of the Residential, Industrial and Commercial sectors was for the years 2001, 2002 and 2003 respectively (displayed in Table 1)¹⁰. To combine the three we convert our results to a common year (2001). For the industrial sector, we assume percentage reductions due to sector composition and self generation remains the same in 2001 as in 2002. For the commercial sector, variations are greater, and therefore we repeat our analysis using the 1999 CBECS survey and interpolate between 1999 and 2003 reductions to obtain estimates for 2001.

We obtain an ‘unexplained’ difference of about 545 KWh per capita for the residential sector, 416 KWh per capita for the industrial sector and 272 KWh per capita for the commercial sector. We conclude that for 2001, up to about 23% of the overall difference between California and US per capita electricity consumption could be due to state policy.

We also present the result of our analysis of the historical data. Figure 2 compares CEC model estimates to the ‘unexplained’ reductions we obtain at different time points in the last

⁹This does not mean that industry has not grown more efficient, only that these efficiencies are likely to have spread nationwide, thus reducing any effects specific to California.

¹⁰Numbers in brackets indicate reductions as a fraction of US per capita consumption, followed by a 95% confidence interval. NE means that a 95% interval could not be estimated due to insufficient information about the source data errors.

Summary of Results	
Residential Sector (2001)	
US per capita residential electricity sales	4253
CA per capita residential electricity sales	2225
Heating load reduction (climate and fuel choices)	340 (8.00±1.36 %)
Cooling load reduction (climate, appliance type)	332 (7.80±1.30 %)
Water Heating load reduction	238 (5.60±0.97 %)
Household income effect	-130 (-3.90±3.60 %)
Household size effect	382 (11.0±4.40 %)
Urban rural distribution	321 (10.4±4.04 %)
Possible policy share	545
Industrial Sector (2002)	
US per capita industrial electricity sales	3475
CA per capita industrial electricity sales	1393
Industry type and size differences	1321 (38.00±3.60 %)
On-site electricity generation differences	257 (7.40 % ±NE)
Possible policy share	504
Commercial Sector (2003)	
US per capita industrial electricity sales	4170
CA per capita industrial electricity sales	2803
Reduction due to lower floor space intensity	1132 (27 % ± NE)
Possible policy share	236

Table 1: Factors contributing to reduced electricity consumption in California (KWh with percentage reductions in parenthesis)

three decades. CEC savings estimates are obtained bottom-up, based on various quantification methodologies applied to utility programs, on a detailed energy system model, and smaller models for various policy measures. Education, training and awareness building programs are excluded from savings due to the difficulty estimation. Details on the methodology used in making forecasts and savings estimates are available in the Energy Demand Forecast Methods Report (California Energy Commission (2005)). The CEC model estimates and our ‘unexplained’ reductions are very similar over time, although in 1980 the ‘unexplained’ reductions are about 50% greater than the CEC estimates of policy-induced energy demand reduction.

In addition, for the residential and commercial sector we can graph the actual California per capita consumption, the impacts of the various factors, and the ‘unexplained’ per capita reductions

(See Figures 3 and 4)¹¹. The qualitative trend of increasing per capita electricity consumption, and an increasing role for policy measures with time, is reflected in our estimates.

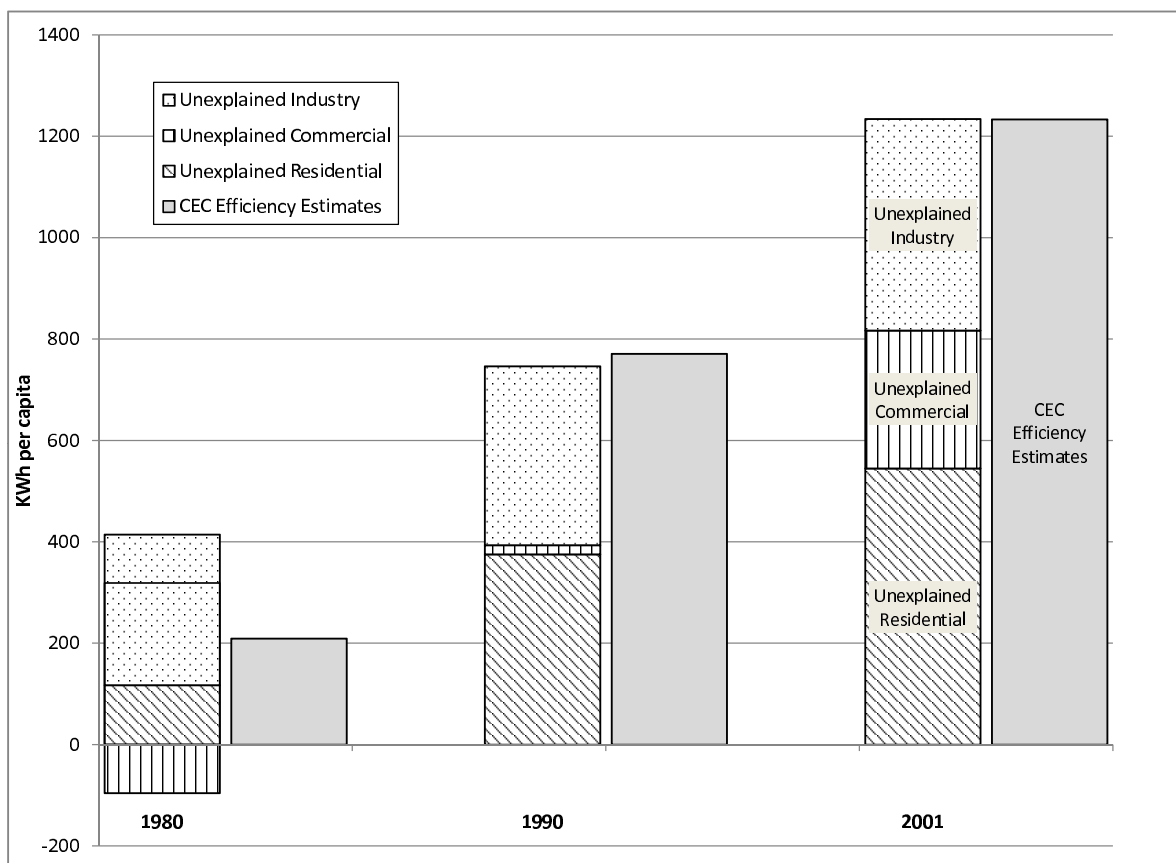


Figure 2: A comparison of CEC savings estimates with upper bound estimates of policy savings, at three time points in the past.

7 Discussion and Conclusions

The purpose of this work is to estimate what fraction of the difference between California and the United States is the result of policy independent characteristics such as climate or demographics, and what fraction may be due to proactive policy measures aimed at saving energy. In order to accomplish this, we estimate the effect of various policy independent factors and successively subtract their contribution from the overall difference.

¹¹This is made difficult for the industrial sector due to the switch in 1997 to the NAICS classification scheme.

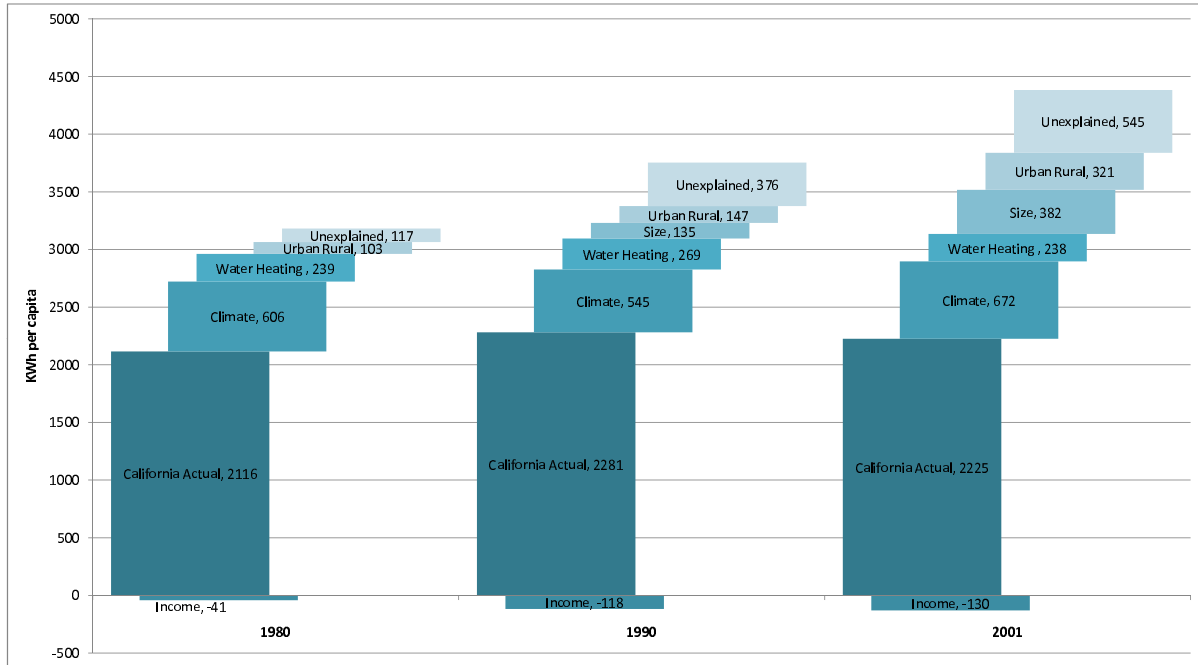


Figure 3: Impacts on Per Capita Residential Sector Consumption: Three Years

We recognize however that there is room for significant improvements in this effort. First, our methodology needs to be seen as an attempt to explain the Rosenfeld curve, i.e. the difference between California and US (all states) electricity consumption figures. Our results do not therefore correct for spillover affects into other states due to California’s policies¹². Accounting for such spillover benefits is a difficult task, but to the extent they exist, they make state policy even more significant than this type of comparison reveals.

Secondly, we acknowledge that there exist potential endogeneity problems in two areas. The first involves indirect influences of policy on some of the other explanatory factors we have studied¹³. The second, potentially more serious, concern involves possible correlations among household characteristics. This is not an issue for those variables for which we have directly estimated end use electricity consumption needs (such as cooling and heating), but is a potential problem for others.

¹²In the case of refrigeration for example, there is evidence indicating that California’s minimum energy efficiency standards increased the efficiency of refrigerators sold in the US as a whole well before federal standards were adopted.

¹³However we do feel that in cases where there are hidden second order effects of policy on other variables, there are benefits in not assigning the ‘credit’ for those effects to policy, insofar as this allows us to judge policy against its claimed and intended consequences.

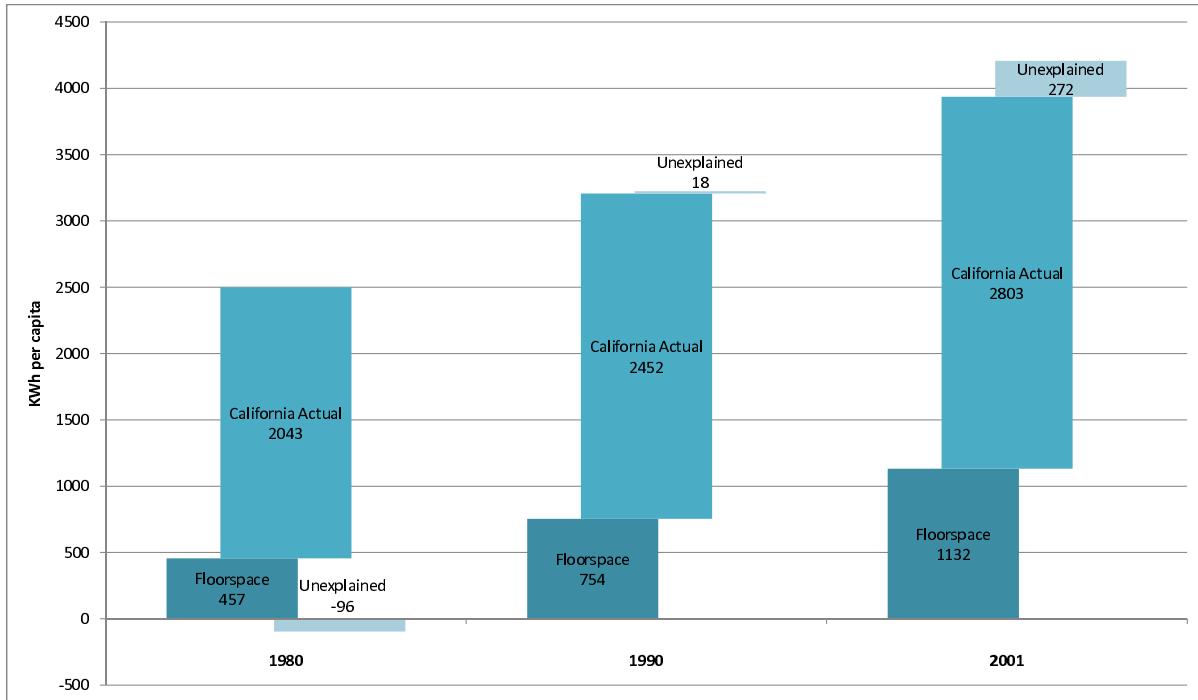


Figure 4: Impacts on Per Capita Commercial Sector Consumption: Three Years

In order to statistically estimate and correct for such dependence we would need enough additional observations - in this case obtainable only from spatial or time series data. Unfortunately household energy use data for California has been collected by the EIA only in recent years¹⁴ and are not available even in those years for almost all states (excepting the 4 largest). Correcting for this is an important objective for future research into this problem, though a complete treatment does not seem possible without data from many more states becoming available. In the present analysis, we attempt to minimize the effects of such correlations by subjectively taking into account cases where strong correlations are intuitively expected. For example, though both housing floorspace and geographical location (urban/rural) are individually significant effects, we include only one in our final estimate of the policy independent share because it seems likely that the two would be significantly correlated.

Finally it would be desirable in subsequent work to carry out a more detailed historical analysis (going back beyond 1980), as well as to separately estimate the effect (if any) of what seem to

¹⁴Since the 1997 RECS to be precise, which is also part of the reason for having to make some of the assumptions referred to in Section 5.

be real lifestyle differences between California and the average US citizen. This last question is of particular interest because public education campaigns are an important policy tool, whose impacts have not been well quantified.

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