

Follow the Leader?
Evaluating California as an electricity model for the future
by
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Abstract

As the search for low carbon sources of electricity in the US continues it makes sense to consider those systems which are already providing electricity without significant CO₂ emissions. In the US there are a few states with emissions which are significantly lower than the national average, California is one such example and it has been pointed to many times as a model for the rest of the country to follow. In determining whether or not these types of changes would be possible at a national level, the differences between the US and California must be understood as well as quantifying what the changes might be. Major differences between the two include climate, generation mix and levels of consumption among others. The changes necessary entail greatly reducing electricity consumption and in addition generating much more electricity from natural gas and renewable sources while almost totally phasing out coal.

While there would be significant reductions in CO₂ emissions and other gases associated with coal combustion by transforming the US electricity system to one like California's, the costs and impacts of such changes make the transition unlikely. Greatly increased dependence on natural gas would lead to higher prices and the use of coal would need to be tightly controlled. On the bright side, the disparity in price between the US and California indicates that as prices rise in the rest of the country, there may be a substantial demand response. In addition there is potential for further demand reductions by implementing the most effective efficiency programs such as decoupling and the re-investment of utility profits. There are many important lessons that can be learned from the experience in California but the path that the US takes to lower CO₂ emissions will likely be implemented differently than how it was in California.

Introduction

California has long been regarded as a leader in energy policy,¹ largely because of its legitimate claim to have one of the lowest energy usages and CO₂ emissions per capita of any state in the nation.² California has been at the forefront of renewable energy development and has been among the nation's leaders in adoption of major renewable energy sources, including solar, wind, geothermal and biomass.³ Perhaps not coincidentally, California has also been one of the nation's leaders in percentage of electricity imports and level of energy prices for all sectors (residential, commercial and industrial).⁴ California's energy imports are more carbon intensive than electricity generated by local sources; Northwest imports are predominantly from large hydro and Southwest imports are primarily from coal.⁵ California has its share of critics regarding the "success" of its energy policy; much of this skepticism centers on increases in costs, changes in job structure and increases in energy imports.⁶

Over time, California has moved towards an energy supply featuring significant natural gas, some renewables, small amounts of nuclear and very little coal. Many scenarios could lead to reduced CO₂ emissions nationwide, and the landscape has the potential to shift rapidly. However, California's supply mix is appealing as a model for the nation because it relies on existing technology. Examining how California has changed as its energy supply has changed over the past 50 years illuminates how the country as a whole might change going forward.

¹ Various Sources; see The Apollo Alliance, "New Energy for States". Amory Lovins, "California Electricity: Facts, Myths, and National Lessons", May 2001. Richard M. Frank, "California and the Future of Environmental Law and Policy", September 2008, for some examples

² Energy Information Administration (EIA), Table R2. "Energy Consumption by Source and Total Consumption per Capita, Ranked by State, 2005"

³ EIA, State Renewable Energy Profiles 2006, May 2008

⁴ EIA, State Electricity Consumption Estimates 1960-2005, February 2008

⁵ EIA, State Renewable Energy Profiles 2006, May 2008

⁶ See Thomas Tanton, "California's Energy Policy: A cautionary tale for the Nation", April 2008, for an example

This historical data can provide significant context for modeled estimations of changes as the CO₂ intensity of the energy supply is reduced and can illustrate economic impacts during the transition to a low carbon energy system.

This paper seeks to answer three fundamental questions about California's usefulness as a model for the future of electricity in the US. The first is: "How does California differ from the rest of the USA, in terms of electricity consumption and generation?" The next question focuses on changes and implications if a California energy model is adopted: "What would the US look like if it followed the CA model for electric consumption and generation?" Finally: "Is national adaptation of the California energy model feasible?" Taken together, the answers to all three questions provide a useful framework for considering how the US might move towards lowering carbon emissions from electricity.

Background and Previous Work on the Subject

Many complex factors led to California's current patterns of energy consumption and generation, and it is important, for purposes of this paper, to understand some of the major causes for its divergence from the rest of the United States. The events surrounding the energy crisis in the mid 1970s provided a catalyst for development of renewable energy and energy efficiency in California. Rising petroleum prices were a driver for these developments, as were federal policies, such as PURPA, which were enacted in response.⁷ As it considered future electric generation alternatives in the 1980s, California faced a difficult situation since it had no indigenous coal reserves, nuclear power was deemed too expensive and it faced water issues which would limit available cooling water. These circumstances created a situation where natural

⁷ Sweeney, "The California Electricity Crisis", 2002

gas, renewable resources and energy efficiency were the most appealing options. This combination of circumstances forced California to move towards a low carbon and energy efficient future long before it was considered a national imperative.

This subject has been addressed in the popular media, in policy papers, and in academic studies. A particular focus has been the consumption of electricity in California, with emphasis on the effects of energy efficiency policies. Arthur Rosenfeld, one of the most noteworthy authors on the topic, was a former head of the California Energy Commission and influenced energy policy development.⁸ His referenced paper estimates the electricity savings from various energy efficiency programs. Others have attempted to quantify the overall effect of efficiency efforts on consumption by trying to control for other contributing factors such as climate, urbanization and average household size, among others.⁹

While not a specific focus of this study, the “electricity crisis” experienced between 2000 and 2001 is another intensely examined facet of electricity in California. The impacts from the electricity crisis can be seen in the results reported in this paper; in many cases, there are notable price spikes over that time period. Opinions on causes of the crisis, and optimal solutions for it, vary widely.¹⁰ Many insights from the crisis are helpful when considering California as an energy model for the rest of the country. Most important are the roles of electricity imports and natural gas prices in creating the crisis. California’s long reliance on electricity imports played a role as a sustained drought in the Northwest limited hydroelectric generation in that

⁸ See for example Rosenfeld and Mcauliffe, “Opportunities in the Building Sector: Managing Climate Change”, 2007

⁹ Sweeney and Sudarshan “Deconstructing the Rosenfeld Curve: Understanding California's Low Per Capita Electricity Consumption”, 2008

¹⁰ See Congressional Budget Office (CBO), “Causes and Lessons of the California Electricity Crisis”, 2001. Taylor and Van Doren, “The California Electricity Crisis: What’s going on, Who’s to blame and What to do”, 2001.

region, and thus limited traditional hydro imports. Thus California ran its highest cost natural gas units at the very time there was a major run up in wholesale gas prices -- clearly an unfavorable situation.¹¹ Demand drives the price of supply, and the California experience serves as a warning about over-reliance on natural gas as a source to generate electricity. The degree of price volatility experienced in California was unprecedented and showed the level of demand elasticity for electricity as prices climbed.

Methods and Materials

To address the major questions of this study, comparisons were made between the US and California using historical data from a wide variety of sources. Major sources of raw data include the Energy Information Administration (EIA), California Energy Commission (CEC), the Bureau of Economic Analysis (BEA) and the US Census. In addition to these sources, many articles and presentations on California and its energy policy were consulted. The EIA was used for data on consumption, generation, capacity, emissions and price. Data from the CEC was used when more specific information on California was needed than was provided from EIA databases. For example, the EIA does not have detailed information about the composition of electricity imports to California. The BEA and the US Census were used to provide the economic and population components for comparisons such as per capita or per unit of GDP.

In most cases, comparisons made between the US and California are from the same data set to eliminate inconsistencies in data collection; however, in some cases it was necessary to compare between sources. (For example, there were situations where the EIA did not have the

¹¹ Ibid.

same level of detail as the CEC did.) When comparisons were made across sources, both sources were checked to make sure that there were no serious discrepancies between them.

Regarding issues related to how the US and California differ, there were a number of different factors to consider. Obviously, California was removed when making comparisons to the rest of the U.S. Since California has such a large proportion of U.S. renewable generation, it would greatly alter the estimations on the additional renewable generation needed elsewhere.. These areas examined for significant differences were: Imported Electricity; Electricity Consumption per Sector (Industrial, Commercial, Residential); Electricity Consumption per Capita; Retail Electricity Prices and Generation Mix. By examining changes in these metrics over time, it is possible to identify where the paths of the US and California have diverged and to see effects of different policies implemented over time.

Figuring out what the US would look like if it generated and consumed electricity like California required a few different comparisons. First was to estimate the changes in the generation mix that would need to occur. This was done by modifying U.S. existing capacity values by the proportion they represent in California. Changes in total CO2 emissions were also calculated using data from the differences comparison and modifying factors from earlier studies.¹² Different demand and generation configurations are also considered, as well as how meeting these goals might move us towards global climate goals.

Based on the differences between the US and California models, it is possible to evaluate what the US would look like if it had a similar profile to California, and to determine the

¹² Sweeney and Sudarshan “Deconstructing the Rosenfeld Curve: Understanding California's Low Per Capita Electricity Consumption”, 2008

feasibility of such a change. For example, by taking the difference between US kWh/GDP and US at CA kWh/GDP, an estimate of the additional GDP which could have been generated is obtained. This estimate suggests what the long term benefits of improved energy efficiency may be, and serves as a point of comparison for the costs to obtain such high levels of energy efficiency.

Results and Observations

The results and observations section is organized around the three principle topics addressed: differences between the U.S. and California; how the U.S. energy landscape would look had it adopted California policies; and an examination of the feasibility of adopting a California energy policy across the U.S.

Differences between the US and California

A look at the adoption of key energy policies in California and at the national level begins to explain the divergence in energy consumption.

Figure 1. U.S. and California Energy Consumption per Capita with key policies¹³

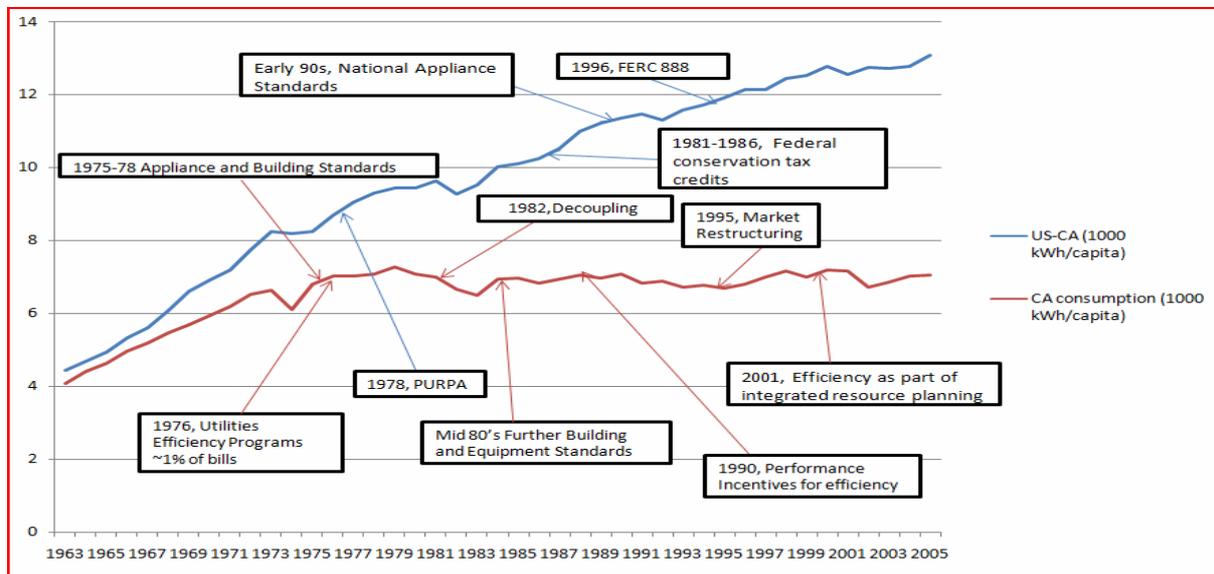


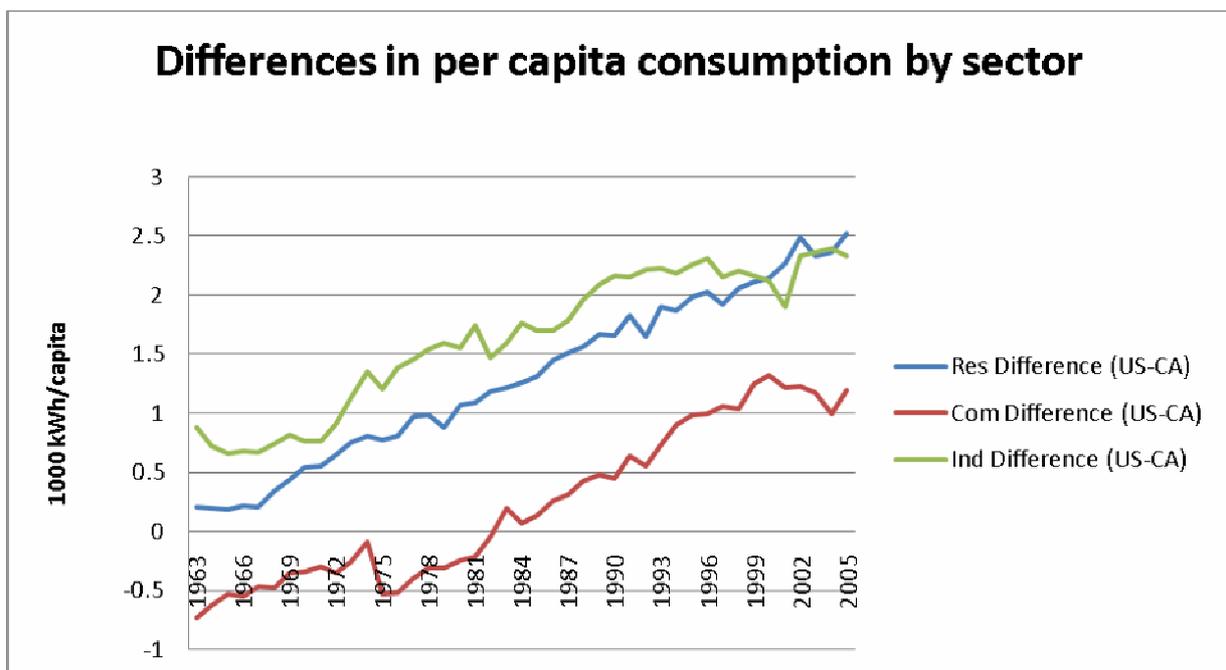
Figure 1 illustrates one fundamental difference between the US and California: the disparity in electricity usage per capita. This figure is a modification of what is often referred to as the “Rosenfeld Curve,” developed by Arthur Rosenfeld. The graph shows the timing of implementation of significant California and U.S. energy policies, illustrating the correlation with consumption and serving as a reference tool. California has been an early adopter in implementing policies affecting energy consumption, and has also refined and revisited them frequently. These policies and their revisions have been essential in keeping demand flat over the years. Energy savings resulting from these efficiency policies are estimated to account for roughly 15% of total demand in 2003.¹⁴ These efficiency policies include building standards for all sectors, appliance standards, solar tax credits for distributed generation and conservation tax

¹³ “State Energy Consumption Estimates 1960-2005”, EIA, February 2008

¹⁴ Rosenfeld and McAuliffe, “Opportunities in the Building Sector: Managing Climate Change”, 2007

credits, among others.¹⁵ In addition to these programs, the decoupling of revenues from sales of electric utilities and natural gas suppliers has been credited with keeping consumption down, as well as the institution of inverted price scales for residential consumers.¹⁶ These policies change the incentive system for sellers and users of energy, reducing the “reward” for higher sales and higher use.

Figure 2. Differences between the US and CA consumption, by sector¹⁷



The overall disparity in energy consumption per capita between the U.S. and California is interesting, and it is further illuminated by examining which sectors contribute most to the difference, as illustrated in Figure 2. This graph represents the difference of per capita consumption in California and the rest of the U.S., broken out by residential, commercial, and

¹⁵ D. Smith, “Electricity Impacts from historical, existing or committed statewide DSM programs”, CEC 1995

¹⁶ R. Risser, “Decoupling in California: More Than Two Decades of Broad Support and Success”, Pacific Gas and Electric, 2006

¹⁷ “State Energy Consumption Estimates 1960-2005”, EIA, February 2008

industrial users. Prior to 1981, the rest of the country consumed less energy per capita in the commercial sector than California did. Many factors can contribute to disparities in energy consumption, including the number of heating and cooling degree days (1100 CDD, 2630 HDD in California, compared to 1577 CDD, 4230 HDD in the rest of the United States). Difference in types of dwelling and the density of population may also play a role, CA has relatively more large apartments than the rest of the country and also more instances of multiple people living in a single room.¹⁸ Both of these factors would affect demand since a greater number of people are sharing spaces, so relatively less space needs to be heated or cooled. The difference in industrial consumption can be at least partially attributed to the fact that California has relatively fewer of the most energy intensive industries than the remainder of the U.S.¹⁹ Likewise, California's relative high level of per capita commercial consumption is partially explained by the fact that California has relatively more businesses that are classified as commercial, including restaurants and services, as well as entertainment and software.)²⁰ Sudarshan and Sweeney estimate the cumulative influence of energy policies to account for 23% of the difference in consumption between the US and CA, my own estimate of the influence of climate is 13% which would leave 54% of the difference to be explained by other factors.²¹

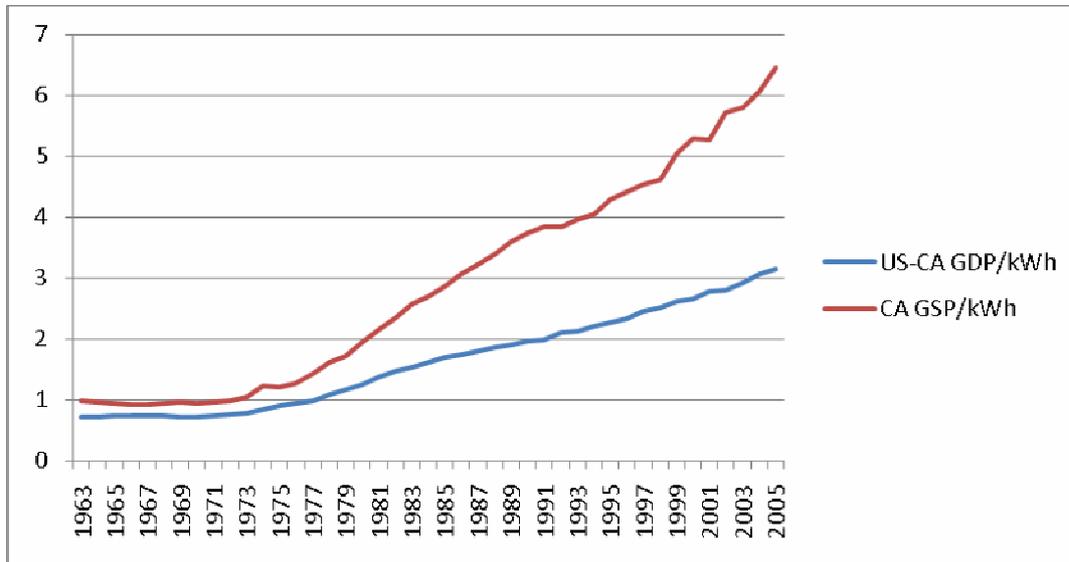
¹⁸ US Census, "2005-2007 American Community Survey", 2007

¹⁹ From BEA, "Regional Economic Accounts", accessed 2008-9

²⁰ Ibid.

²¹ Sweeney and Sudarshan "Deconstructing the Rosenfeld Curve: Understanding California's Low Per Capita Electricity Consumption", 2008

Figure 3. Electricity Intensity²²



For figure 3, electricity intensity is a measure of how many dollars of Gross State Product (GSP) or Gross Domestic Product (GDP) are generated through the consumption of one kWh of electricity. Generally speaking, electricity intensity is a good indicator of both productivity and efficiency. Clearly, California's electricity intensity reflects its business mix, which generates greater product value with less electricity use. It also supports the argument that California's efficiency policy initiatives have been effective and may be worth attempting to apply on a larger scale. Further study is required to determine how much contribution policies may have had specifically, because this measure is influenced by many different factors. It is certain that they have had some effect on the level of consumption in California, although whether the generation of revenue or the consumption of electricity contributes more to the difference in electricity intensity is unknown.

²² Combination of economic data from BEA and electricity consumption data from EIA, accessed 2008-9

Figure 4. Changes in retail electricity prices over time²³

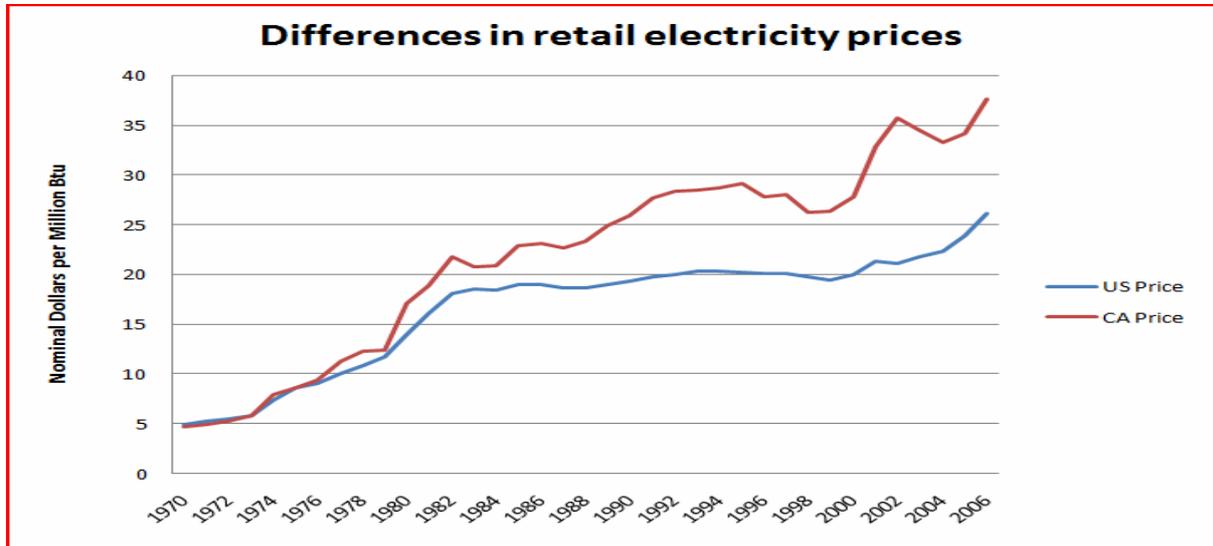


Figure 4 shows the effect of California’s energy choices and policies on the price of retail electricity. California’s prices have significantly exceeded average prices in the rest of the U.S. This figure is almost a mirror image of the consumption patterns illustrated in Figure 1, the “Rosenfeld Curve.” Consumption has been flat in California as prices have climbed, while in the rest of the U.S., consumption has risen as prices have been relatively flat. To some degree, then, price increases resulting in part from policy choices have dampened demand, reduced consumption and led to greater energy efficiency.

²³ Combination of retail electricity price data from EIA’s State Energy Data System (SEDS), accessed 2008-9

Figure 5. Potential effects of price on demand²⁴

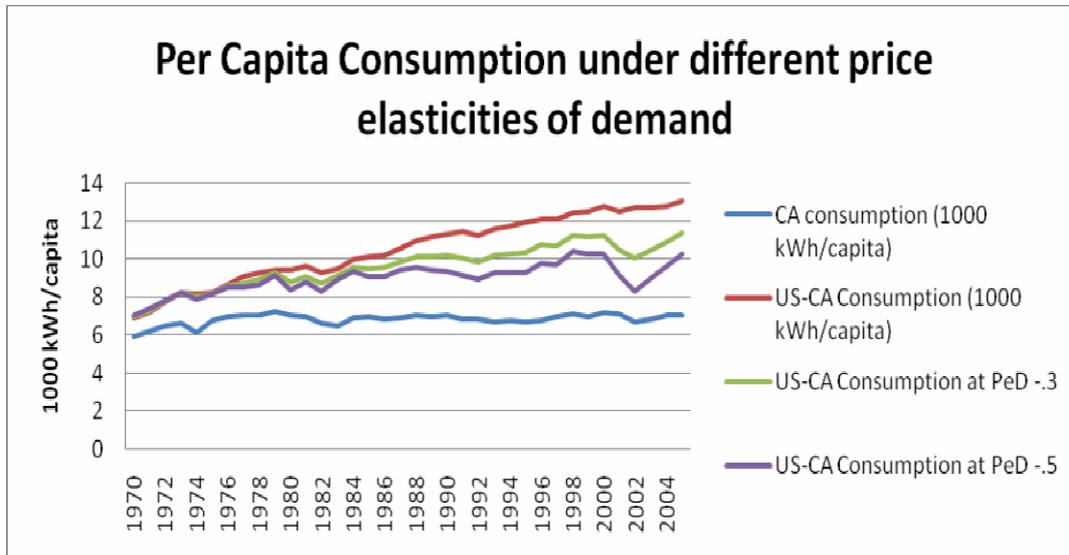


Figure 5 estimates what overall demand in the US would look if prices for electricity had grown like they did in CA. This figure illustrates how significant the influence of price could be, the difference between prices in the US and CA is significant enough to have a noticeable effect on demand even at a relatively low elasticity value. Long term price elasticities could be even higher than those used to make these estimates, since over a long period of time users will be more able to adapt. So depending on what the elasticity of demand is, the rest of the difference could be attributed to other factors like the ones discussed previously.

²⁴ Price Elasticity Estimates based on Mark A. Bernstein and James Griffin, "Regional Differences in the Price Elasticity of Demand for Energy", RAND 2005

Figure 6. Electricity Imports as a percentage of all electricity consumed in CA 1983-2006²⁵

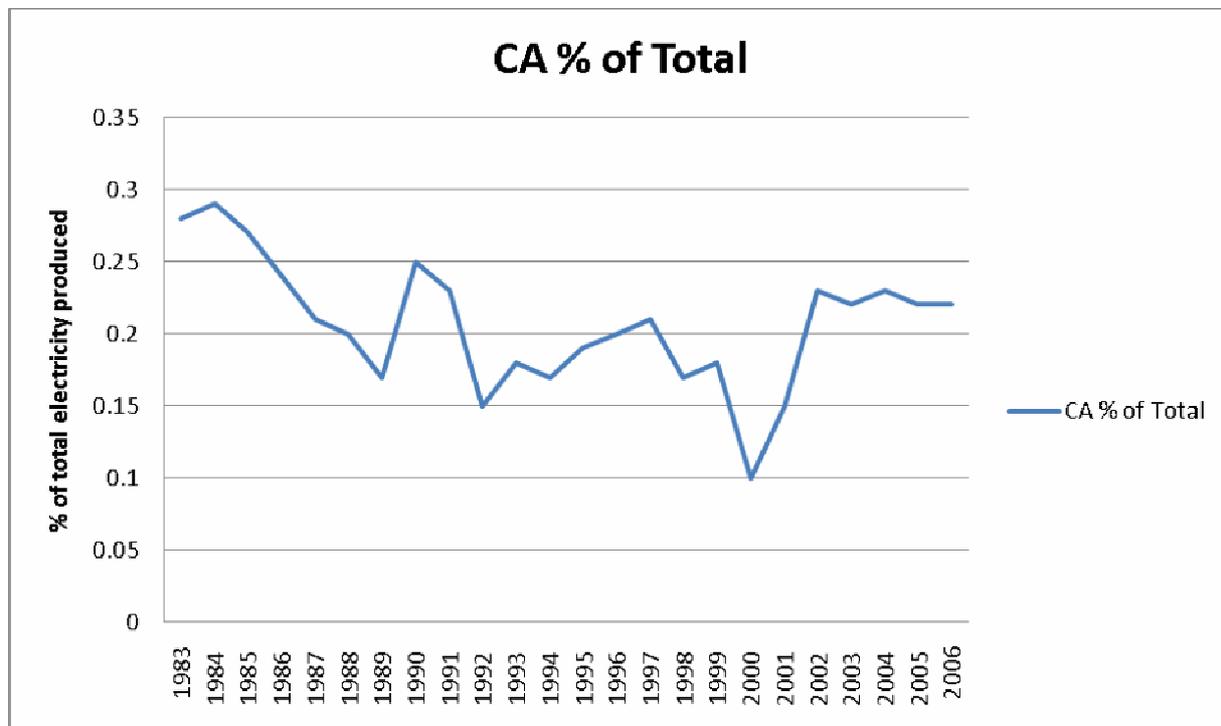


Figure 6 does not show the U.S. proportion of electricity imports for comparison because it is less than 1% over the period, and thus cannot display properly on the graph. Imports of electricity into California come from both the Southwest and the Northwest. Of these, imports from the Southwest are the greatest, and of these coal represents the highest share. The electricity imports from the NW are mainly from large hydro stations in the region so there is fluctuation on these levels based on the amount of rainfall the region receives.²⁶ The significant dip in California electricity imports in the 2000-2001 period, shown in Figure 5, corresponds to a severe drought in the Northwest, which dramatically reduced the amount of electricity available for export from the region. California's reliance on these imports and its emphasis on clean air

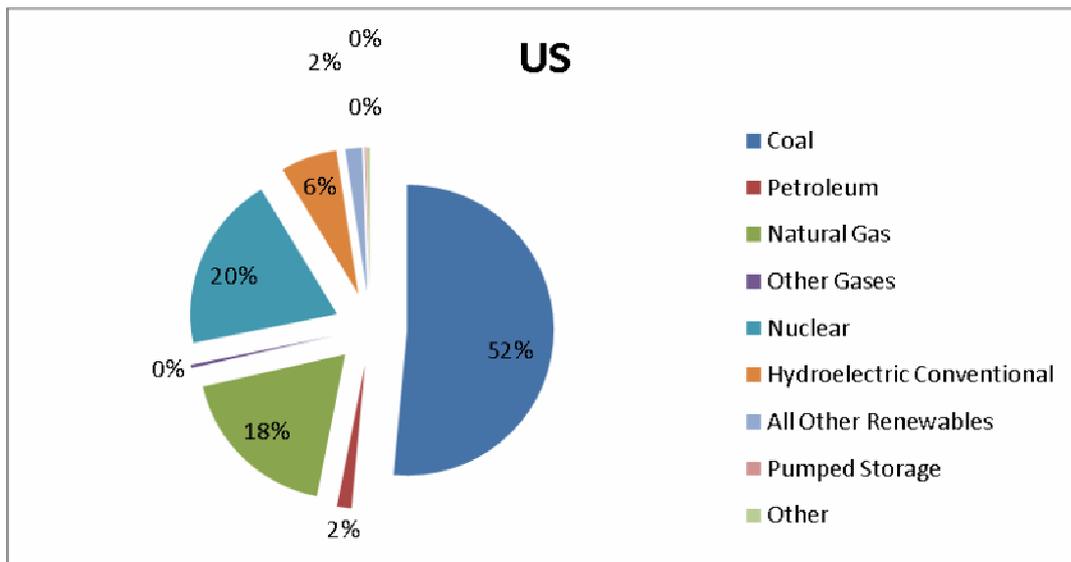
²⁵ From California Electrical Energy Generation, 1983 TO 2005 Total Production by Resource Type (Gigawatt Hours), CEC 2006

²⁶ From CEC "Total System Power 2006", http://energyalmanac.ca.gov/electricity/total_system_power.html

regulation led to a shortage of efficient in-state electricity generators. Thus when imports were not available, older, less efficient generating stations went on line, which further increased prices and contributed to the widely publicized California energy crisis.²⁷ In the past imported electricity from the NW and SW represented a lower cost option for CA, but growing demand in these regions has increased competition for electricity and in turn the cost.²⁸ This could lead to the end of imports in CA; it also seems unlikely the whole nation would rely heavily on imported electricity.

What would the US look like?

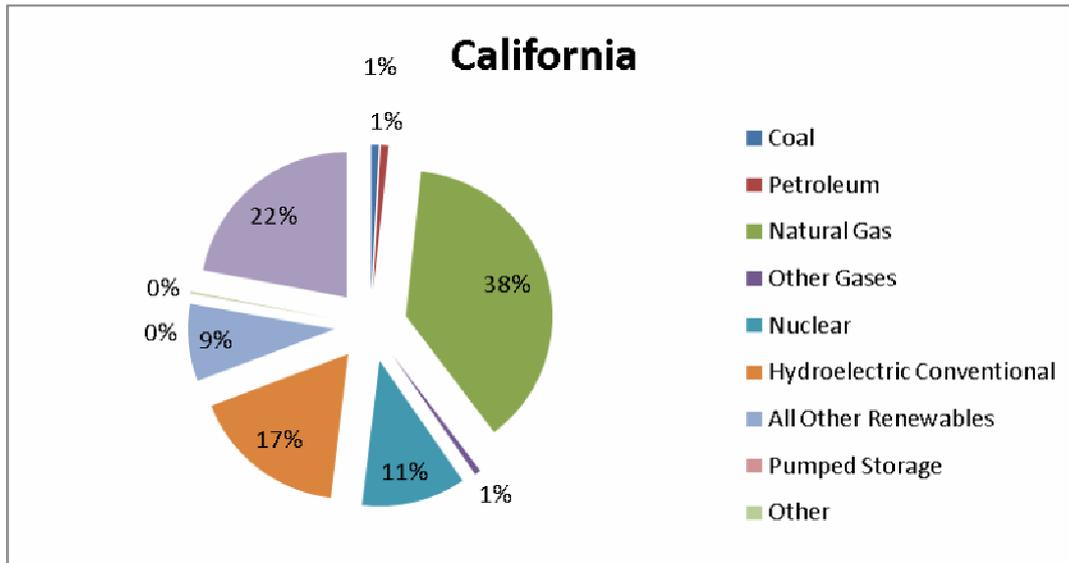
Figure 7. Current US and CA Generation mix (2006)²⁹



²⁷ J. Taylor, "California's Electricity Crisis What's Going On, Who's to Blame, and What to Do", Policy Analysis July 3 2001

²⁸ William J. Keese, "Electricity Supply/Reliability 2000 to 2002", CEC, 2000

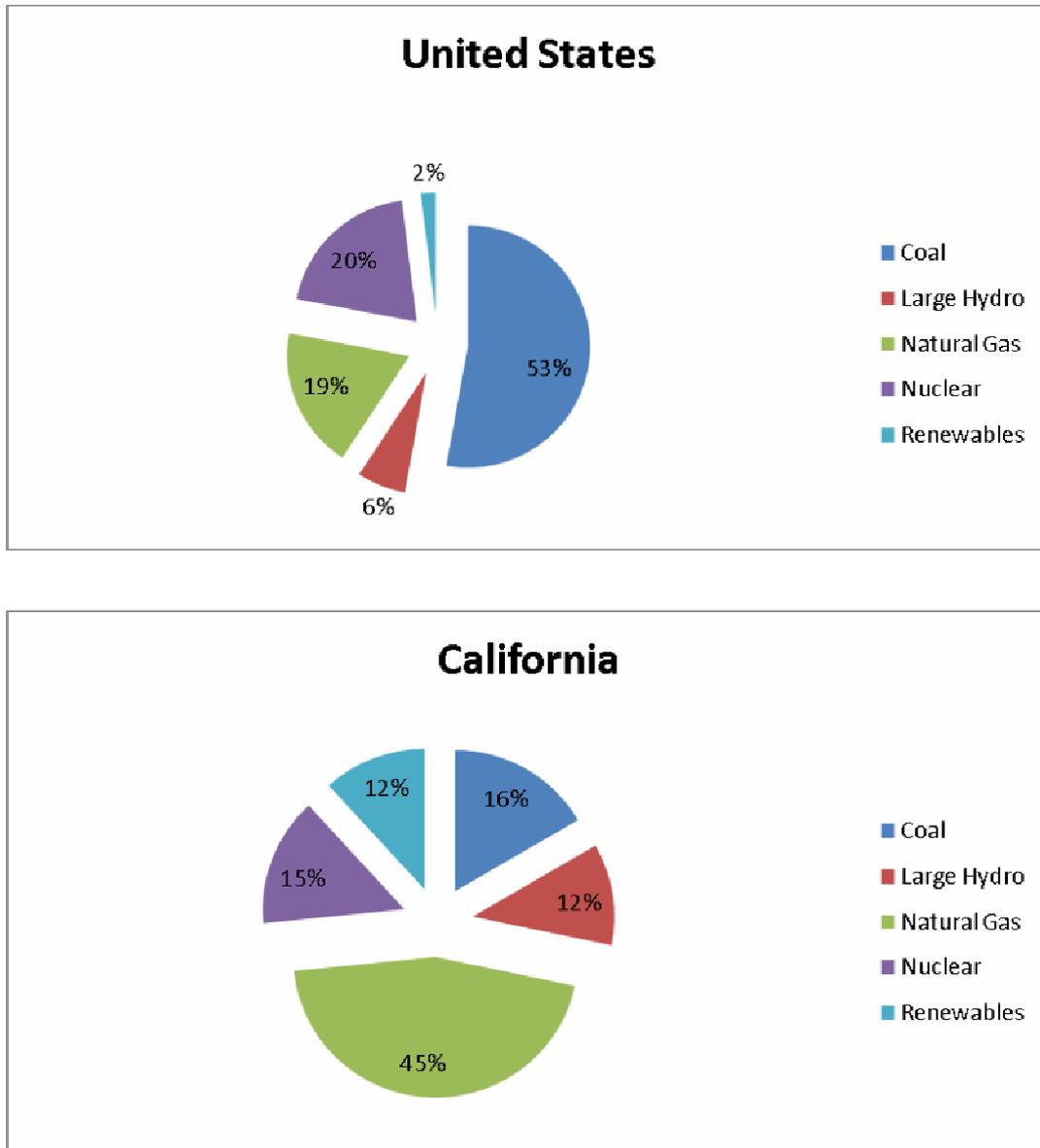
²⁹ From EIA "Historical Generation by State" and CEC "California Electrical Energy Generation, 1983 TO 2005 Total Production by Resource Type (Gigawatt Hours)", accessed 2008-9



California electric consumption patterns clearly differ from the rest of the U.S., and as Figure 7 illustrates, so do the ways in which electricity is generated. The important role of imported power into California is one key difference. California also gets significantly more energy from renewable sources, conventional hydroelectric and natural gas, and relies much less on coal than the rest of the U.S. This difference in generating sources also helps explain why there is a price disparity between the U.S. and California. California’s dependence on natural gas generation is likely the prime reason prices are so much higher. In 2006, natural gas was second highest in cost only to distillate fuel oil for producing electricity, and was roughly four times more costly than coal.³⁰

³⁰ EIA, “State Energy Data 2006: Prices and Expenditures: Table S6a. Electric Power Sector Energy Price Estimates by Source, 2006”, 2006 Figure 7 and 8 based on generation, not capacity

Figure 8. Simplified US and CA Generation (2006)³¹



By eliminating some of the smaller generation categories, such as petroleum, to reduce the overall number of categories, it is possible to integrate the California's imported electricity into the whole. Considering the generation source for electricity imports as part of California's

³¹ Ibid. With additional information from CEC "Total System Power 2006"

native generation enables this comparison. Unfortunately, data on imports does not have the level of detail that is available for in-state generation. Including the sources of electricity imports shows that California’s energy is not as “clean” as may be purported; however, this views shows a generational mix which is well balanced around a core of natural gas. While the changes for the rest of the U.S. to match this generation mix are not as significant as those needed to match the in-state generation of California, they are still major.

Figure 9. Differences in CO2 emissions³²

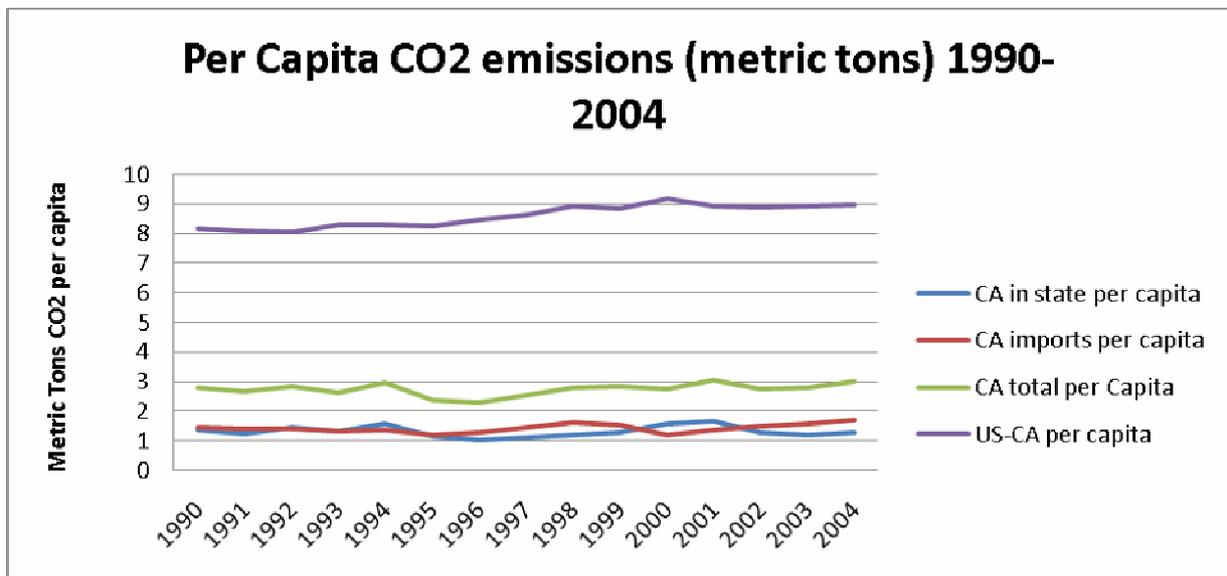


Figure 9 represents perhaps the most compelling reason to implement the kinds of energy policies that have been successful in California. Achieving these results would mean reducing energy demand to California’s levels and emulating their generation mix. California per capita CO₂ emissions, including emissions generated by imports, are roughly 1/3 of the national average, and even less if only in-state generation emissions are considered. Imports of electricity,

³² Calculations based on information from EIA “State Historical Tables from 2006” and CEC “Jan 2007 GHG Inventory Revisions”

which account for only about 20% of California’s energy needs, are equivalent to or even greater (depending on the year in question) than the total CO₂ emissions produced by in-state generation. In addition to the reductions in CO₂ emissions there would be also be decreases in the other air pollutants associated with coal based generation such as SO₂ and particulate matter.

Figure 11. Comparison of the US to other nations

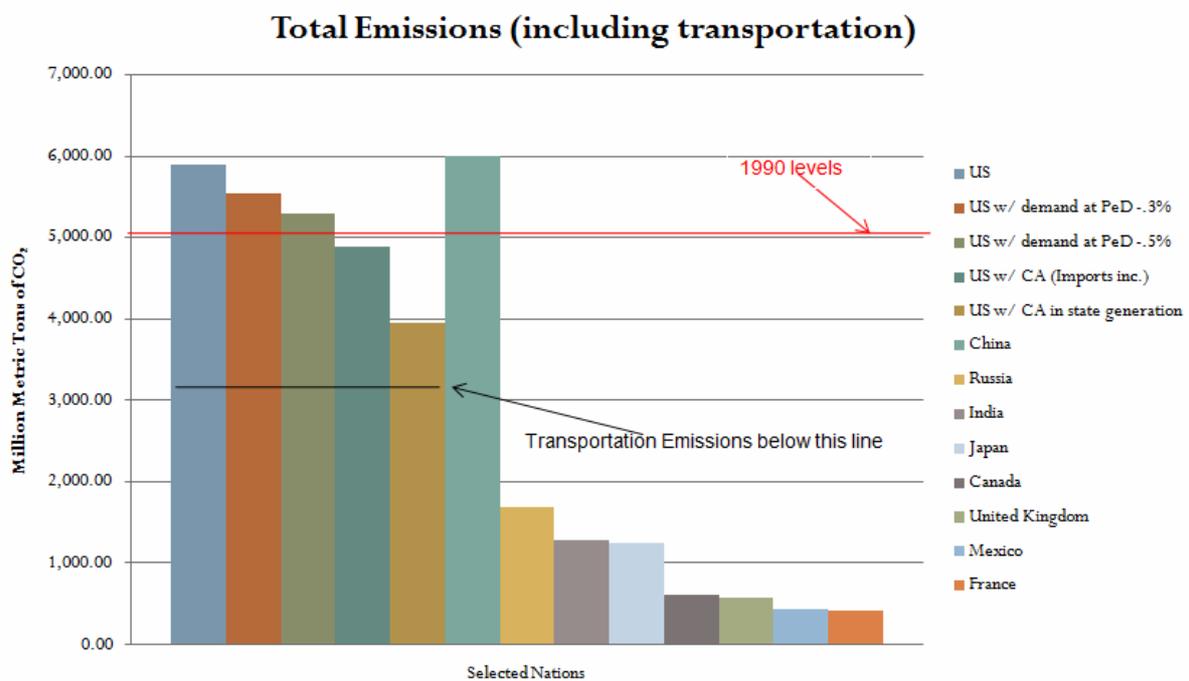


Figure 10 examines what our total emissions would look like under reduced demand or different generation mixes. It is encouraging to see that even with our current generation mix if prices were to rise and cause a drop in demand equal to a PED of -.5, the US would be within range of Kyoto goals with only a small improvement from the transportation sector. Even with current demand 1990 levels would be surpassed under both generation scenarios. Levels would likely be reduced even further since prices would increase under either circumstance, leading to

reduced demand. Total emissions remain higher than any of the nations the US was compared to, except for China but their larger population makes them the clear winner if emissions were measured on a per capita basis.

Is this feasible?

Figure 12. How much more or less does the U.S. need?³³

	Current GW	GW change	End Result (GW)	Annual Change to 2030 (%)	EIA Projected Annual Change to 2030 (%)
Coal	335.6	-328.43	7.17	-12.03	0.50%
Petroleum	61.5	-19.13	42.36	-1.23	0.87%
Natural Gas	407.25	721.99	1129.24	3.46	0.87%
Other Gases	2.33	4.49	6.83	3.64	0.87%
Nuclear	101.19	-13.23	87.95	-0.47	0.50%
Hydroelectric Conventional	67.61	89.43	157.04	2.85	
Wind	14.28	37.42	51.7	4.38	
Solar Thermal and Photovoltaic	0.1	18.72	18.82	19.12	
Wood and Wood Derived Fuels	6.85	5.42	12.27	1.96	
Geothermal	0.41	60.42	60.83	18.12	
Other Biomass	4.28	8.7	12.97	3.77	
			Renewable Average	9.47	1.30%

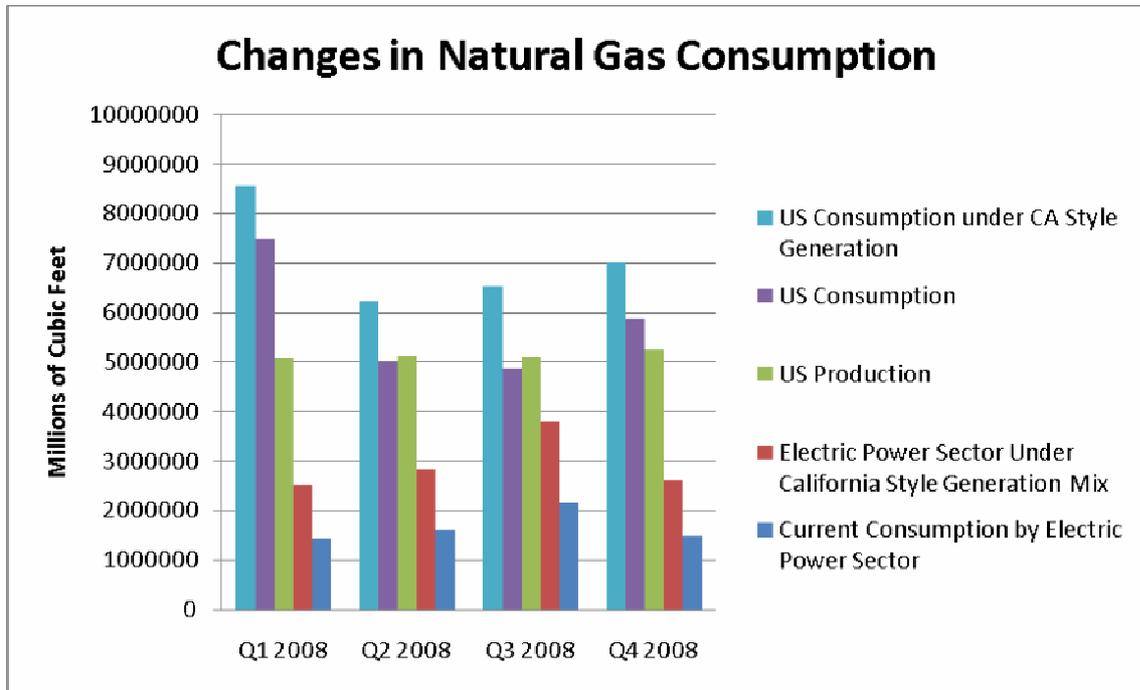
This chart estimates the capacity changes that would be necessary for the US to have a generation profile similar to the in-state generation of CA (figure 7). This scenario would provide the greatest environmental benefits in terms of emissions reductions and growth in renewable energy, but come at the greatest cost. The reductions to coal and increases to natural

³³ Adapted from EIA, "State Historical Tables 2007 (Capacity)", 2009 and EIA, "State Historical Tables for 2007 (Generation)", 2009

gas are the most significant, and these changes are affected by the average capacity factors of the two fuels. Coal plants have an average capacity factor that is roughly three times higher than for natural gas plants, so replacing generation and in turn capacity from coal plants requires a greater number of gas plants. Renewable technologies such as wind and solar have low capacity factors, but have potential to improve and become more acceptable substitutes for natural gas generation. In fact since wind currently has a similar average capacity to natural gas if these resources can continue to be developed as efficiently they could play a bigger role than estimated. In addition wind is one of the few non-hydro renewable resources to be developed not only in California, but around the country as well.³⁴ This means that expanding wind generation is likely more feasible than the expansion of CA-centric renewables like geothermal and solar (CA is where over 80% of both types of this generation are located).

³⁴ Ibid.

Figure 13. Impacts on Natural Gas³⁵



The significant changes that the natural gas markets would undergo make it unlikely that the whole nation could afford to depend primarily on electricity generated from natural gas. Figure 13 represents a high level view of the impacts a change to the generation mix from fig. 6 might entail. The main problem is the fact that with an increase in the use of natural gas to generate electricity there would be no periods in which production exceeds consumption. The US already imports over 16% of our natural gas, most of it from Canada, meeting such a large amount of increased demand would require natural gas from many other sources so more liquefied natural gas (LNG) terminals would need to be developed.³⁶ Another interesting possibility is how an increase in demand for natural gas for electricity generation would also

³⁵ Compiled from EIA, "US Natural Gas Consumption by End Use", "US Dry Natural Gas Production" and "US Natural Gas Deliveries to Electric Power Consumers"

³⁶ EIA, "US Natural Gas Imports and Exports: Issues and Trends 2005", 2005

cause the cost to rise for its use as a home heating fuel. Besides how the increase in demand would lead to an increase in price and possibly volatility, there would also be a considerable cost in developing the infrastructure to acquire and distribute the fuel.

Figure 14. Cost Estimates³⁷

	Capacity Change in Kw	Cost modifiers (\$/kw)	Estimated Cost
Coal	-328430000	-60	19705800000
Petroleum	-19130000	-60	1147800000
Natural Gas	721990000	1165	8.41118E+11
Other Gases	4490000	2100	9429000000
Nuclear	-13230000	-250	3307500000
Hydroelectric Conventional	89430000	2100	1.87803E+11
Wind	37420000	2106	78806520000
Solar Thermal and Photovoltaic	18720000	4994	93487680000
Wood and Wood Derived Fuels	5420000	2100	11382000000
Geothermal	60420000	3170	1.91531E+11
Other Biomass	8700000	2100	18270000000
		Total	\$1,455,989,050,000.00

From figure 14 it is clear that the costs for making sweeping changes in generation capacity escalate quickly and even when spread out over many years would remain significant. There is plenty of uncertainty in these estimates due to the fact both construction and decommissioning costs vary widely based on site specific factors. The costs of solar thermal and solar photovoltaic (PV) vary considerably, so in this case the average of the two was used. If more PV was installed, costs would be even higher whereas more solar thermal would result in lower costs. An estimate for conventional hydroelectric could not be obtained since there have

³⁷ Cost estimates from Stan Kaplan, "Power Plants: Characteristics and Costs", 2008 Congressional Research Service and Schissel et. al, "Coal Fired Power Plants: Construction Costs", July 2008

not been any projects proposed, in this case the average estimate for all power plants was used. However; the fact that there have not been any plants proposed recently does show how difficult it might be to greatly expand the use of large hydropower. In addition to the costs to install the capacity there would be a need to expand infrastructure of all different types including pipelines, transmission lines and on down to the roads needed to access some of the remote areas where renewable resources are most plentiful.

Discussion

Setting aside the desirability of a transformation for the overall U.S. to California's standards for efficiency and generation mix, is such a transformation even feasible, as a practical matter? Clearly, the U.S. must make significant steps to reduce CO₂ emissions, and there is increasing scientific belief that these steps must be taken quickly to avoid potentially disastrous and lasting effects of global warming. These steps, whatever path is taken, will have significant costs, and will demand an unprecedented level of political will.

Virtually any U.S. path to CO₂ emissions reduction, including adoption of California generation mix, will call for a major move from traditional coal-based generation. The obstacles to such a move are familiar ones: coal is an abundant native fuel, with many states reliant on its mining revenue as well as the relatively inexpensive electricity it produces. The political influence and the economic realities of the coal-producing and coal-using states will be formidable considerations as the U.S. moves away from its reliance on coal. If those coal reserves are used for other purposes or in other places, with the same resulting CO₂ emissions, nothing will have been accomplished, and at a high cost. Additionally, natural gas has many

uses other than electricity generation, and arguably, higher value in other applications. Prices of natural gas are more volatile than coal prices, and adequate, stable supplies are uncertain.

Even effective disincentives for coal use, such as a carbon tax or cap and trade policy, would need to be accompanied by mechanisms to prevent the coal from being used for other purposes or being sold to other countries. Coal is most economically moved by rail or barge, so strong regulations and international agreements will be needed to forestall the shipment of U.S. coal outside of the country to produce cheap electricity, which is then imported back to the U.S. Moving away from coal creates political, social, economic and technological issues which seem nearly insurmountable. Thus the exploration of so-called “clean coal” technologies, such as carbon capture and sequestration, will likely continue as a major item on the technology research agenda. Another thing to consider when switching from coal to natural gas as the main fuel is the fact that states with significant amounts of coal are often lacking in both renewables and natural gas reserves.³⁸

If a quick replacement of coal by natural gas seems unlikely, what about dramatically increasing the share of renewable energy in the U.S. generation mix? Given the many issues associated with large hydro stations, it seems unlikely that the U.S. could feasibly double the amount of electricity generated from these sources. But could generation from other renewable sources increase to such a level that it would make up the difference? Only if electricity generated from renewables can increase eightfold, currently there are less than 30 GW of renewable electricity capacity in the US outside of CA and over 250 would be needed. One of the major barriers to this would be the cost; in terms of installed capacity renewable technologies

³⁸ See EIA, “Coal Production and Number of Mines by State and Mine Type, 2007-2006” and “Coal Mining Productivity by State and Mine Type, 2007, 2006”

are all more expensive than natural gas capacity.³⁹ In addition to the sheer volume of increase in renewables, there is the fact that access to renewable energy, such as wind and solar, is not evenly distributed across the country. Thus a move to this level of reliance on renewables would require considerable co-operation between states rich with renewable resources and those without to ensure efficient development. Such cooperation would require federal regulation and mandates to assure that optimal projects were developed where renewable resources were most readily available, with the benefits shared regardless where the renewable resources were generated. Such an approach is unprecedented in the energy sector.

Regarding efficiency initiatives, even if the U.S. applied all of California's demand side management programs and policies on a nationwide level, it would be unlikely to have the same effect, and almost certainly not for the same relative cost. With greater cooperation between states or greater federal involvement, average rates of residential consumption might be significantly lowered by targeting first those areas with relatively fewer heating and cooling degree days, but relatively higher electricity consumption. Simply because of variations in temperature patterns, higher levels of consumption will occur in certain states, making achieving efficiency levels more costly. But policies such as decoupling and increasing costs of electricity as consumption rises can lead to overall decreases in consumption.

Conclusions

Differences between California and the rest of the United States are numerous. However, certain strategies used by California to improve energy efficiency have clearly been effective and can be refined and adapted for wider application. Specifically implementing decoupling, re-

³⁹ Stan Kaplan, "Power Plants: Characteristics and Costs", 2008 Congressional Research Service

investing some portion of the money spent on electricity for efficiency and re-visiting current efficiency policies and standards. Many energy efficiency projects are affordable and low cost, adding to their importance in the current economic climate. As prices for electricity rise, there will be added incentive to pursue efficiency as the time horizon for return on investments is reduced.

Even California itself cannot supply its energy needs without coal imports from the Southwest, so an extreme scenario in which coal plants, coal mines and coal trains became things of the past is unlikely. But adopting an approach which required less reliance on coal and emphasized clean coal technologies would lead to greater use of LNG and further development of the LNG infrastructure, as well as greater use of natural gas and renewables. Increasing this dependence to the same levels that California currently has does not seem feasible but some growth could be desirable depending on what the total environmental benefits were. Electricity generation would vary more widely between states by what types of indigenous resources could be developed most cost effectively, but a means would have to be devised so that all residents could share the benefits of the most cost-effective approaches. Current California generation uses only existing technologies, but new carbon capture and sequestration techniques and use of nuclear power offer further options for the U.S. to reduce carbon emissions from energy production.

The adoption of certain California approaches to energy efficiency and power generation could indeed lead to reductions in CO₂ emissions in the U.S. The barriers to such adoption are not technical, as California uses only existing technologies. However, California has had the political will and the state jurisdictional power to mandate policies it deemed environmentally

prudent. The federal government lacks the authority to initiate the sweeping changes needed to significantly alter the U.S. electricity system. Empowering the federal government to make these kinds of these changes would require states to cede much of their control over electricity generation and over consumer pricing. The focus should first be on developing the appropriate regulatory and jurisdictional framework to enable the kinds of changes that will be necessary if the U.S. is to act quickly to reduce its CO₂ emissions. Neither the lessons of a single state nor the promise of any technology or renewable resource will realize their value until this energy policy framework is developed.

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