CONSULTANT REPORT

DEMAND FORECAST EXPERT PANEL INITIAL ASSESSMENT

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Prepared by: Aspen Environmental Group

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ABSTRACT

The California Energy Commission established the Demand Analysis Expert Panel to evaluate the CEC's approach for developing projections of California's electricity and natural gas demand over a ten-year period. The panel's ultimate objective will be to guide the Commission in making its projections as reliable and useful as possible. In this first report we provide detailed comments on several important issues that will be critical in our evaluations. A summary of these comments contains the following four points:

1. Although the staff appears to be following appropriate modeling strategies given the constraints on their staff time and budget resources, there are opportunities to improve the detailed model structure and the assumptions used for projecting future demands in future IEPR cycles.

2. The Commission staff's current approach for attributing the reductions caused by energy efficiency programs and standards does not appear to systematically bias its long-run projections of future electricity demand growth.

3. We think that the usual dichotomy between end-use and econometric models is not very useful to CEC internal discussions or for interactions with other California agencies. Instead, we prefer to discuss models that are disaggregated by end use or technologies and those that are aggregated to operate in response to a wide set of factors. The Commission staff should plan to develop a hybrid framework that combines the strengths of an end-use process model with a statistical-estimation model.

4. Any modeling approach requires a comprehensive and continuous approach for collecting and analyzing key data. Which data should be included will depend importantly on which policy needs are the CEC's focal points. Collection and analysis of essential data requires adequate and consistent funding.

Keywords: Electricity demand forecast, end-use demand modeling, econometric modeling, hybrid demand modeling, energy efficiency, energy savings, demand reduction, electricity consumption, investor-owned utilities, publicly owned utilities

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Table of Contents

1 Introduction

The California Energy Commission has established the Demand Analysis Expert Panel to evaluate the CEC's approach for developing projections of California's electricity and natural gas demand over a ten-year period. The panel's ultimate objective will be to guide the Commission in making its projections as reliable and useful as possible. In this first report we provide detailed comments on several important issues that will be critical in our evaluations. A summary of these comments contains the following four points:

1. Although the staff appears to be following appropriate modeling strategies given the constraints on their staff time and budget resources, there are opportunities to improve the detailed model structure and the assumptions used for projecting future demands in future IEPR cycles.

2. We have reviewed the recent CEC's adjustments for attributing energy-efficiency improvements in the 2009 IEPR report. We conclude that the Commission staff's current approach for attributing the reductions caused by energy efficiency programs and standards does not appear to systematically bias its long-run projections of future electricity demand growth.

3. We think that the usual dichotomy between end-use and econometric models is not very useful to CEC internal discussions or for interactions with other California agencies. Instead, we prefer to discuss models that are disaggregated by end use or technologies and those that are aggregated to operate in response to a wide set of factors. The Commission staff should plan to develop a hybrid framework that combines the strengths of an end-use process model with a statistical-estimation model.

4. Any modeling approach requires a comprehensive and continuous approach for collecting and analyzing key data. Which data should be included will depend importantly on which policy needs are the CEC's focal points. Collection and analysis of essential data requires adequate and consistent funding.

2 Major Issues

The Demand Analysis Panel will address four basic important points in its initial report back to the California Energy Commission.

1. Are the CEC end-use projections reasonable for establishing the growth in California's aggregate and individual power area electricity demand over the next ten years?

2. Are there grounds for concern that bias may be present in the Commission's estimation of the effects of energy efficiency programs and policies?

3. What models or characteristics are necessary and sufficient to project future energy demand?

4. What are the value and insights derived from the collection of detailed data on energy-efficiency options?

In each area, the panel provides specific recommendations to improve the production of the forecasts themselves and the communication of the key insights.

2.1 Are the CEC end-use projections reasonable for establishing the growth in California's aggregate and individual power area electricity demand over the next ten years?

Any demand projection will contain errors due to a range of factors: incorrect assumptions about future economic and other external conditions, uncertainty about the future response of energy consumption to key external conditions like prices and economic growth (even if these conditions were known with certainty), biases created by omitting important variables, and data measurement barriers among other possible sources.

Although modelers try to minimize these errors, this situation means that every model produces projections that do not match what actually happens. In the words of one famous statistician (George Box): "All models are wrong, but some models are useful." For this reason, many modelers try to reduce the uncertainty about future projections rather than achieve strict accuracy with their projections.

In this sense, the CEC projections do not appear to be biased towards either over-prediction or under-prediction of future electricity loads. Although the panel will need more information and time to understand more fully the CEC approach, the staff appears to be following appropriate modeling strategies given the constraints on their staff time and budget resources.

Sometimes modelers adopt different scenarios to indicate the range over which loads can vary as external economic, demographic and energy conditions change. The CEC now provides three different scenarios representing high, mean and low estimates for electricity loads. One apparent problem with these CEC scenarios is that the external conditions do not vary much between each other. As a result, the high and low demand projections tend to cluster closely to the mean forecasts, implying that there may be little uncertainty when the true conditions may suggest considerable uncertainty about the trends. Over the next ten years there are significant uncertainties that could cause demand forecasts to deviate significantly from a base case forecast. These factors include not only the success of energy-efficiency programs to achieve their goals but also unexpected economic and demographic shifts, uncertainty about how consumers respond to future prices, new developments in the control of greenhouse gas and other environmental emissions, and the deployment of smart grid technologies.

Prior to preparing a projection, it is not possible to determine which of the above problems will create the biggest potential errors. One approach for checking a model's tendency to over or under predict future loads is to compare projections from previous forecasts with actual levels in years where historical data exists. The 2009 IEPR forecast report provides some comparisons of past forecasts with actual historical trends in the appendix. Another useful example is the US Energy Information Administration's retrospective review of its Annual Energy Outlook found at http://205.254.135.24/oiaf/analysispaper/retrospective/index.html.

Another technique is to compare results from alternative and sometimes competing approaches. In this respect, some credence is given the CEC projections by their willingness to prepare projections not only with an end-use model but also with an econometric model. Our general understanding of these two CEC approaches is that the projected demands are frequently similar to each other, but comparing outcomes from models with different structures often requires considerable time and expertise. Moreover, the CEC results for aggregate forecasts by planning area are usually similar to those prepared by the major electric utilities for comparable regions, but some important deviations arise for individual sectors (e.g., residential or commercial) within a planning area. Where differences exist, this approach indicates which assumptions and other revisions should be evaluated more carefully. Past efforts to compare CEC and utility models have not always been able to use similar assumptions for the main exogenous driver variables and focus on the same service areas. The experiences of the Energy Modeling Forum may help to standardize these factors on a more consistent basis. (See http://emf.Stanford.edu.)

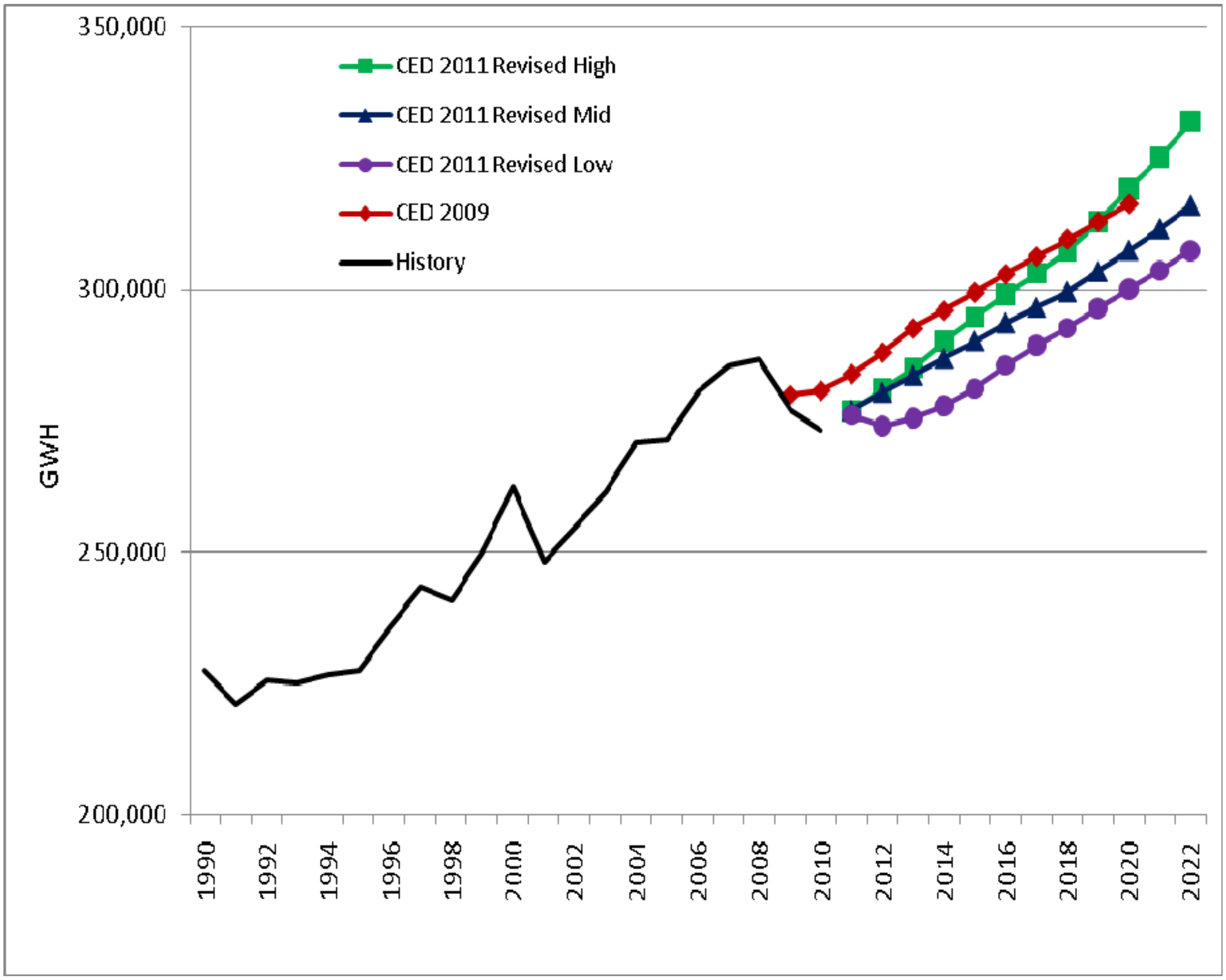
Although the broader dimensions of the CEC's current modeling ***strategy*** appear consistent with good modeling practices and for the current IEPR forecast, the panel thinks that more effort is needed to assess which specific modeling techniques are the best ones going forward. The panel remains concerned about whether a single model with large data needs can meet the CEC's multiple objectives. One approach to improvement is to recode the end-use model to take advantage of expanded computer power and more flexible modeling tools that are now available, compared to when the model was originally constructed. To address the large data needs, a more flexible model could focus on key end uses rather than the whole slate currently included. So, while the forecast appears reasonable for this IEPR forecast, more effort is needed to assess how to improve modeling strategy going forward.

Demand Forecast Range

The CEC Demand Analysis staff has made important improvements in communicating the uncertainty in their 2011 load forecasts. Their projections now include three different cases representing high, mid and low demand conditions associated with different GDP and energy price paths. Generally, the range associated with these three demand projections is roughly comparable to those for other available projections, such as the Annual Energy Outlook for U.S. electricity consumption trends produced by the US Energy Information Administration (EIA) and the Sixth Power Plan for the US Northwest produced by the Northwest Power and Conservation Council (NPCC).

Although charts in Figure 1-1 in the Revised California Energy Demand Forecast 2012-2022 appear to show a clustering of the projected three trends in electricity demand, the apparently narrow range results from the chart being scaled to fit both historical and future electricity

Figure 1-1: Statewide Annual Electricity Consumption



Source: California Energy Commission, 2012

demand trends on the same figure. Table 1 below shows that the Commission's electricity consumption growth paths for California appear comparable to those for the NPCC's growth paths for the US Northwest. When the growth rates for California's electricity demand growth in the CEC projection are compared to those for the USA in the US Energy Information Administration's projections (2011 Annual Energy Outlook), the ranges also appear comparable. This result is particularly the case when attention is focused on the lower part of the table indicating the amount by which the high and mid case growth rates exceed those in the low case.

Table 1 Comparison of Electricity Demand Growth, 2010-2020

	Region	High	Mid	Low
Percent/year				
California Energy Commission	CA	1.57%	1.19%	0.95%
Energy Information Administration	USA	1.07%	0.76%	0.46%
Northwest Power and Conservation Council	NW	1.50%	1.20%	0.80%

Change from low (%pts)				
California Energy Commission	CA	0.62%	0.24%	0.00%
Energy Information Administration	USA	0.62%	0.30%	0.00%
Northwest Power and Conservation Council	NW	0.70%	0.40%	0.00%

The CEC high and low demand projections also include lower and higher energy prices, which conceptually would cause even wider demand projections than those provided by the EIA. The response of electricity demand to different price paths, however, is very modest in the CEC projections. Thus, the CEC energy price assumptions probably do not contribute much additional variation in electricity consumption than would be expected from the high and low economic growth paths alone.

Inflation-adjusted (or real) personal income is an important contributor to these different projected electricity consumption trends. The top set of results in Table 2 show that real income grows faster in the high, mid and low economic growth cases for USA in the EIA outlook than for California in the CEC projections. However, the variation in the high and mid growth cases relative to the low-growth case, shown in the lower part of the table, is not starkly different for the two projections. As a result, the range of economic growth paths in the CEC state results is about the same as those in the EIA national results.

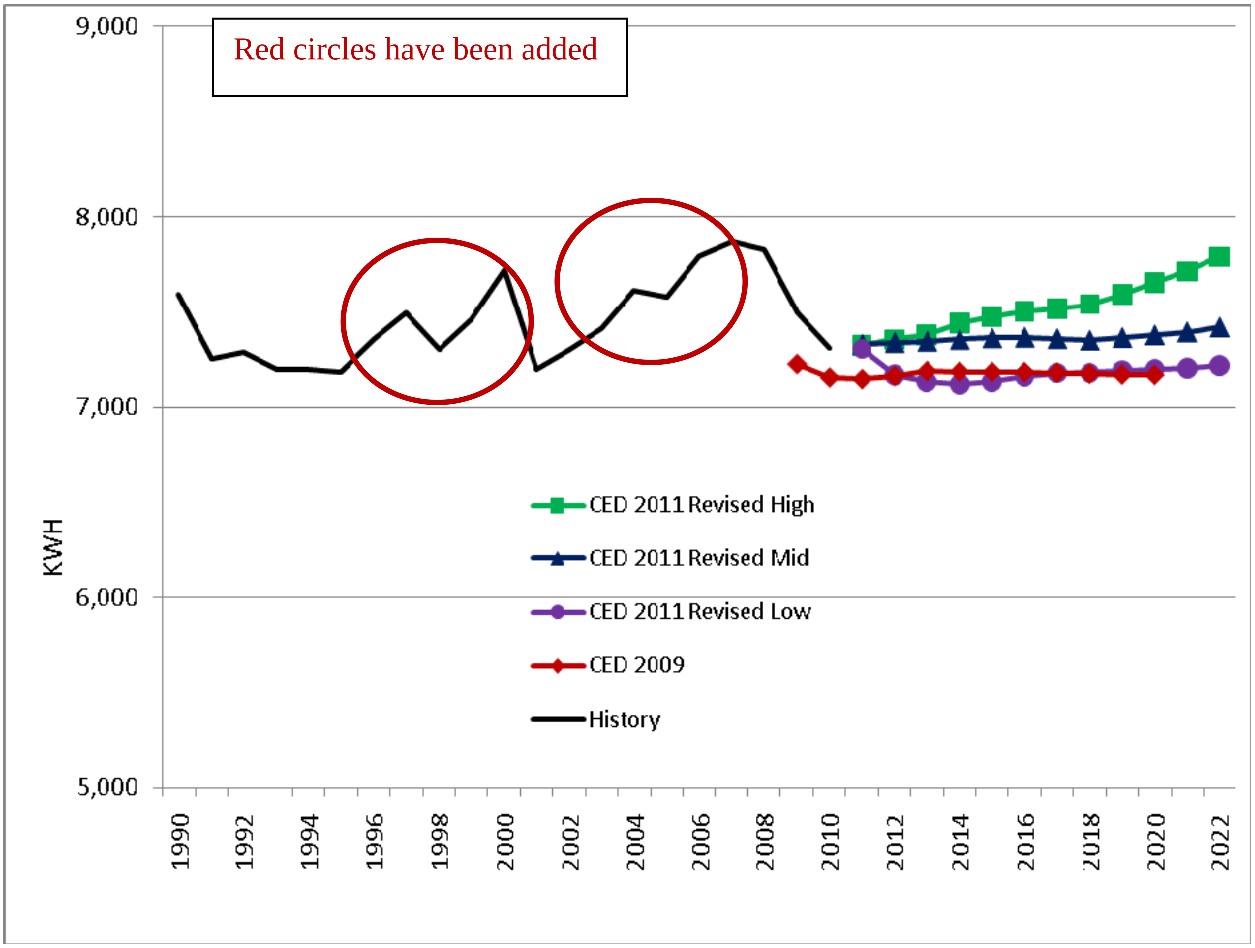
Table 2 Projected Real Income Projections, 2010-2020

	Region	High	Mid	Low
Percent/year				
California Energy Commission	CA	3.34%	3.25%	2.52%
Energy Information Administration	USA	3.08%	2.54%	1.99%
Northwest Power and Conservation Council	NW	#N/A	#N/A	#N/A
Change from low (%pts)				
California Energy Commission	CA	0.82%	0.73%	0.00%
Energy Information Administration	USA	1.10%	0.56%	0.00%
Northwest Power and Conservation Council	NW	#N/A	#N/A	#N/A

The Commission provides a careful comparison between its current range of demand projections and those made in the previous California Energy Demand (CED) projections in 2009. This discussion is quite helpful in understanding which factors have changed during the two years between forecasts.

Another important issue may be the relationship between the future projections and recent historical trends. Figure 1-2 in the CED 2011 shows strong upward electricity consumption per-capita growth in the years leading up to the “dot.com” boom (around the year 2000) as well as the recovery leading up to the financial collapse in the year 2008. The upward electricity consumption trends during these previous periods contrast sharply with the flat projected future consumption trends for the low and mid cases in that figure.

Figure 1-2: Statewide Electricity Annual Consumption per Capita



Source: California Energy Commission, 2012

These trends deserve additional explanation. One possibility is that the California economy may not grow as rapidly over the next ten years as it did in the 1995-2000 and 2001-2008 periods. Comparing economic growth trends in the historical and projected periods may provide a convenient way to explain some of these differences. Alternatively, the Commission's projections may be expecting more stringent energy efficiency standards and programs that would prevent electricity consumption from increasing much in the next decade. Sorting through these various factors would provide important information to policymakers and help them understand future trends for electricity load growth.

Recommendation #1. The Commission staff should continue to report high, mid and low electricity growth projections to convey the uncertainty in these forecasts. The staff should informally check these ranges with those reported by other major planning groups such as the Northwest Power and Conservation Council and the U.S. Energy Information Administration.

Recommendation #2. To the extent that policymakers are interested in how future electricity growth trends are changing over time, the Commission staff might compare projected with recent historical trends. This comparison should include some discussion about how future economic and demographic trends for California are evolving relative to past experience. This review might also underscore the role of conservation policies in influencing aggregate consumption during the projected period in comparison with its recent historical role.

2.2 Are there grounds for concern that bias may be present in the Commission's estimation of the effects of energy efficiency programs and policies?

The representation and analysis of scenarios of energy efficiency (EE) policies and programs is one of the core functions of the Commission's demand modeling. Indeed, this aspect of the modeling has gained importance in recent years, with the California Public Utilities Commission's (CPUC's) mandate to the investor-owned utilities (IOUs) under its jurisdiction to use the Commission's forecasts as a basis for energy-efficiency procurement, as well as the increasing promulgation of new California policies aimed at reducing CO2 emissions through energy demand-side measures. Various stakeholders have subjected this EE component of the forecasts to a significantly elevated level of scrutiny. In this section we first summarize key aspects of the DAO modeling methodology, and with this background then present our assessment of the bias question.

Historical and projected energy consumption, and the effects of policies and programs both retrospectively and prospectively (including but not limited to those focused on EE), are simulated in an integrated fashion using the modeling system. In addition to these effects, the simulations also incorporate the influences of other drivers of energy use, such as population growth and energy prices trends. For accounting purposes, the estimation of specific impacts of EE policies and programs is done by essentially running the model in stages – first without these policies and programs (to obtain the historical "counterfactual"), then adding them in step-by-step, by category. For forecasts, this "spin-up" is then the departure point for running the model into the future. In particular, this approach ensures consistency between past and future program impacts, e.g., by ensuring that the continuing effects of programs already implemented are accounted for when forecasting the effects of new programs.

The representation of policies and programs in the modeling system, and in these simulations, draws upon numerous information sources, including estimates of individual EE program effects been assembled over many years by DAO using utility-reported ("bottom-up") savings from individual programs. These program-level utility estimates have been subject to interpretation, revision, and/or correction by staff on the basis of their knowledge and expert judgment of data quality, measurement, impact persistence, and other issues, including differences between *ex ante* and *ex post* savings estimation. A critical and not-widely understood technical detail is that these estimates cannot be simply entered directly into the model per se, for the following reason. The model represents energy consumption as a function of various drivers, including end-use technology stocks and characteristics, weather, energy prices, building stocks, and so forth. The bottom-up estimates represent not "drivers," however, but *outcomes*. DAO must therefore "map" this type of estimate into the model indirectly. In doing so, additional assumptions must be made to maintain consistency and to avoid double-counting – for example, between utility programs and building codes and standards. The resulting estimates of the *net* savings from programs are therefore different from those yielded by directly aggregating bottom-up estimates.

This logic applies also to model-based projections of EE program effects. For forecasts into future years, DAO draws upon primarily bottom-up- type information provided by CPUC, other parts of the Energy Commission (e.g., for building energy codes and appliance efficiency standards), and other agencies including the Air Resources Board. In all cases, this information must be incorporated into the model in a manner that is consistent with both historical information and with the influences of other drivers of energy use.

This background helps to frame the issue of possible bias in the Commission's forecasts of EE program impacts. Perhaps most important, it serves to highlight the crucial distinction in this regard between bias and uncertainty: "Bias" connotes a *systematic* over- or under-estimation, while in this context "uncertainty" refers to errors in a statistical sense that are by contrast of a *random* character.

As with any other empirical or model-based approach, there is a degree of unavoidable *uncertainty* in the Commission's estimates of EE program effects, both past and future. To begin with, even historical savings from EE programs cannot be determined with complete certainty, regardless of methodology, for several reasons. First, the "raw material" of bottom-up savings estimates during the historical period is known to be problematic. Program evaluation, measurement, and verification (EM&V) methods and practices evolved over a long period of time and continue to change. In particular, it is well-known that EM&V in the earlier decades – the 1970s and 1980s – was weak, most importantly in relying upon *ex ante* estimation. It is not possible to re-estimate program outcomes directly, after the fact. Thus, there is a large element of irreducible uncertainty in historical savings resulting from this underlying and insurmountable data quality problem.

Compounding this uncertainty is the fact that over intervals of years and certainly decades, the aggregate effects of EE programs cannot be accurately estimated solely by aggregating individual program outcomes, regardless of how well the latter are measured, given standard EM&V procedures. This problem exists because there are first-order drivers of energy consumption and factors influencing program impacts that are simply not captured by "bottom-up" evaluation, including price, income (or economic growth), and demographic trends. Gauging the aggregate, long-term impacts of programs therefore requires making assumptions about the workings of such factors in order to construct the counter-factual, "no programs" baseline as well as to distinguish program effects from other influences. Such assumptions take the form of simulation or econometric models, or "hybrids" of the two, including the DAO model. As in energy, economic, and environmental modeling more generally, such models are necessarily approximate representations of the complex mechanisms and dynamics that determine energy consumption. There is not, and cannot be, a single, ultimate, "correct" model of this system, the representation of which is therefore subject to fundamental uncertainty in the modeling domain.

Finally, there is of course uncertainty embedded in the various inputs provided by other Commission units and other agencies, as noted above, on the specifics of prospective EE policy and program implementation and outcomes.

For all of these reasons among others, there is and will remain uncertainty in the DAO's estimations of EE program effects, as would be the case regardless of what technical and analytical methods are applied. Overall, the DAO modeling system can be viewed as a technically well-grounded approximation, incorporating available information about the range of factors that drive energy use and their complex interactions. Notwithstanding the fundamental uncertainty involved, however, we find no reason to conclude that there is *bias* in the Commission's assessments of the impacts of EE programs and policies.

Recommendation #3. The Commission staff's current approach for attributing the reductions caused by energy efficiency programs and standards does not appear to systematically bias its projections of future electricity demand growth. In preparing its long-run projections, the staff should focus on understanding how energy efficiency programs influence aggregate electricity demand trends and refrain from decomposing these total savings into separate measures for utility demand-side management programs, building standards, equipment standards, and market-based responses. The commission does not have the data or the resources to collect the data that would be required for auditing how well specific programs are operating. Focusing on aggregate energy savings would also reduce some possible frictions with other government agencies, such as the California Public Utility Commission, which retains the responsibility for attributing energy savings to specific program activity.

2.3 What models or characteristics are necessary and sufficient to project future energy demand?

The CEC has traditionally used a detailed end-use model for long-term projections of energy demand while utilities in California today are frequently using econometric specifications. Recently, the CEC has also developed an econometric approach.

The oft-heard distinction between econometric (top-down) and end-use (bottom-up) models is somewhat misleading. Econometrics is simply the use of statistics to estimate parameters in an economic model, and can be applied to all models, including models that are disaggregated by end-use (if one has the data). A more helpful distinction is between models that are disaggregated by end-use or technologies and models operating at a more aggregated level (such as simple functions relating the demand for electricity in specific sectors to its price, economic output and other explanatory factors). This distinction between "aggregated" and "technologically explicit" can be combined with a second dimension: the extent to which a model includes empirically-estimated behavioral parameters for portraying technology acquisition decisions of firms and households. Thus, these two model dimensions refer to the degree to which a given model pursues "empirically-estimated behavioral responses" and "technological explicitness".

Empirically-estimated behavioral responses. Aggregated models, being parsimonious, are more amenable to conventional econometric estimation from historical market data. Since real human behavior obviously drives market outcomes, these models claim behavioral responses that have been calibrated to actual market conditions. One of their challenges, however, is that behavior in the future may be different from behavior in the past, given the appearance of new technology / energy options and perhaps prices outside historical ranges, what information is available or used, and even changes in how people make decisions.

Technological explicitness. Government agencies and utilities apply policies to influence the technology / energy choices of firms and households, such as regulations, information programs, subsidies, rate designs and perhaps targeted fees or taxes. Aggregated models are unable to assess or simulate the effect of such policies on specific technology / energy choices as they lack this level of detail. Technologically explicit models can do this. As conventionally applied, however, such models either assume that firms and households always do (or should) choose technologies with the lowest financial cost, or the model user makes a subjective judgment about the likely adoption rate of technologies that are being promoted. This latter attempt at representing behavior is a concern since it usually lacks a transparent link to empirical evidence.

Since both approaches have strengths and weaknesses, modelers have developed, over the past two decades, "hybrid models" that seek to combine technological explicitness with empirically-estimated behavioral parameters. Such models, however, require a substantial investment in disaggregated data collection and econometric analysis. Depending on the modeling objective, and resources available, this approach may be attractive. However, it may also be necessary to replace the econometric estimation of disaggregated behavioral parameters with subjective judgment, as long as this is done in a transparent manner that allows the testing of alternative behavioral assumptions.

Modeling objectives differ and this affects model choice. Where the modeler is interested in short-term changes in demand for electricity or gas in response to changes in price and economic output, the aggregated model with its econometrically-estimated parameters is likely to be appropriate. Where the modeler is interested in the longer term effects of focused regulations that require a specific technology or fuel choice, the disaggregated end-use model, without behavioral realism, is likely to be appropriate. Where, however, the modeler is interested in the likely technology and energy adoption rate in response to non-regulatory, technology-specific policies (prices, rate design, subsidies, information programs, and fees), some type of hybrid model may be most appropriate – again subject to having sufficient resources for this level of analysis. If such resources are not available, then a disaggregated model with adoption rates determined by subjective judgment is likely the only recourse.

Like California, most jurisdictions today have multiple modeling objectives. Like California, most are interested in the effect of a host of regulatory and non-regulatory policies on the adoption rate of more efficient or lower emission technologies and forms of energy. Like California, most are significantly constrained in terms of the resources they can allocate to data collection and disaggregated, technology-specific modeling. If the CEC and other entities in California are able, at some point, to devote more resources to modeling, this should occur in a strategic manner that focuses on key end-uses and critical determinants of energy efficiency and fuel switching.

Review Process and Model Inter-comparisons

These considerations are related to the Commission's current review process for forecasts, especially in the context of the IEPR. This open, public process is noteworthy and indeed laudable, and is an important aspect of the Commission's ongoing analytical work. At the same time, it could be improved in certain details having to do with model transparency (or not), including the bases for critical assumptions. Thus, for example, the interplay of new technology adoption (saturation rates) and technology competition (interfuel substitution) is not always clear in the CEC modeling, both in baseline forecasts and in forecasts in which price changes and environment policies (regulations, subsidies) are likely to interact. Likewise, in *Efficiency Programs: Incorporating Historical Activities into Energy Commission Demand Forecasts* (CEC-200-2011-005-SD) it states P.2 that energy demand reductions due to efficiency programs are incorporated via "post-processing of model results." From comments elsewhere, this appears to be a judgmental downward adjustment of forecast demand based on exogenous estimates by staff of the likely ex poste impacts of programs. This process should be presented and justified in a more transparent manner.

The Commission-supported Demand Analysis Working Group (DAWG) is a significant step forward in this regard. This panel strongly endorses this effort and its continuance and possible expansion. One promising direction here is to bring to bear the structured model inter-comparison methods developed and used by Stanford University's Energy Modeling Forum (EMF) (mentioned earlier in this report). Our observation of the elements of the IEPR having to do with comparison of Commission and IOU forecast results indicate that these methods would be highly applicable and productive in this context. We see an opportunity here for the DAO and the Commission to play a leading role in articulating among the analytical approaches and results used by different stakeholders in California's increasingly complicated energy policy arena.

Hybrid Modeling Approach

The energy modeling community generally embraces the advantages of "hybrid" modeling – the combination of statistical and engineering approaches – for projecting future energy consumption. A unique opportunity exists for the Commission to take its considerable expertise in end-use processes and formulate this knowledge within a hybrid approach. The Commission's recent progress in developing econometric models for electricity consumption provides a further advantage of adopting a hybrid approach.

Although many alternative approaches exist, one option would build conveniently upon the commission's existing model. Regional estimates of end-use saturation levels, average efficiency levels, thermal efficiency levels, and end-use energy estimates could be developed for a reference year, based initially upon reports provided by the U.S. Energy Information Administration (EIA) but updated and refined with the Commission's own internal estimates. The model would represent the average efficiency of the appliance stock in place for each end use and year. Projections of the average efficiency for these appliances and building stocks would depend upon the range of efficiency levels available in the market, the technology performance of each vintage of equipment, estimates about the likely evolution of the equipment's efficiency, and the presence of any legislative or other government standards and programs that might limit the range. As consumers add new vintages of different equipment types, the capital stock changes and projected energy demand adjusts to this new capital configuration. It is useful to think about these series as being input data or independent variables that influence projected energy demand.

An important step in this hybrid approach would be to calibrate the detailed capital stock configuration in order to be consistent with end-use-per-customer data and aggregate weather sensitivity for the area. Initially, the panel recommends that the detailed appliance data be combined into three aggregate end-use variables for cooling, heating, and all other end uses including lighting, cooking, refrigeration, etc. These variables would represent saturation levels, average efficiency levels, and usage trends of the various end-use categories. Efficiency standards and other programs would operate directly on these capital-stock series.

Econometric equations would relate the expected end-use inputs from these capital-stock series to the historical sales data for each utility and region. The approach would also include other variables that could influence short-run utilization decisions, such as weather, price, employee intensity, and economic activity. Essentially, this approach combines the capital stock information with utilization decisions made by consumers in the market place. Average energy use data included in the capital stock series would influence the projections but this input data would not be the only determinant of actual energy consumption.

A statistical approach has an important advantage because it allows the analysis to incorporate explicitly the uncertainty associated with the effect of economic activity, weather, prices, the capital-stock series or some other independent variable on energy demand projections. Confidence intervals can be established for each coefficient associated with an independent variable. There will be a probability (e.g., 95 percent) that an independent variable will have an effect at least as large as some minimum value and less than some maximum value. Additionally, the modeling team can directly test how well the equation forecasts by adopting a backcasting procedure. In this approach one estimates the model for all but the last two or three years of historical data. Using the parameters from this estimation, one would project electricity consumption based upon the actual values for the independent variables like price and economic activity. If lagged consumption is included as an independent variable, the backcast would use the estimated rather than the actual level from the previous year. The errors from this backcast approach can then be compared with another simple metric, such as the change in current consumption equals the change in last year's consumption. Continuous checking of the fitted equations helps the modeling team to understand how the equation fares in determining both future levels as well as whether the equation accurately predicts electricity consumption increases and decreases. A review of backcasts will also emphasize what other factors should be incorporated.

The Commission may also find it useful to consider hybrid modeling techniques that have been developed in various fields of scientific modeling and computation dealing with modeling and analyzing complex systems in the presence of sparse and/or noisy data. Such techniques are relevant when this combination of system complexity and data limitations preclude the direct application of classical statistical parameter estimation methods such as those of econometrics. Bayesian methods, for example, have been applied to the problem of optimal model calibration. Such techniques can be seen as extensions and generalizations of those discussed in the preceding paragraphs.

Recommendation #4. The Commission staff should plan to develop a hybrid framework that combines the strengths of an end-use process model with a statistical-estimation model. The panel recommends that initially the detailed appliance data be combined into three aggregate end-use variables for cooling, heating, and all other end uses including lighting, cooking, refrigeration, etc. These variables would represent saturation levels, average efficiency levels, and usage trends of the various end-use categories. Efficiency standards and other programs would operate directly on these capital-stock series. This approach would allow the Commission to update its projections on an on-going basis and to understand when fundamental factors and relationships may be changing.

2.4 What are the value and insights derived from the collection of detailed data?

Providing quality information and analysis requires considerable expertise in regularly collecting and managing reliable data from a variety of sources.CEC Demand Analysis should rely upon objective, unbiased, representative, and up-to-date information. Data requirements depend upon the purpose of the analysis. The quality and level of detail of the data will limit the quality and level of detail of analysis results. Uncertainties in the data and in model formulation should be explicit. Uncertainties should be quantified to the extent possible. Where rigorous characterization is not possible, what is known about the uncertainties should be stated. For example, an uncertainty can be bounded or it can be characterized as likely larger or smaller relative to other uncertainties. Importance analysis is a technique that can help drive data collection toward reducing uncertainty. It will identify the inputs that contribute the greatest sources of uncertainty to the desired output of the analysis. Moreover, it will identify opportunities to reduce uncertainty through targeted sampling.

Policymaking often requires more detailed data to evaluate the impacts of policies and programs at a granular level (e.g., specific end uses). State policy dictates that evaluations be conducted that will improve our understanding of whether these instruments are effective. Evaluations of the impacts of those policies and programs are likely to be most accurate if conducted at the level of the primary impacts, although secondary effects may also need consideration. Such evaluations will require information on saturations and energy use. Aggregating impacts from details is easier than attributing impacts from aggregate data.

Data should be collected at sufficient detail and quality for policymaking. Time, effort and expense are necessary to collect and process data. The value of the data should be considered in the context of the potential cost or risk associated with lack of – or inaccurate – data. There is usually a tension among level of effort (cost), quality and speed, and it is difficult to have complete up-to-date information quickly and cheaply.

Efficient data collection minimizes duplication. Use of existing data sources, where applicable, is appropriate. Adding incrementally to existing high-quality data collection efforts (“piggybacking”) is often less costly than creating all-new instruments (e.g., surveys), particularly where a representative sample has already been identified. CEC surveys are necessary where sufficient data are not otherwise available from other sources.

Gathering data from direct observation at the finest level of granularity observable provides the most information (e.g., what are the characteristics of an energy-using product at point of sale).Collecting high quality detailed data once may avoid the need for repeated attempts to gather data after the fact and the risk of misinterpretation. Aggregate data can be constructed from detailed data to service models at different scales, but details absent from the data cannot be constructed from aggregate information. Detailed data helps identify differences in responses to policies and programs. If one segment of the target population is non-responsive, and a different segment is highly responsive, this may be instructive for future program design. Such information is not available from too small a sample size or from an average result.

Learning from the full set of data collection experiences over time may provide more insight than calibrating only to observations at a single – even if most recent – point in time. Cross checks may provide insights not available from a single data collection process. One way to improve is to track deviations from expectations and focus on the largest. Use historical time series to identify systematic biases or trends, or – conversely – large unreduced uncertainties (e.g., future price of oil).

Frequency of data collection may be decreased in stable systems, where little change is observed over time.

Detailed data collection can be a useful complement to more aggregate evaluations. Economic systems are often dynamic, with multiple factors influencing impacts. Top-down aggregate econometric estimates may mask specific impacts by dilution due to inclusion of extraneous or unrelated factors in addition to the direct impacts of most relevance. Separating these factors can be difficult, as when attempting to attribute shares of an overall impact to separate factors (e.g., energy prices, information programs, changes in consumer behaviors, technological changes, and structural changes in economic sectors) that occur simultaneously. Separating disaggregated factors is not possible without disaggregated information. One approach to decomposing effects is to measure the overall change, and then model the effect from backing out each of the contributing factors (e.g., what if there had been no technological change). To accomplish this, the model must include each of the contributing factors explicitly.

We also note that the CPUC is in the process of reviewing, improving, and possibly changing its approach to collecting and analyzing data on end-use energy consumption and the impacts of demand-side management programs under its jurisdiction. It is important for the Energy Commission to continue its interactions with the CPUC to ensure complementarity of the two agencies' efforts.

Recommendation #5. The Commission staff should continue to collect and report the type of energy and equipment data that it currently makes publicly available. As it develops its modeling approach for projecting electricity demand, however, the commission should shift more of its focus specifically towards collecting data that will assist in developing more reliable forecasts. This effort will tend to favor improving the quality of data covering the building types, equipment saturation rates, and energy consumption in the major end uses as well as energy prices and the major economic and demographic drivers. The Commission should continue to coordinate with the CPUC on these data collection issues.

3 Recommendations: A Summary

The panel's report identifies several major issues in developing reliable energy demand projections for policymakers. Over the last several years the Commission has made substantial progress in improving both the forecast and the communication of its key insights. Building upon this success, the Commission has a unique opportunity to embark on new efforts that will continue this process. Based upon our initial review of the Commission's forecasting approach, the panel has made the following recommendations:

1. The Commission staff should continue to report high, mid and low electricity growth projections to convey the uncertainty in these forecasts. The staff should informally check these ranges with those reported by other major planning groups such as the Northwest Power and Conservation Council and the U.S. Energy Information Administration.
2. To the extent that policymakers are interested in how future electricity growth trends are changing over time, the Commission staff might compare projected with recent historical trends. This comparison should include some discussion about how future economic and demographic trends for California are evolving relative to past experience. This review

might also underscore the role of conservation policies in influencing aggregate consumption during the projected period in comparison with its recent historical role.

3. The Commission staff's current approach for attributing the reductions caused by energy efficiency programs and standards does not appear to systematically bias its projections of future electricity demand growth. In preparing its long-run projections, the staff should focus on understanding how energy efficiency programs influence aggregate electricity demand trends and refrain from decomposing these total savings into separate measures for utility demand-side management programs, building standards, equipment standards, and market-based responses. The commission does not have the data or the resources to collect the data that would be required for auditing how well specific programs are operating. Focusing on aggregate energy savings would also reduce some possible frictions with other government agencies, such as the California Public Utility Commission, who retain the responsibility for attributing energy savings to specific program activity.
4. The Commission staff should plan to develop a hybrid framework that combines the strengths of an end-use process model with a statistical-estimation model. The panel recommends that initially the detailed appliance data be combined into three aggregate end-use variables for cooling, heating, and all other end uses including lighting, cooking, refrigeration, etc. These variables would represent saturation levels, average efficiency levels, and usage trends of the various end-use categories. Efficiency standards and other programs would operate directly on these capital-stock series. This approach would allow the Commission to update its projections on an on-going basis and to understand when fundamental factors and relationships may be changing.
5. The Commission staff should continue to collect and report the energy and equipment data that it currently makes publicly available. As it develops its modeling approach for projecting electricity demand, the commission should shift more of its focus towards collecting data that will assist in developing more reliable forecasts. This effort will tend to favor improving the quality of data covering the building types, equipment saturation rates, and energy consumption in the major end uses as well as energy prices and the major economic and demographic drivers.