6.1 BACKGROUND OF PROGRAM ELEMENT

The California Energy Commission's AB970-funded LED traffic signals program element provided grants to public agencies for replacing incandescent traffic lamps with those using light-emitting diodes (LEDs). The grants were designed to pay for part of the material and labor costs associated with installing the LED traffic signal modules. The Energy Commission's initial allocation for the LED program element was $10 million. Any public agency that owns and/or operates traffic signals in California during the summer peak period[1] was eligible to apply for and receive an Energy Commission LED traffic signal grant.

In California, there are an estimated 1.8 million traffic signals operating at approximately 40,000 intersections. Replacing the previously-standard incandescent traffic lamps with LED modules can reduce the energy consumption of the affected signal head by 80 to 90 percent. Before 2001, only a small percentage of traffic signals were equipped with LED technology. It is estimated that by the end of 2001, approximately 30–40 percent of California's traffic signals have had their red, amber, green, and/or pedestrian incandescent lamps replaced with LED modules. The percentage of LED traffic signals in California will continue to rise as prices for the modules drop, energy prices remain relatively high, and California's efficiency standards for traffic signals take effect March 1, 2003. The new standards require traffic signals manufactured after March 1, 2003 and sold in California must not exceed a maximum wattage. Currently, only LED traffic signal modules meet this requirement.

In the past, one major barrier to the widespread use of LED traffic signals has been the high initial capital cost. LED modules are 30 to 80 times more costly than traditionally used incandescent lamps. The Energy Commission's AB970-funded program attempted to help overcome this barrier by providing grants to public agencies up to the amounts listed in Table 6-1. The maximum grant amount per public agency was $3.5 million. There was no minimum grant amount. The grant monies could also be used to supplement incentives from publicly owned utilities. However, the combined incentives could not exceed the total project cost (including materials and installation labor) for each module type. Per the contract scope provided by the Energy Commission, Nexant was not responsible for investigating any potential "double-dipping" (meaning double payments of incentives for the same projects) of incentives associated with any municipal LED traffic signal projects.

Table 6-1: Maximum Grant Amounts for LED Modules

LED Module Type	Grant Amount per Module
Red (8-inch and 12-inch balls and arrows)	$ 50.00
Green (8-inch and 12-inch balls and arrows)	$100.00

[1] Summer peak season is defined as non-holiday weekdays between June 1 and September 30, between the hours of 2:00 p.m. and 6:00 p.m.

Amber (8-inch and 12-inch balls and arrows)	$ 50.00
Pedestrian hand (non-hard wired)	$ 25.00
Combination pedestrian hand/walking person	$ 70.00

The Energy Commission conducted a grant solicitation notifying all appropriate and eligible public agencies, from which applications were accepted on a first-come, first-served basis. As of December 31, 2002, all available LED program element funding had been allocated.

6.2 STATUS OF PROGRAM ELEMENT

A total of 57 grantee projects received monies via the LED traffic signals program element. This number includes 14 projects that were not installed and invoiced until after Nexant's last LED traffic signal program element report in December 2001. In fact, two of the 14 new projects (Chico and San Gabriel) were not complete as of December 31, 2002, which was set as the cut-off date for input to this report, and therefore are not included in this document's statistics. This report provides updates on the original 43 projects reported on in 2001, and incorporates the 12 additional projects that were completed in 2002. Updates on the original 43 projects focus on those that were not completely installed as of Nexant's December 2001 report. In those cases, the demand savings estimates are revised to reflect the completed scope and total project savings.

Table 6-2 presents the verified savings and realization rates for each of the 55 grantee projects represented in this report. No additional M&V activities were performed for this program element subsequent to Nexant's last report; therefore, the project-specific realization rates have remained constant, as well as the overall program element realization rate of 94%.

The demand savings provided to the Energy Commission in each grantee's final report is noted in the column entitled "Reported Demand Savings." The demand savings verified by Nexant are provided in the "Verified Demand Savings" column. The realization rates, which provide an indication of how accurately each grantee predicted their respective project demand savings, were derived by dividing the verified demand savings value by the reported demand savings. If the demand savings reported in the grantee's application is the exact amount verified by Nexant, a realization rate of 1.0 would result. Realization rates may be greater than or less than 1.0. A discussion of how demand savings were documented by Nexant follows in the next section.

The –12 projects added to the program and completed in 2002 are included in the table. None of the -12 projects underwent any M&V activities; they are included in the table to give a more complete summary of the program element, and are noted with a double asterisk (**). For those 12 projects, verified demand savings have been calculated using the program-wide realization rate previously calculated.

Table 6-2: LED Traffic Signals Savings Verification Results as of December 31, 2002

Project	Reported Demand Savings	Verified Demand Savings	Realization Rate
City of Alameda	112 kW	112 kW	100%
City of Anaheim	123 kW	84 kW	68%
Town of Apple Valley	38 kW	38 kW	100%

Project	Reported Demand Savings	Verified Demand Savings	Realization Rate
City of Azusa	24 kW	20 kW	83%
City of Baldwin Park	70 kW	46 kW	65%
City of Bell Gardens	53 kW	35 kW	66%
CalTrans*	1,291kW	1,214 kW	*94%*
City of Carpinteria**	4 kW	4 kW	*94%*
City of Chino Hills	61 kW	37 kW	61%
City of Citrus Heights	28 kW	25 kW	89%
City of Costa Mesa	108 kW	57 kW	53%
City of Cudahy	-13 kW	–8 kW	64%
City of Elk Grove	57 kW	59 kW	103%
City of Escondido	54 kW	49 kW	91%
City of Eureka	31 kW	29 kW	93%
City of Folsom	62 kW	55 kW	88%
City of Glendale*	291 kW	274 kW	*94%*
City of Hesperia	34 kW	33 kW	97%
City of Lancaster**	21 kW	20 kW	*94%*
City of Long Beach #1**	103 kW	97 kW	*94%*
City of Long Beach #2**	166 kW	156 kW	*94%*
Los Angeles Dept of Water & Power*	1,115 kW	1,048 kW	*94%*
City of Maywood*	-14 kW	13 kW	95%
City of Mission Viejo	124 kW	146 kW	118%
County of Monterey**	9 kW	8 kW	*94%*
City of Moorpark*	28 kW	26 kW	*94%*
City of Moreno Valley	100 kW	87 kW	87%
City of Palm Springs	117 kW	70 kW	60%
City of Palo Alto*	124 kW	117 kW	*94%*
City of Paramount	50 kW	46 kW	92%
City of Pasadena	45 kW	68 kW	151%
City of Porterville**	14 kW	13 kW	*94%*
City of Rancho Mirage*	45 kW	42 kW	*94%*
City of Redding	143 kW	96 kW	67%
City of Ridgecrest**	17 kW	16 kW	*94%*
Riverside Public Utilities**	279 kW	262 kW	*94%*
City of Rosemead*	82 kW	77 kW	*94%*
City of Roseville	264 kW	264 kW	100%
County of Sacramento	50 kW	37 kW	74%
City of Sacramento	178 kW	185 kW	104%
City of San Buenaventura**	37 kW	35 kW	*94%*
City of San Diego	561 kW	506 kW	90%
City of San Marcos	63 kW	49 kW	78%
City of Santa Barbara	124 kW	248 kW	200%
County of Santa Barbara**	30 kW	28 kW	*94%*
City of Santa Clara*	146 kW	137 kW	*94%*
Santa Clara County*	43 kW	40 kW	*94%*
City of Sebastopol	5 kW	4 kW	80%
City of Simi Valley**	54 kW	51 kW	*94%*
City of South Gate	101 kW	127 kW	126%
City of Temecula	169 kW	125 kW	74%
City of Torrance**	31 kW	29 kW	*94%*
City of Victorville	105 kW	85 kW	81%
City of Westminster	29 kW	95 kW	328%
Town of Woodside	0.2 kW	0.3 kW	150%
Total	**7,040 kW**	**6,632kW**	**94%**

* Utility bills were not available for this project; the program realization rate was used to document the demand savings.
** Project included in program element after completion of M&V activities; no verification of savings was performed by Nexant.

6.3 MV&E APPROACH

The purpose of the measurement, verification, and evaluation (MV&E) efforts summarized above in Table 6-2 was to estimate the demand savings (kW) actually achieved for each project in the LED traffic signals program element, relative to the demand savings estimated in the grantee's application. Demand savings were estimated by each grantee based on 1) their counts of each type of lamp, 2) the wattage of each type of lamp, and 3) stipulated load factors that were provided for each lamp type. The grantees would calculate their estimated demand savings by first estimating the energy savings (kWh) resulting from the lamp replacement. For each intersection, energy savings were estimated by multiplying the load reduction (defined as the difference, in kW, between the incandescent traffic lamp wattage and the LED traffic signal wattage) by the number of stipulated hours of operation (in hours) for each lamp type.. Wattage data was pulled from manufacturer specifications, and would vary from one type of fixture to another. Average hourly peak demand savings were then calculated by dividing the energy savings in the peak period by the total number of hours in the peak period.

The above calculation utilized a stipulated load factor that varied by type of traffic signal module (e.g., red ball main signal, green arrow turn control, etc.). The load factor represents the percentage of time that each signal type is assumed to be operating. It was assumed that the replacement LED traffic signal modules load factors (i.e., hours of operation) were consistent with those for the incandescent traffic signal modules being replaced. The stipulated load factors for the different traffic signal types are provided in Table 6-3.

Table 6-3: Traffic Signal Module - Stipulated Load Factors

Traffic Signal Module Type	Stipulated Average Load Factor (percent)
Red Ball Main Signal	59
Red Arrow Turn Control	81
Green Ball Main Signal	38
Green Arrow Turn Control	16
Amber Ball and Arrow	3
Amber Beacons	50
Pedestrian	90

6.4 PROGRAM ELEMENT MONITORING AND VERIFICATION

Nexant collected data through November 21, 2001, for each of the 43 original projects participating in the program element. The project-specific data collected included: 1) an intersection inventory report, 2) LED specifications for the lamps used in the project, and 3) utility bills, where available, for a sample of the project's intersections.[2] The content and role of each of these data sources is noted below.

<u>Intersection Inventory</u>

[2] Traffic signal electric metering is routinely done by intersection, rather than individually metering each given traffic signal device.

The intersection inventory report was provided as part of the grantee's application. This report estimates, by intersection, the energy and demand savings based on a number of factors including, a) the number of lamps at the intersection, b) the wattages of the pre-installation incandescent lamps as compared to the LED traffic signal modules, and c) the stipulated load factor of each type of traffic signal module. Total project energy and demand savings were then summarized. The demand savings from this calculation was identified as the grantee's reported project demand savings.

LED Lamp Specifications

Nexant reviewed the specifications for the LED traffic signal modules that were installed for each project. The specifications noted the wattages of the modules, which were used in the energy savings calculations within the intersection inventory report and in pursuing the utility billing analysis.

Utility Bill Analysis

In order to verify the energy and demand savings associated with a given LED traffic signal project, Nexant pursued performing actual utility bill comparative analyses. This required that the grantees provide their utility bills for a sample of intersections. The results of the utility bill analyses were then used by Nexant to derive the verified demand savings. Nexant then calculated a project specific realization rate based on the sample intersections reviewed in the billing analysis. The realization rate was derived by dividing the grantee reported demand savings by the billing analysis-driven verified savings. This realization rate was then applied to the overall project's inventory of intersections and reported savings to derive the overall project's verified demand savings.

For 33 of the original 43 projects, the grantees submitted pre-installation and post-installation utility bills from a sample of intersections. The 10 original projects for which utility bills were not provided are indicated by single asterisks (*) in Table 6-2. For most of these 10 projects, utility bills were not available because the grantee city owns the utility and does not generate an individual bill for each intersection. In total, usable utility bills were submitted for 63 intersections—an amount that exceeds the suggested sample size designed to satisfy the Energy Commission's 80% confidence / 20% precision statistical goals.

Nexant next took the realization rates from the 33 analyzed projects and developed a weighted (by demand savings) average to yield a program element realization rate of 94 percent. For the remaining projects (i.e., the 10 projects for which utility bills were not provided, as well as those added in 2002), their project-specific verified demand savings were derived by applying the overall program element realization rate (94%) to the grantee reported demand savings. An error analysis was performed on the realization rates, and the results indicate that the program element realization rate of 94 percent has an uncertainty of 57 percent at the 80 percent confidence level. This means that although Nexant estimates the program element realization rate to be 94%, the error bounds are substantial; statistically, there is 80% confidence that the actual realization rate is between 37% and 151%. The 80% confidence / 20% precision statistical goal was not met mainly because of a few projects with very low or very high realization rates, resulting in a large standard deviation.

6.5 PROGRAM ELEMENT EVALUATION

Using the M&V approach described above, Nexant calculated the program element realization rate to be 94%. As of December 31, 2002, the program element had garnered 6.6 MW of peak demand savings, which was derived by applying the program element realization rate to the composite reported savings of 7.0 MW. Errors in the participant reported demand savings could have occurred because of:

- inaccurate lamp counts,
- incorrect recording of lamp wattages, and
- discrepancies between the actual traffic signal load factors and the stipulated load factors.

These potential error types were addressed in the evaluation initiatives as described below.

Potential Lamp Count Error Assessment

To assess whether there were systematic errors made by the grantees relative to inaccurate lamp counts, Nexant performed inspections on a statistically valid sample of approximately 130 intersections across 14 projects. The 80 percent confidence / 20 percent precision statistical standard was used to select an appropriate number of projects, and intersections within projects, to inspect.

The site inspections involved confirming that LED traffic signal modules had been installed; this was found to be the case at all inspected intersections. The visit also included counting the number of lamps installed within each lamp type. Nexant then compared these counts with the application's intersection inventory, which break each intersection down into the number of red lamps, green turn signals, pedestrian signals, etc. that are to be installed.

Of the 14 projects inspected, none had a significant number of lamp miscounts. While lamp count errors were noticed, there did not appear to be any pattern, either in over-counting or under-counting the number of lamps within each lamp type. Since no consistent counting error was found during the inspections, no adjustments to the reported demand savings were made for lamp count errors in any of the projects.

Potential Lamp Wattage Error Assessment

Lamp wattages were verified through manufacturer specification sheets, and no adjustments were made to the reported demand savings for wattage errors. Due to the difficulty in accessing the traffic signal modules, Nexant did not directly confirm lamp wattages.

Potential wattage errors may have occurred for projects that received CEC funding to replace only one color of LED module if they replaced the other colors on their own, either through internal funding or through funding from another source. In Nexant's utility bill analyses, it is assumed that all non-retrofitted signals (as indicated in the Lighting Inventories) contain incandescent fixtures, and the incandescent lamp wattages were used to calculate energy savings. However, it is possible that a city may have received a rebate from the utility company for one color and used the CEC incentive for the other color. The City of Westminster received rebates from SCE for the red lamps, and incentives from the CEC for the green lamps. If the installation of these projects occurred at the same time, the pre- and post-installation utility bill analyses could be skewed due to lamp wattage discrepancies. If this scenario occurred, it could have contributed to the program element error.

Potential Load Factor Error Assessment

The remaining, and most significant, potential source of error resulted from using stipulated hours of operation, or load factors (provided in Table 6-3). When considered as an average value over a large population, such as the number of traffic signals associated with over 9,700 intersections impacted by this program element, the stipulated load factors are generally accurate. This accuracy is highlighted by the fact that the program realization rate is 94 percent. However, for small populations of traffic signals, such as at a given intersection level, or for a relatively small grantee city, there is less certainty in the applicability of the stipulated load factors. This is because intersection configurations vary drastically, from simple two-direction intersections to more complicated ones with multiple left-turn lanes or where more than two roads meet. For a simple intersection, a red lamp may have a load factor of 50 percent, while at a complicated intersection the red lamp load factor may be 75 percent. Estimating the demand savings using the stipulated load factor of 59 percent would not equate to the actual demand savings in either example. For this reason, it is expected that the site-specific actual demand savings will differ from the demand savings estimated using the stipulated load factors.

While these site-specific variances may be small, the collective error at a given project level may reflect an aggregated impact. This is because, at the project level, the types of intersections within a project are often similar (consider a city with many one-way streets that may have very simple intersections with red lamp load factors close to 50 percent versus a suburban town that may have a majority of complicated intersections with multiple turning lanes, where the red lamp load factor is closer to 75 percent). In these situations, the variances become additive, thereby resulting in a significant error. Using the stipulated load factor of 59 percent for red lamps, the red lamp savings would be overestimated for the city example and underestimated for the suburban town example.

One can overcome these error factors by analyzing the utility bills associated with an intersection meter to determine the difference between the actual pre-installation and post-installation energy consumption. However, a complete billing analysis on each of the 9,700-plus intersections in the program is beyond the scope and budget of this program element's MV&E effort. Therefore, billing analyses were completed for a sample of intersections, and the results were applied to calculate the demand savings for each project, and was then rolled up for the overall program element.

These error factors (most specifically, the stipulated load factor variable) led to project level realization rates that varied from 53 percent to 328 percent. Nexant found that these higher and lower realization rates generally occurred in relation to projects where the applicant cities retrofitted predominately red or predominately green traffic signals, since relatively small differences in the stipulated load factor versus actual load factor are exacerbated when only one color lamp is involved. For example, if a city has average load factors equal to 50 percent for red and 50 percent for green (ignoring amber in this case), then actual savings due to red lamps would be less than predicted (since the stipulated load factor for red main signals is 59 percent), and actual savings due to green lamps would be greater than predicted (since the stipulated load factor for green main signals is only 38 percent). If the example city had equal numbers of red and green lamp retrofits, the greater savings due to green lamps and the reduced savings due to red lamps would somewhat balance each other, resulting in a project realization rate closer to 1.0. However, if this city retrofitted only red lamps, the realized savings would be much lower than predicted, since there would be no counterbalancing savings due to green lamps in the calculations. Similarly, if the city retrofitted only green lamps, the realized savings would be much higher than predicted, since only green lamps would be considered in the savings calculations.

A low realization rate implies that the actual load factors are lower than the stipulated load factors. For example, the city of Costa Mesa had the lowest realization rate (53%). The lamps retrofitted in this project are predominately red (1,451 red versus 509 green), implying that the actual load factors for the red lamps in this city were significantly lower than the stipulated load factors. Conversely, cities with high realization rates most likely have traffic signal load factors higher than the stipulated values. For example, Westminster retrofitted only green traffic signals, and this project had the highest realization rate (328%). This would imply that their green traffic signal load factors are actually higher than the stipulated values. The fact that only green signals were replaced magnifies the effect of the delta between the actual and stipulated load factors.

6.6 PROGRAM ELEMENT COST-EFFECTIVENESS

The program element's cost-effectiveness relative to levelized costs was also examined. The appropriate metric for levelized costs is $/kW-year, with monetary terms expressed in nominal 2001 dollars. For these calculations, kW was defined as kilowatts of peak demand reduction. An operational lifetime of five years was assumed for the LED traffic signal modules. This is a conservative estimate; although the life of the LED modules could be as long as 10 years, safety issues would require that the modules be replaced on a regular schedule, and every five years is a reasonable assumption. Other potential indicators of cost-effectiveness, such as net present value or benefit-cost ratios, are not appropriate for the 2001 program, as they require evaluation and monetization of program benefits. During the period when investment decisions were being made, the state was experiencing frequent power outages. Program benefits could not be calculated under these conditions, as avoided supply cost concepts do not apply in conditions of absolute shortages. The methodology for calculating cost-effectiveness is included in the Appendix.

Table 6-4 provides the cost-effectiveness results for each project (51 in total) that had submitted an invoice to the Energy Commission as of December 31, 2002. Project cost-effectiveness values range from $48/kW-year to $857/kW-year. The program element level cost effectiveness was calculated to be $369/kW-year, as shown in Table 6-4. If the LED modules are replaced less frequently than every five years, the cost effectiveness will improve.

Table 6-4: LED Traffic Signals – Project Cost Effectiveness Results

Project	Invoiced Amount	Verified Demand Savings	Cost-Effectiveness per kW-Year
City of Alameda	$196,380	112 kW	$379
City of Anaheim	$289,090	84 kW	$745
Town of Apple Valley	$46,120	38 kW	$263
City of Azusa	$26,270	20 kW	$284
City of Baldwin Park	$81,210	46 kW	$382
City of Bell Gardens	$85,620	35 kW	$529
CalTrans	$2,593,360	1214 kW	$462
City of Carpinteria	$4,870	4 kW	$263
City of Chino Hills	$70,940	37 kW	$415
City of Citrus Heights	$99,070	25 kW	$857
City of Costa Mesa	$78,020	57 kW	$296
City of Cudahy	$28,300	8 kW	$765
City of Elk Grove	$35,990	59 kW	$132
City of Escondido	$144,180	49 kW	$637
City of Eureka	$47,310	29 kW	$353
City of Folsom	$12,223	55 kW	$48
City of Glendale	$416,960	274 kW	$329
City of Hesperia	$40,470	33 kW	$265
City of Lancaster	$35,940	20 kW	$389
Los Angeles Water & Power	$1,444,800	1048 kW	$298
City of Maywood	$29,840	13 kW	$497
City of Mission Viejo	$93,310	146 kW	$138
County of Monterey	$26,050	8 kW	$705
City of Moorpark	$32,680	26 kW	$272
City of Moreno Valley	$60,500	87 kW	$150
City of Palm Springs	$167,890	70 kW	$519
City of Palo Alto	$195,450	117 kW	$361
City of Paramount	$91,880	46 kW	$432
City of Pasadena	$75,710	68 kW	$241
City of Porterville	$7,635	13 kW	$127
City of Rancho Mirage	$59,630	42 kW	$307
City of Redding	$193,920	96 kW	$437
Riverside Public Utilities	$681,630	262 kW	$563
City of Rosemead	$120,910	77 kW	$340
City of Roseville	$358,720	264 kW	$294
County of Sacramento	$44,560	37 kW	$261
City of Sacramento	$115,680	185 kW	$135
City of San Buenaventura	$96,050	35 kW	$594
City of San Diego	$1,420,820	506 kW	$608
City of San Marcos	$135,760	49 kW	$600
City of Santa Barbara	$161,135	248 kW	$141

Project	Invoiced Amount	Verified Demand Savings	Cost-Effectiveness per kW-Year
City of Santa Clara	$147,000	137 kW	$232
Santa Clara County	$118,610	40 kW	$642
City of Sebastopol	$7,550	4 kW	$408
City of Simi Valley	$80,520	51 kW	$342
City of South Gate	$134,070	127 kW	$228
City of Temecula	$140,870	125 kW	$244
City of Torrance	$30,694	29 kW	$229
City of Victorville	$134,890	85 kW	$343
City of Westminster	$69,310	95 kW	$158
Town of Woodside	$750	0.3 kW	$541
Total	**$10,811,147**	**6,335 kW**	**$369**

6.7 PERSISTENCE VERIFICATION

Nexant conducted persistence verification for the LED Traffic Signals program element to verify that projects selected for monitoring in 2001 had been fitted with LED traffic signal modules and to ensure that any defective LED modules had been replaced with additional LED modules. Because the goal of this work was to assess persistence relative to the 2001 participants, Nexant focused on the 43 projects that were included in the M&V sample. Nexant's persistence verification for this program element consisted of: 1) conducting follow-up site visits to retrofitted intersections and 2) making telephone calls or emailing participants whose intersections had been originally inspected. For the follow-up site visits, Nexant chose a sample of approximately 130 participating intersections and noted whether the traffic signals contained LED modules. The telephone survey consisted of the three questions listed in Table 6-5; however, Nexant also solicited comments and program feedback from the participants who were contacted.

Table 6-5: Persistence Verification Survey Responses

Question asked	"Yes" Responses
Were all LED modules installed?	95%
Have any been replaced?	51%
Have you or would you make replacements with LED modules?	95%

Thirteen of the original 43 projects were verified with on-site visits, while the remaining 30 were pursued via telephone or e-mail surveys. All of Nexant's persistence verification activities took place between November 2002 and early January 2003.

All of the respondents, except one, confirmed their project's LED module installations. The only exception involved the City of Westminster, where new staff had been brought on board who were not familiar with the original installation project and were unclear whether all of the LED modules had been installed.[3]

Nexant's surveying also uncovered that 22 of the 43 original projects (51%) had to replace some amount of the originally installed LED modules. All but one of these (that being LADWP) said that the replacements were again LED modules. LADWP was the only entity that expressed doubts about replacing LED modules with LEDs, because, according to the contacted representative, the decision is within the purview of the LA Department of Transportation, which doesn't pay for its energy bills, and therefore has no financial incentive to use the more expensive energy efficient technologies.

All 21of the participants who had not yet had to replace any LED modules said they would use like replacements in the future.

The majority (72%) of those surveyed felt very positively about the program saying that the incentives were helpful, the program worked well, and they would like to see it expanded if possible. One particularly comprehensive and positive comment was provided by the City of Santa Barbara;

"The incredible energy savings is a great topic of conversation. We are looking at any LED light system including street lights for potential use in the City. This particular program is the best ever to come out of the California Energy Commission."

Several of the respondents said they plan on additional retrofits of other intersections. A few participants remarked about the maintenance savings resulting from the longer life of the LED modules. Some of those questioned had received positive comments from local residents regarding the increased light intensity from the new LED lamps. The lone negative participant comment was in relation to the volume of paperwork associated with the program, specifically that it was necessary to separate out the records for LED modules from those that were not part of the program.

Based on the consistency of results from the site visits and telephone surveys, Nexant has concluded that the LED traffic signal program element's demand and energy savings have persisted. Additionally, participants are very pleased with the LED modules and will use them in the future providing the budget is available to absorb the increased cost over the conventional incandescent lamps.

6.8 CONCLUSIONS

The value of the LED Traffic Signals program element goes beyond just reducing peak summer demand. The energy and peak demand savings achieved should persist year round, and the savings are real and are independent of human behavior or actions. In addition, the energy cost

[3] This staffing and awareness issue may help explain the very substantial disconnect between Westminster's recorded estimated demand savings and Nexant's verified demand savings, resulting in the 328% realization rate.

savings from these projects have reduced traffic signal energy costs for public agencies by up to 70 percent, thereby freeing up funds and resources for other public purposes.

In addition, installation of the LED traffic signal modules has enhanced public safety, as they are brighter and easier to see under all weather conditions. They require less maintenance, as they have an expected life of five years or more, and they also allow for installations of battery backup systems so that lights can be operated during power outages.

AB970 has accelerated the deployment of LED technologies and has provided the state with summer peak load reductions and long-term economic savings that would not have otherwise occurred until 2003 or beyond.[4] The grants provided by the program covered about half the project cost, which was about 25 percent lower than the incentives offered by the IOUs. It is unknown whether a lower Energy Commission incentive or grant would have provided the same level of interest, participation, and encouragement to rapidly install the LED modules before June 1, 2001. With a lower incentive, more projects could have been funded, thus increasing the peak load savings, but it may have taken longer to complete the projects due to the need for a greater funding share by public agencies.

Costs have significantly decreased for the LED modules, which now average about $75 each, compared to over $200 in the late 1990s. Despite the cost reductions, LED traffic signal modules remain substantially more expensive than their incandescent counterparts, which still cost less than $3 per lamp[5]. With public agencies facing budget constraints, it is uncertain whether the continued pace of LED installations can be sustained without some financial assistance. Without financial assistance, public agencies may delay indefinitely optional capital expenditures, unless other market forces compel them to make these projects a high priority.

With an estimated 1.8 million traffic signals in California, the potential to save energy is tremendous. Historically, the high cost of LED traffic signal modules has been a barrier to market penetration. Additionally, a lack of market awareness regarding the technology and its specifications have also been factors in low implementation rates. These barriers were addressed, and in many ways conquered, by the AB970 LED traffic signals program element. Public agencies were able to substantially lower their purchase and subsequent installation costs through this program. The program also provides needed visibility and desired familiarity with the LED technology.

The LED traffic signals program element has been at least partially successful in transforming the California market for LED traffic signals. Without the state's involvement, it is doubtful that many of the participants would have spent the capital to retrofit their incandescent traffic signals with LED modules. The modest demand savings resulting from this program and the costs to achieve these savings are high when compared to other program elements. The program cost-effectiveness was calculated to be $369/kW-year, which is not as cost-effective as the other AB970 program elements

[4] Note subsequent discussion regarding the inclusion of LED traffic signals in California's Building Standards effective 2003.

[5] Consortium for Energy Efficiency, January 17, 2000 press release.

Promoting this valuable energy-saving technology should lead to greater availability of the technology at reduced costs. Increasing the awareness of the technology within California is an additional benefit. These benefits should make it easier for other cities and counties to follow in incorporating LED traffic signal technology at possibly a lower cost. Due to program efforts, the availability of technical specifications, and the lower cost of the modules, the Energy Commission has incorporated LED traffic signal modules into its Building and Appliance Standards. Starting in 2003, all traffic signals sold in California must meet the Caltrans specification and maximum wattage requirements. Currently, only LED traffic signals meet the specifications.

When compared to other AB970 program element energy savings, the LED traffic signals element provides one of the most sustainable solutions to the energy crisis. The successful deployment of LEDs has assisted municipalities in their assessment of energy use, while providing a lasting technology that will provide savings year-round for the lifetime of the technology. A persistence verification audit conducted a year after installation confirms the LED modules have remained in place and continue to save energy. The audit also reveals high satisfaction rates with the program element, and indicates that the participants expect to continue using LED traffic signal modules, and perhaps other LED technologies as well. This sustainability factor, combined with the educational and psychological impacts made in urban planning, should both be equally considered when evaluating the success of LEDs, especially in comparison to some of the shorter-term peak load demand solutions.