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First Year Load Impact Study of Southern California Gas Company's 1994 Direct Assistance Program

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Project Manager

Melissa Cuaycong
Southern California Gas Company

Prepared by

Kenneth Parris
Business Economic Analysis and Research

Craig Tyler
Mykytyn Consulting Group, Inc.

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Summary

First year load impacts for Southern California Gas Company's 1994 residential Direct Assistance Program (DAP) are presented below. The DAP provided assistance to low income customer groups throughout SoCalGas's service territory. The assistance consisted of subsidies for installation of energy conservation measures, energy education, and repair and/or replacement of cooking, water heating, and space heating equipment.

The impacts are provided in three tables. Table 1 summarizes results for all participants combined. While program efforts are delineated by single family homeowners, multi family residents, and mobile homeowners, Table 1 provides an overview of total program results and results by major measure across all households. Table 2 provides results for single family participants, while Table 3 provides results for multi family participants. Mobile home participants and participants in master metered units were not separately analyzed. They do not represent a large part of overall program efforts.

Ex-ante measure impacts are also included in Tables 2 and 3. Ex-ante measure impacts were taken from the 1994 DAP advice letter filing, Advice No. 2267, dated February 1, 1994. The advice letter only provided ex-ante estimates for single family and multi family measures.

Actual 1994 measure counts and implied program savings by measure are calculated using the ex-ante measure savings. Using the ex-post measure counts as weights, the ex-post program savings are approximately 37% of the ex-ante savings for single family and 34% of the ex-ante savings for multi family. When the Appliance Repair and Replacement program impacts are removed, the ex-post program impacts for single family rise to 45% of the ex-ante estimates. The Appliance Repair and Replacement program participants tended to show increased therm usage, all else equal (space heating replacement being the exception). This is not surprising given they had non-operational or malfunctioning appliances. The 1993 results suggested savings from all ARRP measures. This was due to assumptions made in the 1993 conditional demand analysis

measures. This was due to assumptions made in the 1993 conditional demand analysis model regarding intensity of appliance use pre and post repair/replacement.

Annual first year therm savings from 1994 program efforts averaged 29 therms per participating household. Single family participants saved an average of 33 therms, while multi family participants averaged savings of slightly more than 24 therms annually. These are considered to be net savings. A net-to-gross assessment was not conducted for the 1994 Direct Assistance Program. Given the income constraints on this customer group, the recorded actions likely would not have occurred without SoCalGas' program efforts.

It is possible that positive spillover impacts could have occurred in both the low income and non-low-income residential customer groups, but the effort required to estimate such impacts was felt to be too expensive relative to the potential benefits of having an estimate of the spillover impacts.

Therm values defining the 90% and 80% confidence levels for each single family and multi family measure are provided in the detailed unit savings tables in the section entitled Appliance Usage Estimates and Therm Savings Impacts (Tables 11, 12, and 13).

Table 1
All Participants Therm Savings -
Measure Impacts, Measure Counts and Program Impacts

Measure	Ex-Post Measure Impact	Ex-Post Measure Count	Ex-Post Program Impact
Weatherization			
Ceiling Insulation	20.9	5,685	118,703
Wthrstrip/Caulking	4.1	20,218	83,298
Bldg Envelope Repairs	6.1	18,701	113,515
Switch/Outlet Gaskets	3.1	16,506	50,508
Evaporative Cooler Cover	8.3	864	7,171
Roof Vent Cover	4.1	770	3,126
Low Flow Showerhead	8.0	17,745	142,315
Water Heater Blanket	5.7	4,847	27,676
Faucet Aerator	4.0	17,788	71,152
Pipe Insulation	7.4	937	6,906
Appliance Repair and Replacement			
Cooking Replacement	-2.0	1,312	-2,624
Cooking Repair	-18.0	415	-7,470
Water Heating Replc.	-22.0	465	-10,230
Water Heating Repair	-23.0	49	-1,127
Space Heating Replc.	14.0	2,025	28,350
Space Heating Repair	-17.0	693	-11,781
All Measures	28.8	21,547[c]	619,489

Notes:

a. There were no ex-ante measure impacts for all participants. Ex-ante estimates are provided below for single family and multi family participants.

b. Measure counts include multi-metered participants and mobile home participants

c. Estimated number of participants.

Table 2
Single Family Therm Savings -
Measure Impacts, Measure Counts and Program Impacts

Measure	Ex-Ante Measure Impact	Ex-Post Measure Impact	Ex-Post Measure Count	Ex-Post Program Impact
Weatherization				
Ceiling Insulation	38.0	23.7	3,224	76,280
Wthrstrip/Caulking	9.0	4.6	11,262	51,467
Bldg Envelope Repairs	19.0	6.9	10,751	74,289
Switch/Outlet Gaskets	12.0	3.5	9,225	32,195
Evaporative Cooler Cover	77.0	9.2	381	3,517
Roof Vent Cover	16.0	5.7	304	1,733
Low Flow Showerhead	12.0	8.0	9,968	80,043
Water Heater Blanket	5.0	6.0	2,812	16,872
Faucet Aerator	11.0	4.0	10,000	40,000
Pipe Insulation	18.0	7.5	567	4,258
Appliance Repair and Replacement				
Cooking Replacement	37	-2.0	1,312	-2,624
Cooking Repair		-18.0	415	-7,470
Water Heating Replc.	39	-22.0	465	-10,230
Water Heating Repair		-23.0	49	-1,127
Space Heating Replc.	43	14.0	2,025	28,350
Space Heating Repair		-17.0	693	-11,781
All Measures	-	32.9	11,411[b]	375,772

Notes:

a. Ex-Ante Appliance Repair and Replacement values are only available for the combined program, i.e., repair and replacement activities for the given measure type.

b. Estimated number of single family participants.

Table 3
Multi Family Therm Savings -
Measure Impacts, Measure Counts and Program Impacts

Measure	Ex-Ante Measure Impact	Ex-Post Measure Impact	Ex-Post Measure Count	Ex-Post Program Impact
Weatherization				
Ceiling Insulation	24.0	14.0	2,460	34,440
Wthrstrip/Caulking	24.0	3.0	7,566	22,698
Bldg Envelope Repairs	13.0	4.0	6,902	27,608
Switch/Outlet Gaskets	8.0	2.0	5,992	11,984
Evaporative Cooler Cover	56.0	6.0	118	708
Roof Vent Cover	-	-	31	-
Low Flow Showerhead	14.0	8.0	6,544	52,352
Water Heater Blanket	8.0	5.0	1,363	6,815
Faucet Aerator	7.0	4.0	6,530	26,120
Pipe Insulation	18.0	7.0	172	1,204
All Measures	-	24.3	7,566[a]	183,929

Notes:

a. Estimated number of multi family participants.

Introduction

The 1994 Direct Assistance Program (DAP) provided a wide range of assistance to low income customer groups throughout SoCalGas's service territory. The assistance consisted, primarily, of full subsidies for installation of energy conservation measures, energy education, and repair and/or replacement of cooking, water heating, and space heating equipment, when necessary.

It is very important to note that the program also served an equity objective in assisting customers who were highly unlikely or unable to participate in other residential conservation programs because of income constraints. This program allowed income-eligible customers to receive the benefits of energy conservation without the hardship of making up front cash investments.

Additional program benefits included the operation of the Direct Assistance Training Center. The Center provided "hands on" training to students from disadvantaged areas in outreach, assessment, appliance identification, basic home weatherization, advanced weatherization (home repair), mobile home weatherization, inspector training, and supervisor training.

SoCalGas used a variety of community-based organizations (CBO) for locating and recruiting households who qualified for program participation, i.e., households whose annual income is less than the Low Income Weatherization income limits established by the California Public Utilities Commission. Staff from these community-based organizations were trained by SoCalGas in the installation of ceiling insulation and other conservation measures.

There are two major energy programs run under the DAP: 1) the Weatherization Program, and 2) the Appliance Repair and Replacement Program (ARRP). The Weatherization Program focused on the installation of conservation measures in single family, multi family, and mobile homes. Conservation measures were aimed at reducing space heating and water heating energy use. The space heating-related measures

included: ceiling insulation, weatherstripping, caulking, switch and outlet gaskets, evaporative cooler covers, roof vent covers, and building envelope repairs (the repair of windows, walls, and doors to reduce air infiltration). The water heating-related measures included: low-flow showerheads, water heater blankets, faucet aerators, and pipe insulation.

The Appliance Repair and Replacement Program repaired or replaced inoperative or potentially hazardous furnaces, ranges and water heaters for income-eligible customers in owner-occupied homes. This program has been particularly helpful for senior citizens and disabled customers. Typical furnace repairs consisted of the repair or replacement of control units, pilots, and thermostats. Repair of forced air furnaces also included repair or replacement of the fan motor, limit switch, and delay switch. Water heater repairs tended to involve the vent system and the thermocouple on the pilot. Range repairs involved the burner heads and valves, including the safety valve, top pilots, oven pilots, door springs, oven thermostat, electronic ignition devices, and switches.

Furnaces were replaced when they: had cracked or rusted fire boxes that created a significant fire or carbon monoxide risk; when repair parts were unavailable; or when replacement was less costly than repair. Water heaters were replaced when tank leakage was discovered. Ranges were replaced when parts were unavailable or when repair costs exceeded $150.

This report summarizes the results of a statistical analysis aimed at estimating the first year load impacts of the aforementioned elements of the 1994 Direct Assistance Program. The focus of this effort is on the energy use impacts of the DAP, rather than upon the calculation of job creation, skill enhancement, public safety, and public health benefits generated through DAP efforts.

More specifically, the objective of this study was to: 1) estimate the load impacts attributable to the DAP Appliance Repair and Replacement Program efforts, separately for gas space heating, gas water heating, and gas cooking equipment; and 2) estimate the

impact of weatherization and other DAP conservation measures on space heating and water heating therm usage.

These objectives were accomplished using conditional demand analysis (CDA), a statistical technique that disaggregates monthly therm consumption data into appliance-specific average usage. The technique uses individual customer recorded monthly therm usage both before and after installation of conservation measures (and/or repair or replacement of an appliance) to estimate changes in energy usage. Customer-specific demographic information and regional weather data are also directly employed in the estimation process.

The data employed in the analysis, and its development, are outlined below in the section entitled Analytic Data Set Development. The estimation of the CDA model is described in the section entitled Conditional Demand Model Development and load impacts are included in the section entitled Appliance Usage Estimates and Therm Savings Impacts. Appendices include the participant survey instrument, survey results crosstabulations, summary statistics for variables included in the CDA model, and the SAS System output for the CDA model.

Analytic Data Set Development

This section describes the development of the data used in the analysis of the 1994 DAP usage impacts. The required analytic data set was created from the integration of four separate data sets: the 1994 program participant file, SoCalGas's monthly customer billing file, the heating degree day file, and the 1994 Direct Assistance Program Participants Survey file. The relationship of these datasets with respect to the development of the analytic data set is shown in Figure 1. A brief description of each data set follows.

Program Participation Records

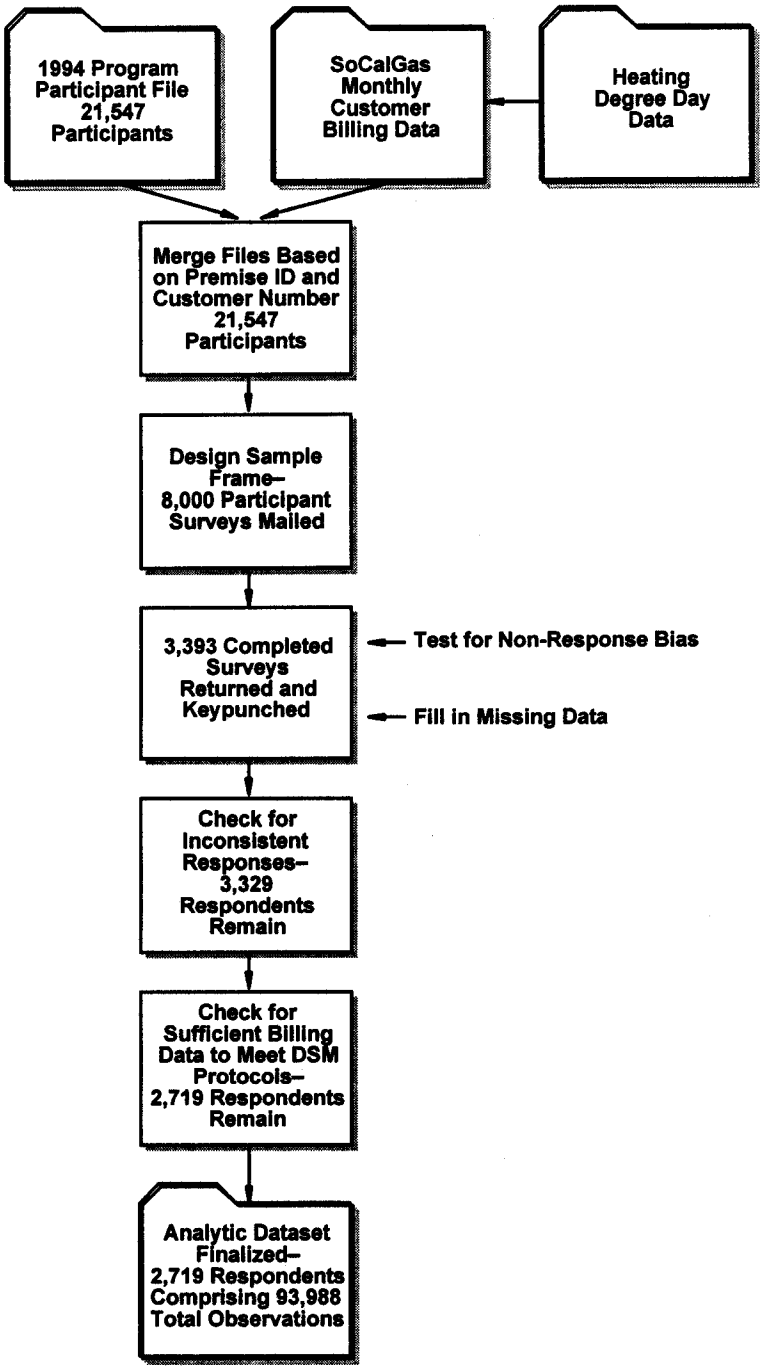
SoCalGas has historically maintained two DAP transaction databases, one for Weatherization Program participants and one for Appliance Repair and Replacement Program participants. These online databases are used to track program transaction activities from eligible customer identification, through verification of eligibility, measure and equipment installation, installation verification, provider (i.e., CBO) request for reimbursement, and check issuance to the provider. The files contain information pertaining to each stage of DAP delivery. The core systems were developed during the late 1980's, but have been modified as the DAP has changed through time. The systems are routinely internally audited and have been reviewed by the California Public Utilities Commission (CPUC).

The Program participation files contain data vital to the estimation of load impacts. Specifically:

- Program the customer participated in (Weatherization and/or ARRP)
- Appliances replaced
- Appliances repaired
- Conservation measures undertaken

- Date each repair, replacement, and measure was implemented
- Premise and customer identification numbers (used to match billing records to the customer)
- Address (used to assign weather data and used in the participant survey implementation)

Figure 1
Analytic Data Set Development



The premise and customer identification numbers are appended to the participation files as customers are submitted for qualification to the program. The customer name, address, and account number from the customer bill are used to identify the premise and customer identification numbers. The participation process does not continue if an accurate identification of the customer on the SoCalGas customer information system cannot be made.

Billing Data

Gas consumption data was obtained from the customer billing files maintained by SoCalGas. The customer billing file contains monthly therm usage for each SoCalGas customer. The correct billing data for each program participant was obtained by matching the premise and customer identification numbers on the DAP participation files with those on the customer billing file. This matching process is superior to matching upon account number because account numbers may change as accounts are refolioed. A 100% match rate was achieved.

Key participant-specific information obtained from the customer billing files included:

- monthly therm consumption for each 1994 DAP participant from January, 1993 through November, 1995
- meter read dates
- monthly billing days

Weather Data

Weather variables were created to account for the effect of weather on space heating energy use and on water heating energy use. For space heating, a set of climate area and billing cycle-specific "heating degree days" variables with a 65 degree Fahrenheit base were created. Daily temperatures were employed to create daily heating degree variables over the billing data time frame. These daily values were aggregated into monthly values for each combination of six SoCalGas weather zones and each possible billing cycle. An

identical process was undertaken using normalized weather (a file of thirty year average weather data maintained by SoCalGas for its service territory and climatic subregions). This process allowed household-specific weather to be employed in the estimation process.

Water heating energy use is partially dependent upon the difference between desired hot water temperature and inlet water temperature. Average daily air temperature was used as a surrogate for inlet water temperature. A similar process to that described above for heating degree days was undertaken with average daily temperature. Household-specific average monthly temperatures were created using actual temperatures and using thirty-year averages.

The heating degree day and average temperature weather variables (both actual and 30 year normalized) were merged with the DAP participant and billing data using address and billing cycle information. The "actual" variables were used for estimation of savings, while the "normalized" variables were used for simulation of the model and calculation of program impacts.

Program Participants Survey

In August 1995, a mail survey of 1994 DAP participants was conducted. The *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs as adopted by CPUC D. 93-05-063* (Protocols), did not require that a comparison group of non-participants be included in the DAP evaluation. The aim of the survey was to obtain household characteristics, appliance utilization and demographic data needed to estimate a conditional demand model.

The first step in the survey process was to determine an appropriate sample frame. The DAP participants were divided into the following six strata. The strata were chosen based upon the primary program participation categories. Target sample sizes were estimated for each stratum to achieve a minimum 10% precision at the 95% confidence level (based on consumption):

Single family Weatherization Program, attic and groundwork	487
Single family Weatherization Program, groundwork only	503
Multiple family Weatherization Program, attic and groundwork	188
Multiple family Weatherization Program, groundwork only	276
Appliance Repair and Replacement Program, some repair	324
Appliance Repair and Replacement Program, replacement only	381

Combination Spanish and English version surveys were mailed to 8,000 participants (see Figure 1). The English version survey instrument is provided in Appendix A. A total of 3,393 surveys were returned, slightly higher than a 42% response rate. The target sample size for each stratum was met with the exception of the multi-family weatherization, attic and groundwork stratum. The 177 completed surveys for that stratum still provided a 10% precision at a 90% confidence interval (the level required by the Protocols).

Table 4 provides the distribution of participants, sample frame, and survey respondents by climate zone. The distribution is quite consistent for each category.

Table 4
1994 Program Participation by Weather Zone

Weather Zone	Participants	Sample Frame	Survey Respondents
Mountain	0.2%	0.2%	0.3%
Lower Desert	4.4%	3.9%	3.9%
Coastal	9.6%	8.0%	8.1%
High Desert	12.2%	13.9%	13.9%
Inland Valleys	24.3%	24.4%	26.6%
Coastal Valleys	49.2%	49.7%	47.0%
Total Customers	21,547	8,000	3,393

The returned surveys were double keypunched and linked with customer identifiers from the program participation files that allowed the survey results to be merged with the participation records, billing data, and weather data described above.

Testing For Sample Nonresponse Bias

After the completed surveys were returned and a database of respondents was created, nonresponse bias tests were performed to make certain that the weights attached to survey respondents accurately represent the 1994 participant population. The nonresponse bias tests were performed by comparing average 1993 usage respondent usage to average 1993 usage of the non-respondents for each of the six strata. A minimum of 6 months of 1993 usage was required to be included in the test; 5,282 of the 8,000 sample frame customers had at least 6 months of usage in 1993 for the surveyed households. Annual average usage values were created by calculating average use per day and scaling by 365.

Using the average annual usage values and standard deviations, t-ratios were generated and the null hypothesis that no significant difference existed between respondent and non-respondent average use was tested. The null hypothesis was rejected when the test statistic value was greater than 1.96. Table 5 below shows the results of the nonresponse bias tests for the six strata.

Table 5
Initial Nonresponse Bias Test Results

		Non-Respondents			Respondents			
Strata	**Sample**	**n**	**Mean**	**Std**	**n**	**Mean**	**Std**	**t-Test**
Weatherization								
Attic & Groundwork Single Fam.	1172	601	510	216	571	520	216	-.79
Groundwork Only Single Fam.	1312	687	495	218	625	480	203	1.29
Attic & Groundwork Multi Fam.	278	158	330	160	120	316	170	.72
Groundwork Only Multi Fam.	431	234	204	169	179	332	176	1.64
Appliance Repair and Replacement								
Repair	820	324	548	225	496	511	230	2.28
Replace	1287	620	524	225	667	492	224	2.55

The fact that the t-test numbers for the two Appliance Repair and Replacement (ARRP) strata are greater than 1.96 suggests that nonresponse bias exists. The bias was corrected by substratifying the strata based on annual therm usage and reweighting the sample. The ARRP repair and replacement strata respondents were each divided into two substrata based on annual consumption level. The ARRP repair group consumption level breakpoint was 590 therms, while the breakpoint for the ARRP replacement group was 420 therms. The results of the nonresponse bias tests after substratifying the two ARRP strata appear in Table 6.

Table 6
Nonresponse Bias Test Results After Substratification

ARRP		Non-Respondents			Respondents			
Strata	Sample	n	Mean	Std	n	Mean	Std	t-Test
Repair <= 590 therms	543	199	406	112	344	392	118	1.30
Repair > 590 therms	277	125	775	164	152	790	191	-.22
Replace <= 420 therms	493	215	317	80	278	304	78	1.77
Replace > 420 therms	794	405	634	199	389	627	196	.56

Inconsistency and Consumption History Screens

The participant survey was double-keyed to ensure accurate transcription of survey responses. In addition, the survey results were reviewed for obvious anomalies. Particular attention was paid to variables that were known to be important in the subsequent statistical assessment.

For example, the square footage variable is very important in the determination of gas space heating use. For this reason household floor space, number of bedrooms and number of residents variables were compared in order to remove respondents with very inconsistent responses to combinations of these variables. Three inconsistency screens were developed involving floor space and number of bedrooms and floor space and the

number of residents. The description of the screening criteria and number of respondents follow:

1. Less than 600 square feet of floor space and six or more bedrooms – 1 respondent deleted

2. More than 2000 square feet of floor space and two or fewer bedrooms –34 respondents deleted

3. Less than 600 feet of floor space and seven or more residents – 29 respondents deleted

A total of 64 respondents were removed from the analysis because of the above mentioned inconsistencies, leaving 3329 respondents (see Table 7 and Figure 1).

The Protocols require a minimum of twelve months of pre installation consumption history and nine months of post installation period consumption history for inclusion in the conditional demand analysis. Billing history information was collected from January, 1993 through November, 1995. A total of 610 survey respondents were dropped because the Protocol consumption history requirements were not achieved.

Table 7 shows the initial distribution of survey respondents by strata.

Table 7
Survey Respondents

Strata	Initial Respondents	Remaining Respondents After Floor Space Screens	Respondents With Sufficient Consumption Data
Weatherization			
Attic & Groundwork - Single Family	803	782	589
Groundwork Only - Single Family	819	802	638
Attic & Groundwork - Multi Family	200	198	129
Groundwork Only - Multi Family	310	304	285
Appliance Repair and Replacement			
Repair < 590 therms	380	374	351
Replacement < 420 therms	315	312	289
Repair > 590 therms	154	154	152
Replacement > 420 therms	412	403	386
Total	3393	3329	2719

The Protocols state that the sample employed in the calculation of program impacts should yield consumption estimates meeting a 90% confidence interval with 10 % precision criterion. The 1994 Direct Assistance Program Participants Survey was intended to provide consumption estimates that met a more stringent 95% confidence interval with 10% precision criterion. As stated previously, the multi family attic and groundwork sample falls below the target number for the 95/10 sample design but still has sufficient size to meet the minimum 90/10 rule stated in the Protocols. The remaining strata each meet the 95/10 target.

Estimation of Missing Values

While 3,393 surveys were returned, respondents sometimes failed to answer certain key questions. Missing values were not significant enough to warrant recontacting the respondents; but there was an attempt to fill in missing values for the following key survey variables: floor space, number of residents, water heater temperature, number of

hot water washing loads, number of clothes drying loads, number of automatic dishwashing loads, space heating fuel, water heating fuel, and cooking fuel.

Regression equations were estimated to fill missing floor space and number of residents. The floor space equation depended upon the number of bedrooms, dwelling type, and home ownership. Approximately 27 percent of the respondents had missing floor space values that were provided using this approach. The number of residents equation depended upon dwelling type, presence of senior citizens, and number of bedrooms. Three percent of the respondents were supplied with values using this approach. Water heater temperature was filled by assigning the average temperature level from homes that answered the water heater temperature question by strata. One third of the respondents were assigned water heater temperature values using the average for their stratum.

For the number of hot water washing loads, number of clothes drying loads, and number of automatic dishwashing loads, missing values were filled by number of residents for households that answered those questions. Five percent of respondents were assigned hot water washing loads, four percent of respondents were assigned clothes drying loads, and two percent of respondents were assigned dishwashing loads using the average value of respondents in the same stratum who answered the question.

Space heating, cooking and water heating missing fuel types were filled by using the baseline allowance code appearing in the Gas Company's customer billing system. This is a preferred approach to using mean values from the survey since the baseline allowance codes are determined through on-site inspection by SoCalGas field staff. Forty-six percent of the space heating fuel types, 14 percent of the water heating fuel types, and 10 percent of the cooking fuel types were assigned using this approach.

The estimation of missing values was the last step in the preparation of the final analytic data set used in the conditional demand analysis described next.

Conditional Demand Model Development

The objectives of the monthly energy use model developed from the merged survey and billing record data base (i.e., the analytic data set) were to:

1. Measure the impact that weatherization measures have on space heating consumption,
2. Measure the impact of conservation measures on water heating consumption, and
3. Measure the usage impacts attributed to the repair and replacement of cooking, water heating and space heating appliances/equipment.

Equipment usage impacts and conservation savings are provided in Tables 1, 2 and 3 within the Summary section of this report. They are also included in Tables 11, 12, and 13 within Appliance Usage Estimates and Therm Savings Impacts, following this section. Space heating equipment usage and related weatherization savings are estimated under normal weather conditions as required by the Protocols.

A detailed presentation of the DAP monthly energy use and load impact equation is provided in this section. An overview of the estimation technique and data sources employed is described first, then the overall energy demand equation is presented. Finally, the appliance-specific equation results are presented with an interpretation of the coefficients.

Estimation Technique

The estimation technique used in this study is conditional demand analysis. The conditional demand technique provides a method of distributing total household natural gas consumption among the gas-using appliances present in the home. In addition, the technique allows estimation of changes in major appliance use due to the installation of conservation measures and/or the repair or replacement of major appliances.

Conditional demand analysis was used in lieu of other approaches for two reasons. First, the approach had been successfully employed to assess the 1993 DAP. A comparison of

1993 and 1994 results was of interest to SoCalGas. Second, other approaches either did not provide the detailed results CDA would afford (i.e., results at an end-use basis for various types of program participants) or would have demanded information that was unavailable (e.g., reasonably accurate energy use priors for individual end-uses across many types of customers).

A change in consumption model, where the change in usage is modeled as a function of the change in weather, as well as changes in conservation from the previous year, was also considered in the early stages of this study. Robust, end-use specific usage estimates could not be derived, so the approach was discarded.

The conditional demand technique is based on the proposition that the natural gas use of each household is the sum of the natural gas used by each of the appliances in the household. In mathematical terms, natural gas use is expressed as:

Use = gsh * GSH + gwh * GWH + grg * GCK + gdy * GDY + gp * PHSPA

where:

Use	is household consumption
gsh	is gas space heating use
GSH	is a gas space heat indicator variable
gwh	is gas water heating use
GWH	is a gas water heating indicator variable
grg	is gas range use
GCK	is a gas range indicator variable
gdy	is gas dryer use
GDY	is a gas dryer indicator variable
gp	is gas pool/spa heating use
PHSPA	is a pool/spa heating indicator variable

The indicator variables take the value of 1 if the appliance is present in the household and 0 if the household does not own or operate the appliance. Most DAP participant households had gas space heating and water heating - the indicator variable for these appliances was 1 for most households. Few of the DAP participant households had pools or spas - the indicator variable was most often 0 - but when a natural gas pool or spa heater is present it has a large impact on household gas consumption.

For each of the above mentioned appliances a usage equation is created. The usage equation relates the expected use of a particular appliance to key factors that will influence its monthly use. For example, the number and age composition of residents

will affect water heater use, square footage of the residence and weather conditions will affect space heating use, and conservation measures, as well as the presence of replaced or repaired equipment, will affect the monthly consumption of specific appliances.

Information for every factor is required for each DAP participant household. The data elements integrated to estimate the appliance equations include:

1) survey data on household appliance ownership, household characteristics, and the condition of the existing appliances,

2) program participant information regarding the date conservation measures were installed, and the measures installed,

3) monthly consumption, meter read date and billing days from company billing records, and,

4) weather data (in heating degree days) in the temperature zone in which each household is located and for the time period covered by each energy bill.

The sources for these data elements were outlined in the section, Analytical Data Set. The discussion that follows details the process of using that data to estimate conditional demand models of appliance energy use.

Estimation Process and Regression Results

A three stage estimation process was employed to obtain a regression model from which reasonable appliance usage estimates and therm savings impacts could be determined. In addition to employing a sound, established theoretical framework, reasonable estimates, from an econometric standpoint, are estimates of regression coefficients that are unbiased and consistent. An unbiased estimate fairly represents the true value of what it is estimating; drawing repeated samples of the same number of program participants and recalculating water heater blanket savings would yield, on average, an unbiased estimate. Consistency refers to sampling distribution. As the sample size grows, a consistent

estimator is one in which the sample distribution becomes more tightly concentrated around the true value of what is being estimated, rather than concentrating around another value.

Traditional econometric theory clearly defines how the properties (e.g., unbiasedness and consistency) of estimated regression coefficients and their estimated standard errors depend on the error structure of the model employed. If the regression error terms are serially correlated (i.e., the value of residuals follow a pattern determined by the value of preceding residuals) or heteroskedastic (i.e., the magnitude of residual values are related to the value of some other variable), the estimated coefficients can be unbiased and consistent, but the standard errors of the coefficients are inconsistent. If the standard errors are inconsistent, hypothesis tests conducted with them may be inaccurate. Of more direct importance to this study, the 90% and 80% confidence intervals developed around the usage and savings estimates would be inaccurate.

The error structure of a model based on a pooled cross-section and time-series data set is likely to be cross-sectionally heteroskedastic and time-wise autoregressive. A CDA model requires a pooled cross-section and time-series data set. Consequently, a CDA model should be tested for serial correlation and heteroskedasticity. Corrections for the presence of serial correlation and/or heteroskedasticity in the error structure should be undertaken, when evidence of these two problems is discovered.

Both of these problems were discovered during the estimation of the conditional demand model for the 1994 DAP. This prompted the use of a three-stage process to develop acceptable estimates of appliance usage of conservation savings. The first stage involved the development of the basic model, its estimation using ordinary least squares, and testing for serial correlation. The second stage involved correcting the first stage results for the presence of serial correlation and testing for heteroskedasticity. The third stage involved correcting the second stage results for the presence of heteroskedasticity. The summary appliance usage and conservation impacts provided in this report employ the third stage model results.

First Stage - Ordinary Least Squares

This stage involved the estimation of a regression equation using ordinary least squares. The initial assumption was that the error terms were not serially correlated, nor heteroskedastic.

The Direct Assistance Program equation was estimated using January, 1993 through November, 1995 billing year data. All households had at least one year of consumption history prior to the installation of conservation and at least nine months of post conservation installation consumption history, as required by the Protocols. The regression equation was weighted to adjust for varying lengths of consumption history present. The weight equaled the inverse of the ratio of monthly observations for the household divided by the average number of observations for all households.

Appendix C contains definitions of the model variables as well as summary statistics (mean, standard deviation, minimum and maximum) for the untransformed variables of the first stage. Appendix D contains the SAS System regression results for all three stages.

The first stage equation yielded an adjusted R-squared value of .43 which is typical for this type of analysis. The estimated model coefficients and their t values are displayed in Tables 8 and 9. Estimated coefficients from all three stages are included in these tables. The results are what was generally anticipated during the formulation of the original specification. Interpretation of individual coefficients is discussed below in the Appliance/Equipment Specific Gas Use Estimation section.

TABLE 8

Conditional Demand Model Parameter Estimates

Space Heating

Space Heating Variables	Ordinary Least Squares		Correction for Serial Correlation		Correction for Heteroskedasticity	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Space Heating (GSH)						
GSH*(SHNW=0)*(1-POST*RSH)	13.21428	50.06	5.64283	19.13	5.21225	24.87
GSH*(SHNW=0)*SUMMER*(1-POST*RSH)	-7.86963	-43.62	-1.88337	-17.19	-1.70699	-18.89
GSH*(SHNW=0)*SQFT*HDD*TIME	-.0000095	-13.95	-.0000015	-2.86	-0.0000017	-2.53
GSH*(SHNW=0)*SQFT*HDD*C_FT	-.0000038	-1.31	.0000013	.39	0.0000009	0.18
GSH*SQFT*HDD*QUAL*NON_SH	.000104	62.15	.0000942	59.26	0.0000947	42.28
GSH*SQFT*HDD*QUAL*NON_SH*WTHR	-.0000649	-17.09	-.0000488	-13.15	-0.0000532	-9.77
GSH*SQFT*HDD*QUAL*NON_SH*OLD	.0000341	27.37	.0000363	30.00	0.0000395	22.98
GSH*SQFT*HDD*QUAL*NON_SH*YOUNG	-.0000307	-17.50	-.0000303	-17.72	-0.0000318	-12.8
GSH*SQFT*HDD*QUAL*(FSH+RSH)*PRE*CKHTB	.0000176	4.72	.0000255	6.15	0.0000248	3.74
GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*PRE	.000104	30.85	.000068	21.69	0.0000746	14.96
GSH*SQFT*HDD*QUAL*RSH*POST	.000153	40.33	.000115	33.56	0.000125	22.76
GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*WTHR	-.000041	-4.57	-.000052	-5.97	-0.000076	-5.41
GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*OLD	.000008	3.15	.000016	8.87	0.000017	4.44
GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*YOUNG	-.000033	-8.94	-.000036	-10.60	-0.000043	-7.7
GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*PRE*LATE	.0000084	2.42	.0000052	1.62	0.0000033	0.63
GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*PRE	.000125	22.93	.000088	17.42	0.0000845	10.09
GSH*SQFT*HDD*QUAL*FSH*POST	.000131	20.41	.000114	19.71	0.000118	12.41
GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*WTHR	-.000132	-8.10	-.000104	-6.95	-0.000107	-4.2
GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*OLD	.000029	7.03	.000019	4.97	0.000032	4.93
GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*YOUNG	.000004	.76	-.000007	-1.55	-0.00001	-1.08
GSH*SQFT*HDD*NQUAL	.000106	47.05	.000104	47.38	0.000104	39.41
GSH*SQFT*HDD*NQUAL*MULTI	-.0000333	-16.32	-.0000296	-15.31	-0.000026	-12.12
GSH*SQFT*HDD*NQUAL*WTHR	-.000012	-2.15	-.0000254	-4.77	-0.0000485	-7.27
GSH*SQFT*HDD*NQUAL*OLD	.000022	10.90	.000022	10.63	0.000023	10.01
GSH*SQFT*HDD*NQUAL*YOUNG	-.000005	-2.24	-.000009	-4.32	-0.000013	-4.64

TABLE 9

Conditional Demand Model Parameter Estimates

Water Heating, Cooking, Clothes Drying, and Pool/Spa Heating

Water Heat, Cooking, Clothes Drying, and Pool/Spa Heating Variables	Ordinary Least Squares		Correction for Serial Correlation		Correction for Heteroskedasticity	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Water Heat (GWH)						
GWH*(WHNW=0)*DT*TIME	.01543	5.50	.02549	8.09	0.01571	5.69
GWH*(WHNW=0)*DT*C_NUM	.03049	11.27	.04732	10.82	0.03246	8.29
GWH*(WHNW=0)*DT*QUAL*RWH*PREW	.297562	23.39	.251515	15.44	0.20285	12.27
GWH*DT*QUAL*RWH*POSTW	.280354	21.82	.277296	16.84	0.23496	14.89
GWH*(WHNW=0)*DT*QUAL*FWH*PREW	.281275	9.43	.240778	5.15	0.18673	4.24
GWH*DT*QUAL*FWH*POSTW	.253700	7.62	.242455	4.98	0.21792	4.94
GWH*DT*QUAL*NON_WH	.270441	40.00	.322926	37.28	0.25825	35.99
GWH*(WHNW=0)*DT*CONS	-.278527	-9.78	-.302137	-9.89	-0.15692	-6.34
GWH*(WHNW=0)*DT*OLD	-.000258	-.08	.000199	.04	-0.01261	-3.44
GWH*(WHNW=0)*DT*YOUNG	-.008741	-2.03	.010151	1.66	0.02555	4.79
GWH*(WHNW=0)*DT*DW*DISHL	.004331	9.01	.002493	3.27	0.00198	2.21
GWH*(WHNW=0)*DT*CW*WASHL	.001749	5.87	.002718	5.43	0.00448	9.02
GWH*DT*NQUAL	.199307	23.12	.242920	20.69	0.24217	27.21
GWH*DT*NQUAL*MULTI	-.021167	-2.83	-.032154	-2.88	-0.04679	-5.94
Cooking (GCK)						
GCK*NUMINHH*QUAL*NON_CK	.6665	8.18	.4363	4.01	1.1701	11.53
GCK*(RGNW=0)*NUMINHH*TIME	.0973	2.75	-.0051	-.12	-0.0037	-0.09
GCK*(RGNW=0)*NUMINHH*QUAL*RRG*PRER	1.3395	11.33	.9286	5.82	1.1892	7.75
GCK*NUMINHH*QUAL*RRG*POSTR	1.3424	10.12	.6454	3.85	1.1967	7.23
GCK*(RGNW=0)*NUMINHH*QUAL*FRG*PRER	1.4196	6.76	.4262	2.28	0.6865	3
GCK*NUMINHH*QUAL*FRG*POSTR	1.0231	4.65	.7762	3.33	1.1898	3.89
GCK*NUMINHH*NQUAL	1.3969	13.06	1.4300	9.11	1.4647	11.33
GCK*NUMINHH*NQUAL*MULTI	-.6144	-6.14	-.1546	-.96	-0.0364	-0.3
GCK*HDD*SQFT*CKHT	.000027	12.33	.000026	11.57	0.000032	9.21
Clothes Drying (GDY)						
GDY*DRYL	.5179	30.38	.4889	16.58	0.3785	13.29
Pool/Spa Heating (PHSPA)						
PHSPA	6.3348	12.57	10.2033	13.21	4.3089	6.15

where:

Variable	Definition
CKHT	use range to space heat indicator
CKHTB	use range to space heat when heater broken indicator
CONS	sum of water heater conservation saving impact
CW	clothes washer indicator
C_FT	change in square footage indicator
C_NUM	change in household residents indicator
DISHL	number of dishwasher loads
DRYL	number of clothes drying loads
DT	difference between tank water and air temperature
DW	dishwasher indicator
FRG	range repaired indicator
FSH	space heater repaired indicator
FWH	water heater repaired indicator
GCK	gas range indicator
GDY	gas dryer indicator
GSH	gas space heating indicator
GWH	gas water heating indicator
HDD	number of heating degree days (base 65)
LATE	appliance repair participant after October, 1994
MULTI	multiple family residence indicator
NON_RG	range not replaced/repaired indicator
NON_SH	space heater not replaced/repaired indicator
NON_WH	water heater not replaced/repaired indicator
NQUAL	households not qualifying for appliance replacement
NUMINHH	number of people in the home
OLD	persons over 65 in the home indicator
POST	post space heater installation period indicator
POSTR	post range installation period indicator
POSTW	post water heater installation period indicator
PRE	pre space heater installation period indicator
PRER	pre range installation period indicator
PREW	pre water heater installation period indicator
QUAL	households that qualify for appliance replacement
RG	range replaced/repaired indicator

Variable	Definition
RGNW	range not working indicator
RRG	range replaced indicator
RSH	space heater replaced indicator
RWH	water heater replaced indicator
SHNW	space heat not working indicator
SQFT	square footage of the home
SUMMER	summer season indicator
TIME	time taking value of 1 in 1993 and 3 in 1995
WASHL	number of hot water clothes washings
WHNW	water heat not working indicator
WTHR	sum of weatherization measures saving impact
YOUNG	persons under 3 in the home indicator

A Durbin Watson statistic was calculated to assess whether serial correlation was present. The Durbin Watson statistic was .492 (not shown in Appendix D output) indicating the presence of serial correlation. Respondent-specific rho values were also calculated. They are shown on page 7 of Appendix D. The average rho value for the dataset is .707.

There also appeared to be significant heteroskedasticity present, based upon a review of the plot of residuals versus monthly therm use (page 4 of Appendix D). Evidence of serial correlation and heteroskedasticity led to the second stage estimation where a serial correlation correction was conducted.

Second Stage - Correction for Serial Correlation

The second stage was actually begun with the estimation of the respondent specific rho values discussed above. The predicted values from the initial conditional energy demand equation were used to estimate the level of correlation in the error term over time for each respondent (i.e., household). This was done by fitting an autoregressive model of order one, an AR(1) model, for each respondent.

The AR(1) model can be described as follows:

$$e_{i,t} = rho_i * e_{i,t-1} + \eta_{i,t}$$

where:

$e_{i,t}$ is the regression error term from the first stage for the i^{th} respondent in month t

$\eta_{i,t}$ is a "white noise" error term for the i^{th} respondent in month t

Estimates of rho_i, ρ_i, are obtained by regressing residuals from the first stage OLS model on the residuals values lagged one period. This is done separately for each respondent.

The estimated ρ_i values are used to transform the dependent variable and all the regressors. It is important to remember that each regressor in Tables 8 and 9 has a time (t) and a household (i) subscript attached to it. These subscripts were left out of the table for presentation purposes. For example, the last variable in Table 8, GSH*SQFT*HDD*NQUAL*YOUNG, should be interpreted as $(GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t}$. The transformation involves replacing the value of $(GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t}$ with the value of $(GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t} - \rho_i * (GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t-1}$.

Next the energy demand equation was reestimated using the transformed variables to correct for the correlation in the error term. This correction generates more consistent regression parameter estimates. The parameter estimates from this second stage are also summarized in Tables 8 and 9. The detailed results are contained in Appendix D beginning on page 9. The adjusted R-squared is .519. With very few exceptions coefficients retained the same signs and magnitudes.

Third Stage - Correction for Heteroskedasticity

The third stage begins with a supplementary regression that serves two ends, it tests for the presence of heteroskedasticity and provides weights that can be used to correct for the heteroskedasticity that does exist. The supplementary regression takes the residuals

computed from the second stage regression and estimates their squared value across households as a function of the number of appliances present in each home, season of the year, and which Direct Assistance Program segment the household belongs. The coefficients and t-values are provided below in Table 10. Note that the coefficient of STOCKTERM has a highly significant t-value. This implies that heteroskedasticity is present, i.e. the variance of the error term is influenced by the magnitude of monthly consumption.

Table 10
Estimated Functional Form of Heteroskedasticity

Variable	Description	Coefficient	t-value
INTERCEPT	regression intercept	14.902	3.17
RRP	ARRP participation indicator	23.350	2.35
WINTER	Dec. - Mar. indicator	135.683	18.88
SPRING	Apr. - June, Nov. indicator	42.936	6.40
WINTER*RRP	Winter indicator interacted with ARRP participation	88.005	5.74
SPRING*RRP	Spring indicator interacted with ARRP participation	19.880	1.40
STOCKTERM	Expected monthly usage based upon respondent-specific appliance holdings and estimated use per appliance from second stage results	.255	46.14
STOCKTERM*RRP	Stock term interacted with ARRP participation	-.071	-6.83

Notes: Indicators are binary variables; ARRP references an Appliance Replacement and Repair Program participant.

The correction for heteroskedasticity involves transforming the dependent and independent variables from the second stage regression using the square root of the predicted values from the supplementary regression. Assume $vhat_{i,t}$ is the square root of the predicted value. Use the previous example variable from Table 9, $(GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t}$, after the second stage transformation. The estimated value of the error term from this third equation was then used to weight the second stage equation, i.e. $(GSH*SQFT*HDD*NQUAL*YOUNG)_{i,t} * vhat_{i,t}$.

The conditional demand model was then reestimated using the transformed values of the dependent and independent variables. The regression coefficients estimated in this third stage have both consistent and unbiased estimates of the error term. They are shown in Tables 8 and 9, as well as in Appendix D.

While there is some loss of observations using this procedure more than 90,300 monthly observations were incorporated in the third stage regression model. The adjusted R-squared value from the third stage regression is .417. This value is very similar to previous study results in the Southern California Gas Company residential markets and is consistent with the first stage results of .432. The parameter estimates from this third stage model were used to calculate program impacts.

Appliance/Equipment Specific Gas Use Estimation

The space heating (gsh), water heating (gwh), cooking (grg), clothes drying (gdy), and pool/spa heating (gp) demand equations for both segments are explained in the remainder of this section.

Gas Space Heating

The actual space heating load is based on customer behavior and the principles of thermodynamics. Therm usage depends upon the efficiency of the heating system, the thermal integrity of the home, the area to be heated, and the desired household indoor temperature. Due to the qualifications of the Direct Assistance Program, four categories of space heating customers are modeled. The categories are:

a) single family homeowners that **did not** need their space heater replaced/repaired,

b) single family homeowners that **needed** their space heater **repaired**,

c) single family homeowners that **needed** their space heater **replaced**, and

d) single family renters and multiple family residents

It is expected that the efficiency of the heating system for those customers that had the space heating system replaced or repaired was worse than the other two categories space heater efficiency prior to repairing the heater or installing the new space heater. Both the survey data and the program participation file provided information concerning whether the existing space heater was inoperative prior to replacement or repair. If the heater was inoperative, the space heating terms were set equal to zero during the months the participant claimed the space heater was not working.

The presence of weatherization measures (attic insulation, caulking/weatherstripping, building envelope repairs, register seal, exhaust vent damper, and evaporative cooler cover) improves the thermal integrity of the home. The program measure file, along with the participant survey, provided information concerning weatherization measures. The dates of measure installation provided a tool to develop pre and post weatherization indicators. It was assumed that customers who claimed weatherization measures existed in the survey, but had no program measure installation information for a particular item, already had the weatherization item present in the home. A term equaling the sum of expected savings (25 percent for attic insulation, 5 percent for caulking/weatherstripping, 7.5 percent for building envelope repairs, 3.5 percent for register sealing, 6 percent for exhaust vent damper, and 10 percent for evaporative cooler covers) from the weatherization items was entered into the equation for each space heating group. These estimates were obtained from conversations with DAP staff.

The desired indoor temperature in the home is thought to be dependent on the age characteristics of the people in the home. Specifically, it was assumed that households with at least one member over 65 years or members under 3 years have higher indoor temperature requirements than other household age formations.

A time trend term incrementing one each year is included to account for the general economic conditions facing low income households (this was suggested by past

reviewers). A term for change in floor space is also included, although the exact timing and whether the change in floor space was an increase or decrease was not known. Note that for the non-qualifying group, differences between single family and multiple family dwellings are taken into account with a multiple family interaction.

The space heating usage model takes the form described below (the coefficient and t-values are provided in Table 8).

gsh = 5.21225 * GSH*(SHNW=0)*(1-POST*RSH)

(t2) - 1.70699 * GSH*(SHNW=0)*SUMMER*(1-POST*RSH)

(t3) - .0000017 * GSH*(SHNW=0)*SQFT*HDD*TIME

(t4) + .0000009 * GSH*(SHNW=0)*SQFT*HDD*C_FT

(t5) + .0000947 * GSH*SQFT*HDD*QUAL*NON_SH

(t6) - .0000532 * GSH*SQFT*HDD*QUAL*NON_SH*WTHR

(t7) + .0000395 * GSH*SQFT*HDD*QUAL*NON_SH*OLD

(t8) - .0000318 * GSH*SQFT*HDD*QUAL*NON_SH*YOUNG

(t9) + .0000248 * GSH*SQFT*HDD*QUAL*(FSH+RSH)*PRE*CKHTB

(t10) + .0000746 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*PRE

(t11) + .000125 * GSH*SQFT*HDD*QUAL*RSH*POST

(t12) - .0000760 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*WTHR

(t13) + .000017 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*OLD

(t14) - .000043 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*YOUNG

(t15) + .0000033 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*PRE*LATE

(t16) + .0000845 * GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*PRE

(t17) + .000118 * GSH*SQFT*HDD*QUAL*FSH*POST

(t18) - .000107 * GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*WTHR

(t19) + .000032 * GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*OLD

(t20) - .000010 * GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*YOUNG

(t21) + .000104 * GSH*SQFT*HDD*NQUAL

(t22) - .000026 * GSH*SQFT*HDD*NQUAL*MULTI

(t23) - .0000485 * GSH*SQFT*HDD*NQUAL*WTHR

(t24) + .000023 * GSH*SQFT*HDD*NQUAL*OLD

(t25) - .000013 * GSH*SQFT*HDD*NQUAL*YOUNG

where the variables are defined following Table 9.

The first two terms capture the space heating pilot light loads. The coefficients have the expected signs with the summer term (t2) capturing the customers who turn off pilot lights during the summer. For households receiving new space heaters, the pilot light load was restricted to zero (Title 20 standards). Terms (t3) and (t4) capture the effects of time and changing floor space have on space heating use. The time trend (t3) has a negative coefficient suggesting that space heating use declines as the years go by. The t4 term has a positive but insignificant coefficient suggesting a overall zero impact on space heating use.

Terms t5 through t8 comprise the single family homeowners that did not need the space heating equipment replaced/repaired. The ratio of t6 to t5, .56, measures the proportion of expected weatherization savings achieved by this group. The presence of senior

citizens (t7) increases space heating use while, somewhat surprisingly, the presence of young children results in lower space heating use.

Term t9 measures the amount of gas used to heat the home via the range for the survey respondents that stated they use cooking equipment to heat while their space heater was not working. The value of t9 is about 35 percent the value of the pre period (t10) space heating replacement group usage. Terms t10 through t15 measures the space heating use for those participants that received a new space heater. The post period use per degree day foot (t11) is nearly 70 percent higher than the pre installation period (t10) value. The weatherization measure impact (t12) is 60 percent the size of the post period usage value. As with the group that did not need a new space heater, the presence of seniors (t13) increases gas use and households with young children (t14) use less space heating energy. A term for the end of the year space heating replacement participants (t15) was included to test for more lenient replacement standards later in the year. The value of t15 is positive, but not significant at the 95 percent level.

Terms t16 through t20 measures the space heating use for those participants that had the space heater repaired. The post period use per degree day foot (t17) is more than 30 percent higher than the pre installation period (t16) value. The weatherization measure impact (t18) is nearly 100 percent the size of the post period usage value. The presence of seniors (t19) increases gas use and households with young children (t20) use less space heating energy although the coefficient is not significantly different than zero.

Terms t21 through t25 measures the space heating use for those participants that were not single family home owners. The multiple family resident use per degree day foot (t22) is more than 25 percent less than the single family renter (t21) value. The weatherization measure impact (t23) is less than 50 percent the size of the single family usage value. The presence of seniors (t24) increases gas use and households with young children (t25) use less space heating energy.

Gas Water Heating

Gas water heating use depends on the temperature of the incoming water, the number of dishwasher loads, the number of hot water clothes washing loads, and the efficiency of the water heater tank. As the case with space heating, four categories of water heating customers are modeled. The categories are:

1. single family homeowners that **did not need** their water heater replaced/repaired,
2. single family homeowners that **needed** their water heater **repaired**,
3. single family homeowners that needed their water heater **replaced**, and
4. single family renters and multiple family residents

The average air temperature during the month is used to approximate the temperature of the incoming water. The survey respondents were asked the water heater temperature setting of the water heater as well as the number of dishwasher loads and hot water clothes washing loads per week.

Four conservation measures impact water heating use. The low flow shower head and faucet aerator impact the volume of water used while pipe insulation and the blanket influence the implied efficiency of the heater tank. A term equaling the sum of expected savings (7.5 percent for the low flow shower head, 3.5 percent for faucet aerator, 6 percent for pipe insulation and 5 percent for heater blanket) from the conservation measures was entered into the water heating equation, based upon conversations with DAP staff.

The water heating usage model takes the form (t-values reported in Table 9):

gwh = .01571 * GWH*(WHNW=0)*DT*TIME

(t2) + .03246 * GWH*(WHNW=0)*DT*C_NUM

(t3) + .20285 * GWH*(WHNW=0)*DT*QUAL*RWH*PREW

(t4) + .23496 * GWH*DT*QUAL*RWH*POSTW

(t5) + .18673 * GWH*(WHNW=0)*DT*QUAL*FWH*PREW

(t6) + .21792 * GWH*DT*QUAL*FWH*POSTW

(t7) + .25825 * GWH*DT*QUAL*NON_WH

(t8) - .15692 * GWH*(WHNW=0)*DT*CONS

(t9) - .01261 * GWH*(WHNW=0)*DT*OLD

(t10) + .02555 * GWH*(WHNW=0)*DT*YOUNG

(t11) + .00198 * GWH*(WHNW=0)*DT*DW*DISHL

(t12) + .00448 * GWH*(WHNW=0)*DT*CW*WASHL

(t13) + .24217 * GWH*DT*NQUAL

(t14) - .04679 * GWH*DT*NQUAL*MULTI

where the variables are defined following Table 9.

The first water heating term captures the impact time has on water heating use. The positive coefficient indicates as the years go by, increased water heating use is experienced. Term t2 measures the impact of changes in household size have on water heating use. The positive coefficient implies an increase in use when the number of household members changes.

Terms t3 and t4 capture the impact of replacing the water heat. The size of the t4 coefficient is over 15 percent higher than the pre installation period water heating use. This result is less dramatic in relative magnitude than the space heater replacement pre and post period terms.

Terms t5 and t6 measure the impact of water heater repair work. The post period term (t6) reflects a 17 percent increase after the water heater was repaired. Term t7 measures water heating use for the single family homeowners that did not need the water heater replaced or repaired. The value of t7 is higher than the post period value for both the repaired and replaced water heating groups.

Water heating conservation impacts are captured in term t8. The value of t8 suggests that more than 60 percent of the expected water heating savings are achieved after conservation is installed. Terms t9 and t10 capture the impacts of seniors and young children on water heating use. The value of t9 (senior citizen impact) is negative while the value of t10 (presence of young children impact) is positive. The values are the opposite of what was measured for the space heating groups. Terms t11 and t12 capture the impact of dishwasher loads and hot water clothes washer loads on water heating use. Both terms have the expected positive signs.

The final terms (t13 and t14) measure water heating use for single family renters and multiple family households. The value of t14 relative to t13 implies multiple family homes use less energy for water heating than single family households.

Gas Cooking

Gas cooking usage is assumed to be dependent upon the number of people in the home. In addition, customers who claimed they use cooking equipment for space heating was modeled. As the case with space and water heating, four categories of cooking customers are modeled. The categories are

1. single family homeowners that **did not need** their cooking system replaced/repaired,
2. single family homeowners that **needed** their cooking system **repaired**,
3. single family homeowners that **needed** their cooking system **replaced**, and
4. single family renters and multiple family residents

The gas cooking usage model takes the form (t-values reported in Table 9):

grg = 1.1701 * GCK*NUMINHH*QUAL*NON_CK

(t2) - .0037 * GCK*(RGNW=0)*NUMINHH*TIME

(t3) + 1.1892 * GCK*(RGNW=0)*NUMINHH*QUAL*RRG*PRER

(t4) + 1.1967 * GCK*NUMINHH*QUAL*RRG*POSTR

(t5) + .6865 * GCK*(RGNW=0)*NUMINHH*QUAL*FRG*PRER

(t6) + 1.1898 * GCK*NUMINHH*QUAL*FRG*POSTR

(t7) + 1.4647 * GCK*NUMINHH*NQUAL

(t8) - .0364 * GCK*NUMINHH*NQUAL*MULTI

(t9) + .000032 * GCK*HDD*SQFT*CKHT

where the variables are defined following Table 9.

The first gas cooking term is the use per person for single family home owner households that did not need cooking equipment replaced or repaired. The value of 1.05 suggests that each person uses slightly more than one therm a month for cooking. The time trend (t2) has a negative coefficient value but is not statistically different than zero.

Terms t3 and t4 measure than cooking replacement usage. The value of t4 is slightly higher than the pre installation (t3) value. Terms t5 and t6 capture the cooking repair pre and post usage. The post period usage (t6) is close to 75 percent higher than the pre period usage. Terms t7 and t8 identifies the single family renter and multiple family household usage. Note that the multiple family term is not statistically different than zero.

Finally, term t9 measures the space heating use from cooking equipment for households that use cooking equipment to space heat on a regular basis. The value is roughly one-third the use per degree day foot value found in the normal space heating usage equation.

Gas Clothes Dryer

Dryer use is expressed as a function of the number of clothes drying loads done in the home. The estimated clothes dryer equation is expressed as follows:

gdy = .3785 * GDY * DRYL

where GDY is the gas dryer indicator and DRYL is the number of clothes drying loads. As expected the clothes drying usage increases as the number of drying loads rise.

Gas Pool/Spa Heat

The pool/spa heat use is expressed as an indicator variable. The estimated pool heating equation is expressed as follows:

gp = 4.309 * PHSPA

where PHSPA is the gas pool/spa heating indicator. The estimated coefficient indicates that roughly 52 therms per year is used by low income households to heat their pool or spa (in the few instances where they had such equipment).

Appliance Usage Estimates and Therm Savings Impacts

This section of the report presents the annual appliance usage estimates as well as the saving impacts from weatherization measures, conservation measures, repaired appliances, and replaced appliances. The space and water heating usage estimates are based on average monthly weather conditions over the past 30 years in the Gas Company weather zones weighted for program participation.

The remainder of the section is organized as follows. First, the method used to estimate appliance usage and associated savings are discussed. Second, the usage and conservation savings estimates are presented.

Method of Calculating Appliance Therm Use

The energy use model regression coefficients displayed in Tables 8 and 9 are employed to predict monthly consumption under normal weather condition values (both heating degree days and average temperature). Households participating in the appliance replacement program had annual appliance energy use values calculated for the following scenarios

a) no weatherization/conservation measures installed and appliances were working prior to repair/replacement

b) appliances were all repair/replaced

c) all weatherization/conservation measures were installed

Customers participating in the weatherization and conservation program had annual appliance energy use values estimated for the two scenarios described below.

a) no weatherization/conservation measures installed

b) all weatherization/conservation measures were installed

Monthly weather conditions, as well as other household characteristics taken from the survey, are held constant throughout all the scenarios for all survey households. This approach permits the differences in appliance usage among the scenarios to truly reflect the therm savings attributed to the measure or repaired/new appliance. Simulation results are presented in the next section.

Appliance Usage and Weatherization Measure Savings Estimates

Appliance specific annual energy use values are provided below. Values for households participating in the appliance replacement program are given first, followed by the weatherization and conservation measure group usage estimates.

Table 11 displays the annual space heating, water heating and cooking energy use estimates for replaced and repaired appliances along with ± therm usage that define the 90% and 80% confidence intervals respectively. The replacement numbers indicate that the water and space heating post-installation period usage values are statistically different from the pre-installation period values. Only space heating use declined after the appliance was replaced. The appliance repaired numbers show usage increases after appliances are repaired, but the cooking usage increase is the only one statistically different than zero.

These results differ from the analysis of the 1993 program where savings were estimated for repair/replacement of furnaces, water heaters, and cooking equipment.

Table 11
Appliance Replacement and Repair Therm Usage/Savings

End-Use	Pre Installation	Post Installation	Therm Savings
Cooking Replacement	53	55 (10.9, 8.5)[b]	-2
Cooking Repair	27	45 (17.2, 13.3)	-18
Water Heating Replc.	159	181 (17.4,13.5)	-22
Water Heating Repair	159	182 (51.6, 40.0)	-23
Space Heating Replc.	228	214 (11.6, 9.0)	14
Space Heating Repair	271	288 (22.4, 17.4)	-17

Notes:

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm usage after participation are the ± therm usage that define the 90% and 80% confidence intervals respectively.

Table 12 lists the weatherization and conservation results with the 90 percent and 80 percent therm confidence band in parenthesis. All the space heating weatherization saving values are statistically different than zero. Ceiling insulation savings are greatest in the repair and replace groups and least in the multiple family direct assistance group.

Table 12
Space Heating Measures Therm Savings

Class	Ceiling Insulation	Weather-strippng/ Caulking	Building Envelope Repairs	Switch/ Outlet Gasket	Evap. Cooler Cover	Roof Vent Cover
ARRP Control	24 (3.4, 2.6)[b]	5 (.6, .5)	7 (.9, .7)	4 (.5, .4)	10 (1.2, .9)	6 (.9, .7)
ARRP Replace	32 (7.4, 5.8)	6 (1.5, 1.1)	10 (2.0, 1.6)	5 (1.0, .8)	13 (4.3, 3.4)	8 (1.7, 1.3)
ARRP Repair	47 (16.1, 12.5)	10 (3.1, 2.4)	14 (4.6, 3.6)	7 (2.4, 1.8)	19 (9.3, 7.3)	11 (1.4, 1.1)
Weatherization Single Family	21 (3.9, 3.0)	4 (.7, .6)	6 (1.0, .8)	3 (.5, .4)	8 (2.7, 2.1)	5 (1.1, .8)
Weatherization Multi Family	14 (2.3, 1.8)	3 (.5, .4)	4 (.7, .5)	2 (.3, .2)	6 (1.7, 1.3)	- -

Notes:

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm savings after participation are the ± therm savings that define the 90% and 80% confidence intervals respectively.

Table 13 provides unit therm savings for water heating measures. As with space heating, all the water heating conservation therm savings are statistically different than zero. The low flow shower heads have the largest therm savings from water heating conservation.

Table 13
Water Heating Measures Therm Savings

Class	Low Flow Showerhead	Water Heater Blanket	Faucet Aerator	Pipe Insulation
ARRP Control	8 (2.2, 1.7)[b]	6 (1.5. 1.2)	4 (1.1, .8)	7 (1.7, 1.3)
ARRP Replace	9 (2.1, 1.7)	6 (1.5, 1.1)	4 (1.1, .8)	- -
ARRP Repair	9 (2.3, 1.8)	6 (1.5, 1.2)	4 (1.1, .8)	- -
Weatherization Single Family	8 (2.2, 1.7)	6 (1.5, 1.2)	4 (1.1, .8)	8 (1.8, 1.4)
Weatherization Multi Family	8 (2.2, 1.7)	5 (1.5, 1.2)	4 (1.1, .8)	7 (1.5, 1.2)

Notes:

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm savings after participation are the ± therm savings that define the 90% and 80% confidence intervals respectively.

All of the therm savings are lower than those employed previously. This is at least partially due to differences in the model employed for the 1993 assessment In so far as DAP planning and funding decisions are influenced by estimated savings, the 1994 results are likely more reliable than the 1993 results.

SUMMARY TABLE: Completed Load Impact Study (February, 1996)
Southern California Gas Company
(In fulfillment of Table 6 of the *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs*)

Study Title

First Year Load Impact Study of Southern California Gas Company's 1994 Direct Assistance Program

Study ID 703

Program/Program Year

Direct Assistance Program (DAP), Program Year 1994

Program Description

SoCalGas' 1994 DAP provided assistance, consisting of subsidies for installation of energy conservation measures, energy education, and repair and/or replacement of cooking, water heating and space heating equipment, to low income customers.

1. **Average Participant Group and Average Comparison Group Usage**
   Not Applicable

2. **Average net and gross end use load impacts for the 1994 program year.**
   (See Tables S1 and S2)

Table S1
Single Family Net Therm Savings -
Measure Impacts, Measure Counts and Program Impacts

Measure	Ex-Ante Measure Impact	Ex-Post Measure Impact	Ex-Post % of Ex-Ante	Confidence Intervals (90%,80%)[c]	Ex-Post Measure Count	Ex-Post Program Impact
Weatherization						
Ceiling Insulation	38.0	23.7	62	(4.8,3.7)	3,224	76,280
Wthrstrip/Caulking	9.0	4.6	51	(.9,.7)	11,262	51,467
Bldg Envelope Repairs	19.0	6.9	36	(1.3,1.0)	10,751	74,289
Switch/Outlet Gaskets	12.0	3.5	29	(.6,.5)	9,225	32,195
Evaporative Cooler Cover	77.0	9.2	12	(4.2,3.2)	381	3,517
Roof Vent Cover	16.0	5.7	36	(.9,.7)	304	1,733
Low Flow Showerhead	12.0	8.0	67	(2.2,1.7)	9,968	80,043
Water Heater Blanket	5.0	6.0	120	(1.5,1.2)	2,812	16,872
Faucet Aerator	11.0	4.0	36	(1.1,.8)	10,000	40,000
Pipe Insulation	18.0	7.5	42	(1.7,1.4)	567	4,258
Appliance Repair and Replacement						
Cooking Replacement	37	-2.0	NA	(10.9,8.5)	1,312	-2,624
Cooking Repair		-18.0	NA	(17.2,23.3)	415	-7,470
Water Heating Replc.	39	-22.0	NA	(17.4,13.5	465	-10,230
Water Heating Repair		-23.0	NA	(51.6,40)	49	-1,127
Space Heating Replc.	43	14.0	NA	(11.6,9)	2,025	28,350
Space Heating Repair		-17.0	NA	(22.4,17.4)	693	-11,781
All Measures	-	32.9	NA		11,411[b]	375,772

Notes:

a. Ex-Ante Appliance Repair and Replacement values are only available for the combined program, i.e., repair and replacement activities for the given measure type.

b. Estimated number of single family participants.

c. The parenthetical values are ± therm savings that define the 90% and 80% confidence intervals respectively.

Table S2
Multi Family Net Therm Savings -
Measure Impacts, Measure Counts and Program Impacts

Measure	Ex-Ante Measure Impact	Ex-Post Measure Impact	Ex-Post % of Ex-Ante	Confidence Intervals (80%,90%)[b]	Ex-Post Measure Count	Ex-Post Program Impact
Weatherization						
Ceiling Insulation	24.0	14.0	58	(2.3,1.8)	2,460	34,440
Wthrstrip/Caulking	24.0	3.0	13	(.5,.4)	7,566	22,698
Bldg Envelope Repairs	13.0	4.0	31	(.7,.5)	6,902	27,608
Switch/Outlet Gaskets	8.0	2.0	25	(.3,.2)	5,992	11,984
Evaporative Cooler Cover	56.0	6.0	11	(1.7,1.3)	118	708
Roof Vent Cover	-	-		-	31	-
Low Flow Showerhead	14.0	8.0	57	(2.2,1.7)	6,544	52,352
Water Heater Blanket	8.0	5.0	63	(1.5,1.2)	1,363	6,815
Faucet Aerator	7.0	4.0	57	(1.1,.8)	6,530	26,120
Pipe Insulation	18.0	7.0	39	(1.5,1.2)	172	1,204
All Measures	-	24.3	NA		7,566[a]	183,929

Notes:
a. Estimated number of multi family participants.
b. The parenthetical values are ± therm savings that define the 90% and 80% confidence intervals respectively.

3. Net to Gross Ratio: 1.0
Impacts in Tables S1 and S2 are net impacts.

4. Designated Unit Intermediate Data
Mean values of intermediate data are shown in Appendix C of the report.

5. Precision of Load Impact Estimates
The precision of the load impact estimates at the 90% and 80% confidence levels are also shown in Tables S1 and S2.

6. Measure Count Data
Measure count data for all program participants are shown in Tables S1 and S2.

7. Market Segment Data

Table S3
1994 Program Participation by Weather Zone

Weather Zone	Participants	Sample Frame	Survey Respondents
Mountain	0.2%	0.2%	0.3%
Lower Desert	4.4%	3.9%	3.9%
Coastal	9.6%	8.0%	8.1%
High Desert	12.2%	13.9%	13.9%
Inland Valleys	24.3%	24.4%	26.6%
Coastal Valleys	49.2%	49.7%	47.0%
Total Customers	21,547	8,000	3,393