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memo

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Subject:	LIEE Refrigerator Replacement Energy Consumption		

Background and Overview of Results

The March 11, 2011 draft report Impact Evaluation of the 2009 California Low Income Energy Efficiency Program calculated program year (PY) 2009 average unit savings of 713 kWh from replacing refrigerators older than 1993. Replacement of these older units with new efficient units creates high average savings for the program due to their high energy consumption relative to the energy consumption of current refrigerator models. In 1993 new Appliance Standards addressing Refrigerators went into effect. Refrigerator units manufactured and sold after the new Standard was enacted use much less energy than equivalent models sold before 1993. Unfortunately, natural unit retirement due to the increasing age of the units combined with the effect of program activities over the last ten years is causing pre-1993 units to become increasingly scarce in LIEE participant homes. This is driving down total program savings even though average per-unit savings remains high. The question then is how to move the program forward to incorporate later model years with the smallest loss of relative average savings to the program as a whole.

This memo documents the results of an analysis performed by KEMA to provide an answer to that question. By modeling the SCE LIEE program data for 1985 to 1992 (status quo), we estimate that the 2011 program would achieve an average per-unit savings of 725 kWh, with the increase in kWh savings over recent program evaluation results caused by continuing degradation of the aging units from 2009 to 2011. KEMA's review of available data on refrigerator shipments, expected lifecycle and refrigerator performance degradation show that adding units manufactured in 1993 to the LIEE Program will shift program savings to approximately 670 kWh for each refrigerator replaced; a loss of 7.6% from the status quo. Increasing the cut-off year to 2000 will result in program average savings of about 475 kWh, a 34.5% reduction in program savings for refrigerators. Table 1 outlines the expected changes in per-year savings and Total Program Average Savings as each year between 1993 and 2000 is incrementally included in the program eligibility criteria:

Table 1: Adjustments to Cumulative Program Savings with Increasing Program Year Criteria

Year	Average Per-Unit kWh Savings by Year	% Surviving Units/year	Full Program Per-Unit Savings from Pre-1993 to…	Marginal Difference	Marginal % Difference	Cumulative Difference from Status Quo	Cumulative % Difference from Status Quo
Pre-1993	725	4%	725				
1993	513	5%	670	-55	-7.6%	-55	-7.6%
1994	488	7%	631	-39	-5.8%	-94	-13.0%
1995	439	9%	595	-36	-5.7%	-130	-18.0%
1996	355	10%	554	-41	-6.8%	-171	-23.6%
1997	462	12%	539	-15	-2.7%	-186	-25.7%
1998	442	15%	524	-15	-2.8%	-201	-27.7%
1999	343	17%	496	-28	-5.3%	-229	-31.6%
2000	345	20%	475	-21	-4.3%	-250	-34.5%

An alternative to a single kWh savings number for all units recycled by the program (pre-and post-the 1992 standard) is to treat the refrigerators manufactured and sold after 1992 as a separate group, with a separate savings estimate. The Low Income programs would continue to use the previously approved savings estimate for pre-1993 units, but add a second "measure" with a different savings estimate for units manufactured after 1992. Table 2 shows the average kWh savings for all units manufactured in a particular year by year; the % Surviving Units by year (percentages are of all LIEE homes with refrigerators manufactured before 2001); and the incremental kWh Savings for units from 1993 to selected end date (e.g. for 1993-4, for 1993-5, for 1993-6, etc.).

Table 2: Average and Cumulative Savings for Post-1992

Year	Average Per-Unit kWh Savings by Year	% Surviving Units/year	"Incremental" Per-Unit Savings from Post-92 to…
Pre-1993	725	4%	
1993	513	5%	513
1994	488	7%	500
1995	439	9%	478
1996	355	10%	444
1997	462	12%	448
1998	442	15%	447
1999	343	17%	426
2000	345	20%	412

Units

Methodology and Assumptions

This analysis relies heavily on a number of assumptions:
- Efficiency degradation – Smoothed 1% efficiency degradation per year
- Unit Distribution
  - o Unit Age Distribution – Distribution of unit age is similar to the U.S. as a whole.
  - o Unit Type Distribution – Distribution of unit types fall into four major categories, similar to the U.S. as a whole.
    - ▪ Top-Freezer refrigerator
    - ▪ Top-Freezer refrigerator with through the door icemaker

- Side-by-side Refrigerator Freezer
- Side-by-side Refrigerator Freezer with through the door icemaker
  - o Replacement Refrigerator UEC – current Energy Star standard for a Top-Freezer refrigerator without through-the-door ice.
- Population – Refrigerator distribution is based on U.S. annual sales data. Annual changes in relative population reflect changes in refrigerators in California. Annual population values for each are from the U.S. Census Bureau.
- LIEE Households with Eligible Refrigerators – Adjustments made to the national shipments of refrigerators to account for LIEE program removal of pre-1993 units over the past decade.

Unit Energy Consumption and Program Savings

The California Energy Commission maintains a list of refrigerators and freezers that have been certified for sale in California (http://www.appliances.energy.ca.gov/). They also have archive lists of units that were once certified for sale and are now not certified. KEMA took the complete list of certified and decertified units and used the dates they were added and removed from the list of currently approved units to determine all the units that were certified for sale in California for each year between 1985 and 2002.

The annual energy consumption for each unit was degraded by 1%/year to arrive at an "in-operation" UEC for that particular unit for any given year in our range. In addition, the equipment characteristics were used to calculate a "Energy Star replacement UEC" using the current Energy Star standard for a Top-Freezer refrigerator without through-the-door ice. The difference between the in-operation UEC and the replacement Energy Star UEC is the savings that would be achieved by replacement of that unit with a new Energy Star Top-freezer refrigerator.

KEMA then calculated the mean UEC for Top-Freezer and Side-by-Side refrigerators both with and without ice from all the units certified for sale in each of our target years (1985 through 2002). Using the national shipments for refrigerators by product type (same four types) we weighted the UECs by equipment type to arrive at a "typical" UEC and savings for each year. This savings value was calibrated using the results of the 2009 LIEE Program Year evaluation to ensure consistency for planning purposes.

Surviving Units in the LIEE Market

The first step in determining the number of units surviving is to determine the total number of units sold in any given year. National sales figures from the national LCC calculator provide a starting point. To determine the number in any given year, this is then multiplied by the ratio of California population to the national population.

We then estimated the likelihood of a unit manufactured in a given year still being present in LIEE homes by applying survival functions from both the national LCC calculator rate and a custom rate derived from the SCE LIEE program data. The survival function was applied to national shipments to get at the percentage chance of survival for units sold in a given year. It was determined that there were only small differences between the national survival function and units removed by the SCE low income homes in recent years, giving us confidence that the national LCC survival

function would be a fair proxy for refrigerator survival in California low income homes for years beyond the eligibility criteria in the SCE LIEE program.

While this survival function provides the number of units replaced to evaluate retrospective calculations, treated homes must be removed to calculate average savings for program scenarios involving new years. According to PG&E provided data, approximately 34% of eligible homes have been treated since 1991. Applying a reduction of 34% to the survival function for pre-1993 unit does not affect the average savings when the program includes only pre-1993 units, assuming these units are all removed in uniform proportion to the number of homes treated. However, due to the reduced amount of pre-1993 units remaining in proportion to later, more efficient model years, average savings does decline at a significantly higher rate.

Conclusions

Savings for refrigerators manufactured earlier than 1993 have average savings of 725 kWh. This value will decrease with any inclusion of post-1992 program years. Average savings is expected to drop from 725 kWh to 670 kWh with the addition of 1993 units, a marginal difference of -7.6%. This is due to both the increased efficiency of 1993 units (513 kWh for 1993 manufactured units) and the ratio of available units. As the supply of pre-1993 units nears exhaustion, their influence on average savings will become increasingly weak.

No other single year addition matches the change that the addition of 1993 year units will have. Including all models older than 10 years (pre-2001) is estimated to change average savings from 725 kWh per replaced refrigerator in PY2011 to 475 kWh (-34.5%). A further revision of the Appliance Standard for refrigerators took effect in 2001. KEMA does not recommend including units past this second adjustment to energy consumption to the LIEE Program eligibility criteria at this time.