



memo

To: Mary O'Drain Date: December 2, 2011

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Subject: ESAP Refrigerator Replacement Eligibility Criteria

Introduction

This memo addresses the issue of optimal eligibility criteria for replacement of refrigerators by the Energy Savings Assistance Program (ESAP). Practically speaking, this memo uses improved, program specific data to update the results from a memo produced in April, 2011 (LIEE - Effect of Expanding Program Year Eligibility_04_18_11.docx). This memo then projects results for multiple criteria forward through 2015. Finally, this memo considers the range of alternative eligibility criteria that are available given the expanded data.

The primary results in this memo illustrate the relative change from criterion to criterion and over time of

- The percent of ESAP population with eligible units, and
- The average expected savings for that group of units.

The actual magnitudes reported in this memo, both percent eligible and expected savings, should be used with caution. Both estimates still, by necessity, rely on a number of assumptions related to nameplate year of manufacture, UEC and expected degradation. These assumptions are consistent for comparisons across criteria and time making the conclusions of relative change more reliable and appropriate than the actual magnitude results themselves. In particular, because the UEC estimates are developed from nameplate UEC with degradation, the expected savings estimates may not reflect the true *in situ* usage of the units that are removed by ESAP.

Background and Assumptions

In April, 2011, KEMA delivered a memo designed to

- Confirm that the number of eligible units based on the existing fixed year-of-manufacture criteria was diminishing year to year, and
- Quantify the effect of adopting a rolling, age-based criteria for eligibility of refrigerators for

the ESAP program.

At the time, KEMA relied heavily on assumptions, stated in the April memo:

- Unit UEC
 - Nameplate UEC based on mean of available units in configuration bin.
 - Efficiency degradation –1% efficiency degradation per year (not compounded)
- Unit Distribution
 - Unit Age Distribution – Distribution of unit age is similar to the U.S. as a whole.
 - Unit Type Distribution - Distribution of Type based on AHAM sales data
 - 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
- Population - U.S. Census data on U.S. and California populations used to prorate national sales data

These assumptions were necessary to model the counts and average UEC for units under the existing eligibility criteria as well as the the effect of changing the eligibility criteria. As expected, the fixed year eligibility criterion did result in fewer units eligible for the program. The alternative criteria increased the range of units that were considered eligible but by doing so accepted units with lower average UECs.

Table 1 provides the original April Memo simulated 2011 program year. The first line of the table shows that under the fixed, pre-1993 year-of-manufacture criterion, only seven percent of ESAP homes would be eligible. The estimated savings level for the unit collected under that criterion would be 725 annual kWh. Each subsequent line of the table moves the manufacture year forward one year. The second line of the table, then, presents results for an eligibility criterion that accepts units manufactured in 1993 and before. With the inclusion of each year the percentage of homes with eligible units increases while the cumulative per unit savings decreases. Since these are 2011 program year results, the last line of the table, “all units manufactured through 2000” also represents the 2011 outcome of a rolling, greater than ten year criterion.

Table 1– April Memo, Program Year 2011 savings across different manufacture year cut-offs

All Units mfg. through	April Memo Estimates		
	Percentage Homes with Eligible Units (Cumulative)	Average Per-Unit kWh Savings	
		by Year	Cumulative -- from Pre-1993 to...
Pre-1993	7%	725	725
1993	9%	513	670
1994	11%	488	631
1995	13%	439	595
1996	16%	355	554
1997	19%	462	539

1998	22%	442	524
1999	26%	343	496
2000	31%	345	475

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Updated Analysis

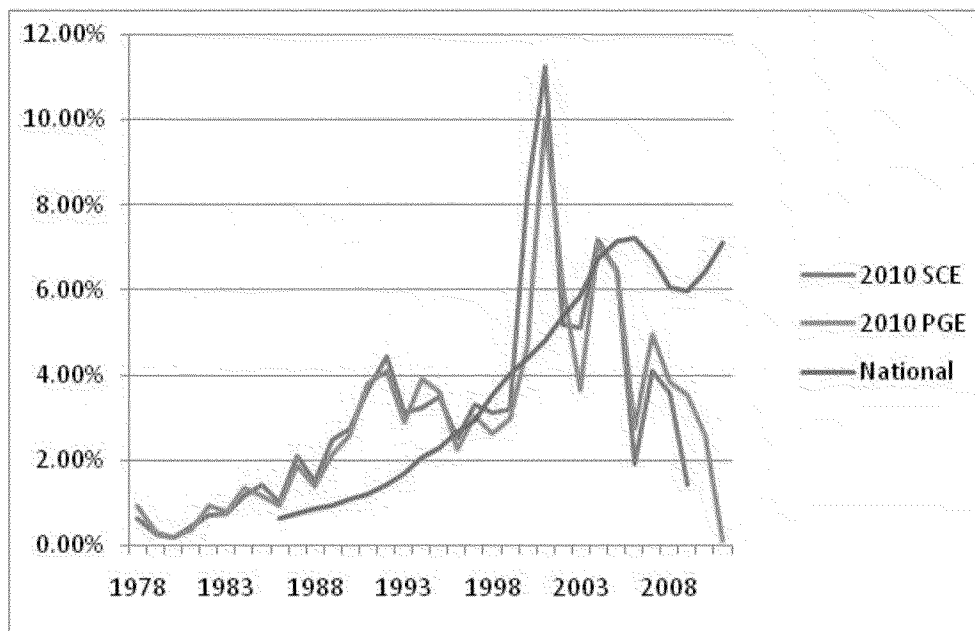
The next steps after the April Memo involved using actual program data to further this analysis with the explicit goal of identifying optimal eligibility criteria for the program. An important first step for the next steps was replacing unit distribution assumptions used for the April memo with actual data based on the program tracking data. Fortunately, the programs track unit information on units at all visited households, so identifying the full distribution of ESAP refrigerators is possible.

Since the April memo KEMA received tracking data from PG&E and SCE. KEMA matched tracking data model numbers to CEC data to look up manufacturer label information on unit characteristics. We succeeded in matching 83% of the units in the SCE data and 70% of the units in the PGE data¹. In particular, KEMA used these matches to determine manufacturer nameplate UEC levels for each refrigerator replaced or observed. SCE data was used for projections of eligible unit populations due to the existence of 3 consecutive years of data.

Figure 1 shows that the ESAP refrigerator year of manufacture distribution does not match the national trend used for the April memo. As expected, ESAP household units are older, with the central mass of the distribution shifted left to older units. The peaks that show up in the ESAP program distributions for SCE and PG&E appear to be an artifact of the CEC data which tracks first manufactured year rather than the year sold. There are peaks just before the 1993 and 2001 code changes indicating that perhaps a disproportionate number of models were put into production (for multiple year runs) just prior to the code change.

Figure 1 – Age Distribution
Prorated surviving national refrigerator population vs PY 2010 SCE and PGE populations

¹ KEMA analyzed the non-matching model numbers for evidence of bias in the matching process. We manually checked over 2000 of the non-matching model numbers using information on how manufacture year is embedded in model numbers. The manually checked units did not exhibit a different



Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

In addition to having the exact distribution of the age of ESAP units, the tracking data also reveals the kinds of units and the UEC. This removes the need for applying assumptions regarding the make-up of the distribution with respect to configuration. It also means that the mean UEC is based on the mix of specific models picked up by the program. The only remaining assumption that remains, then, is application of a one percent per year, non-compounding degradation. KEMA recognizes that there have been numerous attempts to quantify degradation with varying results. Adding a degradation factor recognized that unit do degrade over time even if the actual rate of degradation is unknown.

Table 1 provides the April memo and the updated results side by side. The percentage of homes with eligible units at each year of manufacture increases substantially with the use of the ESAP program distribution. The eligible percent using the fixed, pre-1993 year of manufacture increases from 7 to 19 percent. For units greater than 10 years old in 2011 (year of manufacture 2000) the percent eligible increases from 31 to 47 percent. At the same time, the average savings (UEC minus 400 kWh) is more than 150 kWh higher across the same range of possibilities except for the last year of manufacture in the table where the increase drops to 129 kWh. Most importantly, though, the general trends in the data remain consistent. As the year cut-off moves forward in time, the percentage of units that will be eligible increases by 24 and 28 percentage points, respectively. The savings estimates drop by 250 and 295 kWh, respectively.

Table 2 - April Memo and Update Program Year 2011 savings across different manufacture year cut-offs

All Units mfg. through	April Memo Estimates			Updated Estimates		
	Percentage Homes with Eligible Units (Cumulative)	Average Per-Unit kWh Savings		Percentage Homes with Eligible Units (Cumulative)	Average Per-Unit kWh Savings	
			Cumulative -- from Pre-1993			Cumulative -- from Pre-1993

		by Year				
Pre-1993	7%	725	725	19%	899	899
1993	9%	513	670	22%	421	841
1994	11%	488	631	24%	387	791
1995	13%	439	595	27%	437	752
1996	16%	355	554	30%	482	733
1997	19%	462	539	32%	408	703
1998	22%	442	524	35%	399	678
1999	26%	343	496	38%	398	658
2000	31%	345	475	47%	364	604

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Projecting Forward

The April Memo developed results for various year cut-offs for a single program year, 2010. The single year snapshot was enough to provide approximate relative eligible unit count and UEC levels for different criteria. Given the assumptions on which the analysis was based, it was not productive to attempt to project those results forward to see the result trends over time.

For this analysis we took advantage of the three yearly year-of-manufacture distributions from the SCE data to project the distribution forward. This allows us to projects trends over time for a single criterion. The following three tables present five year projects for the fixed, pre-1993 year of manufacture (status quo) and two age-based criteria, greater than 15 and 10 years.

Table 3 provides the projections for the status quo criterion. Average UEC will increase slightly from 2008 to 2015 due to unit degradation associated with age. The percentage of homes with eligible units will decline from 38 percent to 8 percent by 2015. So, while the update results increase the apparent percentage of eligible units under the status quo criterion, the projection to 2015 shows that the reprieve only lasts through 2015.

Table 3 – Status Quo: Pre 1993 Eligibility (SCE)

Program Year	Last Eligible Year of Manufacture	Average Per Unit UEC	Average Per Unit Savings	Percentage of Homes with Eligible Units
2008	1992	1,299	899	38.6%
2009	1992	1,294	894	32.5%
2010	1992	1,294	894	23.5%
2011	1992	1,299	899	19.1%
2012	1992	1,307	907	15.6%
2013	1992	1,316	916	12.6%
2014	1992	1,325	925	10.1%
2015	1992	1,335	935	8.1%

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Table 4 demonstrates how a greater-than-15-year criterion would function with advancing program years starting in 2008. In 2008, all units made before 1993 (2008 – 15yrs) would be eligible, providing an average UEC of 1,299 and savings of 899. The greater-than-15-year old criterion would also make 38.6 percent of units eligible .

Table 4 – 15 Year Old Unit Eligibility (SCE)

Program Year	Last Eligible Year of Manufacture	Average Per Unit UEC	Average Per Unit Savings	Percentage of Homes with Eligible Units
2008	1992	1,299	899	38.6%
2009	1993	1,240	840	36.4%
2010	1994	1,187	787	29.9%
2011	1995	1,152	752	27.5%
2012	1996	1,134	734	24.6%
2013	1997	1,105	705	22.6%
2014	1998	1,081	681	20.6%
2015	1999	1,061	661	18.6%

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Table 4 demonstrates the same scenario, but using greater-than-10 year old units instead of greater-than-15. Due to the inclusion of units manufactured after 2001, the decline in Average UEC is sharper. However, the percentage of eligible units available increases through 2015.

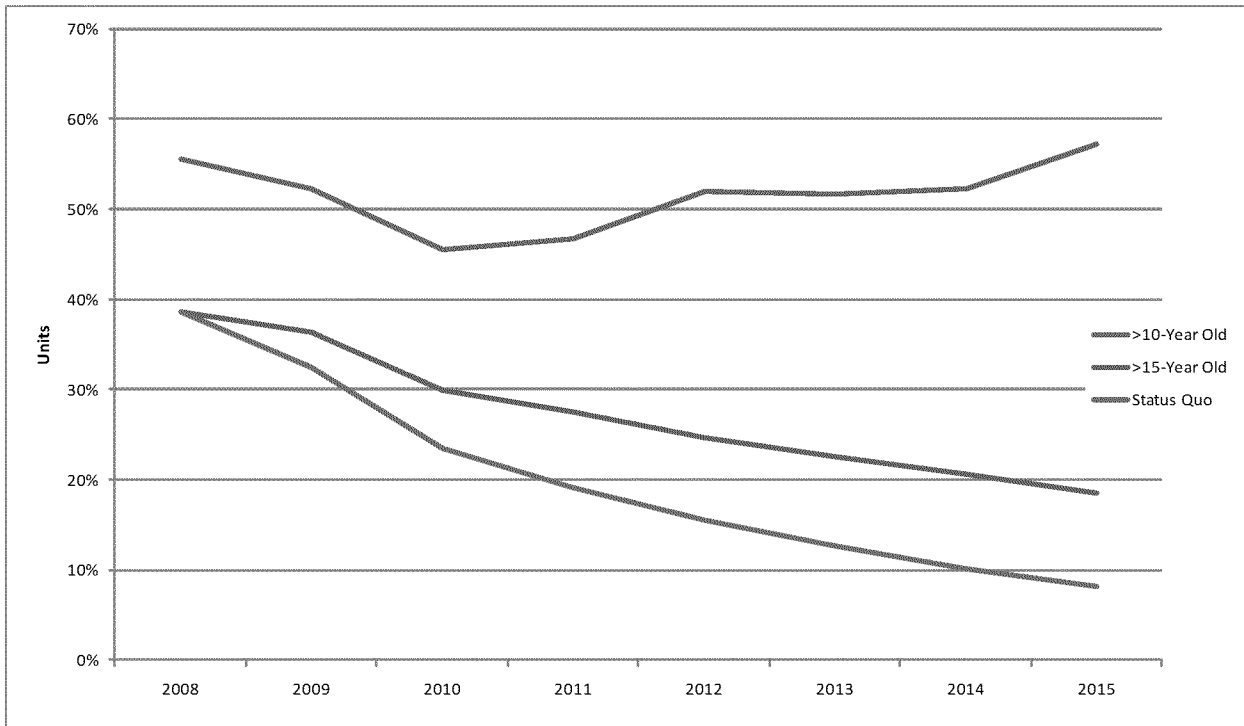
Table 5 – 10 Year Old Unit Eligibility (SCE)

Program Year	Last Year Eligible of Manufacture	Average Per Unit UEC	Average Per Unit Savings	Percentage of Homes with Eligible Units
2008	1997	1,143	743	55.6%
2009	1998	1,108	708	52.3%
2010	1999	1,059	659	45.5%
2011	2000	1,004	604	46.8%
2012	2001	907	507	51.9%
2013	2002	863	463	51.7%
2014	2003	817	417	52.2%
2015	2004	762	362	57.2%

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

For this analysis, we have taken the basic results of the April memo and projected forward. This allows not just comparisons across criteria for a single year, but a comparison of criteria trends. Figure 2 and Figure 3 provide a visual representation of the figures in the preceding three tables. Figure 2 shows that the percent of eligible units for the status quo criterion decreases dramatically over the analysis period. The percentage of eligible units for the greater-than-15 year criterion starts is the same as the status quo criterion in 2008 but decrease more slowly. The percentage of eligible units for the greater-than-10 year criterion starts at a higher percentage than the other two criteria and remain high throughout the period.

**Figure 2: Percent of Households with Eligible Units,
>10 Year, >15 Year and Status Quo Criteria**

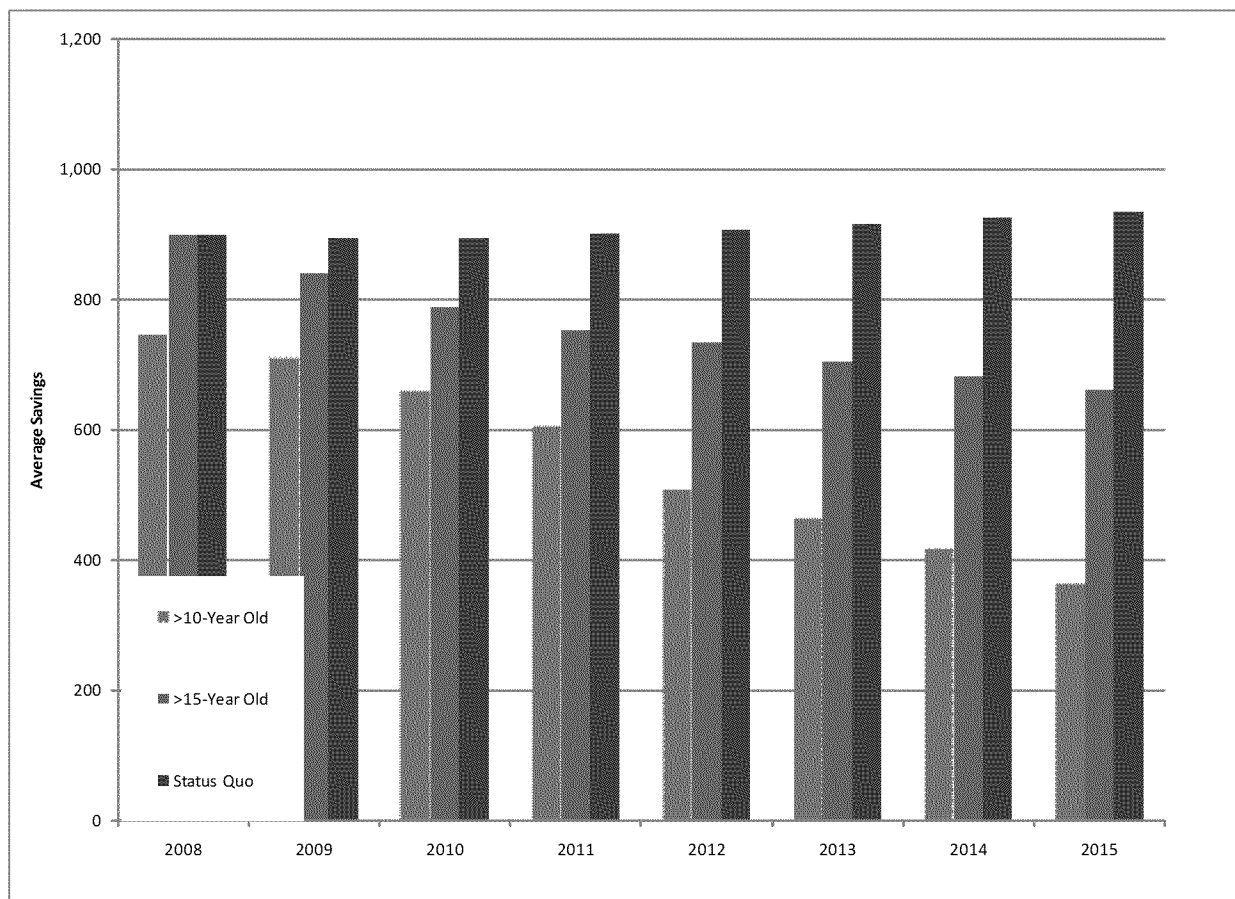


Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

The long-term trends of the age-based criteria are largely driven by the underlying distributions used for the projection. The three years of ESAP data from SCE showed a consistent trend toward a younger overall distribution of unit ages. For those three program years, for each move forward of a single year, the median age moved forward (younger) by almost two years. Clearly this trend could not continue in the long run or within a few years all units would all be less than a year old. For the projection, the median age of the distribution marches forward one year for each program year. This implies that, in the long run, any age-criterion would approach some equilibrium.

Figure 3 illustrates the expected trends in average UEC for the three criteria. The important take away from this figure is the increased gap between the age-based criteria and the status quo criterion moving into the future. A rolling, age-based criterion makes it possible to manage the percentage of eligible units in the population (Figure 2) but at the cost of average UEC. Because the cost of replacing a unit is fixed regardless of the savings generated, the best choice for the program among these options would be the criterion that maintains a sufficient flow of units at the highest level of potential savings.

**Figure 3: Criteria Average Savings,
>10 Year, >15 Year and Status Quo**



Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Additional Eligibility Criteria

The primary purpose of this memo was to explore new criteria for selecting units to replace. The updating of the April memo was primarily for the purpose of updating the year of manufacture and age-based criteria that have already been explored. These criteria provide the baseline eligibility criteria for the comparison of any new criteria that can be developed.

The range of criteria we had hoped to explore included those based on household characteristics as well as unit characteristics. The model number matching gives us superior data for comparing units based on new unit criteria. Unfortunately, the nameplate UEC do not capture the true degradation of units, whether strictly mechanical or as a result of heavy use by a large household, for instance. The degradation adjustment we have applied does mimic the simple trend that a unit from the same year of manufacture will probably use more energy on average as it gets older. It cannot capture the kind of uneven degradation that likely exists among used units. A complete set of true UECs would allow us to identify particular brands that fail sooner than others as well as the approximate effect of an addition household occupant on UEC. These kinds of explorations are just not feasible with the nameplate data.

Age based difficulties

One thing the nameplate data does appear to illustrate is the challenge properly implementing criteria based on age or year of manufacture. We looked at the year of manufacture of a unit as reported by the program compared to the year of manufacture determined by matching CEC data to model numbers². These comparisons indicate that 16% of units that were replaced were manufactured in 1993 or later, thereby not meeting the existing eligibility criterion³. This result highlights the importance of alternative criteria that do not rely so heavily on a difficult to determine parameter such as year of manufacture.

Potential New Criteria

KEMA matched California Energy Commission (CEC) historical model data to model numbers in utility-provided datasets. In addition to UEC, CEC data provides the following variables:

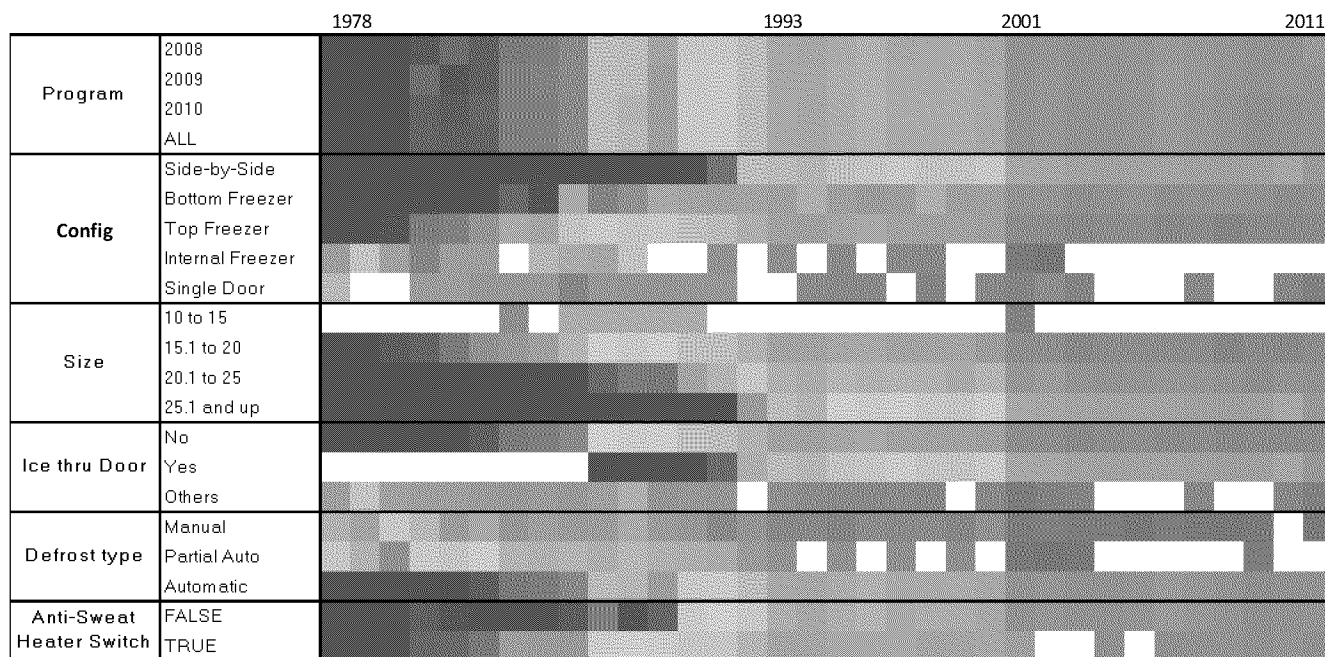
- Size
- Configuration
- Ice maker
- Defrost type
- Anti-Sweat heater Switch

After experiment with more complicated approaches, we found that visual plots of UEC by characteristics were actually more revealing of the underlying structure of the data. Figure 4 summarizes the result of the visual analysis of these variables. The left side of the table has six different sets of characteristics that put the population into group. The colored squares, from left to right, each represent a year of manufacture from 1978 to 2011. The color of the square is determined by the average UEC for that year and characteristic group. Below the table is a legend that illustrates the range of UECs.

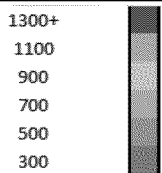
Figure 4 - Heat table of Average UEC: By manufacture year and characteristic

² KEMA used the most conservative assumptions. It is possible that a model can be manufactured across multiple years. For this comparison we assumed that a unit was as old as the CEC match would allow. For example: if a model was manufactured in years 1991-1995, it was assumed that the unit was built in 1991

³Only the SCE data clearly indicated which units were ultimately replaced.



Estimates use assumptions and should be used only to illustrate relative change across criteria and over time



The purpose of looking at the data in this way is to identify characteristics that are associated with higher usage units. The most obvious example, among the criteria displayed here, is the side-by-side configuration relative to other configurations. Even after 1993, the side-by-side configuration has a noticeably higher average UEC. Similarly, units with ice through the door have a higher average UEC. Finally, very large units also have a higher average UEC.

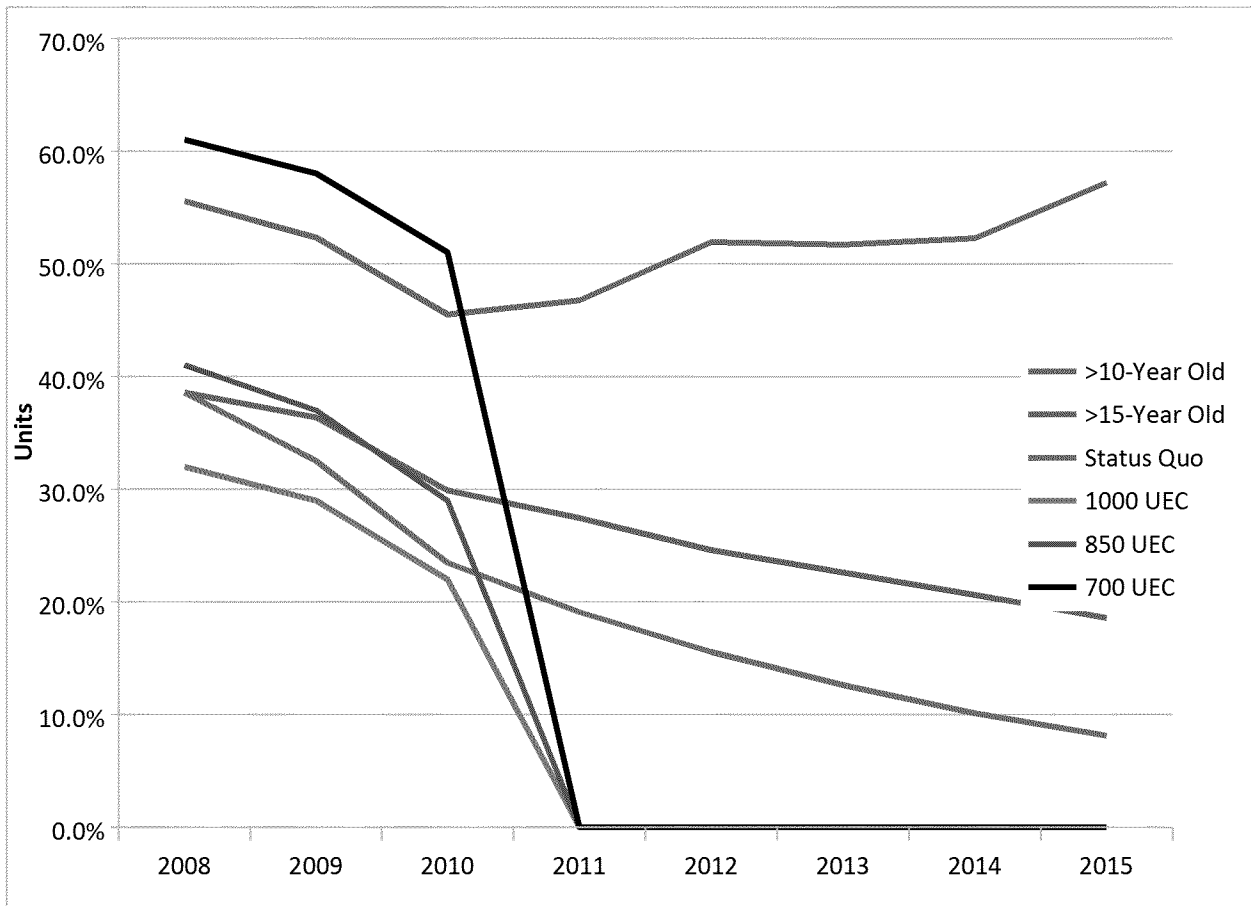
Figure 4 does provide evidence of other characteristics correlated with higher UEC. More importantly, it also provides the ultimate evidence of the importance of the time trend in average UECs. Additional criteria may be able to help fine tune and age-based approach, but the trends make it clear that over time, the bulk of the unit distribution will be pulled from years that are green.

Nameplate UEC Threshold Criteria

Nameplate UEC offers an alternative eligibility criterion in itself. Short of short term metering, there is no better indicator of a unit's *in situ* UEC than its nameplate UEC. While matching unit model numbers to a database to get nameplate data is logistically more complicated it does offer the desirable outcomes of verifiable year of manufacture as well as the added control of unit flow that comes with the nameplate data for both unit age and UEC.

Figure 5 repeats Figure 2 but with three different levels of Nameplate UEC criteria included. These three levels illustrate that the percent of eligibility depends on where the UEC nameplate criteria is established. Furthermore, they offer control over the most important aspect of the eligible units, the average UEC or savings.

**Figure 5-
 Percent of Households with Eligible Units, Nameplate UEC Criteria Included**



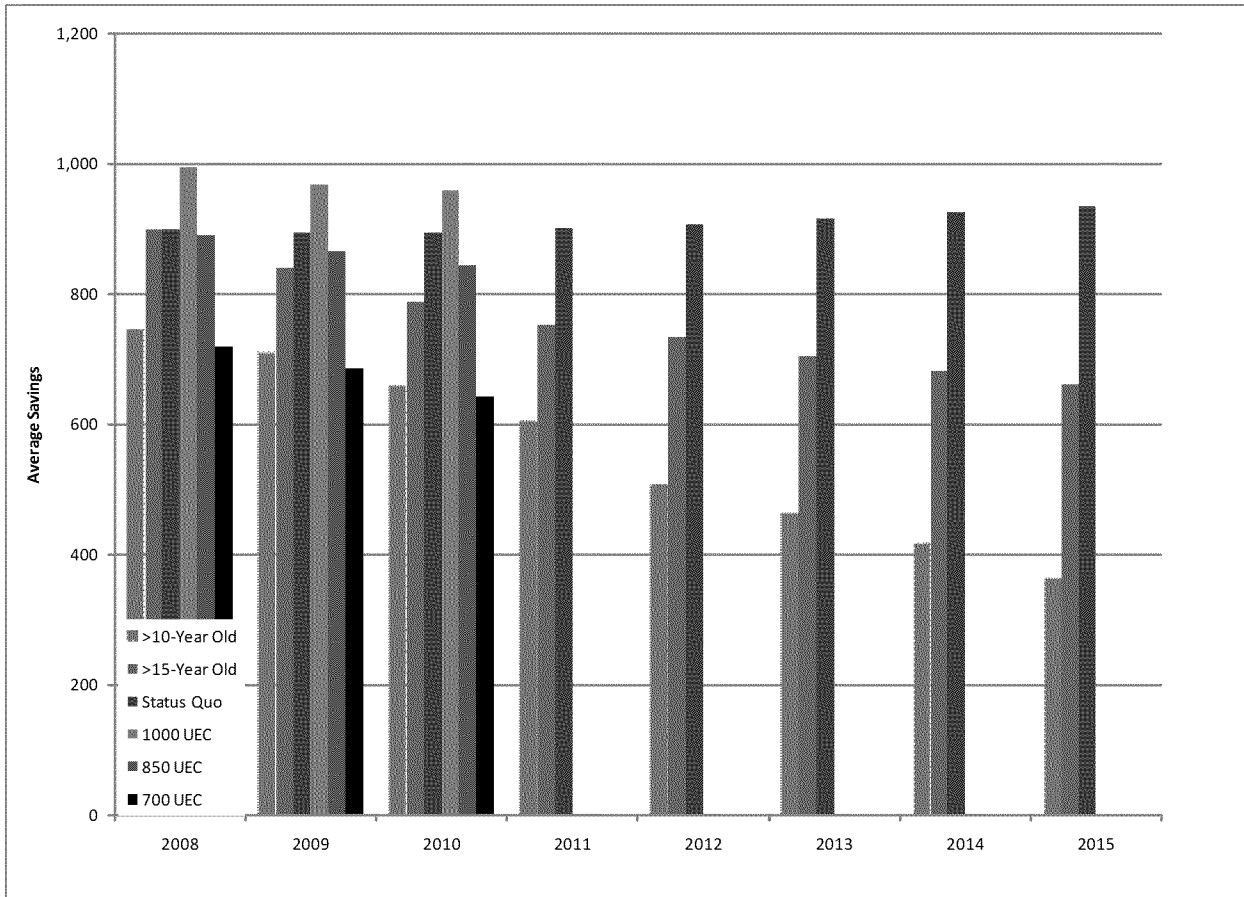
Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Setting the UEC level directly effects how many units are available. Each line represents the percent of homes that meet a given set of criteria. In 2008 for example, the chance of encountering a unit with 1000 UEC was just over 30%. In the same year, the chance of encountering a unit that met the existing criteria was just under 40% and encountering a unit that consumed 700 UEC or more was over 60%. The patterns for units consuming 1000 and 850 UEC are similar to the patterns for units encountered under the status quo and greater-than 15 year old criteria. As units with consumption at these levels are no longer produced, it can be expected that encountering them will become increasingly rare.

In Figure 6, we can see the effect on UEC or savings of the same parameters. As observed previously, the savings for the status quo remains constant. Savings for units over 10 and 15 years old drop, especially for 10 year old units; this pattern is also observed in units with savings of 700 or more. As this lower threshold will catch more efficient units, it can be expected to drop until reaching savings of 300. If similarity with 10 year old units holds, this can be expected within 4 years.

Units with higher level UECs, however, show a different pattern. Units with more than 850 UEC have average savings of approximately 900 in 2008, nearly identical to units greater-than 15 years old. However, the rate of UEC decline for units with more than 850 UEC units is less than half that of the age-based criteria. This decline is even slower for units with more than 1000 UEC.

**Figure 6 - Criteria Average Savings,
 Nameplate UEC Criteria Included**



Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Conclusions

As stated at the outset, the purpose of this memo and analysis is to illustrate the effects of guideline changes. This memo uses improved, program specific data to update the results from a memo produced in April, 2011 (LIEE - Effect of Expanding Program Year Eligibility_04_18_11.docx). This memo then projects results for multiple criteria forward through 2015, with primary results illustrating the relative change from criterion to criterion and over time of

- The percent of ESAP population with eligible units, and
- The average expected savings for that group of units.

The estimates of percent eligible and average savings both increased with this update. The estimated percent eligible for the status quo, pre-1993 eligibility criterion increases from 7 to 19 percent for the program year 2011. Projecting forward, though, the estimated percent eligible drops back to 8 percent by 2015.

Similarly, both the percent eligible and average savings of the greater-than-10 year criterion increased with the update. This increase in savings disappears by year 2013 in the new projections. The projections indicate an average per unit savings of only 362 kWh by 2015, with an ongoing downward trend.

This memo explores the range of possibilities for alternative criteria to improve on the year-of-manufacture or age-based criteria. Our conclusion here is twofold. On the one hand, without extensive unit metering data, it is impossible to identify the true consumption trends by unit or household characteristics. This is because the nameplate UEC data cannot reflect the *in situ* consumption of units. On the other hand, nameplate UEC does offer a reasonable alternative criterion in its own right. Developing an updatable portable app or lookup list of accepted model numbers to match model numbers may represent a challenge, but such a tool would provide value by verifying the specific year of manufacture. Furthermore, such a look up tool would allow for the targeting of units with higher “as new” UECs. This is the best and most direct estimator of *in situ* consumption available. Such a tool will give the program greater flexibility with regards to percentage of eligible units and average per unit savings.

Appendix A

In addition, KEMA also has examined additional requested criteria using projections developed from SCE data. The following tables include estimated values for pre-1999 (Table 6) and pre-2001 (pre-2001) criteria. These estimates were generating using the same data and methods as those in the updated memo. Tables 6 and 7 can be compared to those in the memo. Figure 7 is comparable to Figures 2 and 5. Figure 8 is comparable to Figures 3 and 6.

Table 6 – Pre-1999 Unit Eligibility (SCE)

Program Year	Last Eligible Year of Manufacture	Average UEC	Savings	% of Observed Units
2008	1998	1,123	723	58.7%
2009	1998	1,108	708	52.3%
2010	1998	1,079	679	42.3%
2011	1998	1,078	678	35.4%
2012	1998	1,077	677	29.9%
2013	1998	1,078	678	25.0%
2014	1998	1,081	681	20.6%
2015	1998	1,085	685	16.9%

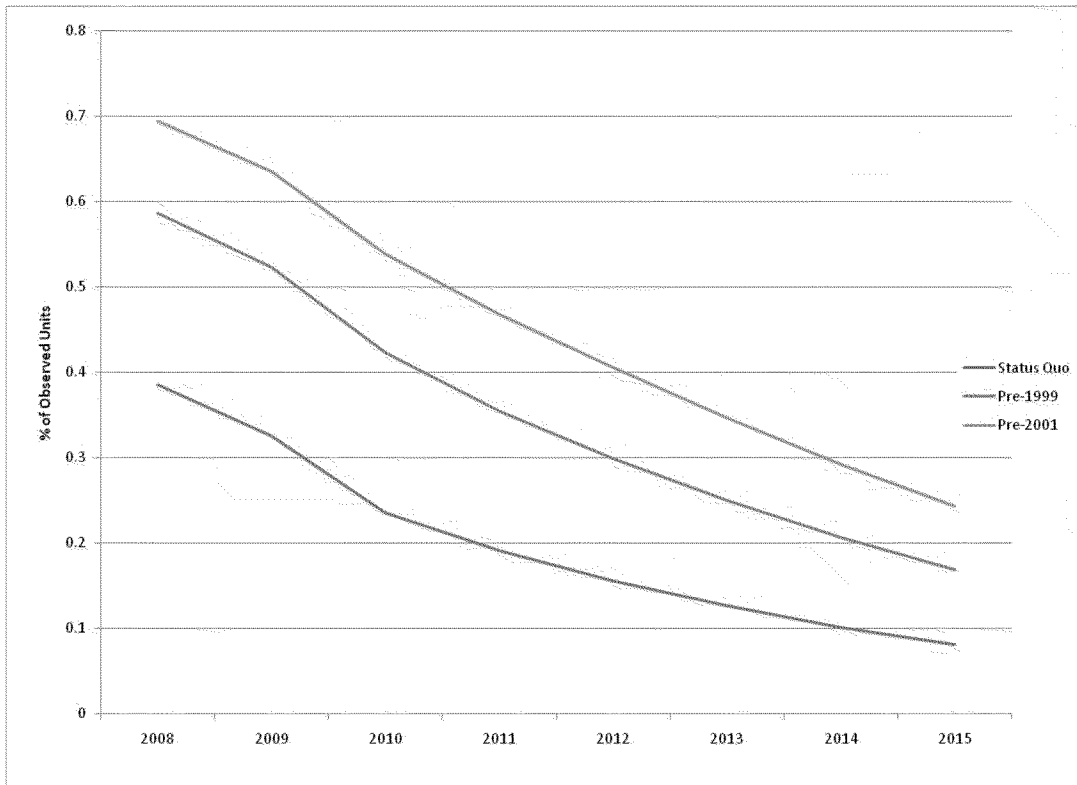
Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Table 7 – Pre-2001 Unit Eligibility (SCE)

Program Year	Last Eligible Year of Manufacture	Average UEC	Savings	% of Observed Units
2008	2000	1,062	662	69.5%
2009	2000	1,045	645	63.6%
2010	2000	1,012	612	53.8%
2011	2000	1,004	604	46.8%
2012	2000	999	599	40.5%
2013	2000	997	597	34.6%
2014	2000	997	597	29.2%
2015	2000	998	598	24.3%

Estimates use assumptions and should be used only to illustrate relative change across criteria and over time

Figure 7- Percent of Households with Eligible Units



**Figure 8 - Criteria Average Savings,
 Nameplate UEC Criteria Included**

