The Avocados, The Golds —The Replaceables?

Can you spot an inefficient refrigerator by its color or its age? Tests reveal which rules a program administrator can depend on.

by James Cavallo and James Mapp

Many states are currently introducing electric baseload components into their low-income weatherization programs. Often replacing refrigerators rises to the top of a reducing baseload to-do list. But which refrigerators should be replaced? Answering that question is a tough challenge for a program designer who has to balance minimizing the probability of replacing efficient refrigerators against creating a decision mechanism that will fit into a weatherization team's routine.

Monitoring refrigerators for an extended period of time is the most accurate method of estimating annual electricity usage. But this method generally places too great a demand on the resources that are available to weatherization program administrators. Recognizing this limitation, the national weatherization program requires only that monitoring must be done for at least 10% of the units replaced. In tandem with this level of monitoring, administrators are looking for a few good rules to guide replacement decisions.

Wisconsin has chosen to jump into the measurement-versus-rule fray by stipulating that all units manufactured before 1990 are eligible for replacement. Like most good rules, the Wisconsin rule is easy to communicate to program staff, requires no calculations in the field, and can be implemented without adding more than a few minutes to the time that staff spends with clients. The rule is often believed to have a high likelihood of choosing units with a savings-investment ratio greater than 1.

Developing a Few Good Rules

Despite the confidence that the Wisconsin Division of Energy has in this rule, it is supporting an analysis of this and three other simple rules that could be implemented. The four rules that the Division has selected for testing are as follows:

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Rule 1: Replace units with an energy rating above a predetermined annual kWh that will yield a savings-investment ratio of 1 or greater.

Rule 2: Replace units manufactured before a particular year.

Rule 3: Replace units with old-fashioned colors.

Rule 4: Replace units that have the nameplate attached in an old-fashioned location.

Managers of baseload programs have discussed using one or more of these rules at different times, but the rules have never been tested empirically, as far as we know. For our experiment, Rule 1 was defined so as to choose refrigerators with an energy rating above 849 kWh. The value 849 was chosen using the *Home Energy* Web calculator (see http://homeenergy.org/hewebsite/consumerinfo/refrigeration2/rsearch.htm). It assumes a replacement refrigerator cost of $400 and a local electric rate of 8 ¢/kWh. Rule 2 was specified as it is for the Wisconsin program: Replace units manufactured before 1990. Rule 3 specified the colors targeted for replacement as brown, gold, and green. Rule 4 was based on the observation that older refrigerators have the nameplate near the base of the front frame, while current models have the nameplate inside the food compartment.

These rules were tested on 31 refrigerators, all of which had a capacity of 10 ft^3 or greater. Nineteen were monitored at a recycling center operated by CSG Services, Incorporated, with the assistance of the center's manager, Barbara Doubek. These refrigerators were randomly chosen as they were unloaded at the recycling center. Twelve were monitored in the kitchens of the Racine/Kenosha weatherization clients with the assistance of Craig Baumstark and Tim Huck of the Racine/Kenosha Community Action Agency. The twelve that were chosen were the first to be visited by the weatherization crew when a wattmeter became available.

We used a statistical analysis to test for the similarity of the two samples. If they were indistinguishable, it would suggest that weatherization agencies could fulfill the 10% monitoring requirement at recycling centers, without taking staff time away from other duties during a site visit. Monitoring at a recycling center also makes it possible to monitor a given refrigerator for an extended period of time—even for the two days

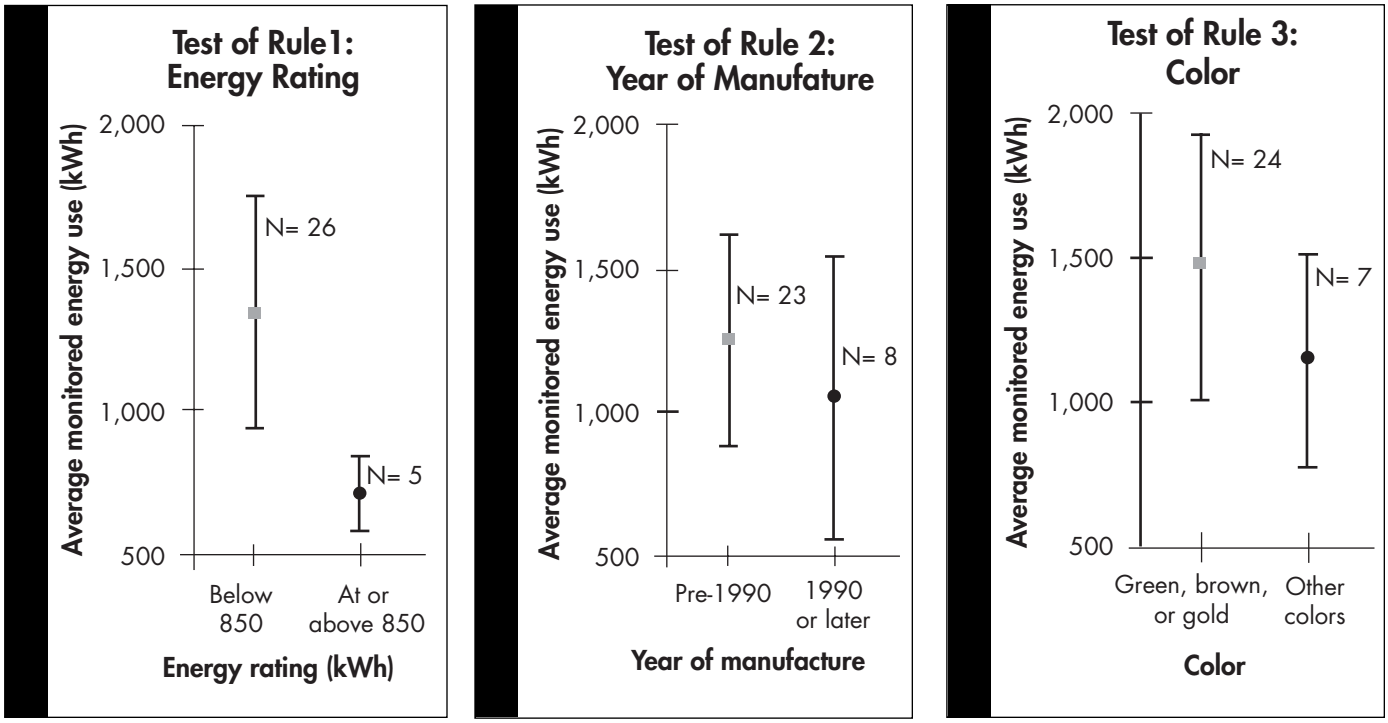

Figure 1 *(left)* shows that a model's energy rating can be a useful guide in deciding which refrigerators to replace. **Figures 2 and 3** *(middle and right)* reveal that neither the year of manufacture nor the color of a unit clearly succeeds in identifying replacement candidates.

needed to ensure that the monitoring period would include a defrost cycle. The results of our analysis did show that there were no significant differences in energy consumption or energy ratings for the refrigerators in these two locations, and that the two samples could be considered to be from a single population. Since ambient temperature can strongly affect energy use, we tested for its effect in these two populations, but our sample size was not large enough to separate out any significant ambient temperature impact for either location.

The data we collected on the 31 refrigerators included one week's worth of monitored energy usage; model and serial numbers; color of the unit; location of the nameplate; temperature differential across the food compartment wall; general condition of the unit; and the settings of the unit, such as the energy saver switch and temperature setting.

Weighing Obedience

Rule 1—replacing refrigerators with an energy rating above 849 kWh—would have selected 26 of the 31 units for replacement, leaving 5 units in the kitchens of the clients (see Figure 1). The average monitored consumption of the units that would have been selected was 1,326 kWh/yr, with a standard deviation of 366. The average consumption for those that would not have been selected was 719 kWh/yr, with a standard deviation of 125. A test of the difference between these two averages was significant, indicating that the rule discriminates between two distinct underlying populations. This rule would have incorrectly chosen two units for replacement that had monitored energy consumption levels below 850 and would not have selected one unit that had a monitored rate above the 849 kWh/yr cutoff level. Even with these misidentifications, we feel that this rule is a useful tool for identifying replacement candidates without conducting extensive monitoring.

Rule 2—replacing units manufactured before 1990—would have selected 23 of the 31 units for replacement (see Figure 2). The refrigerators that would have been replaced had an average monitored consumption of 1,258 kWh/yr, with a standard deviation of 376. The average for the units that would not have been replaced was 1,064 kWh/yr, with a standard deviation of 487. The difference between these two averages is not significant at the 95% confidence level. This is due to the large standard deviations for each. It is interesting to note that 3 of the 23 units that would have been selected for replacement had energy consumption levels below 850 kWh/yr, and 5 of the 8 units that would not have been replaced had energy consumption levels at or above 850. Based on this sample, we must conclude that this rule leaves room for improvement.

Rule 3—replacing units with old-fashioned colors—would have replaced 7 units and would have left 24 refrigerators in place (see Figure 3). The average measured consumption for the 7 units with old-fashioned colors was 1,433 kWh/yr, with a standard deviation of 416. The average for the 24 units that would not have been replaced was 1,168 kWh/yr, with a standard deviation of 392. Again, these averages are not significantly different. Rule 3 was successful in selecting only refrigerators with energy consumption levels measured at or above 850 kWh/yr. However, this rule would have left 17 units in place that had measured consumption levels above the cutoff.

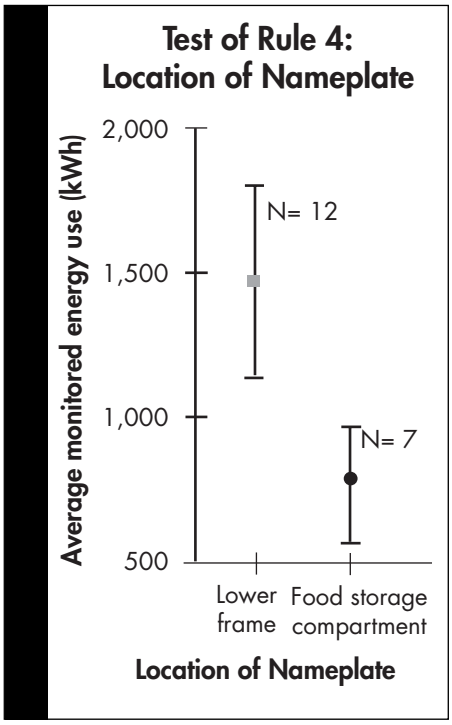


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Figure 4 *(left)* shows that the location of the nameplate can discriminate between inefficient and efficient units. However, this rule should be tested on a larger population. *(top left and right)* Many of the refrigerators that were manufactured before 1980 had their nameplates attached to the lower frames of the units. *(bottom right)* Most current refrigerator models have the nameplate on the inside of the food compartment like this one.

Rule 4—replacing units with the nameplate outside the food compartment—was tested only on the 19 units monitored at the Cudahy recycling center, because the Racine/Kenosha weatherization staff had not collected information on the location of the nameplates. Of those 19 units, 12 had nameplates at the base of the front frame (see Figure 4).

The average monitored consumption of the units with nameplates on the lower frame was 1,459 kWh/yr, with a standard deviation of 305. The average for the units with nameplates in the food compartment was 780 kWh/yr, with a standard deviation of 193. This difference was statistically significant. Rule 4 was successful in selecting for replacement only units that had monitored usage levels at or above 850 kWh/yr. The rule incorrectly excluded from replacement 3 units that had monitored usage at or above that cutoff level. However, we feel that this rule should be tested on a larger population before any agencies implement it.

Cold and Squishy Rules

The four rules presented above are by no means the only rules that could be used in refrigerator replacement programs. One additional rule that was not tested with these data relates to the type of insulation built into a model. Early refrigerator models used fiberglass insulation, which was subject to failure. Moisture from the ambient air would leak onto the freezer compartment and then condense on it and freeze. The ice would form a thermal bridge that degraded the insulating value of the fiberglass. When removed and stored, these units can drip water for days as the ice melts and drains onto the floor.

There are two easy methods of identifying fiberglass-insulated units. Since these units tend to lack insulation around the wiring and tubing that pass into the freezer compartment, one method is to feel for a cold spot on the top exterior surface. The other method relies on understanding that fiberglass has little lateral structural strength. Open the door of the unit, put one hand on the outside and one hand on the inside of the refrigerator wall, and press them together. If the wall flexes, the unit is probably insulated with fiberglass.

The introduction of rigid foam insulation increased the rigidity of the refrigerator wall. Applying this second test to a foam-insulated unit would yield a stiff wall with little give. Foam insulation first began to appear in the mid-1980s, about the same time as the nameplate first moved from the lower frame into the food compartment. Only after about 1992 did rigid foam insulation become fully integrated into the door construction. Fully integrating rigid foam insulation into refrigerator construction resulted in a more efficient unit, so it would be reasonable to test the following rule:

Rule 5: Remove all units with flexible walls containing fiberglass insulation.

Another rule worth testing could be constructed around knowing when certain manufacturers or brands entered or left the market. For example, the Sears Kenmore models were marketed under the Coldspot label until about 1978. Any refrigerator with a Coldspot label has to be more than 20 years old and might be a good candidate for removal and recycling.

In order to test this rule, the semiannual guides published by the Association of Home Appliance Manufacturers could be used to create a listing of which brands appeared or disappeared in which years. Models that have not appeared since the mid-1980s or earlier

include Coldspot, Coronado, J. C. Penney, O'Keefe & Merrit, and Wizard. Signature refrigerators ceased production in 1982 but reappeared in the early 1990s. Removal of the old-fashioned brands could eliminate less efficient units. Thus it would be reasonable to test the following rule:

Rule 6: Remove all models of brands that ceased production by the mid-1980s.

The two additional rules defined here create easy-to-implement, dichotomous choices. Though they have not been tested with the dataset developed so far within the Wisconsin project, these rules could be tested with the statistical methods given above. Of the rules tested by us, clearly the energy rating rule gave the best results. Although the year of manufacture and the color rules proved not to be useful, that might not have been true if we had been able to test them with a larger sample size.

The updated regulations for monitoring 10% of the refrigerators within the weatherization electric baseload program could provide a good dataset for testing and refining such simple, useful rules or even more complicated combinations of rules. Through simple experiments, program administrators not only can identify good rules, but also can adapt rules as programs or the stock of refrigerators change.

In a sense, the methods we describe here offer a way for program administrators to become Bayesian—and reshape their programs, as needed, based on new information acquired through experimentation. To start with, an administrator does not need to know all that there is to know about refrigerators. Instead, he or she can create a rule that seems reasonable, try it, collect data, and test the rule for its efficacy.

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For more information:

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