Refrigerator Replacements for the Weatherization Program

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ABSTRACT

Replacing old, inefficient refrigerators is becoming increasingly cost effective, particularly in low-income households, where most families still own refrigerators manufactured before 1990. In response to several successful refrigerator-replacement pilots over the years, the U.S. Department of Energy (DOE) recently allowed refrigerator replacement under the Weatherization Assistance Program as a new arrow in its conservation-measures quiver.

Local weatherization operators face two key issues as they gear up for refrigerator replacement. Not all refrigerators found in the field consume enough energy to merit being replaced. What should the threshold be, and how can energy consumption by existing refrigerators be reasonably estimated? Second, is it possible to secure co-funding from local electric utilities? (The answer to this second question is frequently "yes.")

This paper discusses a simple tool planners can use to determine energy use thresholds. Energy use can be estimated by referring to consumption data generated via the DOE refrigerator-testing protocol, which is cataloged in databases for retrieval by personal computers or personal data assistants (PDA). The alternative, field-testing using a watt-hour meter, is practiced by most agencies. Virtues and shortcomings of each approach are discussed, and best practices are recommended.

The paper also discusses several practical ways to combine funding from utilities and DOE that not only satisfy both funding sources, but also serve more weatherization clients. For example, a large utility that co-funds the refrigerator replacement work of Indiana's weatherization program links funding to the amount of expected savings, which are so substantial and virtually constant that cost effectiveness from the utility's viewpoint is ensured.

Introduction

Replacing old, inefficient refrigerators with efficient new ones is becoming increasingly cost effective as electric rates increase and new models perform even better than is called for by the stringent energy-efficiency standards of July 2001 (NAECA 2001). The trend favoring cost-effective replacement is especially prevalent in the low-income community, where most families still own refrigerators manufactured before the first energy-efficiency standards for refrigerators were implemented in 1990 (Flack 2000a). Savings from refrigerator replacements of well over 1,000 kWh/year are routine, particularly when at least a modicum of care is taken in selecting which refrigerators to replace (Kinney, Lewis & Clute 1998).

The Weatherization Assistance Program sponsored by the U.S. Department of Energy (DOE) has been in operation for more than 25 years, and more than 900 local agencies deliver energy conservation services through the program. However, refrigerator replacements became an allowable measure for DOE-sponsored weatherization programs only early in 2001 (DOE 2000a, 2000b). Before that, pilot refrigerator-replacement work was accomplished by only a handful of weatherization operators, usually with utility involvement. Pilot weatherization programs in New York State, for example, have achieved overall savings of from 49 to 70 percent from replacing refrigerators, with corresponding savings-to-investment ratios of 1.81 to 2.6 (Kinney, Lewis & Clute 1998). These successes were important factors in DOE's decision to include refrigerator replacement as a new arrow in its conservation-measures quiver.

Opportunities exist for very substantial savings and short paybacks, but savings follows waste. Not all refrigerators found in the field consume enough energy to merit being replaced. Accordingly, in planning new refrigerator programs, what should the consumption threshold be, and how can energy consumption by existing refrigerators be estimated in a reasonable amount of time?

Toward addressing this key question, this paper discusses a simple lookup tool planners can use to determine thresholds ensuring that all units replaced will have a savings-to-investment ratio of 1 or greater[1]. Whenever possible, consumption can be estimated by age-adjusting consumption data for new models of the refrigerator that have been tested via the DOE refrigerator-testing protocol. This information is cataloged in databases for retrieval via hard copy, PC, or personal data assistant (PDA). The alternative, field-testing using a watt-hour meter over some period, is practiced by most agencies at least some of the time. Virtues and shortcomings of each approach are discussed, and best practices are recommended.

The paper also discusses several practical ways to combine funding from utilities and DOE that not only satisfy both funding sources but also serve more weatherization clients. For example, a large utility that co-funds the refrigerator replacement work of Indiana's weatherization program gears funding to the amount of expected savings—from $100 to more than $500 per unit replaced. This ensures cost effectiveness of all refrigerators replaced from the utility's point of view. In practice, this enables weatherization agencies to set thresholds at less than 800 kWh/yr when replacing 15- and 18-cubic-foot refrigerators. The utility also pays for two-hour in-field tests: $20 if the unit is not replaced, $50 if it is.

Pioneering Efforts

In June 1995, the New York State Weatherization Assistance Program requested a waiver from DOE headquarters to conduct pilot refrigerator replacement projects. Principal points made in the request for waiver were as follows:

- The cost of electricity on a Btu/dollars basis is 5 to 10 times the cost of natural gas or fuel oil, the most commonly used fuels for space heating.

[1] Savings-to-investment ratio, also know as a benefit-cost ratio, is the economic figure of merit used by DOE's Weatherization Assistance Program to determine the cost effectiveness of energy conservation measures. The savings-to-investment ratio equals the retail fuel cost savings over the life of a measure, discounted to present value, divided by the cost of the measure (materials, labor, and on-site supervisory personnel). The remaining lifetime of the existing equipment to be replaced has no impact on the savings-to-investment ratio. Weatherization measures are required by DOE to have a savings-to-investment ratio of 1.0 or greater.

- Many tenants whose space and hot-water heating costs are included in their rent must nonetheless pay directly for their electricity costs. Refrigerators, which operate throughout the year, are frequently the largest single consumer of electricity in an apartment.
- Many people, especially lower-income people, have old refrigerators that are quite wasteful of electricity.
- Energy-efficient refrigerators are becoming widely available at attractive costs, particularly if they are bought in bulk.
- Weatherization technicians routinely perform energy audits that could readily be modified to accommodate refrigerator inspection and (when necessary) measurement of energy consumption.
- Good electronic devices for measuring the energy performance of refrigerators are becoming available.
- There is a high probability that refrigerator replacements will yield very favorable ratios of benefits to costs (Kinney, Lewis & Clute 1998).

The DOE approved the waiver request on the condition that co-funding be secured from landlords or utilities and that cost-benefit analyses be conducted. Shortly thereafter, the local Weatherization program in Geneseo, New York, teamed up with the Rochester Gas & Electric Corp. (RG&E) to replace refrigerators in an 80-unit apartment complex. The agency measured consumption on a sample of refrigerators and determined that 54 refrigerators could be replaced cost effectively. A 14-ft^3 model manufactured by Whirlpool was installed, and the savings achieved averaged 69 percent (946 kWh/year) for a very favorable savings-to-investment ratio (SIR) of 2.60.

In New York City, a number of local weatherization agencies are involved in refrigerator replacements in which an approximately equal mix of weatherization money, landlord donations, and funds from Consolidated Edison (Con Ed) are combined to change out refrigerators in buildings with mostly low-income occupants. The result of evaluations of the first 636 of these replacements showed annual savings of 48 percent (455 kWh) with an SIR of 1.81(Kinney, Lewis & Clute 1998). The more favorable SIR achieved by the RG&E project (2.6 as opposed to 1.81) reflects the fact that only units with relatively high consumption were replaced under the RG&E project.

Adding the refrigerator replacement arrow to the weatherization program's quiver of conservation measures should benefit all parties. "Now that we have the regulations in place to allow for refrigerator replacements," observes Gail McKinley, national director of the Weatherization Program, "we're looking forward to providing an even broader range of cost-effective energy savings measures for the people served by our program (McKinley 2001)."

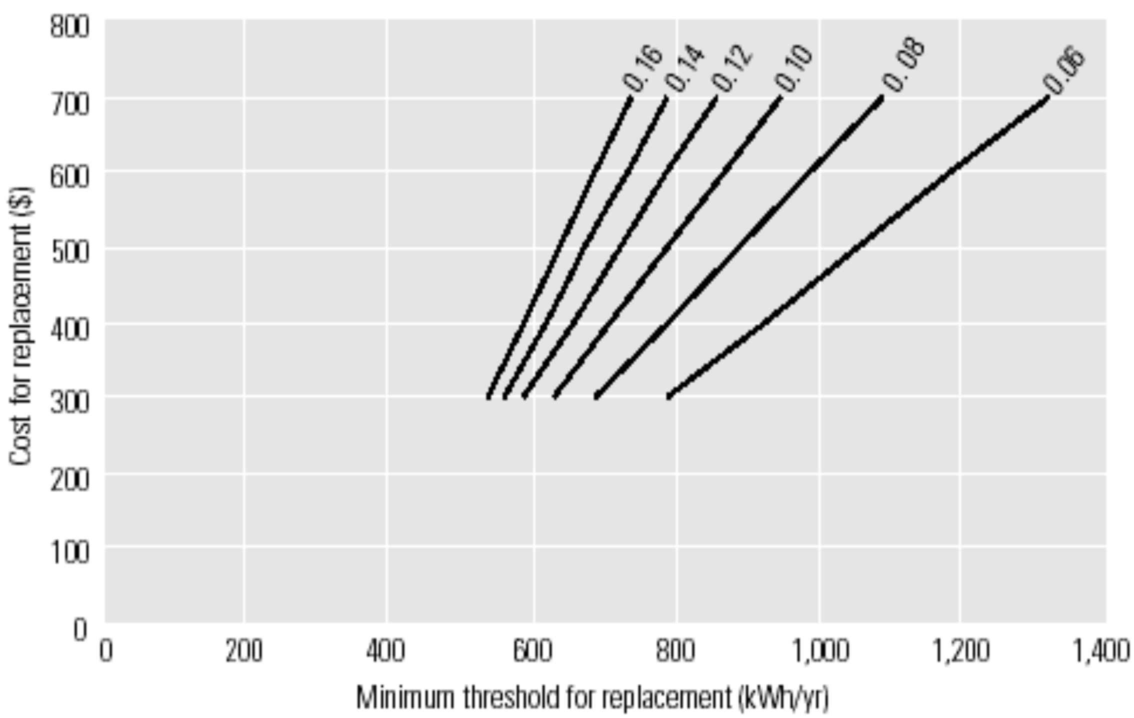
Savings Follow Waste

The more an old refrigerator consumes, the more cost effective it is to replace it with a new one. Accordingly, two key questions need to be addressed in planning and conducting a refrigerator replacement program. First, what is the least amount of energy an old unit should consume to merit being exchanged? Second, what is the most practical way to determine if a given unit consumes energy at rates above the threshold for replacement?

A useful way to plan a refrigerator program is to express the threshold for changing a refrigerator in terms of savings-to-investment ratios (SIRs). SIR is the ratio of the savings expected from a conservation measure over its lifetime (discounted to the present time) to the installed cost of the measure. Hence, an SIR greater than 1 is deemed cost effective. For example, an agency might elect to change out only those old refrigerators that have SIRs of 1 or more. Such a decision will guarantee a cost-effective program, because, if all the refrigerator replacements have SIRs of 1 or above, the average will be substantially greater than 1. Figure 1 shows a family of curves (each representing a different $/kWh electricity price) for defining the threshold where SIRs become 1.0 when the replacement unit will have an annual consumption of 386 kWh/year (like the new 15-ft^3 Maytag unit). Weatherization providers can develop similar curves based on the models of new refrigerators they plan to install in their program. Resources like the ENERGY STAR website (http://www.energystar.gov/products/QualifyingAppliances.xls) can help programs select appropriate new refrigerators for their program.

Figure 1. Energy and Replacement Costs to Achieve A Unity SIR

Points on the electricity cost curves corresponding with given replacement costs on the vertical axis are associated with points on the horizontal axis representing the minimum annual energy that an old refrigerator must consume to achieve an SIR of 1. The curves are set up so that a planner may start out knowing local electric energy cost and the total cost (including administrative) for replacing and recycling old units and may derive a value of annual kWh consumption for an SIR of 1. Alternately, one may start out with a minimum annual energy use of a refrigerator and determine the maximum cost of replacement that will yield an SIR of 1. Assumptions: Replacement unit has an annual consumption of 386 kWh/yr and a lifetime of 20 years. The discount rate is 4.8 percent.



Which Refrigerators Waste Energy?

Unfortunately, old refrigerators do not have annual consumption figures written on them. Nonetheless, knowing how much they consume is clearly critical in managing a refrigerator replacement program (to enable rational decisions on replacement) and quantifying savings (to evaluate program effectiveness and undertake mid-course corrections if appropriate). For replacements decisions, there appears to be a broad middle-ground approach that lies between monitoring no appliances and monitoring all of them.

The process to estimate consumption begins with some empirical observations about several classes of refrigerators. Not all old refrigerators waste substantial energy, but most do. Those that are less wasteful tend to be relatively new—manufactured to 1993 or later federal efficiency standards, for example—or do not include automatic defrost. Many in the latter group are quite old, and some 12-ft^3 models have run at a consumption rate of 500 kWh/year or even lower for half a century (although their power factors are typically around 0.50) (Kinney, Lewis & Clute 1998).

On the other hand, many old units become wasteful over time due to frequent movement or wear and tear. Cracks in the inner lining and tears in old fiberglass insulation soon result in air leakage, condensation, ice formation in the insulation, and rapidly declining performance. Finally, one in approximately 50 old refrigerators develops a slow leak in refrigerant. The result may be manifested by soft ice cream, warm soda, and virtually continuous compressor runs—all undesirable consequences. Some—not all—relatively new units manufactured between 1985 and 1990 have quite poor energy performance. Old hands report (and both DOE and field tests verify) that side-by-side models colored bronze, gold, or avocado routinely use 1,800 kWh/year or even more.

Given these observations, Dennis Flack, who runs a number of refrigerator replacement programs for the Conservation Services Group (CSG), has honed CSG's approach to choosing the right units to replace. "Five or six years ago, we relied more on measurement than we do now," Flack reports. "For most customers, we use a combination of observation, wisdom from the past, and some easy-to-use software we developed using data from AHAM [Association of Home Appliance Manufacturers] and field measurements (Flack 2000a)." The observation part requires some training but is not very complicated. If a refrigerator is functional, new, or only a few years old (and thereby meets 1993 standards), they do not replace it unless it is not working well. If it is an old manual defrost model on its last legs, they replace it. In all other cases, they try hard to find a nameplate and model number to see if they can get a fit with their database that is based in large part on AHAM data.

AHAM publishes energy data for all certified refrigerators, refrigerator-freezers, and freezers. Of particular interest to the refrigerator replacement programs is AHAM's *Refrigerator & Freezer Historical Data Set*, which contains energy data for models manufactured from 1973 to 2002 (AHAM 2002). This database contains information on brand name, model number, year of manufacture, size, and estimated annual energy use based on DOE testing for thousands of residential refrigerators. DOE ratings are based on measurements on new refrigerators. Sometimes field measurements of old units indicate that they have maintained their energy performance pretty well, but, on average, the energy use of older refrigerators increases by 20 to 30 percent over the years. Accordingly, many refrigerator replacement analysis protocols apply a correction factor of 10 to 30 percent to the DOE rating to account for performance degradation due to age (Gettings 2001b).

Decision-Making Tools

There are several analysis tools that help determine when it is cost effective to replace an existing refrigerator with a particular new model. Several tools incorporate the AHAM database, or equivalent, to estimate the annual energy usage of the existing refrigerator. Other tools extrapolate the results of short-term metering to calculate annual energy use estimates. Some tools let the user choose between either energy estimating method.

A simple calculator developed by Alan Mitchell, available for free download at www.EnergyTools.com, extrapolates the results of short-term metering to estimate annual energy use and calculates the SIR of the proposed refrigerator replacement. The AHAM database is incorporated into the most recent version of the National Energy Audit Tool (NEAT 7.1.1), the DOE-sponsored weatherization measure selection tool, which also accounts for performance degradation due to age (Gettings 2001a). NEAT also allows the user to enter short-term monitoring results to which NEAT applies an 8-percent adjustment for defrost cycles as described below.

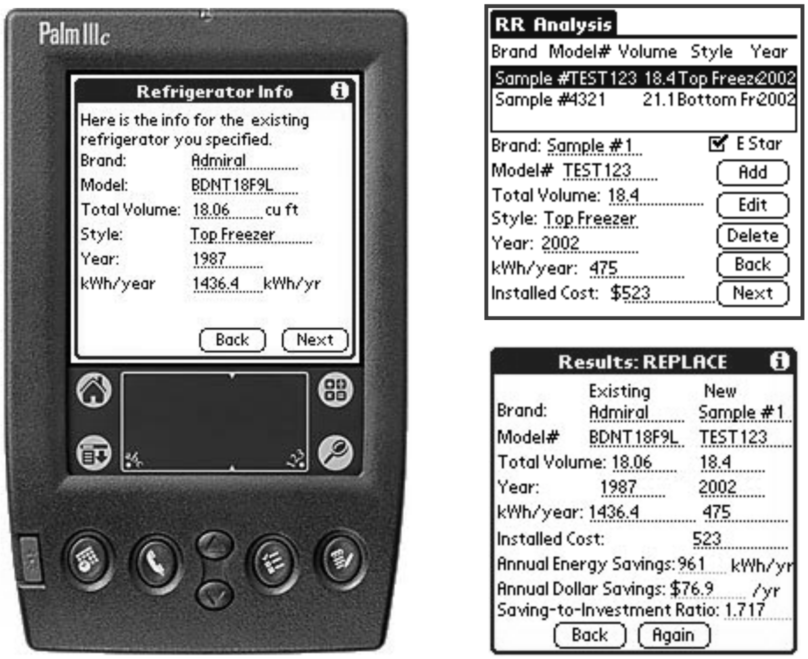
In addition to providing the AHAM energy data for existing refrigerators within NEAT, DOE planned to make the data available in other electronic and hard copy formats to facilitate its use in the field. Unfortunately, AHAM and DOE were unable to negotiate the release of AHAM's historical data set (outside NEAT) to the Weatherization network at a reasonable fee. However, DOE was able to secure similar energy data for over 41,000 refrigerators, refrigerator-freezers, and freezers from Directory of Certified Refrigerators, Freezers, and Refrigerator Freezers published by the California Energy Commission (CEC) from 1979 to 1992 (no directory for 1991 was available).

The CEC database has been incorporated into a recently developed electronic tool, dubbed *Replace?*, to help Weatherization providers determine the cost effectiveness of replacing existing refrigerators during the initial energy audit of income-eligible households. It uses the same calculation methods and assumptions programmed into NEAT and is available for the PC and personal data assistants (PDAs) that use Palm OS. Figure 2 shows the PDA version. Both versions may be downloaded from www.waptac-pic.org/baseload.htm at no charge.

To analyze a potential replacement, the annual energy use of the existing refrigerator is estimated by either locating the brand and model number in the CEC database contained in *Replace?*, entering metering results, or entering some other estimate of annual energy use. The annual energy use and installed cost of the new replacement refrigerator is entered by the user or selected from a list of previously entered units. The user can also edit the electricity price, service life, and discount rate used in the economic calculation. *Replace?* then calculates the savings-to-investment ratio and tells the user if the particular refrigerator replacement specified meets cost-effectiveness criteria for replacement.

Replace? for the PC contains the entire CEC refrigerator database. To keep the file size manageable, the PDA version of *Replace?* contains a subset of the CEC refrigerator database available on two Palm database (.pdb) files. One file contains only refrigerators and refrigerator-freezers (no chest or upright freezers) over 9 cubic feet in total volume. Since some replacement programs may also consider replacing stand-alone freezers, another file contains all models including freezers, but the volume threshold is increased to 10.5 cubic feet to keep the size of the two .pdb files comparable.

Figure 2. PDA-Based *Replace?* Refrigeration Replacement Analyzer



Replace? adjusts the energy use values in the database to account for performance degradation due to age. Alternately, a user may enter the results of refrigerator metering. If the kitchen is substantially warmer or colder during metering than best estimates of average annual temperature in the kitchen, *Replace?* adjusts the metered results to compensate for the temperature difference specified.

When and How to Meter

The preceding procedures represent a practical compromise between a "test 'em all "and a "change 'em all" strategy. Of course, circumstances arise in which there's no clear way to make a judgment on replacement without testing actual consumption. Some middle-aged units are found to be without manufacturers' labels; Dennis Flack estimates this is true for, at most, 2 percent of units (Flack 2000b). On another 20 percent, there is no DOE test data from the AHAM database, but roughly half of these have model numbers that are quite close to those for which there is DOE test data (Flack 2000b). If a number of units are found in an apartment complex, for example, for which no DOE test data is available, testing is clearly appropriate. Furthermore, most program operators find it useful to test a sample of units to verify their decision-making strategy and to evaluate savings. In all such cases, field-testing of actual performance using at least a watt-hour meter is desirable.

It is tricky to get an accurate estimate of a refrigerator's energy use over 8,766 hours (one year) by testing for only an hour or so. Defrost cycles during a short test can completely distort results, and kitchen temperatures during the test that are substantially different from annual ambient temperatures can also produce errors. On the basis of a number of field and chamber tests conducted by Synertech Systems Corp. with 11-channel dataloggers (Kinney

2000; Kinney et al. 1997; Kinney, Lewis & Clute 1998) the authors make the following observations:

- How measured data is to be used is an important consideration in planning a field test. Gathering data to make a simple, binary "replace/don't replace" decision generally requires less accuracy than gathering sample data for evaluating program savings.
- One-hour tests usually generate insufficient data to draw useful inferences, as they are within 10 percent of an accurate estimate only 18 times out of 100. Three-hour tests are within 10 percent of an accurate estimate 90 times out of 100.
- Given the percentages above, the longer a refrigerator test, the better. The "natural period" of a frost-free refrigerator is from the beginning of a defrost period to the beginning of the next defrost period, which can range from 16 to 40 hours, depending on use, control settings, and ambient temperature and humidity. (Some new models have many "mini" defrost cycles, which make it easier to estimate annual performance with shorter-term data.)
- Food loading affects test results. When very short-term tests are conducted (under four hours), doors should be kept shut. If the occupant has recently loaded the refrigerator with warm food or drinks, the compressor will run substantially more than usual for several hours. In this case, testing should be delayed or extended.
- If a defrost cycle occurs during short-term testing, the test should be extended (preferably to 24 hours) or abandoned. If it does not occur, a correction factor of 8 percent should be added when normalizing data to account for the effects of the energy used to defrost plus the extra compressor energy necessary to remove the heat. Simply multiply the measured estimate of annual refrigerator energy use by 1.08. To date, one supplier of small watt-hour meters suitable for field testing, Brand Electronics, has modified its product specifically for Weatherization agencies to signal the occurrence of a defrost run during the testing period. In response to requests from local agencies, Brand Electronics plans to modify this meter, Model 4-1850WX, even further by applying the 1.08 defrost factor to the internal calculations that extrapolate the metering results to an estimate of annual energy use (EnergyTools.com 2002; Knoll 2002).
- Alternatively, on many older refrigerators, it may be possible to reliably ensure that the defrost heater will not come on during metering by advancing the defrost timer past the defrost cycle (Knoll 2001; Emley 2000).
- If there is good reason to suspect that the ambient temperature during the test is substantially different from the average temperature over the year, a correction factor of 2.5 percent per degree F difference should be applied to the result. (If the temperature during the test is cooler than the annual average, the correction factor should increase the estimated annual consumption and vice versa.) For example, if a test is taken on a cool day when the kitchen temperature is 67°F, but the home has no air conditioner and is in a climate zone where summers are long and hot, the field auditor and the resident may conclude that the average kitchen temperature over the year is 72°F. Thus, the estimate of measured performance should be corrected by 72–67 =5°. At 2.5 percent per degree, the correction is 5 x 2.5 percent per degree =12.5 percent. Thus, the measured estimate of annual refrigerator usage should be multiplied by 1.125. In the case of a test taken during the summer when the kitchen

temperature is 80°, yet 71° is a good estimate of the client's annual kitchen temperature, the correction should be applied as follows: 80–71 = 9 degrees difference; 9 x 2.5 percent per degree = 22.5 percent. In this case, the measured estimate of annual refrigerator usage should be multiplied by 1–0.225 = 0.775.

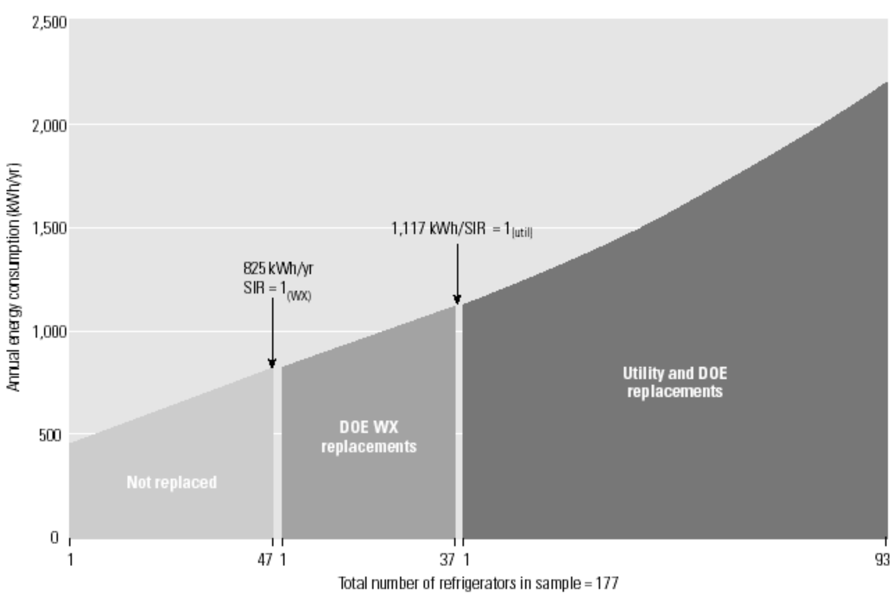
Teaming Up with Utility Programs

Teaming with utility programs can save weatherization programs costs and increase the number of people agencies can serve. However, in deciding on appropriate thresholds of annual consumption old refrigerators must meet in order to meet cost-effectiveness criteria, sometimes utility planners compute savings based on their avoided costs for electricity rather than the substantially higher retail rates paid by customers. Of course, this effectively raises the threshold for eligibility to the point where the number of units that can be cost effectively replaced using utility criteria may represent only a small percentage of refrigerators in the field. This means that fewer people can be served and the cost of providing services is increased because many more units must be inspected for each unit replaced.

There are several possible solutions to this problem. In some cases it may be possible to combine DOE weatherization funds with utility funds so that utility funds are used to replace the most wasteful units and DOE funds to replace other units that are cost effective from the point of view of retail electric rates. As illustrated in Figure 3, this can result in an overall efficient program in which field procedures are simplified, yet an effective use is made of all resources.

Figure 3. Replacement Disposition of a Sample of Old Refrigerators

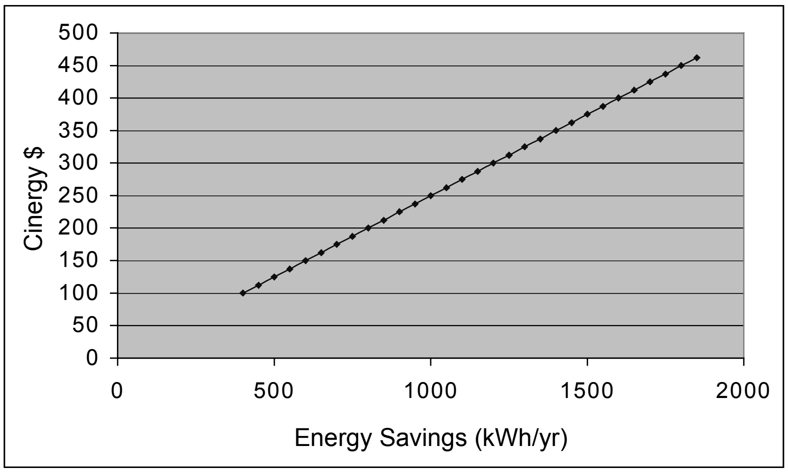
This example of a group of existing refrigerators is ordered according to the units' estimated annual energy use. Refrigerators in the low-energy-use category are sufficiently energy efficient that they should not be replaced, because SIRs would be less than 1 from any perspective. Units in the middle category are cost-effectively replaceable from the perspective of the retail electric rate payer. The highest-energy-using units are cost-effectively replaceable from all perspectives, including that of the utility.



Assumptions: Utility avoided cost is $0.06/kWh, Retail electricity cost is $0.10/kWh, New refrigerator consumes 386 kWh/yr, Cost of new refrigerator + recycling old unit + overhead = $550

Another option is to adopt an arrangement between a co-sponsoring utility and the weatherization agency in which the amount of the utility's payment varies with the likely savings resulting from replacing the old refrigerator with an energy efficient one. This is the way a pilot program in Indiana is presently being conducted with funding from the utility, Cinergy, and the DOE Weatherization Program. During a pilot project scheduled to become fully operational in the Fall of 2002, Cinergy is paying a portion of replacement costs on a sliding scale, beginning at $100 for an estimated savings of 400 kWh/yr, with increments of $50 for each additional 200 kWh of savings. Accordingly, as illustrated in Figure 4, if an old refrigerator consumes 1400 kWh/yr and is replaced by one that uses 400 kWh/yr, Cinergy will pay $250.

Figure 4. Cinergy's Co-Funding of Refrigerator Replacements in Indiana Pilot Project



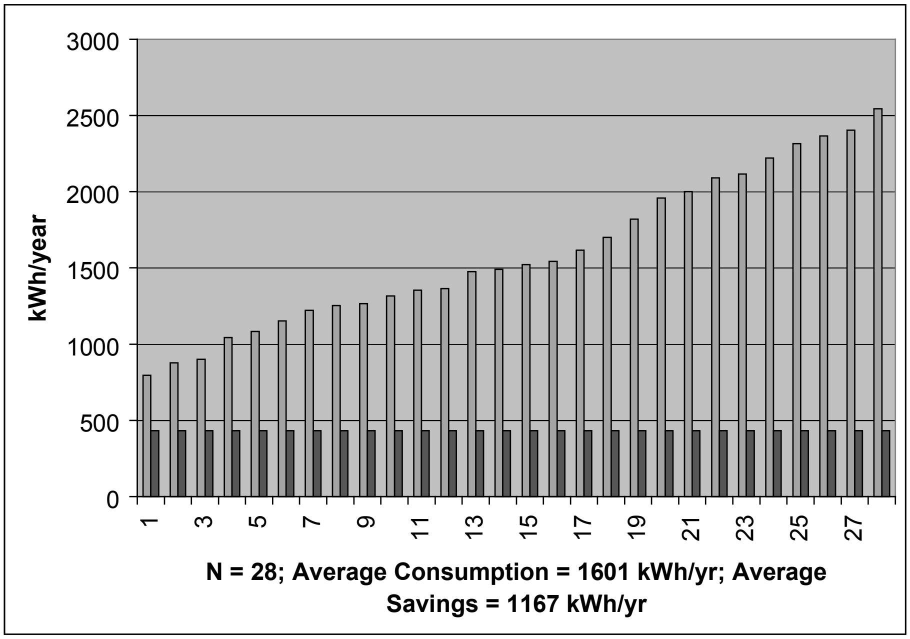
Since the world's largest refrigerator manufacturing plant is Whirlpool's in southern Indiana, the weatherization program does business directly with Whirlpool. The deal with Whirlpool includes the refrigerator itself, delivery to the kitchen, plus removal and the environmentally appropriate demanufacturing of the old unit. Costs and DOE-rated performance for the three sizes of units being replaced are summarized in Table 1.

Table 1. Key Elements of Indiana's Deal with Whirlpool

Model	*Size*	*KWh/yr*	*Cost*
ET5…	15 ft^3	372	$418
ET8…	18 ft^3	434	$503
GR2…	21 ft^3	472	$643

Early findings suggest that the distribution of old refrigerators is working to the advantage of all parties, but some of the lower consuming refrigerators are not yet being replaced (Figure 5). Since the DOE rating of the 18-ft^3 ET8 Whirlpool unit is 434 kWh/yr, co-funding payments from Cinergy are available when old units meter as little as 834 kWh/yr.

Figure 5. Energy Use of Existing Indiana Refrigerators and New 18-ft^3 Replacement Units Using 434 kWh/yr



Conclusion

Armed with an accurate watt-hour meter that signals defrost cycles and decision-making tools like NEAT and *Replace?*, it is possible to design a nimble refrigerator replacement program that performs well, wastes neither human resources nor money to conduct, and significantly reduces energy costs to low-income households. Weatherization programs with such well designed and effective refrigerator replacement components attract utility partners. This leverages the federal Weatherization investment, reduces the energy burden of more low-income households, and rids the grid (and the environment) of more hogs.

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