The Chilling Truth About Appliance Recycling Programs

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This paper reviews recent utility experience with appliance recycling programs. Key issues involved in assessing the energy and environmental impacts of these programs are discussed. Recent survey results are presented which indicate that energy savings from this program type are likely to be well below previous planning estimates. In view of these results, the potential environmental benefits of appliance recycling programs may play a key role for many utilities in assessing the overall benefits of these programs. The potential environmental benefits of different appliance recycling processes are discussed. The paper concludes by noting that the role of utility-sponsored appliance recycling programs may need to be reassessed based on a more comprehensive analysis of the combined energy, environmental and customer service benefits of these programs.

Introduction

Appliance recycling programs are designed to reduce residential energy consumption by offering customers a free convenient way to dispose of older inefficient appliances. In addition to reducing energy consumption, appliance recycling programs provide a valued service for customers. Environmental benefits may also result from ensuring that chlorofluorocarbons (CFCs) in refrigerators, stand alone freezers and room air conditioners are recycled or destroyed rather than released into the atmosphere. CFCs are a major cause of atmospheric ozone depletion as well as a significant contributor to total man-made emissions of greenhouse gases.

With the proliferation of utility-sponsored DSM programs over the last five years, at least twelve utilities have offered appliance recycling programs to residential customers. Refrigerators account for the majority of appliances recycled through these programs, although programs typically include freezers and, in some cases, air conditioners. Initial planning estimates used by many utilities to assess the cost effectiveness of appliance recycling programs typically project annual savings of at least 800 kWh per refrigerator or freezer for a period of up to seven years. However, as field experience with appliance recycling program increases, numerous utilities have begun to reassess and, in some cases, phase-out these programs. Recent developments that may lead utilities to reassess the cost-effectiveness of appliance recycling programs include:

- Survey data consistently indicate extremely high levels of free ridership in appliance recycling programs. In most surveys, only about one-quarter of participants have indicated that they would have kept appliances if recycling programs had not been offered by utilities.

- Although several utilities have sought to verify program savings through statistical billing analysis, results of these analyses also indicate reductions in annual consumption of less than 400 kWh per participant, or less than half of engineering estimates used by most utilities in program planning.

- Federal requirements taking effect in 1992 under the Clean Air Act Amendments of 1990 (CAAA) now require that liquid CFC-12 be recovered from all appliances collected by local governments and waste disposal companies. In practice, the process of recycling liquid refrigerant containing CFC-12 is combined with the recycling of the approximately 200 pounds of scrap metal in each refrigerator or freezer, even in facilities not associated with utility-sponsored programs. Consequently, few (if any) environmental benefits may be attributed to most existing utility-sponsored appliance recycling programs.

The remainder of this paper is organized as follows. First, key issues involved in assessing energy impacts that should be attributed to appliance recycling programs are discussed, along with results of several recent evaluations. Second, indirect benefits of appliance recycling programs as a customer service and as a means of diverting appliances from other channels of disposal are examined. Finally, the potential environmental benefits of utility-sponsored programs that go beyond current federal requirements by requiring the recycling or disposal of CFC-11 contained in solid foam insulation are examined.

Energy Impacts

Survey-Based Estimates of Energy Savings

The most controversial factor in developing survey-based estimates of energy impacts attributable to appliance recycling programs involves assessing what participants are likely to have done with appliances if utility-sponsored program were not offered. Participant surveys provide a means of directly estimating net savings that should be attributed to appliance recycling programs. However, substantial judgment is required in interpreting survey responses to hypothetical questions about what participants would have done if the program were not offered.

As shown in Table 1, most surveys indicate that only about one-fourth of participants would have kept appliances removed through recycling programs if these programs were not offered. Within the context of appliance recycling programs, however, survey data cannot be used to classify participants into neatly defined categories of *free riders* and *non-free riders.* Participants in appliance recycling programs may be classified in a variety of ways:

Appliance Removals versus Replacements. Appliance recycling programs were originally conceived as a means of prompting customers to eliminate the use of secondary appliances. In practice, utility-sponsored programs may cause customers to *eliminate* or *avoid* the use of an older secondary appliance entirely, or to *accelerate the replacement* of old appliances with new more efficient models. First-year savings from the *accelerated replacement* of older appliances can be based on the difference between the annual energy consumption of a typical appliance removed through the program compared to a typical new refrigerator or freezer (see Figure 1). Realistic estimates of first-year savings from *removal* of appliances need to take into account key factors such as the age and annual operating hours of secondary appliances removed through the program. For instance, survey data consistently indicate that many secondary appliances removed through programs would have been kept in storage unplugged or would have been used only part of the year.

Impact on Used Appliance Market. A large segment of program participants indicate that they would have sold or given away used appliances if utility-sponsored appliance recycling programs were not offered. On one hand, it may be argued that many of these appliances could have remained in use as secondary appliances, so that substantial energy savings should be attributed to these program participants. By the same token, however, it may be argued that many of the appliances removed by the participants have little or no value and would have ultimately been thrown away if utility-sponsored programs were not in effect. A third approach for quantifying program-related impacts for these participants is to assume that removal of these appliances from the used appliance market ultimately causes another customer to purchase a new appliance rather than acquiring a used refrigerator or freezer. Given this assumption, program-related savings

Table 1. What Participants Would Do With Refrigerators if Appliance Recycling Programs Were Not in Effect

	Survey Results				
	Utility A		Utility B	Utility C	Utility D
	Survey 1	Survey 2			
Keep	17%	18%	22%	29%	34%
Sell or Give Away	21%	28%	12%	13%	20%
Throw Away[a]	48%	38%	54%	43%	21%
Don't Know	14%	16%	12%	15%	25%

(a) Includes participants indicating they would have had refrigerators removed by appliance retailers or municipalities, hired someone to pick up refrigerators, or taken appliances to recycling centers themselves.

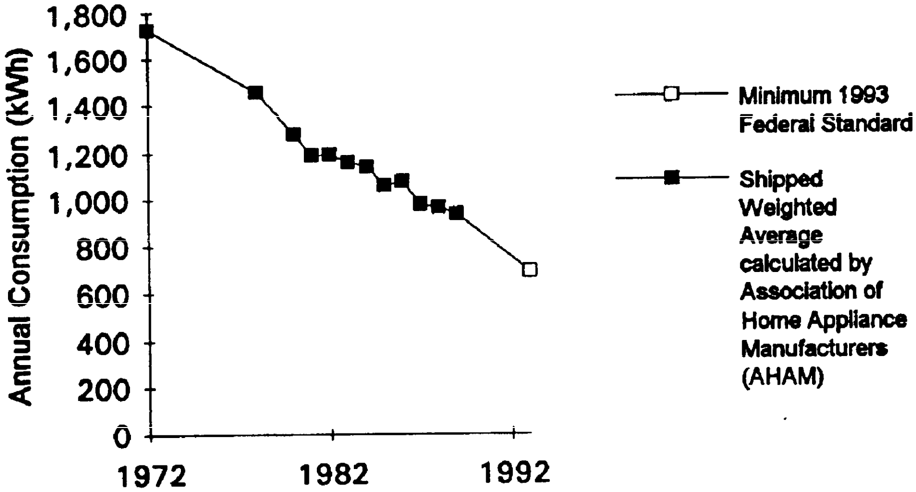

Figure 1. Average Annual Energy Consumption of Refrigerators by Vintage

for these participants can be estimated based on expected savings from *accelerated replacement* of older units with new appliances. As illustrated by this discussion, estimating program-related savings for this group of participants ultimately involves a substantial degree of speculation concerning the actual market for used appliances based on essentially no empirical data.

Free Ridership. Perhaps the most difficult issue in assessing the impacts of appliance recycling programs involves free ridership. As shown in Table 1, most recent surveys show that about two-thirds of program participants would have disposed of used appliances through other channels if utility-sponsored programs were not offered. Although it is commonly assumed that survey data using this type of hypothetical question tends to overestimate free ridership, there are few (if any) more empirical alternatives for estimating free ridership in appliance recycling programs. Even if survey-based estimates of free ridership are discounted as overestimating actual free ridership, the extremely high proportion of participants indicating they would have disposed of appliances through other channels provides compelling indications of very high free ridership in utility-sponsored recycling programs.

Other Participants. In recent surveys, as many as 12 to 40 percent of program participants indicated that they did not know what they would have done with appliances if utilities had not offered recycling programs, as shown in Table 1. Survey-based estimates of net program saving are highly sensitive to assumptions about these program participants. In the absence of additional information, it may be assumed that a portion of these participants would have ultimately kept appliances in use, while others would have disposed of appliances through other channels or merely kept these appliances in storage. One approach used in several recent evaluations is to not include these survey responses in calculating net program savings. In effect, this approach assumes that actions specified by other survey respondents provides the most accurate indicator of what these participants would have ultimately done with appliances. In other evaluations, it has been assumed that these participants would have kept these units in operation as secondary units if utility programs were not in effect. Thus, estimating program-related savings for this group of participants also involves a substantial degree of speculation concerning participants indicating they "don't know" what they would have done with appliances removed through utility-sponsored programs.

Depending on how survey responses are interpreted, survey-based estimates of net program savings may vary by well over ±50 percent. Given the difficulty of verifying program-related savings through billing analysis discussed below, interpretation of survey data may determine whether or not programs are deemed cost-effective, and may have a significant impact on any revenue recovery and financial incentives riding on evaluation results.

Statistical Billing Analysis

To date, only a few utilities have reported results of statistical billing analysis of appliance recycling programs.[1] Results of these analyses indicate annual savings ranging from 279 to about 400 kWh per refrigerator. The limited level of savings detected through billing analysis may be attributed to a number of factors which make it difficult to apply standard techniques of pre-/post statistical billing analysis in the context of appliance recycling programs.

Recent survey results indicate that the majority of participants in appliance recycling programs have replaced an older appliance with a new model. As depicted in Figure 2, substantial energy savings are likely to be detected in the bills of these participants in comparison to a random sample of nonparticipant households. For many participants, however, survey data indicate that this decrease in energy consumption should *not* be attributed to appliance recycling programs, but is actually attributable the natural increase in energy efficiency that results as older appliance stock is replaced with new more efficient models. At the same time, pre-ipost billing analysis does not accurately capture the savings attributable to participants who purchase a new appliance, and then decide to turn in their old unit instead of using it as a secondary appliance due to the effect of appliance recycling programs (see Figure 2). The only cases in which pre-/post billing analysis is apt to accurately capture the effect of appliance recycling programs are when programs prompt customers to remove a secondary appliance previously in use, or when programs prompt customers to accelerate the replacement of old appliances with newer models, as depicted in Figure 2.

In theory, net savings estimates which account for free ridership may be derived through the use of an appropriate nonparticipant comparison group and/or techniques of discrete choice modeling. In practice, use of standard techniques of statistical billing analysis to quantify net savings attributable to recycling programs is complicated by the difficulty of identifying nonparticipant groups that may be used to control for free ridership. Participants in appliance recycling programs clearly

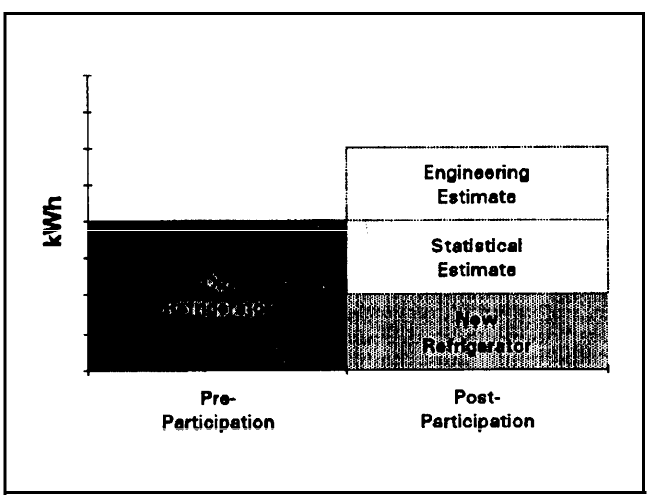

Figure 2. Changes in Participant Energy Consumption

belong to a distinct market segment, composed largely of households which have recently purchased new appliances or which have secondary appliances perceived to be near the end of their service life. Although the eligible market for appliance recycling programs is not easily defined, random nonparticipant samples do not provide appropriate comparison groups for estimating program-related savings. Ultimately, net savings estimates are likely to be highly sensitive to the manner in which the comparison group is defined and the discrete choice modeling approach employed. To date, no evaluation has employed the type of discrete choice *appliance holdings* model described by Ozog and Waldman (1992), which could provide an appropriate means for separating the effects of utility-sponsored programs from other important factors affecting the decision of customers to keep, replace or dispose of older appliances.

Persistence of Savings

Regardless of the precision that may be achieved in measuring short-term program impacts through surveys or billing analysis, total energy benefits from appliance recycling programs are likely to be equally or more dependent on the *persistence* of first-year savings. Currently, cost-effectiveness screening of many appliance recycling programs assumes that savings from each appliance removed will persist for seven years.[2] Unlike most DSM programs, however, the persistence of savings from appliance recycling programs cannot be accurately estimated based on the average service life of residential appliances. For instance, while the average age of refrigerators removed through many recycling programs is approximately 20 years, the average service life of refrigerators is estimated at 15 to 19 years. Instead, the persistence or measure life of savings from appliance recycling programs must be based on the length of time appliances would have continued being used if not removed through utility-sponsored programs.

In one recent evaluation, more empirical estimates of the persistence of savings from removal of older appliances still in working condition were developed by applying principles of conditional probability widely used in actuarial studies and engineering reliability analyses, This approach involves three key steps:

- First, detailed household-level data on the actual service lifetimes of refrigerators were obtained from previous studies by the USDA (1972).

- A statistical probability distribution was then derived from historical data on refrigerator service lifetimes. As shown in Figure 3, a lognormal probability distribution was found to closely fit USDA data on actual refrigerator service lives, particularly for older units exceeding the average expected service life of refrigerators.

- The resulting probability distribution was then used to develop a life *table* showing how first-year savings can be expected to persist each year after program participation, taking into account the age of working appliances removed through the program.

As shown in Figure 3, empirical data on refrigerator service lifetimes indicates that a 20-year-old unit still in working condition can be expected to last *up to* another 15 years. Each additional year, however, the probability that the unit will continue to be kept in service decreases. By combining principles of conditional probability with empirical data on refrigerator service lifetimes, *persistence curves can* be developed representing how first-year savings from removal of an older working refrigerator can be expected to persist each year after program participation (see shaded portion of Figure 4).

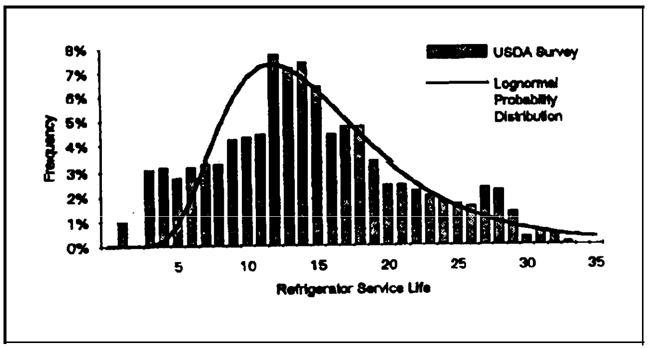

Figure 3. Distribution of Refrigerator Service Lives

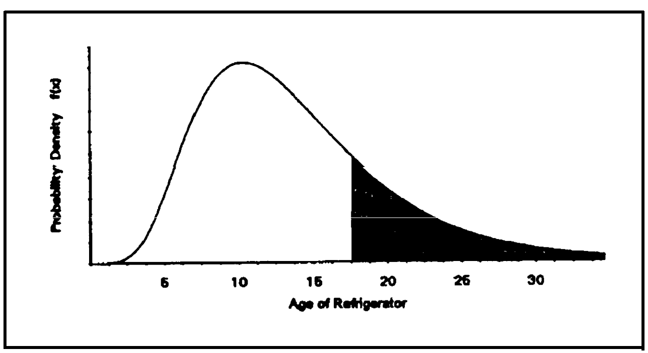

Figure 4. Expected Remaining Life of 18-year-old Refrigerator

For the sake of comparison with standard measure lifetimes used to evaluate DSM program savings, persistence curves representing expected program savings can be converted to *equivalent years* by discounting and levelizing the future stream of expected savings on a net present value basis. When applied to USDA data on appliance service lifetimes shown in Figure 3, this approach indicates that the savings from a typical (20-year-old) appliance removed through a utility-sponsored program can be expected to persist for the levelized net present value equivalent of approximately four years. In contrast, many utilities currently assume that savings from removal of appliances persist for a five to seven year measure life.

Indirect Program Benefits

Without utility-sponsored recycling programs, the responsibility for providing channels of disposal for residential appliances falls primarily on local governments and waste disposal companies. Amendments to the Clean Air Act taking effect in 1992 now require that CFCs used as refrigerants in all residential appliances be recovered. The cost of disposing of appliances in compliance with new federal regulations provides a means of quantizing additional indirect economic benefits of appliance recycling programs to participants and local governments.

In some cases, participants purchasing new appliances may have appliance retailers remove used appliances free-of-charge. For other program participants, however, the avoidance of fees typically charged by local municipalities or private companies for the disposal of residential appliances represent additional indirect economic benefits of program participation. In most areas, new federal requirements have led local governments and contractors responsible for municipal waste disposal to charge a $10 to $20 fee for disposal of used appliances. For customers disposing of appliances through private contractors, recent survey data indicate that average fees range from $25 to $50 for removal of old appliances.

In addition, it must be recognized that appliance recycling programs offer a valued customer service that is not directly comparable to most alternative channels of appliance disposal. At a minimum, many customers disposing of appliances through other channels would be required to move appliances themselves or enlist the help of a friend, relative or neighbor. Although the economic value of this service may be difficult to quantify, results of customer satisfaction surveys indicate that most program participants are extremely satisfied with the service provided by utility-sponsored appliance recycling programs.

From the perspective of local governments and utilities, additional indirect benefits of utility-sponsored appliance recycling programs may result if fees charged do not cover the full cost of removing and disposing old appliances. According to local government officials surveyed in the Midwest, actual disposal costs to municipalities are at least $35 per appliance, compared to fees charged of only $10 to $20. Officials in one municipality reported that in order to reduce the cost of appliance disposal, residents calling to inquire about disposal of appliances are encouraged to first try to have appliances picked-up through a utility-sponsored appliance recycling program.

The "avoided cost" of appliance disposal for local governments and waste companies represent quantifiable indirect benefits which should be considered when the total resource cost (TRC) Test is applied to appliance recycling programs. Total program costs for appliance recycling programs typically range from $125 to $200 per appliance. Assuming that the actual economic cost of disposing of appliances through other channels is at least $35, these indirect economic benefits may offset 17 to 28 percent of total program costs. Assuming an additional *value of service* is provided to customers through appliance recycling programs, indirect program benefits may offset an even greater portion of total program costs. To date, these benefits have not been researched in detail and have not been explicitly included in cost-benefit analyses of appliance recycling programs.

Environmental Benefits

Background on CFCs

CFC emissions account for an estimated 10 percent of total greenhouse gas emissions from human activities (DOE 1990). In addition to contributing to potential global warming, CFCs deplete the stratospheric ozone, which serves as a filter for the ultraviolet radiation that, in excessive amounts, may promote cancer and cataracts in humans and may damage a wide variety of plant and animal life. Until recently, atmospheric concentrations of CFCs had been increasing at an annual rate of between 4 percent and 11 percent.

In 1987, the United States and most other industrialized nations ratified the Montreal Protocol on Protection of the Ozone Layer, which called for a 50 percent reduction in the use of CFCs compared to 1986 levels by 1992. The subsequent London Agreement called for complete elimination of the use of CFCs by 2000, and recent ratification of the Copenhagen Agreement accelerates the complete phase-out of CFCs to January 1, 1996. By January 1989, the production and use of CFCs began being phased-out in accordance with the Montreal Protocol an its subsequent elaboration. Because of the environmental impact of CFCs, the U.S. government has also imposed a substantial federal tax on CFC-11 and CFC-12, which is scheduled to reach $4.90/lb. by 1999, or more than twice the cost of these refrigerants in 1992 (Neiss 1992).

Even when production of CFCs ceases, there will be a large inventory of the compounds located in the insulation and cooling systems of existing appliances. Under current disposal practices and regulations, much of these CFCs will be emitted gradually over a period of years as existing equipment stock is replaced. As a result, atmospheric concentrations of CFCs are projected to peak up to 40 years after production of CFCs is stopped (DOE 1990). Since CFCs have an estimated atmospheric life of 65 to 150 years, the potential effects of higher CFC concentrations in the atmosphere may persist for several future generations.

Ultimately, the level of CFCs that accumulate in the atmosphere will depend to a large extent on future regulations and practices adopted by private industry for the operation and disposal of existing equipment stocks containing CFCs. The price of CFC refrigerants is expected to increase significantly over the next decade due to an increasing tax rate and decreased availability. The rising cost of CFC refrigerants is expected to create a significant economic incentive for new servicing and repair practices to reduce CFC leaks in commercial HVAC equipment, which can reach up to 20 percent over time. In addition, concern about the CFC issue is leading the commercial sector to consider replacing or retrofitting existing equipment so that alternative refrigerants may be used (Neiss 1992).

In the residential sector, future CFC emissions are likely to be affected by three key developments:

- As noted above, federal regulations taking effect in 1992 require the recovery and recycling of CFC-12 from liquid refrigerants during the servicing and disposal of residential appliances.

- Within the last year, several utility-sponsored appliance recycling programs have been planned or implemented which include the recycling or destruction of CFC-11 in foam insulation. It is estimated that there are two to five times as much CFC-11 in each appliance as CFC-12 (Shepard et al. 1994).

- Within the next few years, super-efficient CFC-free refrigerators will become commercially available as a result of the Golden Carrot program sponsored by a consortium of U.S. utilities. When this occurs, utility recycling programs could serve as means of promoting the accelerated replacement of older units with super-efficient CFC-free refrigerators.

Impact of Appliance Recycling Programs on CFC Emissions

Many utilities currently offering appliance recycling programs see the environmental benefits as a secondary objective. However, due to federal regulations requiring that liquid CFC-12 refrigerants be recovered, combined with the scrap value of the 200 lbs. of metal in a typical appliance, most residential appliances are currently recycled even in areas where utility-sponsored recycling programs are not offered. Therefore, few environmental benefits may be attributed to utility-sponsored appliance recycling programs unless programs involve recycling processes that reduce emissions of CFC-11 contained in insulating polyurethane foam.

Research indicates that the amount of CFC-11 in polyurethane foam in refrigerators is about two to five times greater than the amount of CFC-12 in the liquid refrigerant loop. However, there is currently no regulation governing the disposal of CFC-11 in the foam insulation of residential appliances. Under standard appliance disposal practice, foam insulation within appliances is shredded as part of the process of recycling metal panels, so that a substantial amount of the CFC-11 in foam insulation is emitted into the atmosphere.

Currently, there are two major options for reducing or eliminating emissions of CFC-11 during the disposal of residential appliances: CFC-11 may be recovered from foam insulation for reuse, or may be thermally destroyed through incineration. A key issue that may be addressed through future research involves the relative reduction in CFC-11 emissions achieved from these two alternative methods. A detailed discussion of the process of recovery of CFC-11 from foam insulation for reuse can be found in another article of these conference proceedings (Wall 1994). A description of the alternative approach based on the thermal destruction of CFC-11 through incineration is described by Hall and Hutchinson (1993). A detailed analysis of CFC-11 emissions resulting from different appliance disposal and recycling processes can also be found in Shepard et al. (1994).

Environmental Benefits of Reduced CFC-11 Emissions

Incorporating the potential environmental benefits of reduced CFC-11 emissions into cost-benefit analyses of appliance recycling programs ultimately requires that a direct economic value be assigned to emissions of CFC-11. Table 2 shows estimates of the economic value of reducing emissions of CFC-11 in terms of both greenhouse warming and ozone depletion from two recent studies (UNEP 1989 and 1991; cited in Kopko 1992). As shown in Table 2, recent scientific evidence indicates that feedback effects of CFC emissions may essentially offset the initial effects of CFCs on global warming. At the same time, however, recent evidence of more rapid ozone depletion suggests that the overall environmental costs of CFC emissions are higher than previously estimated.

As shown in Table 2, the potential environmental benefits of reducing CFC emissions are attributable primarily to a slowing of ozone depletion. Estimates of the costs associated with ozone depletion used in this analysis are based on deaths and injuries associated with increased incidence of skin cancer and other health effects (Kopko 1992). It should be noted that estimates presented in this paper are not based on an extensive review of the methodology used to develop these estimates or other studies which may have quantified the environmental costs of CFC emissions. Thus, results presented in this paper are intended to merely provide an indication of the approximate magnitude of the potential environmental benefits associated with appliance recycling programs that include provisions for the reduction of CFC-11 emissions.

Table 2. Estimated Environmental Benefit of Reducing CFC-11 Emissions ($/lb)

Low Environmental Benefit[a]	
Ozone depletion from chlorine	$ 50
Greenhouse effect	$ 35
Total	**$ 85**
High Environmental Benefits[b]	
Ozone depletion from chlorine	$150
Greenhouse effect	$ 35
Cooling effect from ozone depletion	$-35
Total	**$150**

(a) UNEP (1989) cited by Kopco (1992)
(b) UNEP (1991) cited by Kopco (1992)

Table 3 quantifies the potential environmental benefits of eliminating CFC emissions during the process of residential appliance disposal. Table 4 shows the potential contribution of CFC-11 in foam insulation of residential appliances in terms of total current production and total CFC emissions in the U.S. As shown in Table 3, the potential benefits of disposal methods that completely eliminating emission of CFC-11 in foam insulation may range from $75 to $225 per appliance, compared to current program costs ranging from about $125 to $200 per appliance (without recycling or incineration of CFC-11). This analysis suggests that from a societal perspective, the cost-effectiveness of appliance recycling programs may be greatly improved by program designs that include the recycling or thermal destruction of CFC-11 in foam insulation.

At the same time, however, data presented in Table 4 indicate that CFC emissions from foam insulation in

Table 3. Potential Environmental Benefit of Eliminating CFC-11 Emissions from Appliance Disposal

Low Benefit	
Ozone depletion only	$ 75
Ozone depletion and greenhouse effects	$127
High Benefits	
Ozone depletion only	$225
Ozone depletion and greenhouse effects	$225

Based on estimated environmental cost of CFC-11 emissions shown in Table 2.

Assumes average of 1.5 lbs of CFC-11 per appliance (Shepard et al. 1994).

Table 4. Estimated CFC-11 Emissions from Disposal of Residential Appliances in U.S.

Existing appliance stock[(a)]	142 million
Average service life	17 years
Appliances retired per year	8.35 million
CFC-11 per appliance[(b)]	1.5 lb
CFC-11 released per year	5,695 tons
Percent of Total U.S. Production of CFCs[(c)]	3.76%
Percent of Total U.S. CFC Emissions[(d)]	5.38%

(a) Estimate based on recent appliance stock and growth rates (EIA 1990).
(b) Shepard et al. (1994)
(c) Based on estimated CFC production in U.S. of 333,000 tons in 1986 (EPA 1988).
(d) Based on estimated CFC emissions in U.S. of 233,000 tons in 1990 (EPA 1993).

residential refrigerators and freezers may account for only about 2.4 percent of total CFC emissions in the U.S. Thus, while the environmental benefits of reducing CFC-11 emissions from the disposal of residential appliances may be significant on a *per appliance* basis, it should be noted that appliance recycling programs represent a very small part of any overall national or global strategy for reducing ozone depletion.

Conclusion

Recent experience with appliance recycling programs suggests that energy savings attributable to appliance recycling programs may be well below previous planning estimates due to high levels of free ridership and a shorter persistence of savings from removal of older appliances. Based on these results, many appliance recycling programs are not likely to be cost effective on the basis of energy savings alone. At the same time, appliance recycling programs represent a means of tapping a source of energy savings while providing a valued service to residential customers and local communities. To date, few if any utilities have quantified the indirect economic benefits of appliance recycling programs as a customer service and as a means of diverting appliances from other channels of disposal. These indirect economic benefits are highly tangible and quantifiable, and should in theory be included in applying the total resource cost (TRC) test (TRC) to assess the cost-effectiveness of appliance recycling programs. When offered as part of a comprehensive portfolio of DSM programs, appliance recycling programs may also provide an opportunity for a larger number of residential customers to share in the benefits of utility-sponsored DSM programs, making rate increases associated with DSM expenditures more equitable for all residential customers over the long term.

When appliance recycling programs were originally instituted, utility-sponsored programs resulted in recycling of CFC-12 in liquid refrigerants that would not otherwise have occurred. Utility-sponsored programs have encouraged the development of several national companies specializing in residential appliance recycling. However, with new federal regulations requiring the recovery of liquid refrigerants, few if any environmental benefits can be attributed to most utility-sponsored recycling programs. To achieve significant environmental benefits, recycling programs must again be designed to exceed federal regulations by requiring use of methods to reduce emission of CFC-11 from foam insulation in appliances. Results presented in this paper indicate that the potential environmental benefits of modifying programs to require the recycling or incineration of CFC-11 in foam insulation may exceed all other energy and indirect economic program benefits combined. With this program modification, utility-sponsored programs may again play a role in promoting the development of advanced CFC recycling and disposal technologies not yet required by law. As super-efficient CFC-free appliances become commercially available over the next few years, appliance recycling programs may also play an important role in promoting the accelerated replacement of older appliances with new super-efficient models.

Although explicit consideration of indirect economic and environmental benefits may play a critical role in determining the cost-effectiveness of appliance recycling programs, factoring these benefits into the analysis requires careful consideration of the role utilities are willing to assume in the area of residential appliance disposal and global environmental protection. For instance, while the value of appliance recycling programs as a customer service value and the "avoided costs" to local communities of having appliances removed through utility-sponsored programs may have a major effect on program cost-effectiveness, there is little precedent for explicitly including this type of indirect economic benefit into the cost-benefit analyses of DSM utility programs. Similarly, while reducing emissions of CFC-11 from foam insulation may result in significant global environmental benefits, it can be argued that the problem of ozone depletion should be addressed on a national and international level based on a comprehensive analysis of different options for reducing CFC emissions.

Endnotes

1. Twelve utilities known to have implemented appliance recycling programs were contacted by telephone and fax as part of a survey conducted to collect information for this paper. Most utilities indicated they would response to the survey, but did not provide any of the program information requested.

2. Most utilities appear to be using the assumption of a seven year measure life based on planning estimates obtained from the Wisconsin Center for Demand-Side Management. One utility providing more detailed program information reported using a measure life of five years to assess program cost-effectiveness.

References

Energy Information Administration. 1990. *Housing Characteristics.* DOE/EIA0314 (90), U.S. Department of Energy, Washington, D.C.

Energy Information Administration. 1993. *Emissions of Greenhouse Gases in the United States 1985–1990.* DOE/EIA0573(93), U.S. Department of Energy, Washington, D.C.

Hall, M. E., and M. A. Hutchinson. 1993. "Refrigerator Recycling and CFC-11 Insulating Foam: A New Approach." *Proceedings: Demand Side Management and the Global Environment Conference,* pp. 237-240. Electric Power Research Institute, Palo Alto, CA, and Edison Electric Institute, Washington, D.C.

Kopko, William L. 1992. "Analysis of Overall Environmental Impact from CFC Alternatives in Commercial Building Cooling Applications," 1992 *Summer Study on Energy Eficiency in Buildings.* Volume 9, pp. 9.99-9.105. American Council for an Energy-Efficient Economy, Washington, D.C.

Neis, R. C. 1992, *CFCs and Electric Chillers: Selection of Large Capacity Chillers in the 1990s,* prepared by Gilbert & Associates for the Electric Power Research Institute, EPRI 298317, March.

Ozog, M. T., and D. M. Waldman 1992. "Behavioral Model of Free Riders in DSM Programs." *1992 Summer Study on Energy Efficiency in Buildings.* Volume 7, pp. 7.175-7.180. American Council for an Energy-Efficient Economy, Washington, D.C.

Shepard, M. et al. (1994), *Appliance Recycling and CFCs,* E Source, Technical Report, Boulder, Colorado, June.

UNEP, August 1989. *Scientific Assessment of Stratospheric Ozone: 1989.*

UNEP, November 1991. *Synthesis of the Reports of the Ozone Scientific Assessment Panel, Environmental Effects Assessment Panel, Technology and Economic Assessment Panel.*

U.S. Department of Agriculture (USDA) 1972. Agricultural Research Service, July.

U.S. Department of Energy (USDOE) 1990. The Economics of Long-Term Global Climate Change: A Preliminary Assessment—Report of an Interagency Task Force. Springfield, VA, National Technical Information Service.