New Smart Protocols to Avoid Lost Opportunities and Maximize Impact of Residential Retrofit Programs

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"Smart protocols" are second generation delivery mechanisms for residential retrofit DSM programs that allow installers to quickly and simply perform sophisticated site-specific analyses of opportunities for cost-effective DSM resource acquisition. This approach can reduce the lost opportunities created through simpler and more generic approaches to DSM measure installation. It can also help to increase energy savings and program net benefits.

For example, most residential-lighting direct-installation programs use simple economic installation rules (e.g., minimum daily usage hours). In contrast, smart protocols recognize that unique retrofit opportunities occur at varying hours of use per day, that the cost of specific retrofit product options (not just the average product) should be considered and that performance and customer acceptance are critical to long-term persistence of savings. In utility programs in Vermont, Maryland and the District of Columbia where this type of lighting protocol has been first implemented, the result appears to be unprecedented numbers of lighting retrofits, unprecedented levels of energy savings and very high levels of customer satisfaction and measure retention. Similarly, a "smart protocol" approach to retrofit insulation can consider the site-specific heating and/or cooling equipment efficiency and other relevant site-specific factors, together with avoided costs, to yield a site-specific maximum cost per square foot for retrofit insulation. Such field protocols have been developed for a wide range of residential retrofit measures and reduced to simple tables which can be used in the field. This paper includes several example protocols and discusses field experience to date.

Introduction

Since every cost-effective demand-side resource available to utilities is, by definition, less expensive than the cheapest supply option according to the definition used, failing to acquire such resources means that ratepayers will be required to collectively spend more on energy services than is necessary. Thus, one of the most fundamental goals of any utility demand-side management (DSM) program, or portfolio of programs, should be to acquire the maximum level of cost-effective demand-side resources possible from each participant, as determined by the appropriate benefit-cost test.

Residential retrofit programs offer special challenges in this regard. While the level of demand-side resources available from such programs can be substantial, the resources are very dispersed. The absolute magnitude of savings that can be achieved from each individual home, for example, is very small compared to the savings that can be achieved from individual commercial buildings or industrial facilities. This requires that many homes must be reached in order to acquire substantial demand-side resources. Further, the demand-side resources within each home are usually dispersed among many end uses. Lighting, water heating, space cooling and heating are just the most commonly addressed. Moreover, it is often necessary to assess the cost-effectiveness of any number of competing and/or interactive candidate retrofit measures to select those which will result in maximum cost-effective resource acquisition. This suggests the need for a complex, in-depth analysis of each home. But with program delivery budgets severely constrained by the limited DSM resources available in each home, most residential retrofit programs resort to simplified analyses or "one-size-fits-all" prescriptive strategies based on an analysis of the average home, with a resultant tendency to fall short of the optimal level of demand-side resource acquisition.

Although these challenges are not unique to residential retrofit programs, they are uniquely important to them. A very large portion of the cost of residential DSM programs that deliver services directly to customer homes is the cost of recruiting the participant and physically getting to the home. Thus, once in the home, it becomes critically important to identify and treat as many opportunities for cost-effective resource acquisition as possible. While it is important to be aware of the primary and most common opportunities for cost-effective retrofit, it is also important to have a program design which can respond to less common and site-specific niche opportunities for cost-effective resource acquisition. Every cost-effective opportunity that is missed may be rendered a lost opportunity by the failure to treat it, as it may never again be cost-effective to visit the same site. Moreover, every cost-effective opportunity that is missed reduces program cost-effectiveness by reducing the benefits over which the relatively high costs of program delivery must be spread.

While the identification and treatment of the maximum possible cost-effective retrofit opportunities is a key to achieving the goal of acquiring maximum, cost-effective demand-side resources, it is not sufficient. It is also critical that each cost-effective retrofit opportunity be treated with the best measure available. Different candidate retrofit products have different costs, produce different savings, will deliver demand-side resources over different periods of time and will have different levels of customer acceptance. Installation of the option which produces the greatest net benefits (total avoided cost benefits less total measure costs), after accounting for customer acceptance and persistence of savings, will maximize support for program delivery costs, increase program cost-effectiveness, and minimize customers' costs of energy services.

Thus, the critical challenge facing retrofit program designers and implementers is to find ways to improve both the identification of opportunities for implementation of DSM measures and the selection of the optimal retrofit measure for each opportunity identified (including consideration of both net benefits hypothetically provided by the measure and customer acceptance), while minimizing program complexity and the cost of program delivery.

Beginning in 1992, several innovative utility programs in Vermont, Maryland and the District of Columbia have incorporated new tools which address this challenge. These second-generation program delivery tools, which we call "smart protocols", enable program field staff to perform very site-specific analyses of the cost-effectiveness, appropriateness and acceptability of a wide range of DSM measure applications, without an overly-complicated or lengthy on-site analysis process. As a result, although utility direct install programs which use these protocols are still in their infancy, these programs appear to be cost-effectively acquiring unprecedented levels of demand-side resources.

"Smart Protocol" Opportunities

Residential retrofit DSM programs generally can be divided into two distinct groups. The first group can be classified as "direct installation" programs. Under these programs, contractors directly install a variety of low cost measures, such as lighting products, water conservation measures (i.e., faucet aerators and low-flow showerheads), water heater wraps and set-back thermostats. Such programs are typically appropriate for customers whose end uses and levels of energy use do not warrant a more detailed analysis or higher level of service (e.g., an electric DSM program serving customers who do not use electricity for space heating, cooling or water heating). For want of a better term, we classify the second group "audit-based" programs. In these programs, typically delivered to customers where there is more potential for efficiency savings due to higher levels of energy use, the program addresses opportunities for savings from more complex, major measures, such as air sealing, duct sealing, insulation measures and HVAC equipment improvements.

There are applications for smart protocols in both of these types of retrofit programs. While they can be of great benefit to both, they may be crucial for direct installation programs. Because direct installation programs focus on smaller demand-side resources with relatively small per unit savings, such programs may not be cost-effective at all if they cannot acquire close to the maximum cost-effective potential in each participating home.

Many utilities across the country have implemented a variety of residential direct installation programs, with guidance on which measures to install coming in many forms (Greer et al. 1992; Cowell et al. 1992; Granda 1992; Hewitt et al. 1992). Most first-generation direct install programs have used simplistic approaches to retrofit decision-making in which only a limited range of measures and products are made available for installation, often including arbitrary limits on the number of measures that can be installed in each home (e.g., a maximum number of compact fluorescent bulbs per customer). These programs generally have been guided by very simple decision tools. At their worst, product installation is guided only by where it fits or where it is missing ("install the compact fluorescent bulb wherever you can" or "caulk any cracks around windows and door frames that are not already caulked"). Slightly better are advisory guidelines that attempt to incorporate some consideration of the level of energy savings possible into the installer's retrofit decision. In such programs, installers or homeowners may be told to put compact fluorescent bulbs in the fixtures that are used the most or to caulk where you can feel a draft. Even better programs have explicit protocols based on prior economic screening of measures under average conditions. Under these programs, installers may be instructed to ask the occupants of the home which lights are typically used more than a certain amount (e.g., more than three hours a day) and to install screw-in compact fluorescent bulb only in those fixtures (assuming they fit).

Even the best of these approaches, however, fails to maximize net benefits from each retrofit opportunity. This is because they miss some cost-effective resource opportunities, because they do not always install the measure with the greatest net benefits and/or because they fail to adequately address quality performance and acceptance issues. Many cost-effective opportunities for resource acquisition can be missed when retrofit guidelines are based on cost-effectiveness screening which assumes average conditions rather than site-specific conditions. For example, the determination of the minimum threshold hours of use for most residential retrofit lighting measures is typically based on cost-effectiveness screening that assumes an average screw-in compact fluorescent bulb (CFL), with its associated average cost and average wattage, will on average, replace an incandescent bulb of certain wattage. Importantly, however, the cost of efficient lighting products and the savings they offer vary widely. For example, even if the average bulb is not cost-effective at a certain number of hours of use, a less expensive retrofit bulb may be.

Similarly, it makes no sense to exclude products from consideration simply because they are not cost-effective for the average retrofit situation. For high usage locations, for example, the retrofit which yields the greatest net benefit well may be a hard-wired lighting fixture which would not be the best choice for an average usage opportunity. Instead, the potential for cost-effective retrofits should be considered for every lighting socket individually. For sockets with low hours of use and/or low existing wattage, the number (if any) of cost-effective retrofit options will be limited to the least expensive products with the highest savings. More options will be available for sockets with high hours of use and/or high existing wattage. In all cases, the most cost-effective option (i.e., the one with the greatest net benefits) that is acceptable to the customer and that the customer can be expected to continue to use should be installed.

Finally, it is imprudent to install measures that pass cost-effectiveness screening if they will be removed or not used because they do not meet quality requirements of the customer. Appearance, light levels, performance over time, maintenance requirements and other factors which impact customer acceptance must all be considered. Installation guidelines that do not adequately involve the customer in the selection of a measure for each application will lead to higher levels of customer dissatisfaction and lower rates of measure retention, with the final result being that the program is not as cost-effective as theorized.

Smart Protocols for Residential Lighting Retrofits

Experience of Washington Electric Cooperative

In early 1992, the Washington Electric Cooperative (WEC) began implementation of a direct install program (one of seven DSM programs offered) designed to provide residential customers of moderate electric usage (2500 kWh/year to 8000 kWh/year) with the immediate installation of low-cost demand-side resource measures, analysis and treatment of any major resource acquisition opportunities, and consumer education. Under this program, all customers visited receive cost-effective lighting products; those with electric water heat also receive water conservation measures and tank wraps when appropriate.

The WEC program places a high priority on identifying all cost-effective opportunities for lighting retrofits and maximizing the net benefits of each retrofit. There are two principal reasons for this emphasis. First, although WEC's avoided costs are relatively high, the saturation rates of electric space heating and air conditioning in its service territory are extremely low. This makes lighting one of the principal electrical end-uses in WEC's residential sector (90% of WEC's sales are to residential customers). Second, WEC is one of the most rural utilities in New England and has a very low customer density. This increases the fixed costs per customer of delivering a residential retrofit program. To offset relatively high program delivery costs, it is imperative that the net benefits of demand-side resources acquired from each customer be as high as possible. This has been accomplished through the development and use of a smart protocol for lighting retrofits. Table 1 is a simplified reproduction of only part of the WEC protocol for indoor lighting products (a similar protocol exists for outdoor products), which include both screw-ins and hard-wired fixtures.

Although it appears somewhat complicated, the protocol is actually very easy to use. Energy Specialists begin by asking customers how many hours each lamp is typically used each day. They then use this information, together with the wattage of the inefficient lighting product currently in use, to identify all possible retrofit options based on all relevant site conditions. As Table 1 illustrates, retrofit options are listed in rank order, for each combination of daily burn time and lamp wattage to be replaced, according to the net benefits they would provide (using WEC's avoided cost assumptions).

Table 1. WEC Protocol for Indoor Lighting

Daily Burn Time	Lamp Wattage to be Replaced	ID	% of Incandescent Lumens	Product Name	Net Benefits
1.0	25	T7O1	147%	7W "Twin" CFL (new)	$4.37
	40	T9O1	102%	9W "Twin" CFL	$16.04
		Q9O1	98%	9W "Quad" CFL (new)	$11.46
		T13O1	150%	13W "Twin" CFL	$13.14
		Q13O1	146%	13W "Quad" CFL	$9.46
	60	T13O1	87%	13W "Twin" CFL,	$22.87
		Q1301	84%	13W "Quad" CFL,	$19.50
		Q22O1	117%	22W "Quad" CFL,	$10.03
		MG151	87%	15W Globe, M, AIO	$0.84
	75	Q22O1	85%	22W "Quad" CFL,	$21.59
		LA221	124%	22W "Circular" CFL,	$19.82
		Q28R1	113%	28W "Quad" CFL	$8.38
		HA521	82%	52W Tungsten-	$2.16
	100	LA301	116%	30W Circular CFL,	$27.30
		LA301	116%	30W Circular CFL,	$24.10
		Q28R1	78%	28W "Quad" CFL,	$20.31
		SL231	75%	23W "Triple bi-ax"	$13.98
		HA721	82%	72W Tungsten-	$3.67
		EL271	75%	27W "Quad" CFL,	$1.41
	200	FOR41.0	76%	52W Drum Fixture	$3.89
		CI721.0	91%	72W Circline	$2.04
2.0	25	T7O2	147%	7W "Twin" CFL	$14.48
	40	T9O2	102%	9W "Twin" CFL	
		Q9O2	98%	9W "Quad" CFL	$36.40
		T13O1	150%	13W "Twin" CFL	$32.50
		Q13O1	146%	13W "Quad" CFL	$26.54
	60	T13O2	87%	13W "Twin" CFL,	$46.39
		Q1302	84%	13W "Quad" CFL,	$42.00
		Q22O2	117%	22W "Quad" CFL,	$27.21
		MG152	87%	15W Globe, M, AIO	$7.97
		ML162	87%	16W Quad CFL,	$7.81
		EL152	87%	15W CFL, E, AIO	$1.45
	75	Q22O2	85%	22W "Quad" CFL,	$47.54
		LA222	124%	22W "Circular" CFL,	$45.82
		Q28R2	113%	28W "Quad" CFL	$24.10
		CA182	78%	18W CFL, E, AIO	$8.49
		SY18	75%	18W CFL, E, AIO	$8.15
		EL202	85%	20W "Quad"	$7.98
		SL202	85%	20W "Triple bi-ax"	$3.91
		FOR22.0	125%	26W Drum Fixture	$2.79
		SL232	110%	23W "Triple bi-ax"	$2.34
	100	LA302	116%	30W Circular CFL,	$61.35
		Q28R2	78%	28W "Quad" CFL,	$55.43
		LA302	116%	30W Circular CFL,	$55.22
		FOR22.0	87%	26W Drum Fixture	$34.11
		EL272	75%	27W "Quad" CFL,	$12.78
		FDMD2.0	87%	26W Dimondlite	$8.83
		FOR32.0	131%	39W Drum Fixture	$1.44
		HA722	82%	72W Tungsten-	$1.06
	120	CI322.0	87%	32W Circline	$45.58
		FOR32.0	131%	39W Drum Fixture	$30.59
	150	FOR32.0	78% to 105%	39W Drum Fixture	$72.26
		FOR42.0	104% to 140%	52W Drum Fixture	$35.68
	200	FOR42.0	76%	52W Drum Fixture	$98.31

Table 1. (contd)

Daily Burn Time	Lamp Wattage to be Replaced	ID	% of Incandescent Lumens	Product Name	Net Benefits
3.0	25	T7O3	147%	7W "Twin" CFL (new)	$22.86
	40	T9O3	102%	9W "Twin" CFL	$41.20
		Q9O3	98%	9W "Quad" CFL (new)	$36.40
		T13O3	150%	13W "Twin" CFL	$32.50
		Q13O3	146%	13W "Quad" CFL	$26.54
		EL113	102%	11W CFL, E, AIO	$6.38
	60	T13O3	87%	13W "Twin" CFL,	$63.96
		Q1303	84%	13W "Quad" CFL,	$58.01
		Q22O3	117%	22W "Quad" CFL,	$40.83
		MG153	87%	15W Globe, M, AIO	$22.86
		EL153	87%	15W CFL, E, AIO	$19.01
		FGLB3.0	84%	13W Globe Fixture	$17.67
		CA183	107%	18W,CFL, E, AIO	$17.00
		SY183	107%	18W Quad (Sylv)	$16.90
		SL153	87%	15W CFL, E, AIO, Triple "bi-ax"	$16.25
		EL203	117%	20W "Quad"	$15.32
		SL203	117%	20W "Triple bi-ax"	$12.92
		ML163	87%	16W Quad CFL,	$10.74
		HA423	84%	42W Tungsten-	$1.33
	75	Q22O3	85%	22W "Quad" CFL,	$68.14
		LA223	124%	22W "Circular" CFL,	$66.44
		Q28R3	113%	28W "Quad" CFL	$42.40
		FOR23.0	125%	26W Drum Fixture	$31.23
		CA183	78%	18W CFL, E, AIO	$28.90
		SY183	78%	18W CFL, E, AIO	$28.00
		EL203	85%	20W "Quad"	$27.88
		SL203	85%	20W "Triple bi-ax"	$25.48
		SL233	110%	23W "Triple bi-ax" CFL,	$23.40
		EL273	110%	27W CFL, E, AIO	$18.03
		HA523	82%	52W Tungsten-	$3.84
	100	Q28R3	78%	28W "Quad" CFL,	$82.99
		LA303	116%	30W Circular CFL,	$80.69
		FOR23.0	87%	26W Drum Fixture	$78.20
		LA303	116%	30W Circular CFL,	$72.13
		FDMD3.0	87%	26W Dimondlite	$52.93
		SL233	75%	23W "Triple bi-ax" CFL,	$39.00
		EL273	75%	27W "Quad" CFL,	$37.16
		FOR33.0	131%	39W Drum Fixture	$34.23
		HA723	82%	72W Tungsten-	$5.07
	120	CI323.0	87%	32W Circline	$102.76
	150	FOR33.0	78% to 105%	39W Drum Fixture	$140.46
		CI543.0	80% to 110%	54W Circline	$132.56
		FOR42.0	104% to 140%	52W Drum Fixture	$35.68
		CI722.0	124% to 150%	72W Circline	$32.33
	200	CI723.0	91%	72W Circline	$188.63
		FOR43.0	76%	52W Drum Fixture	$186.51

There are many complex factors that can be addressed in calculations of net benefits from residential lighting measures that are not explicitly enumerated in Table 1. These include the expected lifetime of the measure (which can be influenced by installation conditions), expected measure retention rates and interactions with the heating and cooling loads of a building. All of these factors are implicitly accounted for in the WEC protocol (i.e., in the estimates of net benefits for each measure), except for interaction with heating and cooling loads. This issue has not been addressed both because of the extremely low saturations of electric heat and air conditioning in WEC's service territory and because of the assumed low utilizability of internal heat gains from residential lighting.[1] It is worth noting that decisions regarding whether and how to address such issues in cost-effectiveness screening of lighting measures must be made whether or not a smart protocol is used to guide installation decisions.

Energy Specialists using WEC's installation protocol seek to install the retrofit option that will generate the greatest net benefits appropriate to the circumstance. However, other selection criteria are also used to ensure that persistence of savings is maximized. The following considerations are evaluated for each potential retrofit, in consultation with the customer where appropriate:

1. Is the lamp or fixture used for task or area lighting? Is the use appropriate for the situation? In some cases, it is acceptable to reduce background illumination while increasing task lighting illumination.
2. Does the bulb currently being used exceed the specifications for the fixture? Many customers do not realize that certain fixtures specify the maximum recommended wattage. In such cases, retrofits can bring the use of fixtures into compliance with the manufacturer's specifications.
3. Will the retrofit make the lamp or fixture unsafe or difficult to use? The energy specialist determines whether the product with greatest net benefits has physical characteristics which would interfere with the design of the lamp or fixture making it unstable, difficult to change, or otherwise unsuitable for a location.
4. Are operating characteristics of the energy efficient bulb unsuitable for the proposed location? Initial flicker, time delay to full lumen output, ballast noise, and color rendition are among the issues considered in determining whether the proposed retrofit is appropriate and acceptable for a given location.
5. Do characteristics of the proposed location make a retrofit unsuitable? Insufficient ventilation of heat build-up, wet locations, and dimmer controls could all preclude installation of lamps and fixtures. Product selection is limited in outdoor locations to those products which perform at low temperatures.
6. Is the pre-retrofit light level excessive or deficient. In 18% of the WEC program retrofits, the Energy Specialist has increased mean lumen output by at least 50% and still achieved cost-effective savings. In 12% of the WEC program retrofits, mean lumen outputs have been reduced by more than 20%. All retrofits which reduce mean lumen output are made only when the resultant illumination level is deemed to be appropriate to the location and is agreed to by the customer. On average, WEC program retrofits have increased mean lumen output by 4%.

One of the critical features of the WEC program design is that a very wide variety of products are available. All told, 47 different lighting products have been installed in customer homes to date. This wide range of products gives Energy Specialists the flexibility necessary to ensure that the maximum possible number of cost-effective retrofit opportunities identified are treated with a retrofit product that will both maximize benefits and satisfy the customer. For example, as Table 2 illustrates, 20% of the bulbs installed under the WEC program to date have been tungsten-halogen bulbs. Using the WEC protocol, as shown in Table 1, tungsten-halogen bulbs should be seldom, if ever, the first choice as a retrofit based solely on the net benefits they produce. However, the program does install these bulbs when preferable CFL products do not fit in a fixture, when the light is on a dimmer, or when a customer is not pleased with the quality of products yielding greater benefits. This is the type of niche opportunity and quality assurance that is missed when retrofit options are limited (e.g., when there are only one or two types of screw-in CFLs) and no hard-wired fixtures are offered.

Table 2. WEC Lighting Installations by Bulb Type and Year

	Electronic All-in-Ones	Electronic Components	Magnetic All-in-Ones	Magnetic Components	Fixtures	Halogens	Totals
3/92 - 2/93	700	113	644	1,302	187	978	3,924
3/93 - 2/94	2,821	249	534	1,404	160	1,112	6,280
TOTALS	3,521	362	1,178	2,706	347	2,090	10,204
	34.5%	3.5%	11.5%	26.5%	3.4%	20.5%	100%

Approximately 10% of the electronically-ballasted bulbs and roughly 70% of the magnetically-ballasted bulbs installed under the WEC program are products in which the ballast and the bulb are separate components. With these kind of products, the bulb can be replaced without also replacing the ballast (which typically lasts twice as long as the bulb). Thus, these products are likely to offer savings over a longer period of time, a benefit reflected in the protocol but missed by utility programs using only all-in-one bulbs.

The results produced by the use of this protocol have been very impressive. Perhaps most striking is that over the first two years of implementation the program installed an average of 9.3 lighting products per home. This penetration rate is estimated to produce gross per participant savings of 502 kWh/year and $200 in net benefits to WEC. These estimates are necessarily approximate because they are based on customer reported hours of usage for retrofit products. Although some studies have found customer estimates of lighting use to be overstated (NEPSCO 1993), others have found customers' estimates to show good agreement with metered results (Goett et al. 1992). Nevertheless, the measure penetration levels and estimated impacts from this program are unprecedented in utility DSM programs addressing residential lighting. Moreover, surveys of program participants suggest that these results have been achieved with high customer satisfaction and high probability of the persistence of savings. A recent process evaluation of the program reports that only 3% of the participants in the program expressed any dissatisfaction, and that 95% of the bulbs installed, in some cases installed nearly two years before the evaluation, were still in place (Hamilton Consulting and Energy Research Group 1994).

The Experience of PEPCO

A similar protocol for direct installation of residential lighting was developed by the Potomac Electric Power Company (PEPCO) and has been used in two different residential retrofit programs since early 1993. The first program, which is called "Apartments Plus", addresses multi-family housing with direct installation of lighting and hot water conservation measures, as well as energy education services. The second program, which serves single family homes with a wide range of comprehensive DSM retrofit services called "Home Fitness". Both use a lighting protocol very similar to that used in the WEC program, but with somewhat fewer products. The PEPCO program includes fifteen different screw-in lighting products, of which 13 are compact fluorescent and 2 are tungsten-halogen bulbs.

The Apartments Plus program served 16,407 apartments (the vast majority gas-heated) between its initiation in early February 1993 and December 31, 1993. Roughly two-thirds of the apartments served were in the District of Columbia; the remainder were in Maryland. During this period, the program served low-income apartments almost exclusively, most of which were in public housing. Typical program delivery involved initial marketing to a building owner and a tenant meeting to explain and promote the program, followed by door-to-door direct installation conducted by a crew of extensively-trained installation specialists. Complete data on bulb installations and energy savings from the program are currently available for apartments served in Maryland. Each of these units received an average of 8.0 bulbs, of which 87% were compact fluorescent. Based on customer estimated hours of usage for the installed products, gross per participant savings from the program are estimated to be over 550 kWh/year.

The Home Fitness program was initiated in 1992 with pilot program delivery to selected groups of PEPCO customers in Maryland. These groups were selected to have characteristics representative of selected customer segments of particular interest for preliminary assessment of Home Fitness program delivery mechanisms. It should be noted that all of the participants in 1993 were either classified as being "all electric" or were gas-heated homes on time-of-use rates. In this respect they were not necessarily representative of potential future program participants. Nevertheless, the results from this program have been remarkable. For the 491 Maryland homes served by this program in 1993, the average number of bulbs installed was 16.7 per home, of which roughly 76% were compact fluorescent bulbs. Preliminary indications are that nearly as many bulbs were installed in each of the 807 homes served by the program in the District of Columbia. Based on customer reported hours of usage for the products, gross per participant savings from the program are estimated to be 1219 kWh per home.

Smart Protocols for Thermal Measures

Thermal Load Reduction Measures for Residential Buildings

Perhaps the best known example of a smart protocol for thermal measures is the "economic stop policy" commonly used to guide blower-door directed air sealing. Because of their ability to measure air leakage rates as well as to identify air leakage locations, blower doors have made it possible to determine when it is no longer cost-effective to continue air leakage reduction efforts (Schlegel 1990). Since every cubic foot of air which has been heated or cooled, and which leaks out of a building, is replaced by an equal volume of air requiring heating or cooling, the energy cost penalty for a given volume of air leakage can be readily calculated. Clearly, if the cost to reduce the leakage rate by a particular amount is greater than the value of the resulting energy savings, there is no economic benefit to continuing to seal remaining leakage points. Conversely, so long as the value of the saved energy is greater than the cost of saving that energy, air sealing should continue. The focus is often then placed, as it should be, on major by-passes rather than the typically less important, but traditional, locations served by weatherstripping, caulking, and outlet gaskets.

Economic stop policies for blower-door directed air sealing based on local energy and installation prices, as well as other local concerns, have become increasingly common in low-income weatherization programs since, by definition, they result in cost-effective air sealing work. This approach is easily transferable to DSM programs by using the net present value of utility avoided cost benefits as the unit of economic value against which incremental levels of air sealing work are measured. Table 3 provides a simple example of a smart protocol for determining the economic stop point for a given utility avoided cost, site-specific heating system efficiency and a given labor rate (material costs generally represent only a small fraction of the cost of air sealing). In program delivery, this is adapted to local costs and coupled with a second protocol to address concerns for indoor air quality by incorporating such variables as the number of people in the household or the number of bedrooms. In addition, different protocols are used for homes heated with different fuels and for homes with and without air conditioning.

The basic principle behind this instance of a smart protocol for air sealing can be extended to other thermal measures being considered for retrofit on a given site. The issues associated with other possible thermal measures are, however, more complex, particularly with respect to installation costs. In the case of blower-door directed air sealing, the cost-benefit analysis effectively is being determined as the installation progresses. Once air sealing is no longer cost-effective, the measure is completed. Other thermal measures, such as installing additional insulation in an attic, are not strictly analogous. Costs and benefits for the specific site must be determined *before* the installation process begins, rather than *during* the installation process. As a result, many residential retrofit DSM programs use guidelines based on average circumstances to determine whether insulation should be added.

For example, a retrofit DSM program may prescribe R-38 for any attics with less than a certain amount of insulation, presuming that benefits will exceed costs in the aggregate. This approach lowers program cost-effectiveness because it results in insulation being added to homes in which such additions may not be cost-effective. It also fails to capture all cost-effective demand-side resources because homes in which it would be cost-effective to increase insulation to levels above R-38 do not receive as much insulation as is cost-effective.

A smart protocol is easily developed, however, which recognizes the local costs and benefits of incremental increases in, for example, attic insulation. This is possible by using a matrix which provides the cost-effectiveness ceiling for installation costs, given a particular combination of existing insulation levels and overall heating (and/or cooling) system seasonal efficiencies (as opposed to name-plate ratings), using utility-specific avoided costs. The respective variables affecting cost-effectiveness are then accommodated (including the perspective provided by consumption histories) in a single table and easily used in the field, providing immediate answers to such key questions as, is it worth adding more insulation to this attic and, if so, how much? This approach also allows accounting for the site-specific cost variability of efficiency measures. For example, if adding insulation in a particular home is unusually costly, such that the cost would exceed the maximum cost per square foot shown on the protocol table, it should not be installed in that home. Conversely, the protocol table provides the information necessary for determining the maximum insulation level consistent with the utility-specific avoided costs, thereby ensuring the ability to acquire the maximum level of cost-effective demand-side resources.

Table 3. Air Leakage Control Economic Stop Policies (with sample values)

overall heating system efficiency with distribution	90%	86%	82%	78%	74%	70%
maximum total labor hours to achieve last 100 cfm @ 50 Pascals reduction	2.2	2.3	2.4	2.5	2.6	2.7

Table 4 is a simplified, hypothetical example of a smart protocol for attic insulation for a natural gas utility DSM program. Note that although the table presents insulation levels in inches, it could be adapted to express insulation levels according to R-values. A more complete table could also include a wider range of mechanical system efficiencies and combinations of existing and new attic insulation levels.

An example can be considered assuming that there currently are six inches of insulation in an attic and the overall heating system efficiency is 70%. Use of the sample table indicates that the net present value of the benefits resulting from increasing insulation depth to nine inches is $0.21/square foot, whereas increasing insulation depth to twelve inches is provides benefits of $0.37/square foot. Accordingly, if it is not possible to increase insulation depth to twelve inches for less than $0.37/square foot, but it is possible to increase insulation depth to nine inches for less than $0.21/square foot, then insulation depth should be increased to nine inches. Suppose that a heating system upgrade also is being contemplated since there is evidence of a cracked heat exchanger. How would an increase in efficiency affect the cost-effectiveness of retrofitting more attic insulation? Again, the table provides site-specific guidance. Presuming a new 90% system seasonal efficiency and the earlier sample values, it would be cost-effective to install an additional six inches of insulation if the installation would cost less than $0.28/square foot .

In similar fashion, other tables may be developed for other typical retrofit measures using whatever local considerations are at issue, whether for specific measures or for generic improvement benefit values per MMBtu of first-year savings and estimated measure life.

In the fall of 1993, PEPCO's Home Fitness residential DSM program began to use a set of comprehensive smart protocols, similar to those presented above, to capture the full scope of cost-effectively available resources from each site. The protocols being used by PEPCO address both the electric heating and cooling benefits of a wide range of efficiency measures, including insulation, air sealing and duct sealing. Although complete data on the results of the program are not yet available, the installation contractor providing service delivery of the Home Fitness program reports no difficulties in using the smart protocols established for the program, either in their use on site or in training new employees in their use, as well as in meeting the safeguards installed to ensure least cost installations. Further, the contractor is enthusiastic about the complete range of energy efficiency services he is able to provide PEPCO customers, with the assistance of PEPCO financial incentives designed to achieve maximum levels of measure implementation.

Thermal Efficiency Measures for Residential Buildings

Similar smart protocols can be valuable in determining when a mechanical system contractor should be engaged, either to remedy system inefficiencies or to switch a system to a different fuel. Again, broad policies based on typical circumstances are extremely likely either to miss specific opportunities for substantial savings which are cost-effective to achieve, or to result in particular installations which are not cost-effective. HVAC tune-ups are especially vulnerable to these difficulties since program field personnel typically are not trained (or equipped) to determine when, for example, a heat pump no longer is

Table 4. Sample Attic Insulation Values Table NPV of Improvement Benefits, Per Square Foot of Retrofit

Inches of Insulation		Overall Heating System Seasonal Efficiency				
Before	**After**	**70%**	**75%**	**80%**	**85%**	**90%**
0	6	$7.33	$6.84	$6.41	$6.04	$5.70
0	9	$7.54	$7.04	$6.60	$6.21	$8.87
0	12	$7.69	$7.18	$6.73	$6.34	$5.98
3	6	$0.47	$0.44	$0.42	$0.39	$0.37
3	9	$0.69	$0.64	$0.60	$0.57	$0.53
3	12	$0.84	$0.79	$0.74	$0.69	$0.65
6	9	$0.21	$0.20	$0.19	$0.18	$0.17
6	12	$0.37	$0.34	$0.32	$0.30	$0.28
9	12	$0.15	$0.14	$0.13	$0.13	$0.12

operating at optimal efficiency, whether for cooling or heating. The result tends to be policies which encourage calling for HVAC contractor follow-up "just-in-case" or to exclude mechanical system tune-ups entirely on the grounds that typically they are not cost-effective. In either event, optimal results do not ensue.

The PEPCO Home Fitness program includes a smart protocol designed to identify when major efficiency modifications to a heat pump or a central air conditioner are likely to be cost effective. The PEPCO field personnel delivering the initial on-site services measures air flow rates, and temperature differentials between supply and return systems, to identify systems which are outside of protocol guidelines and which are likely to result in benefits greater than the cost of servicing to correct refrigerant charge or air flow. The PEPCO service provider, a general weatherization services contractor, reports no difficulties in using this, or any of the other smart protocols incorporated into the PEPCO residential DSM program. Indeed, training in appropriate use of the smart protocols is sufficiently simple that the contractor has been able to quickly expand capacity to meet contract quotas and eagerly looks forward to bidding on other DSM contracts in the area. In any event, the result for PEPCO is assurance that maximum cost-effective opportunities for savings are being identified and acted upon, as well as assurance that non-cost-effective measures are being ignored, based on the installation costs and energy benefits specific to the site.

A final example of a smart protocol which can reap large rewards for the utility, as well as for the customer and for society at large, is one which makes site specific determinations of energy used for domestic hot water to identify circumstances in which it would be cost-effective to switch fuels. The WEC residential DSM program in Vermont makes use of a spreadsheet-based program loaded onto a palm-top computer to calculate DHW energy from such site specific characteristics as past consumption history disaggregated by major end uses, the number of occupants and their ages, water heater size and energy factor, and measured DHW temperatures to determine the parameters of fuel-switching cost-effectiveness. Hard-copy versions are also available. Either allows on-site determination of the site-specific cost-effectiveness of fuel-switching. A household with only moderate DHW use and an electric water heater, for example, still may be a cost-effective opportunity for fuel-switching if a boiler is used for space heating. In such cases, the boiler can be used to cost-effectively provide domestic hot water as well as space heat. Another household with high DHW use and an electric water heater, however, may not constitute a cost-effective fuel-switching opportunity since site conditions would result in excessively high installation or operating costs. Again, a smart protocol allows distinguishing between such cases and determining which, if at all, constitutes an opportunity for yielding cost-effective benefits. The WEC experience with fuel switching through use of their smart DHW protocol also has been positive. Another paper in these Proceedings, "Beyond the Tank Wrap—Field Experience Implementing Domestic Hot Water Fuel-Substitution in an Electric DSM Program" by Cawley et al., examines this WEC DSM program in more complete detail.

Conclusion

At its most basic level, the charge of DSM program designers and operators is to acquire the maximum possible level of demand-side resources available at a cost that is less than utility avoided costs. There are essentially two tasks that must be undertaken to achieve this goal. The first is to identify all possible cost-effective DSM resource acquisition opportunities. The second is to identify the DSM treatment that will yield the greatest net benefits from each cost-effective opportunity identified, after taking into account customer acceptance of DSM options. A set of decision rules is necessary to accomplish each of these tasks.

To date, many utility DSM programs for the residential sector have established simple decision rules for both identifying cost-effective DSM resources and acquiring them. These decision rules are typically designed to ensure that on average the DSM program will be cost-effective. That is, they make assumptions about the conditions that will typically be encountered by program operators and assess whether the DSM measure most commonly used to address a particular DSM resource opportunity would be cost-effective under those average conditions. These simple decision rules result in a less than optimal DSM program design, particularly in residential retrofit programs. They forgo the often substantial cost-effective DSM resources that are available under atypical conditions in a home. They also result in the installation of measures which, even if cost-effective, produce lower net benefits for the utility, its ratepayers and society than could have been achieved with different measures. These limitations have been felt to be necessary because either there were no better alternatives available, more sophisticated methods were seen as more complex, or, perhaps most importantly, more sophisticated methods were seen as being too costly relative to the benefits that they would achieve.

As this paper suggests, this need not be true. Smart protocols that are simple to use and add little to the cost of program delivery can help benefit DSM programs by both identifying site-specific demand-side resource opportunities and identifying the treatment for each opportunity that yields the greatest net benefits.

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Endnote

1. If and where interactions between residential lighting and heating/cooling loads are determined to be significant, it could be appropriate to develop different protocols for homes with or without air conditioning, or varying with the type of fuel used for space heating. There is little known of the actual magnitude of such interactions in residential buildings, and virtually no empirical data. Some modelling has been done which suggests the utilizability of generic internal heat gains in residential buildings is relatively low (Palmiter and Kennedy 1983). In developing the impacts for the WEC and PEPCO protocols, it was assumed that the heating and cooling impact of lighting retrofits was quite small due to their location and timing.

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