PA Consulting Group

Subject **Focus on Energy Evaluation**

Residential Technologies Incremental Cost Review

To Oscar Bloch;
Public Service Commission of Wisconsin

cc Kathy Kuntz, Sara Van de Grift, Bobbi Fey;
Wisconsin Energy Conservation Corporation

From Steven Drake, Eric Rambo, Bryan Ward;
PA Consulting Group

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Introduction

End-user incremental costs are one of the most critical inputs to benefit-cost (b/c) analysis. On the benefit side of the equation, substantial analytical effort has gone into determining net savings for each program. The customer cost side of the test is equally critical to the overall result, however, and demands an equivalent level of attention.

PA Consulting Group has conducted an incremental cost analysis for Wisconsin Focus on Energy's (Focus) Residential Programs. PA reviewed incremental cost data from a variety of sources for Focus's primary residential energy-saving technologies as well as other energy efficient measures. This review was largely based on secondary data sources, that is, numbers published in other reports and deemed savings databases, augmented by independent research where measures are not well represented in published databases or where weather and other factors make their application to Wisconsin inappropriate.

The incremental cost estimates reported here are ratios of average measure cost per dollar of avoided costs. These are applied as multipliers to reported savings values in the simple formula:

energy savings × incremental cost multiplier = incremental cost.

These values will be applied to the simple b/c calculation in the next 2009 semiannual report and in future b/c reports.[1]

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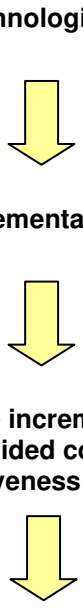
[1] These estimates were not completed and reviewed in time to be included in the semiannual report for the first half of 2009.

It is a significant challenge to reduce the complexity of technology offerings across numerous end-uses to a manageable set of incremental costs. This memo discusses our approach to this analysis, including how the measure-level incremental costs (shown in Table 6) are aggregated for use in b/c analysis, presents the results of that aggregation (Table 5 in the section titled "Incremental Cost Estimates"), and briefly discusses the challenges and limitations to developing incremental cost estimates. A bibliography of all of the secondary sources used is provided at the end of this document.

Analysis Approach

In general, we used a bottom-up approach to reviewing and estimating incremental costs for measures installed through Focus residential programs. While it was not feasible to research incremental costs for every individual measure installed through residential programs, we researched costs at the measure level for technologies most central to Focus residential program savings and then aggregated these estimates into measure categories to be used in the 2009 b/c analysis. Figure 1 summarizes our approach in estimating incremental costs for Focus residential programs.

Figure 1. Summary of Incremental Cost Analysis Approach for Residential Programs



Primary Measure Selection

As a first step in evaluating incremental costs for Focus's residential programs, we identified the most important energy efficient technologies used in these programs from the standpoint of savings. Using data extracted from WECC's data-tracking system on July 14, 2008, we identified measures that account for at least 0.5 percent of total annual electric energy savings, peak demand reduction, or gas savings in the residential sector. This limit allowed PA to capture the measures that accounted for the vast majority of sector savings and represented a manageable set of technologies on which to focus our research efforts. The PA team also identified a small number of technologies that did not meet the 0.5 percent savings criterion but seemed an important part of residential energy efficiency programs. These measures included some ENERGY STAR® appliances and equipment such as dishwashers, refrigerators, and ceiling fans, as well as LED exit signs for multi-family units and high efficiency central air conditioning with a SEER rating 17 or above.

Based on these criteria, the PA team targeted 45 technologies for which to collect and analyze measure-level incremental cost data.[2] These measures, representing approximately 96 percent of total electric savings and 88 percent of total gas savings from residential programs, are shown in Table 1.

Defining Incremental Cost

Incremental cost is the additional expense to the customer for installing an energy efficient technology instead of a less efficient, baseline technology. For most efficient technologies, the incremental cost is specified on a *replace-on-failure* basis. This condition assumes that the decision to choose high efficiency equipment over less efficient equipment is contingent on the failure of the existing measure. In these instances, the incremental cost is typically simply the difference in the material cost of the measure. For example, the incremental cost of replacing an inefficient air conditioner with an efficient air conditioner would be the added cost of purchasing the more efficient unit. The cost of installation for replace-on-failure measures would only be included where installation of the efficient measure is more expensive than installation of the baseline measure.

For some energy efficient technologies, however, the replace-on-failure condition is not appropriate because the technologies have no realistic baseline alternative with an associated cost. For example, the alternative to adding insulation to a building shell typically is doing nothing, simply because insulation does not fail, *per se*. Likewise, installing a low-flow showerhead or faucet aerator in an existing building, or taking weatherization measures, are not considered an alternative to measures because typically there has been no associated failure. In these instances, the incremental cost is the *full* cost of the energy efficient technology, combining the cost of the equipment and its proper installation.

[2] The energy savings criteria listed above identified two custom ACES measures—"cost of service" and "non-carpet flooring over radiant heat"—that we did not include in our analysis due to a lack of available cost data.

It is important to note that this analysis does not attempt to estimate incremental costs for *early replacement* installations, where high efficiency technologies are installed to replace less-efficient equipment prior to the existing equipment failing. To appropriately estimate the incremental cost of these types of installations, one would need to estimate the remaining useful life of the existing equipment. The full cost of the high efficiency measure would need to be discounted by this period, as the customer would have eventually needed to replace the existing measure when it failed. Without having data on the remaining useful life of existing measures for early replacements, we are unable to estimate incremental costs for measures installed under this condition.

Table 1 shows the appropriate incremental cost definition for the energy efficient technologies from Focus Residential Programs included in this analysis.

Table 1. Measure Incremental Cost Definitions

Replace-on-Failure (Difference Compared to Baseline Cost)	
Ceiling fan	SEER 18
Clothes washers Tier 2	SEER 19
Clothes washers Tier 3	SEER 20
ENERGY STAR clothes washers	Boiler 90+ AFUE
ENERGY STAR clothes washers – common area	Boiler 90+ AFUE – custom
ENERGY STAR dishwasher	Boiler 90+ AFUE w/DHW – custom
ENERGY STAR dehumidifier	Boiler 83-89 AFUE – custom
ENERGY STAR refrigerator	Furnace 90+ AFUE w/ ECM
CFLs	LED exit sign
CFL fixtures	LED holiday lights
Torchiere	DHW sealed combustion
ENERGY STAR room AC	Power vent with EF of .80 or greater
SEER 14	Thermal (at least 80% AFUE)
SEER 15	Certified Home
SEER 16	ENERGY STAR windows
SEER 17	Ground source heat pump - custom
No Baseline (Full Material Cost and Installation Cost)	
Steam trap replacement	Home weatherization
Air sealing	Sidewall insulation
Attic insulation	Sill box insulation
Duct sealing	Faucet aerator
Floor insulation	Showerhead
Flue Closure	Water heating conversion
Foundation insulation	Water heating conversion – custom

Incremental Cost per Unit

For most measures, the PA team developed incremental costs from a review of published sources, including California's Database for Energy Efficient Resources (DEER), the Department of Energy (DOE), the American Council for an Energy Efficient Economy (ACEEE), and various market potential studies. For some measures, we also contacted local

equipment dealers and consulted other secondary sources. The source we used to establish the incremental cost of each measure is documented in the bibliography and in Table 6.

For most technologies, PA researched simple dollar estimates of incremental costs for installing these energy efficient measures. For some custom Apartment & Condo Efficiency Services program (ACES) measures, however, we researched incremental costs in dollars per unit of energy saved (in kWh or therms) instead of per measure, as the verified savings for these measures varied greatly across projects. This approach dampens the unknown effect of extraneous factors that may be responsible for the variance in energy savings for a given measure, such as the size and scope of individual projects. We then applied this dollar per unit of energy saved estimate to the average verified savings for each measure in the tracking database to calculate a dollar estimate. We used this latter approach for custom boilers, ground source heat pumps, and custom water heating conversions.

For our estimates we sought the most recent and most local cost data available. In the case of CFLs, for instance, we relied on Focus evaluation data from the *Second Annual Comprehensive CFL Market Effects Study* prepared by Glacier Consulting.[3] For this study, Glacier collected sales data from retailers in Wisconsin that accounted for 94 percent of all rewards paid in 2007. Using this data, we were able to estimate the average price of CFLs available in Wisconsin.

Where reliable local data were not available, we used several national sources, including DEER and DOE. Most recently updated in 2008, DEER provides detailed cost estimates for several energy efficient technologies based on extensive primary and secondary research. DEER uses data from retailer surveys, California program evaluations, manufacturer pricing, and other secondary sources for its cost estimates. The DOE's ENERGY STAR product website also reports cost estimates for several residential technologies using recent national industry and retail pricing data ranging in date from 2007 to 2009. The relevance of these sources to the Wisconsin economy is most suitable with respect to nationally distributed measures where installation costs are not factored in. For others, we made an effort to adjust costs based on Wisconsin labor costs and other relevant considerations.

Table 2 shows a comparison of our findings with the incremental cost estimates per unit, where available, that are currently being used for Focus on Energy's residential programs. The current values shown in Table 2 are from a spreadsheet of deemed incremental costs for selected residential measures provided to PA by WECC in August 2009.

[3] Rick Winch and Tom Talerico, Glacier Consulting Group. *Second Annual Comprehensive CFL Market Effects Study.* September 30, 2008.

Table 2. Unit Incremental Cost Comparison with Current Estimates for Focus on Energy Residential Programs

Measure	Current Incremental Cost per Unit ($)	Current Incremental Cost Source	Review Findings Incremental Cost per Unit ($)	Review Source
Clothes Washers Tier 2	200	ENERGY STAR	400	Conversations with contractors and FY08 rebate data
Clothes Washers Tier 3	200	ENERGY STAR	400	Conversations with contractors and FY08 rebate data
ES Refrigerator	250	ENERGY STAR	30	ENERGY STAR (2009)
SEER 14	250	Contractor survey (2007)	300	Conversations with contractors and DEER
SEER 15	300	Contractor survey (2007)	714	DEER, consistent with conversations with contractors
SEER 16	750	Contractor survey (2007)	1071	DEER, consistent with conversations with contractors
Furnace 90%+ AFUE w/ECM	950	Conversations with contractors	910	*Net-to-gross Savings Adjustments for ECM Furnaces*
Flue Closure	75	Conversations with contractors	110	Conversations with contractors
CFL	3	ENERGY STAR	2.88	*Second Annual Comprehensive CFL Market Effects Study*
CFL Fixtures	37	ENERGY STAR	25	ENERGY STAR (2009)
Torchiere	37	ENERGY STAR	42	Minnesota Deemed Savings Database
Water Heating Conversion	500	Conversations with contractors	500	Vermont Electric Efficiency Potential Study

Particularly noteworthy are the higher values we recommend for HVAC cooling measures and two of three appliances, i.e., approximately two times the values currently in use. Further, Table 3 shows a comparison of our findings for whole-home technologies to estimates, where available, used in the last b/c analysis.

Table 3. Unit Incremental Cost Comparison for Whole-Home Measures with Estimates Used in Last Benefit-cost Analysis

Measure	Incremental Cost per Unit Used in Last B/C Analysis ($)	Review Findings Incremental Cost per Unit ($)	Review Source
Air Sealing	375	304	ACEEE Texas Potential Study
Attic Insulation	900	959	Comparison of contractor estimates and American Housing Survey (AHS)
Sidewall Insulation	1,800	1,279	DEER and AHS

Incremental Cost Relative to Avoided Energy Costs

Simply comparing dollar-per-unit incremental costs is not very useful in comparing the cost-effectiveness of different technologies, as measures with higher incremental costs are often also higher energy savers. To facilitate comparison (and aggregation) of the cost-effectiveness of energy efficient technologies, PA calculated each measure's incremental cost relative to its avoided energy costs. Avoided cost is defined as the market value of the energy saved over the lifetime of the energy efficient measure calculated, on a per-unit basis, using the formulas below.

(1) $Lifetime\ kWh\ saved = \sum (kWh / (1 + D)^{Y-1})$

$Lifetime\ therms\ saved = \sum (therms / (1 + D)^{Y-1})$

$Lifetime\ kW\ saved = \sum (kW / (1 + D)^{Y-1})$

Where:

- Y is year of operation, from 1 through the measure life of the technology[4]
- D is a constant annual discount rate (assumed to be 0.05)

(2) *Lifetime Avoided Cost*
= (Lifetime kWh saved × $/kWh) + (Lifetime therms saved × $/therm) + (Lifetime kW saved × $/kW)

Where:

- $/kWh is market price per kWh (assumed to be $0.0793)
- $/therm is market price per therm (assumed to be $0.9350)
- $/kW is market price per kW (assumed to be $116)[5]

[4] Sources for measure lives are documented in the bibliography.

[5] These are the avoided costs for electric and gas that were originally agreed upon for use in the 2009 benefit-cost report and documented in a memo on the subject of b/c scenarios to Oscar Bloch and Carol Stemrich from Bobbi Tannenbaum on April 30, 2009. Subsequently, it was determined that the values

If the ratio of the incremental cost to the lifetime avoided cost is less than 1, the avoided cost of the measure is greater than the incremental cost and the measure is cost-effective. Conversely, if this ratio is greater than 1, the incremental cost outweighs the lifetime avoided cost and the measure is not cost-effective.

In addition to the full measure life, PA also calculated the ratio of the incremental cost in dollars to the *first-year* avoided energy cost. One can interpret this ratio as an approximate simple payback period in years, without any energy savings discount over the life of the measure.

Aggregating to Measure Categories for the Benefit-cost Analysis

The cost side of the b/c equation requires an incremental cost estimate for every historic measure installed through Focus programs. In prior years, Focus program planners and evaluators have simplified the complexity of this data requirement by combining similar measures into broader measure categories. The incremental cost then becomes an average across the category, usually weighted by some indicator of each measure's importance. For the current analysis, the PA team has followed the same approach, collapsing measure-level estimates found through our review into measure categories to be used for b/c analysis. This level of aggregation represents the incremental cost for installing a certain *type* of measure, instead of a specific technology.

In an effort to maintain consistency, PA followed as closely as possible the measure-category assignments used in the previous b/c analysis. For some programs, however, PA added measure categories to provide more detail. This was based on information we collected from our review. For instance, in the 2007 b/c analysis, ACES included only one measure category ("other") to represent all technologies installed through the program. To provide greater precision in estimating program incremental costs and to help illuminate which types of measures are most cost effective and which are least cost effective, PA disaggregated ACES measures into seven different categories.

Table 4 lists the categories used in the b/c analysis and the incremental cost measures included in each category.

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for avoided costs would be based on market prices and would account for variation in prices for peak vs. non-peak periods. However, that does not affect the results of this memo; it only highlights that care needs to be taken in how the incremental costs are applied.

Table 4. Aggregation of Analysis Measures into Benefit-cost Categories

Benefit-cost Measure Category	Incremental Cost Measures
Apartment and Condominium Efficiency Services	
CFL	CFL
CFL Fixtures	CFL Fixtures
Other	Boiler 83%-89% - Custom
	Boiler 90% or Greater - Custom
	Boiler 90% or Greater w/DHW - Custom
	SEER 14
	DHW Sealed Combustion
	ES Clothes Washer
	ES Clothes Washer - Common Area
	ES Dehumidifier
	ES Dishwasher
	ES Refrigerator
	ES Room AC
	ES Windows
	Furnace 90%+ AFUE w/ECM
	Ground Source Heat Pump - Custom
	LED Exit Sign
	Steam Trap Replacement
	Attic/Ceiling Insulation
	Sidewall Insulation
	Water Heating Conversion - Custom
	Ground Source Heat Pump - Custom
Showerhead - Gas	Showerhead - Gas
Showerhead - Electric	Showerhead - Electric
Faucet Aerator - Gas	Faucet Aerator - Gas
Faucet Aerator - Electric	Faucet Aerator - Electric
Efficient Heating and Cooling Initiative	
Other	Boiler 90% or Greater
	Flue Closure
ECM Furnace	Furnace 90%+ AFUE w/ECM
SEER 12*	N/A
SEER 13*	N/A
SEER 14	SEER 14
SEER 15	SEER 15
SEER 16	SEER 16
SEER 17+	SEER 17
	SEER 18
	SEER 19
	SEER 20

Benefit-cost Measure Category	Incremental Cost Measures
ENERGY STAR Products	
CFL	CFL
CFL Fixtures	CFL Fixtures
	Torchiere
Other Lighting	Ceiling Fan
	LED Holiday
Other Appliances	ES Dehumidifier
	ES Refrigerator
Other	Flue Closure
	Power Vent with EF of .80 or Greater
	Thermal (At least 80% AFUE)
Clothes Washers	Clothes Washers Tier 2
	Clothes Washers Tier 3
Home Performance with ENERGY STAR	
Other Shell	Duct Sealing
	Floor Insulation
	Foundation Insulation
	Sill Box Insulation
Other**	N/A
ECM Furnace*	ECM Furnace (EHCI)
SEER 12*	N/A
SEER 13*	N/A
SEER 14+*	N/A
Air Sealing	Air Sealing
Attic Insulation	Attic/Ceiling Insulation
Sidewall Insulation	Sidewall Insulation
Targeted Home Performance with ENERGY STAR	
Home Weatherization	Home Weatherization
Other**	Home Weatherization
Wisconsin ENERGY STAR Homes	
Certified Home	Certified Home
ECM Furnace*	ECM Furnace (EHCI)
SEER 12*	N/A
SEER 13*	N/A
SEER 14+*	N/A
Other**	Certified Home
Head Start	
CFL	CFL

* Previous b/c analysis categories with no FY08 installations; included only for historical program measures

** Weighted average of all incremental cost analysis measures for the program

For some programs, the previous b/c analysis included historic measure categories that, as of FY08, are no longer among the measures installed. For instance, central air conditioners and ECM furnaces were previously installed through Home Performance with ENERGY STAR

(HPWES) and Wisconsin ENERGY STAR Homes (WESH) but now are installed exclusively through Efficient Heating & Cooling (EHCI). We decided to continue to include these measure categories in the current b/c analysis—and hence in our incremental cost review—to represent the full range of measures historically installed through these programs dating back to FY02. Thus, for SEER 12 and SEER 13 air conditioners, we defaulted to the incremental cost dollar values used in the 2007 b/c analysis. Due to changes in code, SEER 13 is currently the baseline efficiency level for central air conditioners under a replace-on-failure condition. As a result, these measures are no longer installed through Focus residential programs. However, we still needed to include incremental costs for these air conditioners installed in earlier program years when the baseline was a less efficient unit. For this reason, we do not recommend any changes to the previous incremental cost estimates for these measures.

In the previous b/c analysis, air conditioners with efficiency levels of SEER 14 or above were grouped into one category. Considering the shift toward installing higher efficiency air conditioners the EHCI in recent years, we felt it necessary to provide a more detailed set of categories in the current b/c analysis. For HPWES and WESH, however, we again default to the incremental cost estimates used in the last b/c analysis as air conditioners are no longer installed through these programs.

ECM furnaces were included in our incremental cost review, so we simply applied our dollar per unit incremental cost estimate to the historic ECM installations in HPWES and WESH.

For each measure category, we calculated a savings-weighted average of incremental costs. The weight of each measure within each category is its contribution to energy savings, calculated as the frequency of installations multiplied by the lifetime avoided cost per unit.[6]

To make the costs of measures comparable within a category, we expressed them as an incremental cost multiplier, which is the ratio of dollars of incremental cost to dollars of avoided cost. To roll these together into a single category we calculated an average of the incremental cost multipliers, weighted by the relative proportion of savings in FY08. Thus, to estimate the incremental cost for program savings in any given year, the incremental cost multiplier is applied to the savings for that category. We have used first-year verified gross savings as the basis for the multipliers we plan to use in future semiannual and b/c reports; however lifetime verified gross multipliers would serve equally well. In Table 5, we show both sets of multipliers.

We note that aggregating in this way is more stable than aggregating on the basis of an average incremental cost per installation, if those values are to be applied over multiple periods. That is because the underlying variance is much less, taking advantage of the correlation between cost and savings as the measures are combined. For instance, we estimated the incremental cost of a SEER 17 air conditioner to be $1,666 and the incremental cost of a SEER 20 air conditioner to be $2,919. The difference is about $1,250, a 75 percent increase over the incremental cost of the SEER 17. The ratio of incremental costs to first-year avoided costs is much closer: 20.82 for SEER 17 and 23.77 for SEER 20. This is only a 14 percent increase between SEER 17 and SEER 20. Thus, change over time in the proportions

[6] We us the same approach to average the lifetime of measure within each category. Measure lifetime is used for estimating lifetime avoided costs.

of the installed measures within a category introduces less error using the average-avoided-cost-based multiplier than if a straight average-cost-per-installation multiplier were used.

Even though this approach to aggregating measures is more stable than a straight averaging of costs, it is still sensitive to changes over time in the proportion of each measure, suggesting the value of re-weighting each category on a regular basis.

We note that under this approach incremental cost estimates for a single measure category usually vary from one program to another. This is due to differences in the relative proportion of that measure installed and differences in the share of energy savings attributed to it.

The previous b/c analysis also included a category to represent "other" measures, i.e. measures that did not fall under any of the denominated set of measure categories. For the ACES, EHCI, and ENERGY STAR Products (ESP) programs, we estimated "other" measures by taking a weighted average (by avoided cost) of the incremental cost estimates for the technologies included in our review that did not fit into another b/c category. For example, incremental costs for "other" measures in ESP were estimated from a weighted average of the incremental costs of power vent water heaters, 80 percent or greater thermal water heaters, and flue closures. We took this approach for these programs because we had selected and researched incremental costs for multiple "other" technologies that account for the most FY08 energy savings among all "other" technologies through the program.

For HPWES, Targeted Home Performance with ENERGY STAR (THPWES), and WESH, we reviewed few or no technologies that did not fit into one of our b/c categories. As a result, we estimated the incremental costs for "other" measures in each program by taking a weighted average of the estimated incremental costs of *all* technologies we reviewed for that program. Once again, our rationale for this approach centers on the high proportion of residential energy savings achieved by the technologies we selected for review. In the cases of THPWES and WESH, we only reviewed home weatherization and certified home, respectively, as these two measures account for the majority of avoided costs for these programs. For this reason, the "other" categories for these two programs take on the same incremental cost relative to avoided costs estimates as these measure categories.

Incremental Cost Estimates

Table 5 represents our estimate of incremental costs relative to first-year and lifetime avoided costs (verified gross), by program and measure categories used in the most recent b/c analysis. The values in either column can serve as a multiplier against energy savings, as long as they are applied to the correct savings value; i.e., first-year or lifetime. Detailed measure-level data with estimates for each technology averaged across all residential programs are shown in Table 6.

Table 5. Benefit-cost Category Level Incremental Costs Relative to Avoided Costs

Benefit-cost Measure Category	Incremental Cost per Dollar First-Year Avoided Cost ($)	Incremental Cost per Dollar Lifetime Avoided Cost ($)
Apartment and Condominium Efficiency Services		
CFL	0.73	0.14
CFL Fixtures	0.69	0.13
Other	6.64	0.53
Showerheads - Gas	1.19	0.15
Showerheads - Electric	0.69	0.09
Faucet Aerators - Gas	0.86	0.11
Faucet Aerators - Electric	0.51	0.06
Efficient Heating and Cooling Initiative		
Other	17.56	1.34
ECM Furnace	10.02	0.71
SEER 12*	3.91	0.30
SEER 13*	5.66	0.43
SEER 14	11.70	0.89
SEER 15	14.86	1.14
SEER 16	15.45	1.18
SEER 17+	21.58	1.65
ENERGY STAR Products		
CFL	0.71	0.13
CFL Fixtures	2.62	0.48
Other Lighting	4.99	0.38
Other Appliances	0.70	0.07
Other	5.89	0.52
Clothes Washers	17.84	1.92
Home Performance with ENERGY STAR		
Other Shell	13.26	0.90
Other	7.54	0.51
ECM Furnace*	10.02	0.71
SEER 12*	3.91	0.30
SEER 13*	5.66	0.43
SEER 14+*	6.42	0.49
Air Sealing	4.03	0.27
Attic Insulation	8.95	0.61
Sidewall Insulation	5.80	0.39
Targeted Home Performance with ENERGY STAR		
Other	17.73	1.35
Home Weatherization	17.73	1.35
Wisconsin ENERGY STAR Homes		
Other	8.93	0.60
ECM Furnace	10.02	0.71
SEER 12*	3.91	0.30

Benefit-cost Measure Category	Incremental Cost per Dollar First-Year Avoided Cost ($)	Incremental Cost per Dollar Lifetime Avoided Cost ($)
SEER 13*	5.66	0.43
SEER 14+*	6.56	0.50
Certified Home	8.93	0.60
Head Start		
CFL	0.65	0.12

* Previous b/c analysis categories with no FY08 installations; included only for historical program measures

Table 5 shows that CFLs and water saving measures (i.e., low-flow showerheads and faucet aerators) are among the most cost-effective measures across programs. These measures generally have simple payback periods of less than one year. Conversely, Table 5 shows that efficient central air conditioners and ENERGY STAR clothes washers are among the least cost-effective energy efficient technologies in residential programs. These technologies show simple payback periods approaching, and in some cases *exceeding*, their useful measure life.

Challenges and Limitations in Estimating Incremental Cost

Generating point estimates of the incremental cost of energy efficient technologies poses several challenges, especially for some of the more complex custom measures in the ACES program. These challenges present several limitations to our estimates.

First, some energy efficient measures are customized to a given building, as the appropriate size and efficiency of these measures vary greatly by individual building specifications. Many HVAC, shell, and water heating technologies fall into this category. These variations in size and efficiency factors affect the cost of the technologies, making it difficult to generalize dollar estimates of their incremental cost. In our analysis, we addressed this problem in several different ways. As previously stated, for some measures where using a deemed dollar amount per unit was not feasible, we researched levelized costs and applied those estimates to verified savings reported in the FY08 Focus data.

For some other measures, such as insulation measures and windows, we addressed this problem by estimating the characteristics of a "typical" Wisconsin home and applying deemed savings under these assumptions. To estimate the characteristics of a typical single-family home and multi-family home (for ACES), we used the 2005 US Census Department's American Housing Survey (AHS) data for Census Region 2[7]. We then estimated the most appropriate measure specifications that would be installed in this typical home. For example, the AHS estimates that on average, Wisconsin single family homes (excluding mobile homes) have 2,131 square feet of living space and 2 floors. Given this data, we used a 3.5 ton air

[7] In addition to the AHS, we also relied on the ACEEE Report *Energizing Virginia: Efficiency First* to estimate window coverage for single family homes.

conditioning unit, which is an appropriate capacity for this size home[8]. Also, given this information, we estimated that an average home has (2,131 / 2) = 1,066 square feet of ceiling coverage. For ACES, the AHS estimates that an average multifamily building has 33,425 square feet of living space and 3.3 floors. Using this data, we estimated an average of (33,425 / 3.3) = 10,129 square feet of ceiling coverage. We then applied the cost per square foot of upgrading insulation in the ceiling to the recommended levels for Wisconsin to this estimate, assuming full insulation coverage.

Also, in some cases it is difficult to parse the confounding effect of factors such as availability, brand name, and other consumer preferences from the costs of energy efficiency. This challenge is especially significant in the case of residential appliances such as refrigerators and dishwashers, where there are numerous manufacturers competing in the marketplace.

Another challenge in evaluating incremental costs is assessing the differences in the market price of energy efficient equipment and services across different geographies. Undoubtedly, there are differences in the cost to the consumer from region to region across the country, as well as between rural and urban areas within the same region. Some of the most detailed cost data available is from the DEER database, which originates in California and was a source we relied upon for many of our dollar estimates. Without fully understanding differences in the energy efficiency market between California and Wisconsin, we must be cautious in generalizing those estimates to Wisconsin customers. Further, there is likely significant variation in material and service cost between rural and urban areas *within* the state in addition to regional differences. These factors are notable limitations of the data and would be an area for future refinement of incremental cost estimates.

Additionally, this analysis does not account for changes in market prices of energy efficient technologies and baseline measures over the time period of the historic b/c analysis itself (i.e., FY02 through FY09). With the exception of SEER 12 and SEER 13 air conditioners, where we have frozen the incremental cost at the point where they were dropped out of the Focus offering, we apply incremental cost estimates reported here for all program years. This was reasonable in previous years when Focus was less mature and error introduced by this simplification was minimal. As Focus matures, however, it is an area where a refinement in our approach may be warranted.

Finally, and as previously mentioned, one of the most important limitations of our approach is that we aggregate measure-level estimates to the b/c category level through weighting by avoided costs from FY08 installations. Thus, the weights accurately reflect program activities from that year but, to the extent that the distribution of measures installed varies from year to year within a given program, do not accurately reflect the average incremental costs for other years. As noted, we made an effort to reduce this problem through our estimate of a ratio of incremental cost to first-year avoided cost. Where these ratios themselves are quite different for the aggregated measures, however, weighting problems may be significant. Clearly, this problem is especially relevant for the “other” b/c categories, which often aggregate quite dissimilar types of technologies.

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[8] We acknowledge that appropriate sizing of air conditioning units is dependent on more factors than square footage of living space. We use square footage as a guideline for estimation based on its close relationship with HVAC sizing and the availability of the data.

An obvious way to address this problem would be to re-weight measures within each category by their historic savings distribution for each individual program year. However, insofar as the available data are adequate to do an annual re-weighting, the aggregation process itself possibly could be avoided altogether and a measure-level estimate of incremental costs obtained. Clearly, this “measure-level” estimate would still require some form of aggregation across the large number of different measures installed, but it would be aggregation at a much lower level with lower variance among the aggregated measures and hence greater stability. We believe it will be fruitful to further elucidate the strengths and weaknesses of these two alternatives to the approach that was used for the pending b/c analysis; i.e., frequent re-weighting of the incremental cost multipliers or use of a much finer-grained level of analysis. Given the complexity of the underlying reality, it may very well be that a combination of the two approaches is best.

Table 6. Measure-level Data with Estimates Averaged Across all Residential Programs

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
Ceiling Fan	Appliances	ENERGY STAR ceiling fan	conventional ceiling fan	unit	10	ENERGY STAR	86	ENERGY STAR savings calculator	175.00	0.00	0.00	112.52	0.76	6.20
Clothes Washers Tier 2	Appliances	CEE Tier 2 (MEF=2.0)	MEF=1.26	unit	12	FY07 FOE Interim Benefit-Cost Analysis	400	Comparison of local market data and FY08 Focus rebate data	187.20	6.10	0.00	191.25	2.09	19.46
Clothes Washers Tier 3	Appliances	CEE Tier 3 (MEF=2.2)	MEF=1.26	unit	12	FY07 FOE Interim Benefit-Cost Analysis	400	Comparison of local market data and FY08 Focus rebate data	218.99	7.01	0.00	222.57	1.80	16.73
ES Clothes Washer	Appliances	ENERGY STAR clothes washer (minimum MEF=1.8)	conventional clothes washer	unit	12	FY07 FOE Interim Benefit-Cost Analysis	400	Comparison of local market data and FY08 Focus rebate data	123.36	18.16	0.00	249.04	1.61	14.95
ES Clothes Washer - Common Area	Appliances	Commercial ENERGY STAR clothes washer (minimum MEF=1.8);	conventional clothes washer	unit	12	FY07 FOE Interim Benefit-Cost Analysis	400	Comparison of local market data and FY08 Focus rebate data	384.00	22.00	0.00	474.82	0.84	7.84
ES Dehumidifier	Appliances	ENERGY STAR dehumidifier	conventional dehumidifier	unit	12	ENERGY STAR	0	Minnesota Deemed Savings Database, ENERGY STAR savings calculator	50.00	0.00	0.00	36.90	0.00	0.00
ES Dishwasher	Appliances	ENERGY STAR dishwasher	conventional dishwasher	unit	11	ENERGY STAR	50	Vermont Electric Efficiency Potential Study	50.68	3.33	0.00	62.17	0.80	7.01
ES Refrigerator	Appliances	ENERGY STAR refrigerator	conventional refrigerator	unit	13	ENERGY STAR	30	ENERGY STAR savings calculator, Vermont Electric Efficiency Potential Study	71.15	0.00	0.01	62.64	0.48	4.72

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
Boiler 83%-89% - Custom	Boilers	85 AFUE for space heating	80 AFUE	unit	20	ENERGY STAR	36,424	ENERGY STAR savings calculator	0.00	4,639.27	0.00	56,760.38	0.64	8.40
Boiler 90% or Greater	Boilers	90+ AFUE for space heating (deemed savings)	80 AFUE	unit	20	Assumed same as 83%-89% Boiler	1,911	WECC contractor survey, 2007; calculated using a non-weighted average of 90%+ modulating boiler equipment and installation costs compared to 83% non-modulating	0.00	98.00	0.00	1,199.01	1.59	20.86
Boiler 90% or Greater - Custom	Boilers	90+ AFUE for space heating	80 AFUE	unit	20	Assumed same as 83%-89% Boiler	4,645	Calculated by applying $/therm (estimated by using Boiler 90% or Greater $/unit and ENERGY STAR savings calculator savings) to FY08 verified savings	0.00	525.86	-0.07	6,328.68	0.73	9.60
Boiler 90% or Greater w/DHW - Custom	Boilers	90+ AFUE for space/water heating	80 AFUE	unit	20	Assumed same as 83%-89% Boiler	12,982	Calculated by applying $/therm (estimated by using Boiler 90% or Greater $/unit and ENERGY STAR savings calculator savings) to FY08 verified savings	434.24	1,469.79	0.00	18,433.09	0.70	9.22

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
ES Room AC	Cooling Equipment	ENERGY STAR room AC (EER=10.8)	EER=9.8	unit	9	ENERGY STAR	30	ENERGY STAR savings calculator	29.60	0.00	0.11	114.14	0.26	1.96
SEER 14	Cooling Equipment	SEER 14 split-system air conditioner, 3 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	300	Comparison of local contractor estimates and DEER	73.78	0.00	0.17	335.42	0.89	11.70
SEER 15	Cooling Equipment	SEER 15 split-system air conditioner, 3 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	714	DEER, consistent with local contractor estimates	140.13	0.00	0.32	628.76	1.14	14.86
SEER 16	Cooling Equipment	SEER 16 split-system air conditioner, 3 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	1,071	DEER, consistent with local contractor estimates	197.81	0.00	0.46	907.10	1.18	15.45
SEER 17	Cooling Equipment	SEER 17 split-system air conditioner, 3.5 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	1,666	DEER	239.18	0.00	0.53	1,047.09	1.59	20.82
SEER 18	Cooling Equipment	SEER 18 split-system air conditioner, 3.5 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	2,086	DEER	301.59	0.00	0.71	1,384.40	1.51	19.72
SEER 19	Cooling Equipment	SEER 19 split-system air conditioner, 3.5 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	2,503	DEER	341.94	0.00	0.76	1,515.57	1.65	21.61
SEER 20	Cooling Equipment	SEER 20 split-system air conditioner, 3.5 ton	SEER 13	unit	20	FY07 FOE Interim Benefit-Cost Analysis	2,919	DEER	364.29	0.00	0.81	1,606.78	1.82	23.77
Ground Source Heat Pump - Custom	Ground Source Heat Pump	EER=14	SEER 13 air-source heat pump	unit	18	ACEEE report Emerging Technologies Report, 2007	7,303	Calculated by applying ACEEE Emerging Technologies Report, 2006 $/kWh to FY08 verified savings	7,437.57	3,201.14	5.57	51,908.91	0.14	1.73

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
Furnace 90%+ AFUE w/ECM	Heating Equipment	90%+ AFUE w/ ECM fan motor	90%+ AFUE w/o ECM fan motor	unit	23	FY07 FOE Interim Benefit-Cost Analysis	910	FY08 FOE Net-to-gross Savings Adjustments for ECM Furnaces	785.50	16.91	0.11	1,286.55	0.71	10.02
Steam Trap Replacement	Heating Equipment	steam trap replacement	None	unit	5	DOE Federal Technology Alert: Steam Trap Performance Assessment	94	DOE Federal Technology Alert: Steam Trap Performance Assessment	0.00	165.92	0.00	705.24	0.13	0.61
Air Sealing	Shell	air infiltration reduction	None	home	25	FY07 FOE Interim Benefit-Cost Analysis	304	ACEEE report Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to Meet Texas's Growing Electricity Needs	0.00	82.08	0.00	1,135.70	0.27	3.96
Attic/Ceiling Insulation	Shell	add R-30, blown	None	home	25	FY07 FOE Interim Benefit-Cost Analysis	959	Calculated using local contractor $/sq ft estimates and American Housing Survey building characteristics	154.44	87.26	0.11	1,584.96	0.61	8.95
Attic/Ceiling Insulation - ACES	Shell	add R-30, blown	None	building	25	FY07 FOE Interim Benefit-Cost Analysis	9,116	Calculated using local contractor $/sq ft estimates and American Housing Survey building characteristics	42.85	412.65	0.00	5,760.06	1.58	23.42

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
Duct Sealing	Shell	material and installation	None	home	25	ACEEE report Emerging Energy Saving Technologies and Practices for the Building Sector as of 2004	498	DEER	981.82	76.36	0.09	2,364.88	0.21	3.11
ES Windows	Shell	.35-U, clear	.67-U, clear	home	25	GDS Measure Life Report, 2007	912	Calculated using DEER cost estimates and American Housing Survey multifamily building characteristics (assumed 15% wall coverage)	2,170.50	360.58	1.66	10,382.40	0.09	1.30
Floor Insulation	Shell	R-30, blown	R-0	home	25	Assumed same as wall/attic insulation	959	Calculated using Attic/Ceiling $/sq ft and American Housing Survey building characteristics	121.80	65.31	0.09	1,195.34	0.80	11.87
Flue Closure	Shell	closing unused chimney	None	unit	25	Assumed same as duct sealing	110	Comparison of contractor estimates	0.00	60.00	0.00	830.20	0.13	1.96
Foundation Insulation	Shell	R-11, material and installation	R-5	home	25	Assumed same as wall/attic insulation	900	Lucas, 2003	137.83	93.53	0.00	1,455.96	0.62	9.15
Home Weatherization	Shell	insulation and weatherization	None	home	20	Vermont Electric Efficiency Potential Study	7,000	Calculated (90% of average THPES incentives)	1,192.00	295.00	0.21	5,166.17	1.35	17.73

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
Sidewall Insulation	Shell	R-13, blown	R-0	home	25	FY07 FOE Interim Benefit-Cost Analysis	1,279	Calculated using DEER cost estimates and American Housing Survey building characteristics	285.53	180.43	0.25	3,261.69	0.39	5.80
Sidewall Insulation - ACES	Shell	R-13, blown	R-0	building	25	FY07 FOE Interim Benefit-Cost Analysis	9,521	Calculated using DEER cost estimates and American Housing Survey building characteristics	21.67	526.33	0.00	7,308.16	1.30	19.28
Sill Box Insulation	Shell	spray foam insulation	None	home	25	Assumed same as wall/attic insulation	740	Comparison of local contractor estimates	52.03	33.06	0.00	518.54	1.43	21.12
CFL	CFL	CFL bulb	incandescent bulb	unit	6	FY07 FOE Interim Benefit-Cost Analysis	3	Weighted average of available products in Wisconsin per the Focus on Energy Second Annual Comprehensive CFL Market Effects Study; ENERGY STAR savings calculator for baseline cost	46.68	0.00	0.00	21.57	0.13	0.71
CFL Fixtures	CFL Fixtures	CFL fixtures	conventional fixture	unit	6	Assumed same as CFL	25	ENERGY STAR savings calculator	108.27	0.00	0.00	48.59	0.51	2.74
Torchiere	CFL Fixtures	torchiere	incandescent fixture	unit	8	GDS Measure Life Report, 2007	42	Minnesota Deemed Savings Database	349.00	0.00	0.01	195.54	0.21	1.46
LED Exit Sign	LED Lighting	LED exit sign	incandescent exit sign	unit	10	Minnesota Deemed Savings Database	20	Minnesota Deemed Savings Database	298.65	0.00	0.02	212.28	0.09	0.76

Incremental Cost Measure	Measure Category	Description	Baseline	Unit	Measure Life	Measure Life Source	Incremental Cost Dollars	Incremental Cost Dollars Source	Verified kWh per Unit	Verified Therms per Unit	Verified kW per Unit	Overall Avoided Cost	Incremental Cost Dollars per Dollar Lifetime Avoided Cost	Incremental Cost Dollars per Dollar Avoided Cost Year 1
LED Holiday	LED Lighting	LED holiday lights	incandescent holiday lights	unit	20	Minnesota Deemed Savings Database	6	Consumer Reports; compared with market data	15.20	0.00	0.00	15.77	0.38	4.98
Certified Home	Certified Home	ENERGY STAR certified home	proposed 2008 IECC code-compliant home	home	25	Assumed	805	ACEEE report Energizing Virginia: Efficiency First, ENERGY STAR savings calculator	0.00	96.41	0.00	1,334.01	0.60	8.93
Water Heating Conversion	Water Heating Conversion	electric to gas water heating	None	unit	10	Vermont Electric Efficiency Potential Study	500	Vermont Electric Efficiency Potential Study	3,280.00	-26.00	0.25	2,146.90	0.23	1.89
Water Heating Conversion - Custom	Water Heating Conversion	electric to gas water heating	None	unit	10	Vermont Electric Efficiency Potential Study	22,733	Calculated by applying Vermont Electric Efficiency Potential Study $/kWh to FY08 verified savings	140,194.25	-6,311.25	20.00	61,103.67	0.37	3.02
DHW Sealed Combustion	Water Heating Equipment	sealed-combustion water heater	gas water heater, EF=.58	unit	13	Assumed same as Water Heater	407	Comparison of market data, DEER	0.00	726.64	0.00	6,701.20	0.06	0.60
Power Vent with EF of .80 or Greater	Water Heating Equipment	Power Vent water heater with EF of .80 or greater	natural venting water heater	unit	15	WECC deemed savings	500	WECC deemed savings	-49.26	45.00	0.00	410.62	1.22	13.27
Thermal (At least 80% AFUE)	Water Heating Equipment	condensing unit (thermal efficiency 90% +)	less efficient gas water heater	unit	15	WECC deemed savings	250	WECC deemed savings	0.00	85.00	0.00	866.17	0.29	3.15
Faucet Aerator	Water Saving Measures	.5 gallon/minute	no faucet aerators	unit	10	Minnesota Deemed Savings Database	7	DEER	46.21	5.79	0.00	73.64	0.09	0.72
Low Flow Showerhead	Water Saving Measures	.25 gallon/minute	2.5 gallon/minute showerhead	unit	10	Minnesota Deemed Savings Database	29	DEER	153.91	18.71	0.00	240.83	0.12	0.98

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