Meta results in NEB/NEIs – progress in NEB values, attribution to measures, and state adoption into cost-effectiveness tests

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Abstract

Serious analysis of NEBs has been around for more than 20 years. There are now well more than 300 studies estimating NEB values from around the US and internationally. These results cover hundreds of programs and include thousands of survey results, financial calculations and model runs. Unfortunately, research tended to re-hash most of the same NEB categories and calculations that had been estimated since the early 2000s – until recently. This paper reviews the status of quantitative NEBs work (with a focus on the residential side), examines gaps, and assembles recent work and provides new research that works to address two key issues:

- Values for NEBs for some key health and other benefits, and
- Demonstrates practical approaches for attributing program-wide benefits to measure.

This paper also examines the degree to which NEBs are being considered and adopted into State cost-effectiveness tests around the US. We review the activity in considering and adopting NEBs over time, and what states are doing in incorporating NEBs in tests including: adders (adding a deemed dollar or percentage amount to the value of energy savings to stand in for a bundle of NEBs), "easy-to-measure" NEBs, all NEBs (estimating a wide range of NEBs), or a hybrid of these approaches, including an adder element and an estimated element. Our research shows steady and increasing interest in NEBs by states since 2001, with most states touching on the issue by 2010 and continuing to increase since then. The paper discusses NEB treatment, values, and processes in different states, and discusses some of the barriers and opportunities to greater adoption in the future – barriers related to concerns about NEBs possibly introducing additional risk into benefit-cost tests, and opportunities as NEBs measurement improves and as states become more comfortable introducing NEBs because they are in place in more and more states.

Introduction

Energy efficiency programs deliver more impacts than simply the energy savings that are the primary purpose for most programs. These other impacts are called non-energy benefits, non-energy impacts, (NEBs/NEIs) or multiple benefits, and they are realized by the program participants themselves (e.g. comfort), the utility (e.g. fewer bill-related calls), and society at large (e.g. fewer emissions or more jobs). Research to quantify, and not just hypothesize about NEBs began in the mid-1990s (Magouirk 1995, Skumatz 1997), and the body of literature continues to grow. There are numerous reviews of the literature that look for quantitative estimates from studies across the country that can be adapted to a local program (Skumatz 2009, NMR 2011, Itron 2016, Apprise 2018 and many others), or review and assess quantitative methods applied (Skumatz and Gardner 2002, Summit Blue 2006, Skumatz, et.al. 2010), or discuss the "state of NEBs", gaps, and broad results and progress in adoption by States (NEEP 2017, Skumatz 2012–2016). This paper focuses instead on two main topics in NEBs:

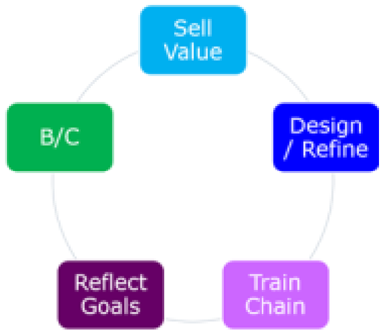

Figure 1. Main Uses of NEBs. Source: Skumatz 2009.

- A review of recent progress addressing two key gaps in NEBs, including new NEBs, and the issue of identifying measure-specific NEBs; and
- Progress, opportunities and barriers in state adoption of NEBs into cost-effectiveness tests.

NEBs are not just studied for NEBs' sake. They have multiple uses (Figure 1).

Sell Value: NEBs can be used in marketing, to help potential program participants recognize the value of the benefits they may receive from adopting the energy efficient measures, expanding their computations of return on investment (ROI) from participation from including only energy savings to include the broader list of net benefits associated with the measures.

Design/Refine: The NEB values can be used to help optimize program design and delivery. Given a fixed budget, the NEBs values can help identify the best mix of measures and/or program targeting to maximize program benefits or return. Groups with greatest return can be targeted, and the positive and negative NEBs can be extremely informative in setting the appropriate level of financial incentives to gain the participation desired, or to identify and offset any negative NEBs (aka "barriers") associated with the program or its measures.

- **Train the Chain**: The program's delivery and success often depend on the performance of implementers, and an array of upstream actors for market transformation programs. Making sure these actors are cognizant of NEBs valued by potential participants – and delivered by the equipment included in the program – improves participation and measure uptake.
- **Reflect Goals**: Low income programs have goals beyond energy savings (e.g. hardship goals, etc.), and some other programs do as well (e.g. job creation goals for ARRA programs). NEBs specifically reflect the value and performance toward an array of "non-energy" goals.
- **Benefit-Cost Test**: Utilities and regulators use benefit-cost tests to make decisions about energy efficiency (EE) measures, programs, and portfolios. Including a fuller array of the net benefits from programs (estimated as NEBs) – beyond energy savings – reduces bias in decision-making and resource allocation regarding programs.

Research on New NEBs

For some time, little progress was made in expanding the types of NEBs estimated beyond tweaking estimates that were developed in the early 2000s. That work generally covered the basic NEBs as listed in Table 1.

On the residential side, there was interest in other NEBs, but little new quantitative work emerged until about 2015, and that work focused in the area of health and safety (Hawkins 2016, more mentioned below). For most programs, energy savings is the program goal, and that is primarily measured using impact evaluations. NEBs are not the focus. Historically, most NEB progress seems to pioneer in low income programs, where energy savings are not the driver for the program. In the US and internationally, part of the rationale for many of these programs has to do with hardship/easing burdens, and concern over making homes healthier. As a result, NEBs are important because they are the method of measuring these impacts.

The area is new, and there is not a great deal of convergence on methods or assumptions yet, and the results are provided as "apples and oranges" but a review of the new literature finds the following effects and values from improved conditions indoors or measures delivered. Research is on-going; results are provided in Table 2.

Not quantified, but also discussed in literature include: Formaldehyde benefits, hypertension and cardiovascular disease reductions, Mental health improvements, Moisture effects, radon, sinusitis, throat irritation, and VOC health effects and reductions in wheezing (in Cowan 2016), and effects on safety and ventilation (TecMarketWorks and Skumatz 2001 and NMR 2011), scalding (Tonn 2014, Shields 2013).

Societal Health Costs: In forthcoming work for California, SERA used EPA's COBRA model to estimate the societal health benefits from reduced criteria emission from generation at \$119–\$269/1,000 kWh saved. In addition, this study includes estimate of other health and safety costs (Skumatz et. al. 2019).

In other areas, we see newer estimating work adding to the body of quantitative literature, and these estimates address attributable changes in use of short-term loans, detergent use, educational outcomes, landfill reductions, and other NEBs.

Recent Progress – Attribution of NEBs to Measures in Multi-Measure Programs

There are four main methods (Figure 2) used to estimate individual NEB values: 1) direct estimation using data from the utility or from a participant business (e.g. arrearage study); 2) an attributable change in an incidence or occurrence times an appropriate valuation (e.g. X fewer minutes of billing-related phone calls per household times marginal CSR wage rate at a utility); 3) third party models (e.g. identifying emission reductions or job and economic multiplier impacts), and 4) survey-based methods (e.g. reports on the relative value of comfort, or fewer sick days experienced, which are then valued).

Estimating the wide variety of NEBs usually requires nearly all these methods; some NEBs are best estimated with models, and others require surveys.

Most of the survey-based work on NEBs in the residential sector has been conducted "program wide", sampling randomly from participants because these surveys are often modules that

Table 1. NEBs commonly estimated and typical values (Residential Weatherization Program).

Subtotals by major categories Weatherization Programs	Dollar NEB Values Range Low-High		Typical Value	Percentage NEB Values Range Low-High		Typical Value
UTILITY PERSPECTIVE						
Payment-related	$2.55 -	$14.50	$6.40	1% -	14.5%	4.7%
Added if Low Income subsidies avoided	$3.00 -	$25.00	$13.00	4% -	29.0%	16.4%
Service Related	$0.10 -	$8.50	$3.25	0.1% -	2.7%	0.8%
Other Primary Utility	$0.13 -	$2.60	$1.40	2.1% -	3.3%	2.4%
TOTAL UTILITY NEBs	$5.78 -	$50.60	$24.05	7.4% -	49.5%	24.4%
UTILITY NEBs MULTIPLIER	3% -	25%	12%			
SOCIETAL PERSPECTIVE						
Economic	$8.00 -	$340.00	$115.00	3.0% -	237.6%	31.1%
Environmental / Emissions	$3.00 -	$180.00	$60.00	0.7% -	57.9%	7.1%
H&S equipment / fires	$0.00 -	$0.30	$0.00	0.3% -	0.3%	0.0%
Health Care	$0.00 -	$0.00	$0.00	0.0% -	0.0%	0.0%
Water / Wastewater infrastructure	$1.00 -	$28.00	$15.00	0.9% -	33.1%	17.0%
TOTAL SOCIETAL NEBs	$12.00 -	$548.30	$190.00	5.0% -	329.0%	55.3%
SOCIETAL NEBs MULTIPLIER	6% -	274%	95%			
PARTICIPANT PERSPECTIVE						
Water and Other bills	$2.85 -	$54.00	$15.00	4.5% -	63.4%	20.0%
Financial / customer service	$0.27 -	$36.70	$3.60	8.7% -	16.4%	3.4%
Economic Dev'p / Hardship	$0.00 -	$115.00	$75.00	26.3% -	55.3%	8.0%
Equipment Operations	$26.00 -	$127.00	$82.00	17.1% -	42.7%	28.4%
Comfort, Noise, Related	$26.00 -	$105.00	$69.00	12.2% -	51.3%	26.6%
Health / Safety	$3.02 -	$100.50	$16.50	1.5% -	59.5%	12.8%
Control / Education and Contributions	$26.25 -	$177.00	$89.75	19.8% -	72.0%	26.2%
Home Improvements	$10.50 -	$77.00	$36.00	8.3% -	38.4%	18.8%
Special / reliability / other	$0.00 -	$4.05	$0.00	0.0% -	4.8%	0.0%
TOTAL PARTICIPANT NEBs	$94.89 -	$796.25	$386.85	98.5% -	403.8%	144.1%
PARTICIPANT NEBs MULTIPLIER	47% -	398%	193%			
All NEBs Multipliers: **Relative to Bill Savings**						
Utility	3% -	25%	12%	7% -	49%	24%
Societal	6% -	274%	95%	5% -	329%	55%
Participant	47% -	398%	193%	99% -	404%	144%
ALL Multiplers - relative to bill savings	56% -	698%	300%	111% -	782%	224%
NOTE: Ltd variation for emissions are for peak / off-peak focused programs.						

(Source: Skumatz 2014) Percentages represent percent of the customer's program savings (bill savings). Note the percentage and dollar savings columns include some different program lists, so they are not strictly translatable

Table 2. Recent Health-Related NEBs Results.

Fewer missed days at work: • $149.45/household(hh)/year (Hawkins et. al., 2016) • $16.20/hh/yr (Tonn 2014) • $201/hh/yr (Tonn 2018) *Aggregate "health" benefits, valued at:* • $0.13-$19 /hh/yr, depending on customer sector, heating/cooling system, and program targets (Brant and Justi 2013); • $4 for non-low-income households and $19 for low income retrofits (NMR 2011) • €36 million program-wide in the UK (Payne, et. al. 2015) *Improved air quality, valued at:* • $156/ year and lifetime value of $4,363 (Summit Blue 2006) *Reduced asthma symptoms:* • Excess cold weather asthma mortality reduction potential (Light retrofits: 40 %. Medium retrofits: 60 %. Deep Retrofits: 80 %. New building - base standard: 70 %. Net zero energy buildings: 100 %. Passive houses: 100 %. Surviving non-retrofitted buildings 0 %.). The co-benefits of additional energy efficiency improvement actions coupled with strong social policies in 2030 could deliver these additional gains in public health: around 22 300 DALYs of avoided asthma due to indoor dampness. and the avoided economic damage of 2.6 billion EUR (Combi 2018) • $9.99 per participant per year to be applied over 10 years; societal perspective estimate of $322.01/hh/yr for 10 years (Hawkins, et. al. 2016) • 12 % fewer asthma emergency room visits (EEFA, 2016) • $15/hh/yr over 10 years; societal perspective $186.25/hh/yr for 10 years (ORNL 2014) • $2009 total benefit lifetime per household (Tonn 2018)	*Reduced allergy symptoms:* • 12 % reduction in children's allergies and 5% reduction in adult hay fever for window replacement (Jacobs 2016 cited in Cowan 2016) • 13 % reduction in eczema or allergies (Francisco 2016, cited in Cowan 2016) Reduced medical costs: • $4-$5/participant per year (doctor visits and related costs), and $1/hh/yr medications (Skumatz et.al. 2005) • $24 million in saved uninsured medial costs and lost work for program (Oppenheim and MacGregor, 2002) *Moisture and mold-related illnesses: Moisture and mold were also likely to still be seen at the time of the inspection, but 43 % of the mold issues were resolved by the customer. (Apprise 2018)* *Carbon Monoxide:* • $36.98 for the five-year life per unit (Hawkins et. al., 2016) • $6.38/low income household / yr in avoided carbon monoxide poisonings (NMR 2011) *Reduced fires/safety:* • $93.84 annual per unit (Hawkins, et. al., 2016) • $37.40/hh/year in avoided fire deaths, $0.03 avoided injuries, $1.24 avoided property damage (NMR, 2011) • $22 million (avoided fire damage), program wide (Oppenheim and MacGregor, 2002) *Improved safety, aggregate:* • 1–12 % of utility bill savings per year (Russell, et.al. 2015) • $45.05 per measure (Brant et.al., 2013) • $181/year or lifetime value $5072 (Summit Blue 2006) • $20-26/hh/yr (Skumatz, et. al. 2005)

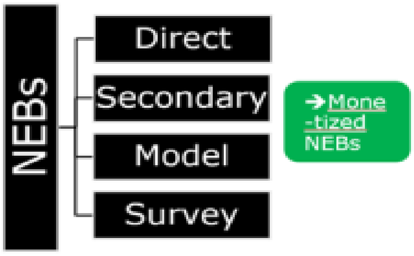

Figure 2. NEB Monetization. Source: Skumatz 2009.

are added to process evaluation questionnaires. However, this means that most of the existing research on residential NEBs (for the retrofit types of programs that are the most studied), the NEBs are program-wide, and the results cannot be adjusted when the utility changes measure mix in the program or targets the program to different participants. That also limits the use of program-wide NEBs for planning purposes because scenario analysis can't be accommodated (again, adding or subtracting individual measures, for example).

Given the interest in measure-based estimates, there are four ways to derived measure-specific NEBs from whole building retrofit programs:

1. Stratified-Sample Estimates: Conduct NEB studies that sample participants using stratified techniques that allow enough respondents to estimate NEBs separately by measure[1];
2. Regression: Use regression analysis to statistically tease apart measure-specific values, attributing the total (or individual) NEB values to measures;
3. Savings share: Allocate program level NEBs to measures in proportion to the savings individual measures produce;
4. Across the Board/no disaggregation: Assign all program measures the same program-level NEBs multiplier (Percent of retail energy costs saved).

Pros and Cons: Given budget and pre-planning, the method that uses sampling specifically based on measures is the preferred approach. However, this has rarely been the approach for NEB studies (with some exceptions). All but the stratified-sampling approach can be applied "after the fact", and the regression and sampling approaches have the advantage of being able to identify impacts associated with demographics and other influencing factors. Savings sharing and "across the board" approaches are by far the simplest and least expensive. "Across the board" approaches have the weakness that they will assign NEBs to some measures that may not apply (comfort to water heaters) but would be right on average. The regression approach requires data and, as it turns out, needs to be applied in a more nuanced way to provide strong estimates.

We have found examples of the use of all these approaches to disaggregate program-level savings to measures in the literature, and they are discussed in historical order.

1. Where those measures are installed outside a "bundle". This statistical "identification" problem arises in both 1 and 3. When some measures are installed together, or when all households get some measures, separate NEBs would not be available for each measure, but could be estimated for the "bundle".

Across the Board: As one example, the Low-Income Public Purpose NEB estimation model (TecMarketWorks and Skumatz, 2001) was used for many years to estimate NEBs for the Low-Income programs offered by California's Investor Owned Utilities (IOUs). The model developed a total NEB estimate (with breakdown by individual NEB categories), and the total was applied, as a ratio or value, program-wide. No attribution to measures was initially constructed; a retrofit using a savings-based method was later applied (discussed below).

Regression: An early study (McClain, Skumatz and Gardner 2006) recognized that program-wide NEBs limited the use of the NEB estimates as the measures (or target populations) change in programs over time and limited the transferability of NEBs to programs elsewhere that included different measures. The authors were also interested in whether certain measures were responsible for the majority of NEBs, or whether many were responsible for the perceived value, and whether NEBs were higher in demographically-sensitive households. The internally-funded work was an initial exploration to determine if regression-based approaches could work, and the project was only partly successful. The study used information from a single-family weatherization program and used regression analysis (linear and logit) to model total NEB values against the measures installed in anyone's home. Demographic factors were also included. The results showed that households that received insulation had the highest NEBs, and other measures with stronger NEBs were furnace repair/replacement, caulking, hot water heater equipment, new appliances, and others. Some, unexpectedly, were not positive (including CFLs, new thermostats, fans, and air conditioners). This does not mean the NEBs were negative; rather, the NEBs were lower than the constant term. The study also found indications that that NEB perceptions vary based on the demographics of the residents – with stronger NEBs for households with children, and negative results for homes with elderly residents (an unexpected result). The study showed promise for the use of regressions to gain more robust results from program-wide NEB studies, but also identified that the issue needed more complex modeling. This work is updated later in this paper.

Measure-Based Estimates Another study (Skumatz 2006) of a multi-measure program took the approach of sampling directly on specific measures within the program. This study (Skumatz, 2006) conducted NEBs surveys for the program, a broad-based appliance program (EnergyStar® products program), but divided the sample to provide enough response to identify NEBs for each appliance measure in the program. The results on NEBs by measure for those measures included in the study are presented in Table 3. Skumatz 2006 also presents the breakdown of the individual NEBs for each of these pieces of equipment. That information follows in Figure 6. Unfortunately, the lighting research covered CFLs, not LEDs, limiting the on-going usefulness of that portion of the work (Table 4).

Attributed by Savings: Table 5 provides an example of the method of allocating NEBs based on the share of program savings delivered by the measure. This study is from Massachusetts, and the results are used to attribute NEB values to their causal measures. The study identified a combined participant NEB value for the weatherization program of 114 %, which is very in line with the other studies noted in this working paper. The allocations between measures are shown in Table 6. The study examined 16 measures and 7 NEBs.

Table 3. Estimates of Appliance NEBs as a Percent of Measure Savings (Skumatz 2006).

Household appliances	Refriger-ators	Dish-washers	Clothes Washer	Room Air Conditioner	CFL Bulbs	Lighting Fixture
NEB Multiplier as a percent of the measure's energy savings	29 %	65 %	27–54 %	71 %	45–90 %	30 %

Table 4. Skumatz 2006: Share of Total Appliance NEBs for Individual NEB Categories.

Percent of Total Measure NEB by Category	O&M	Appear-ance	Perfor-mance	Lifetime	Noise	Satis-faction	Comfort	Lite Qual	Safety	Ability to Sell Home	Avoid Moves	Water Sav	Environmen-tal Ethic	Total
Refrigerators	9%	4%	13%	7%	10%	17%	9%	0%	2%	11%	3%	0%	15%	100%
Dishwashers	5%	4%	8%	8%	9%	11%	6%	0%	4%	8%	8%	12%	17%	100%
Clothes Washers	5%	4%	8%	10%	5%	10%	8%	0%	5%	6%	7%	14%	18%	100%
Room AC	6%	7%	10%	8%	11%	10%	9%	0%	8%	7%	8%	0%	16%	100%
Bulbs (CFL)	8%	3%	10%	13%	1%	13%	8%	11%	7%	4%	4%	0%	18%	100%
Lighting Fixtures (CFL)	6%	6%	12%	9%	4%	10%	8%	5%	7%	9%	9%	0%	15%	100%

Table 5. Assigning NEB Values to Measure Savings, Apportioning on Energy Savings for Measures. (NMR 2011) (non-low income multifamily).

Attribution of NEI Values to Energy Efficiency Measures, Non-low-income Participants, Dollars per Measure (kWh savings-based)

	Thermal Comfort		Noise Reduction		Health Impacts		Property Values		Equipm't Maint.		Lighting Quality		Home Durability	
	% bill savings	$	% bill savings	$	% bill savings	$	% bill savings	$	% bill savings	$	% bill savings	$	% bill savings	$
Sample size by NEI	*209*	*180*	*147*	*187*	*209*	*190*	*209*	*171*	*139*	*125*	*47*	*41*	*209*	*188*
Air Sealing	8%	$10.13	16%	$4.88	8%	$0.32	7%	$135.83	-	-	-	-	8%	$3.95
Appliance (refrigerators & freezers)	-	-	-	-	-	-	<1%	$1.44	-	-	-	-	-	-
Cooling Systems	3%	$3.92	9%	$2.83	3%	$0.13	3%	$62.65	6%	$7.54	-	-	3%	$1.54
Duct Sealing	<1%	$0.16	-	-	<1%	$0.01	<1%	$2.51	-	-	-	-	<1%	$0.06
Heating & Cooling systems	4%	$5.05	-	-	4%	$0.16	4%	$80.69	8%	$9.42	-	-	4%	$1.98
Heating & Hot Water systems	1%	$1.83	-	-	1%	$0.06	1%	$29.17	3%	$3.41	-	-	1%	$0.72
Heating Systems	39%	$48.63	-	-	39%	$1.56	34%	$678.52	83%	$102.40	-	-	36%	$17.42
Hot Water Systems	-	-	-	-	-	-	4%	$82.56	-	-	-	-	4%	$2.13
Insulations	20%	$25.15	37%	$11.54	20%	$0.80	9%	$378.05	-	-	-	-	20%	$9.82
Lighting	-	-	-	-	-	-	5%	$96.61	-	-	100%	$49.00	-	-
Service to Heating or Cooling System	<1%	$0.47	-	-	<1%	$0.01	<1%	$7.44	1%	$0.87	-	-	<1%	$0.18
Low Flow Showerhead	-	-	-	-	-	-	<1%	$0.03	-	-	-	-	-	-
AC System Sizing	<1%	$0.19	-	-	<1%	$0.01	<1%	$3.01	<1%	$0.37	-	-	<1%	$0.07
Programmable Thermo	3%	$3.99	-	-	3%	$0.13	3%	$51.49	-	-	-	-	3%	$1.33
Window	1%	$0.68	2%	$0.54	1%	$0.02	<1%	$6.72	-	-	-	-	<1%	$0.21
Weatherization	20%	$25.00	36%	$11.22	20%	$0.79	19%	$381.25	-	-	-	-	19%	$9.57
Total Value	100%	$125	100%	$31	100%	$4	100%	$1,998	100%	$124	100%	$49	100%	$49

NMR / TetraTech: (Weighted mean value of all respondents) (note: a cell with "-" indicates that the measure does not reasonably impact the individual NEI)

Table 6. Total of NEB value by Measures as a Percent of Bill Savings (NMR 2011).

Measure vs. Sum of NEBs – Multiple of associated bill savings	% bill savings	Measure vs. Sum of NEBs – Multiple of associated bill savings	% bill savings
Air Sealing	47 %	Insulation	116 %
Appliance (refrigerators and freezers)	1 %	Lighting	105 %
Cooling systems	27 %	Service to heating or cooling system	4 %
Duct Sealing	4 %	Low Flow Showerhead	1 %
Heating & Cooling system	24 %	AC system sizing	4 %
Heating & Hot water system	7 %	Programmable Thermostat	12 %
Heating system	231 %	Window	6 %
Hot Water System	8 %	Weatherization	114 %

NEW RESEARCH ON ATTRIBUTION – REVISITING DISAGGREGATION BY REGRESSION

The author revisited efforts to apply regression analysis to the issue of assigning program-wide NEB impacts to the various contributing measures (Skumatz, 2019). This time, a more refined, two-step approach was used. First, a mapping of the logical causal relationships by energy end use was developed, and then OLS regressions were run to for each category of NEBs (comfort, etc.) only against its logically-contributing end use and then the contributing measures. In some cases, an extra "measure" was added – program-wide. This is because some NEBs derive from the program itself in whole, rather than an individual measure; an example might be improvements in the ability to control bills, which may be influenced by the overall knowledge gained through program participation. In addition, the study also examined whether participant demographics also affected the NEB values. We used data from a survey-based NEBs project SERA had conducted that had 18 measures and 20 NEBs. In this on-going work, the regression work performed extremely well as a method of attributing program-wide NEB values to the measures that could reasonably be identified as responsible for that NEB's effects. All but seven values exceed 90 % t-statistic values; three only meet 80 %. The results are presented in Table 7.

The results show sensible disaggregation to sources. Comfort was linked to measures in heating/ventilation (HV) and shell end uses (7 measures contributed). Water savings derived from water heater and (certain) appliances replacement (2 measures). External noise was affected by shell measures (insulation and structural fixes). Home safety was linked to five measures: smoke detectors, repairs to windows and doors, and furnace work (5 measures). In this draft work, health effects are linked to furnace repair, draftiness and CO monitors (3 measures). Home appearance factors that resonate (and help sell the home) include furnace work, fans, new appliances, and repair doors and windows (6 measures). Examining the results from the other direction shows that furnace replacement and repair contributes to 8–11 NEBs, and window and door repairs are also contributors to multiple NEBs. New appliances help stimulate value for 5 NEBs. Through their influence on thermal comfort and their high energy use (and savings), furnace measures affect valued NEBs including: comfort, bill payment, equipment reliability, home's ability to control bills, moving, performance, bill-payment issues, ability to help alleviate environmental issues, illnesses, and home safety. Additional work in progress by the authors is finding that specific demographic factors (customer subgroups) also affected estimated – and measure-attributed – NEB values.

In our work to apply these results to current and future NEBs work, we are using a combination of sources. Some NEBs are best calculated using surveys, but others derive better estimates if they are based on financial calculations (Skumatz and Khawaja 2010). For example, our best estimate of the NEB from enhanced measure lifetimes from replaced equipment is based on the difference between new lifetime and remaining useful life of the replaced equipment, and the computation is based on the savings per year in deferred purchase price. These data are being used in concert with the measure-based estimates above (for appliances) and financial computations for other NEBs to develop a hybrid, but well-grounded and justifiable, disaggregation of NEBs from program-wide to individual measures. This will remain an important bridge until more program-wide NEBs studies conduct their surveys using measure-based sampling. While this is a work in progress at this point, the results demonstrate that this kind of disaggregation work can expand the usefulness of a program-wide (or unstratified) NEBs survey going forward or as a re-examination of past NEBs survey work.

Table 7. Results Using Regression Analysis to Allocate Program NEBs to Measures.

Measure Group	Measure	A. Comfort	B: Ability to Pay Bill	C: Light quality / quanity	D: Noise inside (appliance)	E: Noise outside	F: Eqpt reliability	G Appearance/ ability to sell	H: Control over bill	I: Moving	J: Eqpt performance / features	K: Bill calls	M: Ability to Help Enviro	N. Health & missed days	O: Water bill costs /Savings	P: Home safety	# of NEBs/measure
HV	Furnace repairs	17%	17%				23%	9%	15%		14%		18%			14%	8
HV	Furnace replace	14%	21%				34%	7%	11%	16%	19%	55%	19%	21%		15%	11
HV	Fan		13%					5%									2
HV	Vents - fix / replace	8%	24%						7%				16%				4
AC	Air Conditioning									84%							1
Water	Hot water repair																0
Water	Hot water replace														70%		1
Shell	insulation	18%	25%			34%						45%					4
Shell	Tests for Drafts													27%			1
Shell	Caulk windows																0
Shell	Seal crawlspace	16%							21%								2
Shell	Fix doors	14%				22%		7%	9%							13%	5
Shell	Fix windows	13%				44%	43%	14%	10%							15%	6
Lighting	CFL bulbs			100%									48%				2
Appliances	Appliances				100%			59%	28%		67%				30%		5
CO&Smoke	CO / Smoke detectors													52%		43%	2
Number of Measures Contributing		7	5	1	1	3	3	6	7	2	3	2	4	3	2	5	

Source: Skumatz 2019, may be used with permission of author

State Activity in NEBs

NEBs have been used for marketing widely, and to design and refine programs for increased benefits (especially in low income programs). And their value in reflecting the low-income program goals, and in helping vendors "think" more like the customers is understood. Arguably the most important application for NEBs is for Benefit-Cost testing at the utility or state level. This has been a major target for the application of NEBs since 2001, when the LIPPT project (TecMarketWorks and Skumatz, 2001) first estimated NEBs and identified which were most purposely considered in the State's test based on symmetry in the test's perspective. Using a benefit cost test that includes costs but excludes classes of associated benefits is biased. However, admittedly, research on NEBs was still new, and adoption was an uphill battle. For the next 10 years, progress continued the research front, but progress in introducing NEBs into state tests was limited. Over time, a few states introduced modest adders as placeholders, recognizing the NEBs gap and bias. Colorado, Vermont, Oregon, and others conducted NEB studies, and made progress, which provided a track record for other states. In the last 5–7 years, the number of states seriously considering NEBs as a part of their benefit-cost tests has grown. Some have been spurred on by the activities of intervenors, others have introduced the initiative from inside the agencies. A number of states are currently revisiting their benefit-cost test design and associated policy decisions from a holistic standpoint. A number are using the steps in the National Standard Practice Manual/NSPM (NSPM 2017) themselves or facilitated by consultants.

The number of states talking about, considering, or going through processes to add NEBs to the benefit-cost process is growing. The authors conducted extensive work analyzing filings, testimony, reports, rulings, and other documents, and conducted numerous interviews to track consideration of NEBs across the US over time. Figure 3 shows the pattern in the number of states including references to NEBs in their filings annually from the mid-1990s to 2017. Growth started in 2002 and has been fairly consistent since; the years 2009 and 2014 show significant increases in the number of states showing attention to NEBs.

The map in Figure 4 highlights those states with mandatory or optional NEBs in cost-effectiveness tests. Our research examined the status of NEBs consideration by state or regional entities. Our research breaks down state progress by status:

- 18 have already adopted NEBs as a broad adder (and we provide that value);
- 12 allow a low income (LI) NEBs adder or other special NEBs-related treatment for NEBs/NEIs;
- 19 incorporate measured NEBs into treatment for programs, measures, or portfolios, either for "easily measured" or "quantifiable" NEBs, specific subsets, or broader interpretations;[2]
- 9 have been ordered in some way/to some degree to work toward incorporating NEBs into the cost-effectiveness process;

2. For additional description of the treatment of which NEBs are allowed, see Skumatz 2016.

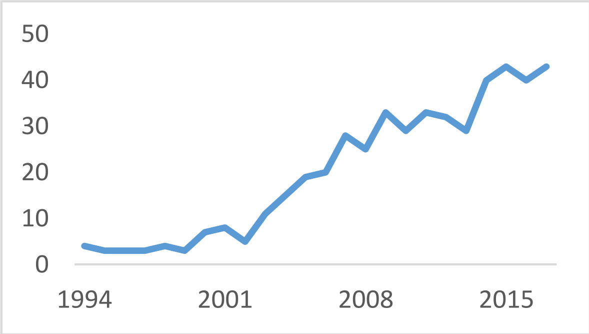

Figure 3. Number of States Considering NEBs. Source: Skumatz Economic Research Associates, 2018.

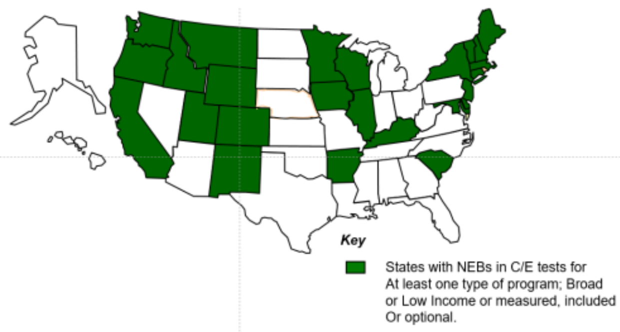

Figure 4. States with NEBs in C/E Tests. Source: Skumatz Economic Research Associates, 2018.

- 12 have had testimony on NEBs submitted in the proceedings; and
- 5 have a working group or collaborative working on the treatment of NEBs (this is not a complete list, as it includes some states with ongoing committees, etc.).

There are many states with entries in multiple columns, as they may have been ordered to consider NEBs in the process and have an active committee, or have NEBs that are both adders and measured (hybrid jurisdictions including BC, CA, CO, DC, IL, MA, MD, NY, NW, OR, RI, VT, WI). Ten states have low income NEBs in place (CA, CO, DC, MA, NH, NM, NY, RI, UT, VT). Other states have seen testimony introduced without current values adopted (CT, DE, ID, MI, MO, NV, NH, PA, VA, VA) and multiple states with collaboratives have been addressing or reviewing the topic. Much activity has been occurring. A review of the range of values for NEB adders in place in different states show that broad adders vary from: 5 %–7.5 % for specific gas adders; 10 %–15 % for electric or broad adders; 10–30 % for low income adders, and a variety of monetary value adders (Skumatz 2014).

Why NEBs Aren't Widespread in Benefit-Cost Tests: Reliability of NEBs – a "Relative Problem"

Progress has been made in more than half the states. What is holding NEBs back in other states? Overwhelmingly, the most common response is concerns about introducing a non-rigorous-derived value into the official benefit-cost testing process.

This argument might have been more valid in 2001, but with more than 300 studies of NEBs, a robust literature using financial computations, vetted models and academically-derived survey approaches, the argument seems less appropriate. This concern can be put into context by examining the Benefit Cost equation itself and exploring the actual quality and reliability of the entries already included in the equation – and compare their relative reliability and risk to those associated with NEBs.

RELATIVE RISKS FROM THE BENEFIT-COST COMPUTATION

The basic B/C equation presented below is based on the present value of a stream of benefits (with a calculation involving NTG, savings, NEBs, and Lifetimes and other items), divided by factors related to the present value of incremental program costs. Many of these inputs are potentially unreliable – and potentially more unreliable than NEBs.

B/C = f[PV[NTG*(EESav+Net NEB)*Lifetime] /PV(Cost)…]

Where: B/C=benefit-cost; f="function of"; PV=present value; NTG-net to gross; Sav=first year energy savings; lifetime or estimated useful lifetime (EUL) of installed measures.

Energy efficiency savings values are repeatedly measured (with impact evaluations), but there are at least four other inputs that have reliability issues, with consequent potential impacts on B/C results: NTG, EUL, discount rate for present value, and costs.

Net to Gross (NTG): The estimated net-to-gross rate reflects the estimated percent of gross savings that should be attributed to the program exceeding what would have happened without the program, and properly consists of two components – free ridership (FR) and spillover (SO)[3]. FR and SO are typically survey-based, using self-responses to questions about motivation and decision-making. This introduces risk and error into the B/C computations. Another error introduced in many states is the omission of SO from NTG estimates (as harder to measure). However, this introduces bias because spillover levels depend on the program type; market transformation and education programs may have a great deal of spillover. Including spillover (perhaps 2–20 % depending on programs, based on our research) could affect the B/C test results and favor some kinds of programs more than others.

Discount Rate: Three main discount rates have been used in B/C equations, all of which are meant to reflect risks associated with investment (Skumatz 2015a, Skumatz 2015b): the Utility's Weighted Average Cost of Capital (WACC; often 3–8 % or more); a societal discount rate (~3 % in Vermont, for example); and the 10 year treasury or prime rate return (~0.5 % to 2 %). The WACC reflects the risk associated with the utility's investments, mostly in generation, transmission, and distribution assets. The relative risk for investment in energy efficiency programs (at least mature "widget" programs), would potentially be expected to be less than a utility's investment in generation plants, which can have substantial risks of delays, cost overruns in labor, materials, or unknown technology (and potentially, the risk of disallowance). Energy efficiency programs generally can be funded from expenses and tend to occur in very controllable ways (programs can be halted midstream, delete measures, etc.). Thus, efficiency programs should have lower discount rates than generation resources (which usually use WACC). Social discount rates have been argued; the lower threshold for this investment might be the treasury returns, which could be considered an appropriate return for an investment of little to no risk. In regulatory environments where utilities are rate-basing and not rate-basing the costs, the conclusions remain the same. In rate-basing, the risk of recovery is lower for energy efficiency programs than generation, and without rate-basing, the risk from investments from working capital do not need to reflect the capital-based risk embedded in the WACC. For low income program, the most suitable discount rate may in fact be very low, if programs are approved – or required – by regulators. As a result, discount rates in different locales have varied from 1% to about 8 %. This has a dramatic effect on the present value computation for benefits. Program measures with 20-year EULs would lose 70% of their value based on the difference between a 3 % vs. 8 % discount rate. This choice matters and affects B/C test results significantly.[4]

Measure Lifetimes: Total lifetime savings is estimated by multiplying the useful life (EUL) of the installed equipment by the first-year savings of the measure. A review of measure lifetimes (Skumatz et. al. 2009) finds that: 1) lifetime values for individual measures can vary widely between states (a factor of two or more for some measures), and 2) the values that are used are rarely based on statistical underpinnings. An additional note is 3) the values are based on the values have been in place for more than 20 years in many cases, and even if they were accurate, they may no longer be appropriate for the newer mechanics and efficiency/operations decay behavior associated with new technologies being installed. In updated work, the authors assembled data on EULs adopted in more than 30 agencies around North America and compared the high and low values for each of more than 67 pieces of equipment. Our analysis showed that although there is little variation for some measures, others vary by double or more. Of the 67 measures examined, the average variation from high to low was 66 %, and the median was 40 %, implying for half the observations had EULs varying for same measures by more than 40% high to low. The difference in actual years of median lifetime exceeds 15 years, with the median and average at 5 and 6.4 years, respectively. Of course, the impact matters more for measures with shorter lifetimes, but the point remains the same: not only are the values not well researched, they vary widely, and this directly affects the computed savings valued in the B/C test. In other research, we have prioritized some of the most critical measures for follow-up analysis.

3. In simple terms, "free riders" are customers who take the program incentive, but would have purchased the efficient measure without the program ("cost" the program but benefits aren't attributable to the program). "Spillover" reflects customers who are induced to purchase energy efficient measures because of program influences, but do not participate or get rebates from the program (do not "cost" the program but benefits are attributable). The first factor decreases the savings attributable to the program and the spillover factors increase the savings that can be counted as program-attributable. Note that officially, there are multiple types of spillover – participant in-program (participants purchase measures promoted by the program, but do not get their incentive), participant outside-program (participants seek out other EE equipment), and non-participant spillover (the remainder of the market that undertakes EE behaviors without participating in the program directly (or costing the program).

4. It would affect the denominator as well (costs) but costs are generally one-year program cost, and not discounted or valued into the future.

Benefits Exceed Savings Alone: The estimated savings[5], usually derived from an impact evaluation or approved M&V or deemed savings process, is the one input that probably does not have substantial reliability issues. However, Benefit-Cost assessment should be based on all attributable benefits and the associated costs (incremental on both sides). NEB shows participant NEBs are often equal to energy savings, utility NEBs may be on the order of 10 % of savings, and societal benefits (largely jobs and emissions) can be very substantial. Precise estimates of savings omit these values that may more than double the total program or measure benefits. In summary, many elements in the B/C equations have uncertainties, and NEBs are not necessarily the weakest link in the equation. The introduction of an estimated value for NEBs automatically serves to decrease bias in the B/C test, because to omit a value effectively introduces a value of zero. The literature clearly indicates the value is positive and substantial – and definitely non-zero.

NEB estimates include uncertainty, with different errors associated with NEBs estimated from modeling sources, impact sources, surveys, etc. NEBs have been measured repeatedly, consistently, using defensible methods, and with good rigor, even those based on surveys. Most importantly, NEBs should not be held to an artificially higher (or lower) standard than the other elements of the benefit-cost test, which are also necessarily imperfect, as we point out. Including NEBs estimates reduces the bias in B/C-based decision-making.

Further, it has been argued that introducing NEBs would cause more programs to pass the B/C test, exceeding budgets. However, that will not be the only effect. The revised B/C tests will affect which programs pass by most – given that those with more or higher valued benefits will see the largest effect on B/C test results. The change should better allocate funds across programs, no matter what budget level is selected.

Summary and Conclusions

NEBs research seems to have become a more visible research topic over time, and recently three has been added attention to expanding the types of NEBs being measured. This work has focused on health and safety NEBs, both in the US and internationally, an area that had been considered a gap in the literature. This paper brings a reasonably credible approach to addressing another gap in NEBs – the derivation of measure-based NEBs. An improved regression approach shows logical, sensible assignments of NEBs across measures, and measure causing NEBs. Gaps beyond measure-based NEBs estimates remain, including:

- There is limited research on expanded utility NEBs (reliability, etc.)
- There is good progress in health, but transferability is an issue, and this area needs more research.
- Societal NEBs beyond model-based emissions and jobs are still rare, with gaps in topics related to national and system security, and important infrastructure-based NEBs
- The reasonableness of transferring NEBs from one jurisdiction or study to another area depends on the NEB category (weather sensitive or not, etc.), the program's measures, and targets, and more studies including this information clearly would facilitate transferability of results.
- There are relatively few studies on commercial NEBs, and results are not widely disseminated.

Research should focus on the NEBs most appropriate for Total Resource Cost Tests (TRC) and Societal Cost Tests (SCT), but frankly, a wide variety are theoretically appropriate for inclusion. There is no need for additional literature reviews, but quantitative studies are valuable, and many potential users won't accept NEBs unless they are local. NEBs studies are inexpensive to conduct; for that subsample of NEBs that need program-specific, survey-based information, they are a relatively easy and inexpensive add-on to program process evaluation surveys. The best studies would sample by measures, but the regression work pioneered in this paper suggest some after-study regression work can enhance the measure-based usefulness of the many studies of program-wide NEBs. And measuring every little NEB isn't necessarily the goal. In fact, including scores of NEBs may lead to a delay in NEBs progress at the state level because decision-makers may argue over individual NEBs, harming progress in readily-agreed NEB values. Research might better focus on explorations that identify which NEBs are large enough to matter and be worth considering – and making a case for.

Progress continues at the state level. The NSPM is being self-administered in some states, and consultant-facilitated process in others. It seems about time to revisit the tests from the bottom up. As part of this, NEBs research is likely to remain a focus. We certainly suggest additional NEBs research, but we also draw attention to the fact that research is also badly needed to update and improve the existing weak elements in the Benefit-Cost test to bring decision-making around EE programs up in quality all-around.

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