Measuring a Decade of Market Transformation: the Pacific Northwest Integrated Design Lab Network

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ABSTRACT

This paper documents the *direct energy savings* and *energy efficiency market transformation impacts* of a multi-state design assistance program in the Pacific Northwest. The paper addresses three specific aims. 1) It provides a conservative and justified estimate of the direct energy savings associated with design assistance activities of a market transformation program from 2001-2010. 2) It provides a rigorous methodology to evaluate direct energy savings associated with design assistance market transformation programs. 3) It examines the merits of a low-cost replicable method to predict energy savings in new buildings by evaluating the *integrated design process*. Applying the recommended analysis method, and assuming a 12-year measure life, the *direct* energy savings of the population (626 buildings; 51,262,000 ft^2) is estimated as 45.3 aMW (electric), and 265,738 therms (non-electric). If the entire contracted program budget were divided into the electric savings only, the Lab Network cost per kWh saved ranged from \$0.0016 - \$0.003 using the recommended method and \$0.0092 per kWh using the most conservative method. These figures do not isolate contextual influences or represent total resource cost. Statistically significant correlations (r^2=0.1-0.3) between integrated design scores and energy savings are reported and indicate that the model holds promise, but needs refinement.

Introduction

The Northwest Energy Efficiency Alliance (NEEA) is an energy efficiency market transformation (MT) (Eckman, Benner, & Gordon, 1992) organization funded by electric utilities in the Pacific Northwest (PNW). The total resource cost (TRC) is expected to be between \$0.01-\$0.035/kWh saved by program activities (Northwest Energy Efficiency Alliance, 2006, 2010). In 2000, NEEA began funding regional university-based laboratories (Lab Network), in conjunction with other NEEA implementation contractors, to provide technical design assistance and project-based education (Hellmund, Van Den Wymelenberg, & Baker, 2008; Jennings, Loveland, & Montgomery, 2010; Van Den Wymelenberg, Coles, Djunaedy, & Acker, 2009) for the promotion of energy efficiency in commercial buildings as part of their BetterBricks program (NEEA-BB). In 2006, NEEA-BB introduced its vision of the *integrated design*[1] (Brown & Cole, 2006) process in order to transform the "energy-related business practices in Northwest buildings" ("About Us - Betterbricks," n.d.).

MT involves diffusing knowledge to and changing the values and behaviors of many individuals and organizations. Evaluating MT is complex, especially when compared to utility demand-side management (DSM) programs, and requires regular monitoring of behaviors,

[1] Integrated design synthesizes climate, use, loads and systems resulting in a more comfortable and productive environment, and a building that is more energy-efficient than current best practices.

attitudes, process development, technology and market development (Neij, 2001). See Blumstein et al. (2000) Neij (2001), Vine et al. (2006) for more about MT evaluation theory and evaluation[2]. Because NEEA's funding comes from electric utilities, which are responsible to public regulating agencies and influenced by investment principles, cost-effectiveness and expenditure prudency must be maintained. Direct energy savings from program activities is thus one important measure of success.[3] However, evaluating energy savings from MT programs in commercial buildings is complex and expensive. Neij (2001) suggests that 5-10% of the cost of MT programs must be dedicated to evaluation. The identification of an appropriate baseline and the interpretation of the collected modeled or utility energy consumption data are controversial. Evaluating long-term multi-state design assistance must also accommodate jurisdictions adopting energy codes asynchronously, and multiple evolving utility incentive programs. There is also evidence of new practices by which utilities recover the cost of efficiency (Idaho Power Company, 2011) and increased regulations to achieve all cost-effective efficiency (State of Washington Department of Commerce, 2006), thus continuing to increase the scrutiny of MT evaluation methods. The Northwest Power and Conservation Council's Regional Technical Forum (RTF) plays a critical role in validating energy savings from technologies and practices in the PNW. The RTF is an advisory committee established in 1999 "…to develop standards to verify and evaluate conservation savings" ("Regional Technical Forum," n.d.). However, the RTF's mechanisms are primarily applied to equipment driven measures (e.g. retrofitting light fixtures) rather than business practices and design process approaches (e.g. the integrated design process) or passive architectural design strategies (e.g. nighttime ventilation of mass).

Early NEEA-BB evaluations established a useful evaluation framework and documented energy savings in categories defined within that framework (Heschong Mahone Group, 2007, 2008). HMG (2007) proposed a three-part evaluation framework: 1) *direct involvement* 2) *direct influence*, and 3) *indirect influence*. Direct and indirect influences capture the MT effects of the program while direct involvement captures the energy savings directly involved with the program. Due in part to limited evaluation funding, subsequent NEEA-BB evaluations have not adequately measured direct energy savings or indirect energy savings using MT indicators. Based upon cumulative evaluations from 2006-2010, the *direct involvement* energy savings from the design assistance program were reported as 1.65 aMW and 565,255 therms of natural gas (Research Into Action & ECONorthwest, 2010; The Cadmus Group, 2009). These savings represent only 39 *direct involvement* buildings (3,893,767 SF) of the 481 *direct involvement* buildings in NEEA's database for the same period. Reported modeled savings (26 of 39 buildings) were reduced by a *savings realization ratio* (SRR) (The Cadmus Group, 2009) of 0.63 (based upon just four buildings with both actual and simulated data). The determination of the SRR did not account for differences in weather, patterns of occupancy, or as-built system definitions between the consumption data and the modeled code baseline as is recommended by the International Performance Measurement and Verification Protocol (IPMVP) (DOE EERE IPMVP Committee, 2002). One report stated that program "impacts to date far exceed the savings the impact evaluators have found" (Research Into Action & ECONorthwest, 2010).

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[2] Vine et al. (2006) state; "Beginning in 1995, energy efficiency programs eligible for utility incentives (shareholder earnings) had to be cost-effective on a forecast basis. Each shared-savings program had to pass both the TRC and UC [utility cost] tests of cost-effectiveness as a condition for funding. General information programs were excluded from these tests because of the extreme difficulty in establishing meaningful estimates of their load impacts."

[3] However the primary measure of MT success is arguably the business practice change and reduction of market barriers that ultimately generate far greater energy savings than direct program activities.

Market Progress Evaluation Reports (MPER)[4] have tracked indicators of program progress and the most recent report (McRae et al., 2010) suggests substantial progress has been made but also stated "…there was still very little data to tie these changes to energy savings." A comprehensive and cost-effective methodology has not yet been established to measure energy savings from MT effects of the design assistance program(Research Into Action & ECONorthwest, 2010).

The objectives of this paper are: 1) to provide a conservative and justified estimate of the direct energy savings associated with design assistance activities of a MT program from 2001-2010; 2) to provide a rigorous methodology to evaluate direct energy savings associated with design assistance MT programs while building upon previous program evaluations (Heschong Mahone Group, 2007, 2008; Research Into Action & ECONorthwest, 2010; The Cadmus Group, 2009); 3) to examine the merits of a low-cost replicable method to predict energy savings in new buildings by evaluating the *integrated design process*.

Methodology

Population and Sample Definitions

A list of 722 buildings in which the Lab Network had *direct involvement* was compiled from NEEA's database.[5] Accurate square footage (SF) data were collected on 626 of the 722 buildings, comprising 51,262,000 ft^2 (population). An attempt was made to collect energy consumption data on the entire population and data were available for 130 buildings (14,020,000 ft^2), representing over 25% of the population SF (sample).

Data Collection

Determining energy consumption data for the baselines. In any energy efficiency evaluation, the methodology for establishing baseline and actual energy use data is critical. Turner and Frankel (2008) reported the energy savings of 121 LEED buildings by comparing consumption data to data from the 2003 Commercial Building Energy Consumption Survey (CBECS) (2006). Newsham et al. (2009) noted that the CBECS national average baseline data used by Turner and Frankel varied widely in terms of building age, size and activity type and, therefore, suggested a CBECS filtering process based on activity type, climate zone, age and size, so that each of the LEED buildings had one paired-match building from CBECS. Finally, Scofield (2009) challenged that the averaging method used for the Energy Use Intensity (EUI) data in the two previous studies should not be the building-weighted average because buildings of different sizes behave differently and, therefore, proposed a gross-square-footage-weighted average (gsf-weighted average). Scofield's analysis revealed fewer savings than the previous studies. Our paper expands the baseline filtering methods developed by Newsham et al. (2009), and both EUI and Energy Savings Intensity[6] (ESI) data are presented using the gsf-weighted averaging method as described by Scofield (2009).

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[4] Reports available at: http://neea.org/research/evaluationreports.aspx (BetterBricks tab).

[5] Due to changes in NEEA's database in 2005-2006, data from many of the projects entered previously were lost, thus the actual number of project consultations is greater than reported.

6 Energy Savings Intensity (ESI) is a metric of energy savings per SF. ESI is defined as the amount of energy saved per SF and is calculated thusly: (EUI baseline - EUI consumed (via either an energy model or utility data).

Because baseline databases vary greatly, several baseline methodologies are presented and compared. These include the EPA's Energy Star Target Finder[7,8] data, the DOE Energy Information Administration (EIA) 2003 CBECS microdata[9], NEEA's Commercial Building Stock Assessment (CBSA) microdata (The Cadmus Group & Ecotope, 2009), and energy modeled baselines of a code compliant design. Baselines are described in EUI values and are shown as split by fuel type and combined for all fuels. CBSA data were collected in NEEA territory, are normalized to Typical Meteorological Year (TMY) weather data, can not be parsed by climate zone, and are not recommended for use with hospitals (Baylon, Robison, & Kennedy, 2008). CBECS data include information on climate, detailed building type, and major fuels consumption, are based upon a single weather year and city location is excluded so weather normalization is not possible, and has some limitations in usage with some building types. Target Finder is based largely on CBECS data with some exceptions due to building type sample limitations (Environmental Protection Agency - ENERGY STAR, 2011). Our sample buildings' type, actual SF, actual zip code (climate region), default facility characteristics and other necessary data were entered into Target Finder to establish the relevant baseline. Default values for facility characteristics are recommended by Target Finder and are dependent upon building SF and space type.[10] Given that the industry's primary professional organizations (AIA and ASHRAE) have adopted the Architecture 2030[11] Challenge, CBECS National Average ($CBECS_{NA}$) data were calculated to support the recommended baseline method of Architecture 2030. Building upon Newsham et al. (2009), CBECS data were filtered by Climate Zone and Principal Building Activity Plus ($CBECS_{CZ\_PBAP}$). We also replicated the most conservative of their baseline methods, which filters $CBECS_{CZ\_PBAP}$ further by Size and Age (CBECScz_pbap_s_a). For baseline details see Van Den Wymelenberg et al. (2010).

Additionally, a total of 94 valid (peer-reviewed) building energy models were collected. Of these, 11 were LEED reviewed and 11 were reviewed as part of Oregon's State Energy Efficiency Design program. According to ASHRAE Standard 90.1 Appendix G, modeled energy consumption data should not be expected to match utility energy consumption data for a host of reasons, including weather and building occupancy (2007). Nonetheless, models are a common evaluation tool and therefore were compared herein. The IPMVP (DOE EERE IPMVP Committee, 2002) provides guidance for minimizing model error by applying a TMY weather normalization routine to utility data, and field verifying operational profiles. However, implementing IPMVP is not practical on a large sample due to cost.

Baseline comparisons. For a detailed discussion of the strengths and limitations of each baseline method on a building by building basis see Van Den Wymelenberg et al. (2010). The variability between baseline data methods are summarized in Table 1 and Figure 1.

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7 http://www.energystar.gov/index.cfm?fuseaction=target_finder

8 http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

9 http://www.eia.doe.gov/emeu/cbecs/

10 http://www.energystar.gov/ia/business/tools_resources/target_finder/help/Target_Finder_Help_Guide.htm

11http://www.energystar.gov/ia/business/tools_resources/new_bldg_design/2003_CBECSPerformanceTargetsTable.pdf, http://architecture2030.org/files/2030_Challenge_Targets_National.pdf, this method suggests that users determine the Target Finder value if available, but when a Target Finder value is not available for a building type, CBECS national average data is to be used.

Table 1. Baseline EUI Ratio Comparisons of Most Common Building Types in Sample
(ra = regional average, cz = climate zone, pbap = the detailed principle building activity, na = national average, s= building size filter applied, a= building age filter applied)

OFFICE (n=27)	CBSA_ra	CBECS_na	CBECS_cz_pbap	CBECS_cz_pbap_s_a	Target Finder	Code Baseline Model
CBSA_ra	1.00	-	1.03	0.89	1.02	0.82
CBECS_na	-	-	-	-	-	-
CBECS_cz_pbap	0.97	-	1.00	0.86	0.98	0.79
CBECS_cz_pbap _s_a	1.12	-	1.16	1.00	1.14	0.92
Target Finder	0.98	-	1.02	0.88	1.00	0.81
Code Baseline	1.22	-	1.26	1.09	1.24	1.00

UNIVERSITY (n=17)	CBSA_ra	CBECS_na	CBECS_cz_pbap	CBECS_cz _pbap_s_a	Target Finder	Code Baseline Model
CBSA_ra	1.00	1.00	1.42	-	-	0.61
CBECS_na	1.00	1.00	1.42	-	-	0.61
CBECS_cz_pbap	0.70	0.70	1.00	-	-	0.43
CBECS_cz_pbap _s_a	-	-	-	-	-	-
Target Finder	-	-	-	-	-	-
Code Baseline	1.64	1.64	2.33	-	-	1.00

K-12 SCHOOL (n=41)	CBSA_ra	CBECS_na	CBECS_cz_pbap	CBECS_cz_pbap_s_a	Target Finder	Code Baseline Model
CBSA_ra	1.00	-	1.02	1.22	0.96	0.70
CBECS_na	-	-	-	-	-	-
CBECS_cz_pbap	0.98	-	1.00	1.20	0.94	0.69
CBECS_cz_pbap _s_a	0.82	-	0.84	1.00	0.79	0.58
Target Finder	1.04	-	1.06	1.27	1.00	0.73
Code Baseline	1.43	-	1.45	1.73	1.37	1.00

INPATIENT H.C. (n=9)	CBSA_ra	CBECS_na	CBECS_cz_pbap	CBECS_cz _pbap_s_a	Target Finder	Code Baseline Model
CBSA_ra	1.00	1.30	1.52	1.44	1.83	1.19
CBECS_na	0.77	1.00	1.17	1.11	1.41	0.91
CBECS_cz_pbap	0.66	0.86	1.00	0.95	1.21	0.78
CBECS_cz_pbap _s_a	0.69	0.90	1.05	1.00	1.27	0.82
Target Finder	0.55	0.71	0.83	0.79	1.00	0.65
Code Baseline	0.84	1.10	1.28	1.21	1.54	1.00

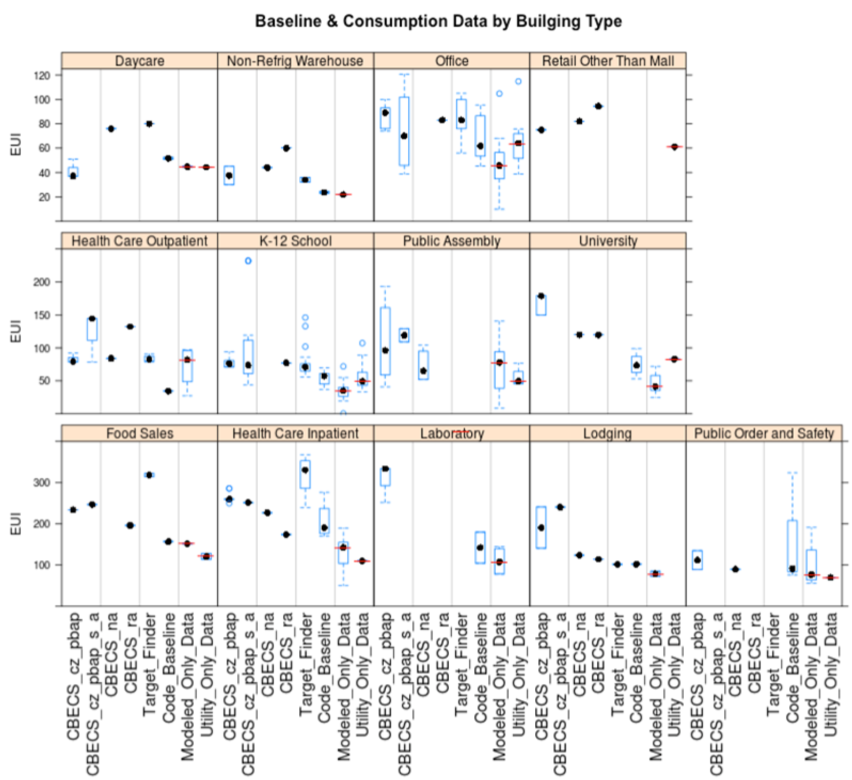

Figure 1. Box Plots of Multiple Baselines with Utility and Modeled Consumption Data

Determining energy consumption data for the sample. Utility energy consumption data were collected from owners, operators, architects, engineers, or directly from utilities with owner permission for as many of the buildings in the population as possible, and a sample of 50 were gathered. The main factor limiting access to utility data was that owners did not sign the utility release waivers in a timely fashion. Other reasons were that buildings had not been occupied for a full year, were under construction, or were in design stages. Furthermore, some utility data were omitted because meters were confounded by multiple architectural additions and renovations or had substantial missing data. Building operators and designers were telephoned to verify SF, occupancy date, number and definition of utility meters, and systems installed were verified via COMcheck™ documents. Utility consumption data were reviewed to identify extremely high or low energy use and follow-up investigations were conducted to correct questionable data (e.g. confirm SF, utility meter numbers). Modeled consumption data for the sample were collected following the procedures described above for the code baseline models.

Quantifying the Integrated Design Process

In order to determine if the level of *integrated design* (ID) process correlated with energy savings, each sample building was scored (using a three level scale) on seven aspects of ID, and a regression was conducted with percent energy saved using multiple baselines. The scores from seven aspects (below) of the ID process were factored into a single ID process score from 0-100 for each sample building. A detailed methodology for ID scoring is reported elsewhere (Van Den Wymelenberg et al., 2010). The purpose of this exercise was to characterize the ID process and establish an effective and inexpensive method to predict energy savings of projects at the end of the design phase using its level of ID score. The aspects of integrated design scored were:

1) The design team established building performance goals (quantitative or qualitative) and compared the building's performance (during design) to these goals.
2) The design team worked outside of normal disciplines to identify and exploit synergies between climate, use, building and site design, and system selection and design.
3) Energy efficiency related analyses were completed to inform design decisions.
4) The design team considered climate as a resource.
5) The design team considered occupancy schedules an comfort criteria as malleable.
6) The design team designed the building to create small loads.
7) The design team matched the system design to actual loads.

Characterizing the Cost-effectiveness of the Lab Network

In order to characterize the cost-effectiveness of *direct involvement* program activities, the financial investment of NEEA in the Lab Network was determined from the initial start date of NEEA funding until the end of 2010. Then, the estimated sample savings data were extrapolated to the population. Two values are reported for each of a selected set of savings calculation methods: 1) the entire Lab Network NEEA-funded operating budget, and 2) the budget explicitly associated with Lab Network design assistance. The Lab Network has contracts with NEEA for other activities (e.g. product and service development, education and training). Therefore, the cost-effectiveness is calculated using both cost figures providing a bounded range.

The most appropriate method is to consider only the design assistance budget, while the most conservative approach is to use the entire budget. The energy savings from the various calculation methods are divided into each of these figures to provide a cost per unit of energy.

Attribution and Extrapolation

Previous program evaluations have raised concerns over both the attribution of savings to the program as well as extrapolation of sample data to the population (Research Into Action & ECONorthwest, 2010). It must be made clear that this research did not directly address attribution, however the most recent NEEA-BB evaluation reported program attribution in a preliminary fashion (SBW Consulting & Ridge and Associates, 2011). This paper provides justification for extrapolating savings from the sample to the population. Previous NEEA evaluations concluded that energy savings analyses had included too few buildings, which were not selected randomly, and were biased due to the heavy reliance on LEED model data in order to justify extrapolation. Furthermore, they noted that the information about the characteristics of both the sample and the population was insufficient to justify extrapolation.

To overcome these issues the sample must be representative of the population for the most important energy consumption related characteristics, namely building type and size. Statistical analyses were conducted to describe the SF-distribution by building type for each baseline methodology. Other potentially relevant factors, such as building type and SF by climate zone or by level of ID, were not considered to be as influential as building type and size with regard to energy use and were not considered in the statistical analyses.

Calculations

Energy savings on lab network direct involvement projects. Several combinations of modeled/utility consumption data and baseline data were conducted. There are two general types of consumption data available, those from utility meters and those from energy models. In order to use the largest sample possible, these data sets are combined for some methods, and they are also presented separately for some methods to provide more detail. There are four resultant methods to generate the consumption data sample; A) uses utility data if available and modeled data otherwise (Utility then Modeled), B) uses modeled data if available and utility data otherwise (Modeled then Utility), C) reduces the sample to buildings with Utility Data Only and D) reduces the sample to buildings with Modeled Data Only. These four consumption data methods are considered for each of the baseline datasets. In order to use the largest sample possible, CBECS and Target Finder baselines were combined. This is the recommended practice by both EPA and EIA. Target Finder and CBECS data were combined two ways. One way is according to EPA, EIA and Architecture 2030 recommended practices, such that Target Finder data were used if available, and $CBECS_{NA}$ was used otherwise (Target Finder then $CBECS_{NA}$). The second way used Target Finder data if available and $CBECS_{CZ\_PBAP}$ otherwise (Target Finder then $CBECS_{CZ\_PBAP}$) to provide a more conservative approach. Finally, if data were available, modeled code baseline and proposed modeled runs were compared. In total, 29 calculation methods for estimated savings are provided and are detailed in Table .

Method 25 was selected for purposes of running several types of analyses in this paper. It was selected because it is founded upon the two most widely industry-referenced energy consumption baselines (Target Finder and CBECS are used by the 2030 Challenge as adopted by

ASHRAE and AIA). It also employs a balanced approach in terms of levels of conservatism for important analysis factors, it supports filtering by very specific building type designation and climate zone in the baseline datasets, and perhaps most importantly, it represents one of only a few potential methods that provide baseline data for the full sample of 130 buildings. The largest sample is also the sample that best represents the population (discussed below, Figure 3). Finally, since Method 25 follows the Architecture 2030 recommended practice, it also is the one that most directly addresses NEEA's Board-Approved efficiency goals for the new construction market, which reference the 2030 Challenge (Northwest Energy Efficiency Alliance, 2010).

Energy savings associated with the integrated design process. To describe the savings associated with the ID process, ID process ratings were compared to the percent savings from all 29 calculation methods and regression lines were fit. In addition to Method 25, Method 29 is reported since it most directly relates to the design process and is the type of data most likely to be available when energy savings predictions are made.

Estimating the benefit-cost ratio of the lab network. The sample results from selected savings calculation methods were extrapolated to the population in order to support cost effectiveness estimates. A conservative estimated measure life of 12 years was used (common practice of utility incentive programs). The total Lab Network budget, and the portion of the budgets associated with design assistance, was divided into the energy savings figures from each baseline method to provide a cost per unit energy for the role of the Lab Network in these projects.

Relationship of the sample to the population. In order to support a decision to extrapolate savings data from the sample to the population, these two groups were analyzed for their distribution in terms of SF by building type. The results are shown in Figure 3.

Results

Results are provided for all fuels combined, and for electric and non-electric fuels splits for all 29 methods in Figure 4. The ESI associated with the sample ranged from 17.4 kBTU/SF*YR (filtered n=31; Method 15) to 81.4 kBTU/SF*YR (filtered n=53; Method 20) for the designation of *all fuels*. The smallest figure resulted from using Utility Data Only and $\text{CBECS}_{\text{cz\_pbap\_s\_a}}$ baselines. The largest figure resulted from using Modeled Data Only and Target Finder only baselines. When *electric consumption only* is considered, the ESI associated with the sample ranged from 2.5 kWh/SF*YR (filtered n=31; Method 15) to 10.1 kWh/SF*YR (filtered n=53; Method 20). This represents 0.29-1.15 average Megawatts[12] (aMW) saved per million square feet. Once again, the smallest figure resulted from using Utility Data Only and $\text{CBECS}_{\text{cz\_pbap\_s\_a}}$ baselines, and the largest figure resulted from using Modeled Data Only and Target Finder only baselines. Finally, for the designation of *non-electric fuels only* the ESI associated with the sample ranged from 9.4 kBTU/SF*YR (filtered n=31; Method 15) to 57.1 kBTU/SF*YR (filtered n=29; Method 16). Once again, the smallest figure resulted from using Utility Data Only and $\text{CBECS}_{\text{cz\_pbap\_s\_a}}$ baselines, however, the largest figure resulted from using Modeled Data Only and $\text{CBECS}_{\text{cz\_pbap\_s\_a}}$ baselines.

[12] Average Megawatt - A unit of energy output that is equivalent to the energy produced by the continuous operation of 1 megawatt of capacity over a period of a year (8,760 hours).

Percent Savings

The percent savings graph below (Figure 2) shows the range of savings for the sample using Method 25. The graph shows that 116 of 130 buildings (89%) save energy and 95 buildings (73%) save at least 25% energy using this baseline. It is also shown that 38% of the sample save at least 50% energy using this baseline, thus keeping pace with the period's relevant Architecture 2030 Challenge milestone. Architecture 2030 provided equivalency estimates for PNW energy codes relative to the 2003 CBECS national average data set (Mazria & Kershner, 2008). Their estimates suggest that in order to be 50% better than CBECS 2003 national average, a building needs to be 30% below International Energy Conservation Code (IECC) 2006, and 25% below the period's relevant Oregon and Washington Energy Codes. Therefore, a dashed line was inserted at 25% savings to indicate the sample buildings exceeding the relevant code. It should be noted that using 25% as the code threshold is a conservative estimate of code performance because: 1) Architecture 2030 used the strictest IECC code in place during the design of any of the buildings in the sample (a similar case can be made for OR and WA codes) and, 2) Method 25 was used to develop the percent savings graph shown below, and this method is more conservative than the CBECS national average because it uses climate zone filtering.

Extrapolating Savings from Sample to Population

In order to justify extrapolating savings data, it must be established that the sample data are representative of the population. Figure 3 reveals that the distribution of the sample is very similar to the distribution of the population when using Method 25. These data are reported elsewhere (Van Den Wymelenberg et al., 2010) for each baseline method.

Population savings: All fuels combined. The ESI associated with the sample ranged from 17.4 kBTU/SF*YR (n=31) to 81.4 kBTU/SF*YR (n=53) for the designation of all fuels. Assuming the SF of the population (51,262,000 ft^2) and a 12-year measure life, the estimated savings for all fuels ranges from 10.70-50.09 TBTU.

Population savings: Electric only. The ESI associated with the sample ranged from 2.5 kWh/SF*YR (n=31) to 10.1 kWh/SF*YR (n=53) for the designation of electricity only. Assuming the SF of the population (51,262,000 ft^2) and a 12-year measure life, the estimated savings for electricity only ranges from 1.54-6.19 TWh. The sample represents 0.29-1.15 average Megawatts[13] (aMW) saved per million square feet and assuming the SF of the population (51,262,000 ft^2), the estimated savings is 14.62-58.85 aMW.

Population savings: Non-electric only. The ESI associated with the sample ranged from 9.4 kBTU/SF*YR (n=31) to 57.1 kBTU/SF*YR (n=29) for the designation of non-electric fuels only. Assuming the SF of the population (51,262,000 ft^2) and a 12-year measure life, the estimated savings for non-electric fuels ranges from 5.78-35.13 TBTU.

[13] Average Megawatt - A unit of energy output that is equivalent to the energy produced by the continuous operation of 1 megawatt of capacity over a period of a year (8,760 hours).

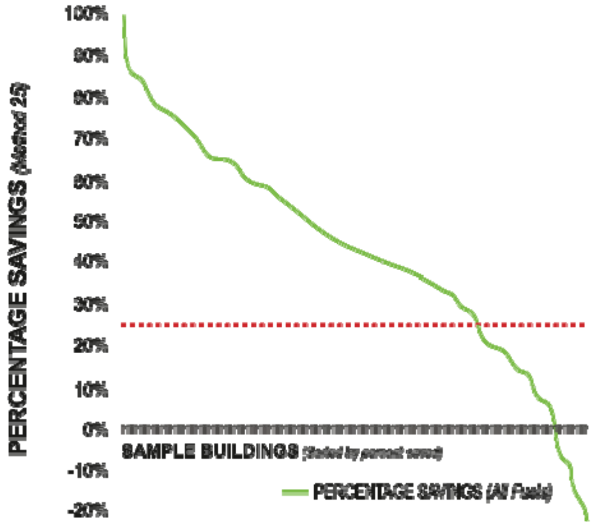

Figure 2. Percent Energy Savings for All Fuels (Method 25)

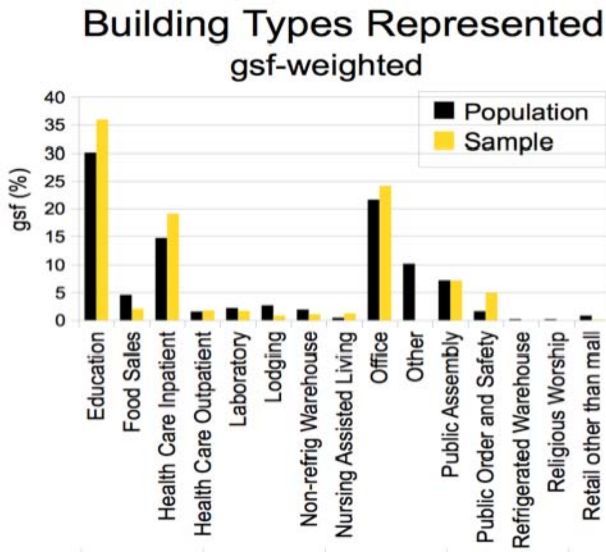

Figure 3. Comparison of Sample & Pop. by CBECS PBAP Type & Area (Method 25)

Table 2. Definition: 29 Calc. Methods

(ra = regional average, cz = climate zone, pbap = detailed principle building activity, na = national average, s = size filter, a = age filter)

Method	Consumption Data Used	Baseline Data Used
1	Utility then Modeled	PNW Commercial Building Stock Assessment Regional Average filtered by building type (CBSA_ra)
2	Modeled then Utility	CBSA_ra
3	Utility Data Only	CBSA_ra
4	Modeled Data Only	CBSA_ra
5	Utility then Modeled	CBECS National Average (CBECS_na)
6	Modeled then Utility	CBECS_na
7	Utility Data Only	CBECS_na
8	Modeled Data Only	CBECS_na
9	Utility then Modeled	CBECS filtered by climate zone and Principal Building Activity Plus (CBECS_cz_pbap)
10	Modeled then Utility	CBECS_cz_pbap
11	Utility Data Only	CBECS_cz_pbap
12	Modeled Data Only	CBECS_cz_pbap
13	Utility then Modeled	CBECS filtered by cz, pbap, size (s) and age (a) (CBECS_cz_pbap_s_a)
14	Modeled then Utility	CBECS_cz_pbap_s_a
15	Utility Data Only	CBECS_cz_pbap_s_a
16	Modeled Data Only	CBECS_cz_pbap_s_a
17	Utility then Modeled	Target Finder (TF)
18	Modeled then Utility	TF
19	Utility Data Only	TF
20	Modeled Data Only	TF
21	Utility then Modeled	TF then CBECS_na (if TF is unavailable)
22	Modeled then Utility	TF then CBECS_na (if TF is unavailable)
23	Utility Data Only	TF then CBECS_na (if TF is unavailable)
24	Modeled Data Only	TF then CBECS_na (if TF is unavailable)
25	Utility then Modeled	Target Finder (TF) then CBECScz_pbap (if TF is unavailable)
26	Modeled then Utility	TF then CBECScz_pbap (if TF is unavailable)
27	Utility Data Only	TF then CBECScz_pbap (if TF is unavailable)
28	Modeled Data Only	TF then CBECScz_pbap (if TF is unavailable)
29	Modeled Data Only	Code Compliant Energy Model

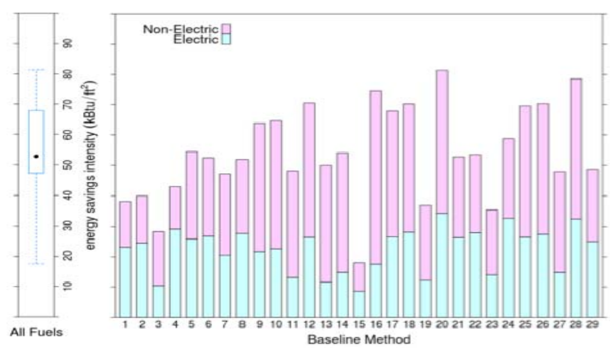

Figure 4. All Fuels Energy Savings Intensity

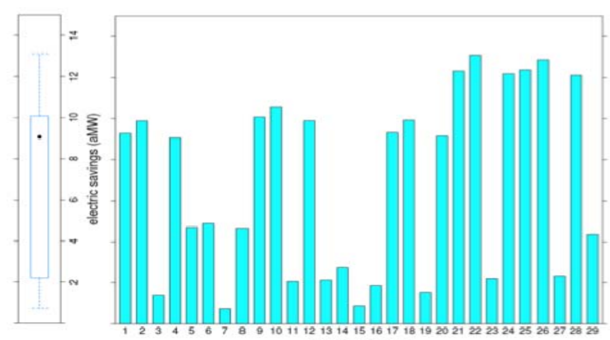

Figure 5. Electric Savings (aMW)

Estimating the Cost-effectiveness of the Lab Network

The Lab Network total budget from NEEA during the period from 2001-2010 was $14,125,969 while the design assistance budget was $7,433,675 of that total. Given the savings figures described in above and these cost values, Table 3 below describes the cost per unit energy for the role of the Lab Network in the project savings. Considering all fuel sources savings (and Method 25), the cost per kBTU of energy saved was $0.0003 (assuming the entire Lab Network budget is divided into the savings) or $0.0002 (assuming the design assistance budget is divided into the savings). If these budgets were divided into the electric savings only, the cost per kWh saved was $0.003 (entire budget) or $0.0016 (design assistance budget). If these budgets were divided into the non-electric savings only, the cost per kBTU saved was $0.0005 (entire budget) or $0.0003 (design assistance budget). Furthermore, even the most conservative estimate (Method 15 in Figure 4) shows savings at approximately $0.009 per kWh saved.

Table 3. Extrapolated Cost Per Unit Energy Savings (Defined Budget / Each Fuel Type

Summary of Cost Benefit Analysis (Assuming Lab Network Population SF)	All Fuels (kBTU)			Electric Only (kWh)			Non-electric Only (kBTU)		
	most conserv.	**recommended**	conservative	most conserv.	**recommended**	conservative	most conserv.	**recommended**	conservative
	Method 15	**Method 25**	Method 20	Method 15	**Method 25**	Method 20	Method 15	**Method 25**	Method 16
Energy saved of the population (637 buildings, 59.66 million SF) assuming 12 year measure life	10,702,247,629	**42,774,804,546**	50,091,840,941	1,536,563,507	**4,761,167,507**	6,186,274,277	5,780,626,506	**26,537,808,997**	35,125,373,205
Cost per unit energy - entire Lab Network budget	$0.00132	**$0.00033**	$0.00028	$0.00919	**$0.00297**	$0.00228	$0.00244	**$0.00053**	$0.00040
Cost per unit energy - technical assistance Lab Network budget only	$0.00069	**$0.00017**	$0.00015	$0.00484	**$0.00156**	$0.00120	$0.00129	**$0.00028**	$0.00021

Attribution of energy savings to the program. While this research did not directly deal with attribution, a NEEA evaluation report was recently released that addressed with attribution in a preliminary fashion (SBW Consulting & Ridge and Associates, 2011). The recent external evaluation was the first to address the attribution of energy savings to the program discussed herein in any manner. It examined four buildings in detail of the 31 buildings from the program that gained occupancy in 2010. In total, the 31 buildings comprised approximately 3,000,000 SF. A total of 884,288 kWh and 21,230 therms of (first year) validated savings were reported and 83% of the electric savings and 100% of the gas savings were attributed to program effects. With the reported savings data, we calculated the Lab Network cost-effectiveness based upon the average technical assistance budget from 2006-2008 (the influential program period for these 31 buildings). Based upon these data, the Lab Network technical assistance cost was $0.0078 per kWh saved and $0.23 per therm saved. These data provide some corroboration for the savings and cost-effectiveness data reported above as part of the research documented in this paper.

Representative Savings Associated with the Integrated Design Process

The ID scores were fit to the sample percent energy savings data (using Method 25) as shown in Figure 6-left. Then, each building in the sample was placed into one of three bins based upon its ID rating (Figure 6-right) and the bins were tested for significant differences. Using these preliminary results, a simplified estimated percent savings calculator is proposed that can be applied to any building type to predict savings based upon the ID process rating. Tests of significance, and difference of means data for each bin of ID scores are shown in Table 5. The predicted percent savings figures reference the baseline data used in Method 25 but can be calculated using any baseline method included in this paper. The best scores came from Method 29 (Figure 6-right). This is not surprising given that this method is the best description of estimated energy use during the design process specifically.

Table 4 shows a detailed distribution of the level of ID ratings in the sample, while Table 5 shows the distribution for the bin analysis chosen and the mean percent savings for each group (group one = 22.5%, group two = 39.6%, and group three = 50.7%).

Table 4. Sample Distribution for Level of Integrated Design

Level of Int. Des.	Percent of Sample
0-20%	8.1%
21-40%	13.0%
41-60%	26.0%
61-80%	20.3%
81-100%	32.5%

Table 5. Bin Analysis Statistics for Level of Integrated Design using Method 25

Bin Analysis of Int. Des. & % Energy Savings (Method 25)					
Group Test	P-value	Mean of 1st Term		Mean of 2nd Term	
01 – 02	0.0526	22.5%		39.6%	
01 – 03	0.0040	22.5%		50.7%	
02 – 03	0.0393	39.6%		50.7%	
Bins	Int. Des.	(n)	Mean	Min	Max
1	0.0 – 0.3	18	22.5%	-71.2%	58.2%
2	0.3 – 0.8	62	39.6%	-8.9%	79.4%
3	0.8 – 1.0	40	50.7%	-17.2%	99.5%

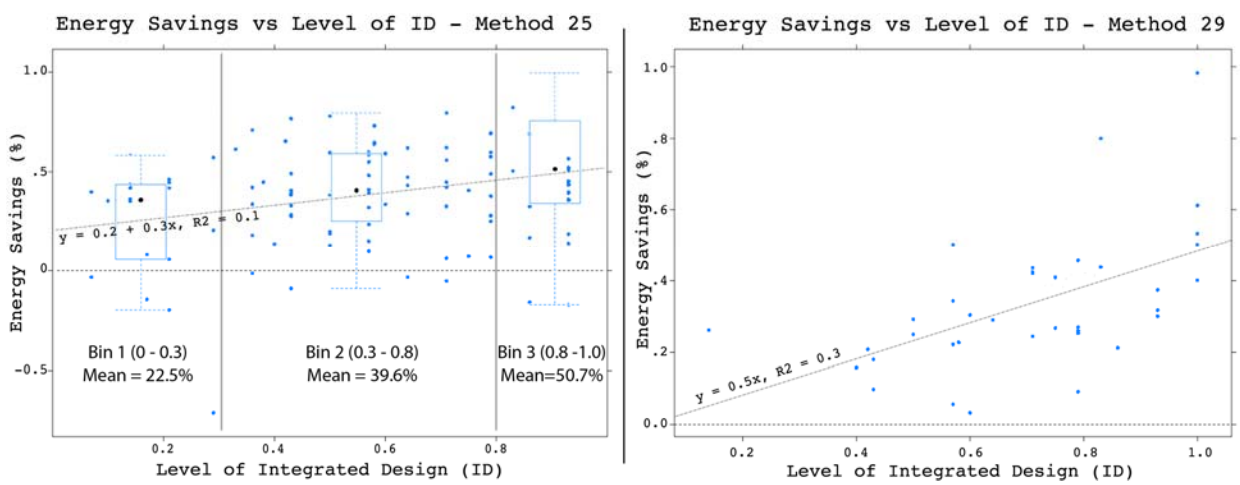

Figure 6. Percent Energy Savings Plotted Against 'Level of Integrated Design' with Bin Analysis for Method 25 (left), Method 29 (right)

Discussion

This paper provides a conservative and justified estimate of the direct energy savings associated with a design assistance MT program for a ten-year period and provides a rigorous and cost-effective methodology to evaluate direct energy savings associated with regional MT design assistance programs in a broader sense. Applying the recommended analysis method (Method 25) and assuming a 12-year measure life, the direct energy savings of the population (626 buildings; 51,262,000 ft^2) is estimated as 45.3 aMW (electric only), and 265,738,089 therms (non-electric only). When the entire ten-year program budget (not just the design assistance portion) was divided into the electric savings only, the Lab Network cost per kWh saved ranged from $0.0016 - $0.003 using the recommended method (Method 25) and $0.0092 per kWh using the most conservative method (Method 15). These figures are conservative since no credit is given to non-electric savings or the fact that the ID process influences measures that last beyond a 12-year measure life. Still, these costs are far below NEEA's cost effectiveness threshold ($0.01-$0.035/kWh) and are within the range of a technology-based MT program (Poirazis, Blomsterberg, & Wall, 2008). While this research did not address attribution, a separate external review of a very small building sample has suggested that over 80% of the validated energy savings re attributable to the Lab Network program effects (SBW Consulting & Ridge and Associates, 2011). Nonetheless, these attribution results are preliminary and any cost-effectiveness calculations reported herein should not be considered final until attribution has been more rigorously evaluated. Furthermore, the administration costs incurred by NEEA and incentives and associated costs paid by utilities need to be included in a TRC effectiveness calculation, and to date these data have not been attained.

Future research and program implementation aims to rigorously address the attribution of the estimated savings to the NEEA-BB program through improved record keeping of interventions recommended by program implementers, improved branding of program products and services for market recognition, and additional follow up interviews with design and construction teams to establish causal connections to decision making and program products and services. Future research also aims to estimate the administration costs of NEEA staff and utility staff in support of the program activity and to document the direct utility incentives paid to projects in order to improve the accuracy of the cost-effectiveness estimates.

It is not surprising that the range of savings estimates varies widely depending on the baseline dataset and the calculation method selected. It is noteworthy that the CBSA data set was consistently the most energy efficient baseline and that the Modeled Data Only calculation methods (e.g. Methods 16 & 20) consistently showed the most predicted savings while the Utility Data Only calculation methods (e.g. Methods 15 & 31) consistently showed the least savings for each of the baseline datasets. There is almost a four-fold difference between the least and most conservative calculation methods. This suggests any MT program design must be very specific regarding baseline data source when setting goals and metrics for evaluation. This paper recommends Method 25 be used when evaluating future MT program implementation of this type because it comports industry standard energy savings goals, it supports evaluation of the greatest number of building types, and it employs a balanced approach in terms of levels of conservatism for important analysis factors (e.g. use of utility and modeled consumption data, filtering by specific building type designation and climate zone in the baseline datasets).

This paper provides preliminary guidance for a cost-effective and replicable method to predict energy savings in new buildings by evaluating the *ID process*. While t-tests showed significant differences between low, medium and high bins of the level of ID, rather low correlation coefficients between level of ID and energy saved suggest further research is needed to improve the model and tailor it to specific buildings types. Furthermore, it takes an unbiased, yet intimately involved, evaluator to create an integrated design process score using the proposed methodology. This method should be developed further, so that independent interviews with design team members can produce ID level scores. We recommended this method be pursued in the future as a means to reduce the cost of program evaluation and determination of direct and potentially indirect program energy savings.

Transforming the market for services (ID process) is different than one for products (i.e. windows, lamps). Products are tangible, and therefore, evaluating by counting installations is relatively straightforward. Process changes (i.e. how services are developed and delivered) are more difficult to identify and quantify, especially when they are embedded in another process like engineering or architectural design. Changes in building designers' capabilities (their knowledge) is more important for saving energy in the long run than the savings from individual design assistance projects. Indirect savings are likely to far exceed the program's direct energy savings. Therefore, NEEA's next steps in evaluating MT effects could include creating energy savings estimates associated with key progress indicators. That said, on average NEEA budgets approximately 7% of total program costs to evaluation, and to date, NEEA evaluation contractors and program staff have not been able to establish such indirect savings multipliers for progress indicators. The program's *direct involvement* energy savings reported herein appear to provide sufficient cost-effectiveness justification without determining MT effects, thus raising the following questions. Is it prudent to invest substantial additional resources to provide savings estimates from complicated MT effects? Or, would it be more appropriate to preserve these funds for additional cost-effective program delivery and simplify the *direct involvement* savings evaluation while improving the attribution data stream? The answers to these questions depend greatly on several contextual motivating factors.

The Northwest Power and Conservation Council's Sixth Plan (released February 2010, see Appendix E, page E-8) identified ID of buildings as having the potential to save 60 aMW by 2029 (Northwest Power and Conservation Council, 2010) and identified barriers to ID. While this paper does not isolate energy savings from design process improvements separate from discreet technologically driven savings, it does provide support for these estimates given that in a 10-year period, for a population of just 626 buildings, that between14.62-58.85 aMW of electric savings were attained. Furthermore, this preliminary period included several years of development of the ID theory, which suggests that future savings of applying this process may be greater. However, in order for programs such as these to survive and thrive, specific baseline and energy savings calculation methodologies must be specified, program implementation and evaluation design must account for attribution, and key design process MT indicators must be associated with defensible 'deemed' or 'deemed-calculated' energy savings.

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