Exploring Non-energy Benefits and Impacts of Energy Efficiency Measures:

Advanced Lighting Controls

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1. Introduction

Non-energy benefits (NEBs), also called non-energy impacts (NEIs), are the array of attributable positive and negative effects beyond energy savings that are delivered with the installation of energy efficiency equipment.[1] In the case of commercial lighting and building controls, these effects can accrue to utilities (e.g., better bill payment behaviors due to lower bills), to society (e.g., fewer emissions and associated illnesses), and to the businesses installing the equipment (e.g., lower maintenance costs for the businesses; more responsive light quality across a day for occupants). It is the last set of effects – those on businesses and their occupants – that is the primary focus of this study. If derived in a credible way, and if fully valued, monetized, and internalized, these effects could be included in a benefit-cost assessment for equipment decision-making that includes all, or more of, the net benefits over the costs instead of an incomplete assessment including only energy savings over costs. This has the potential to increase uptake of controls measures in utility programs and marketplace transactions.

The DesignLights Consortium (DLC) contracted with Skumatz Economic Research Associates, Inc. (SERA) to study non-energy benefits (or non-energy impacts) for advanced lighting controls (ALC) technologies. The project's goal was to develop and validate an approach for estimating NEBs for these measures, which could be potentially used by the DLC's members. NEIs associated with energy efficiency (EE) programs and measures at utilities have been studied and estimated for more than 20 years. SERA adapted best industry practices to estimate total and individual NEB category values for decisionmakers and occupants overall and for four business types. As a result of the project's efforts, SERA developed quantitative estimates of NEBs associated with two separate groups that have first-hand experience with the systems in situ – managers or decisionmakers and occupants. The results had reasonable statistical properties, but the results for individual strata (business type, lighting control type, business size, or northern vs. southern latitudes in the U.S.) were only occasionally different from the mean at traditional statistical threshold levels.

NEBs Were Significant

The value of estimated NEBs for each of the three stakeholder groups interviewed is displayed in the sidebar to the right. Total NEB values were statistically higher for warehouses and lower for schools (decisionmakers), results were mixed for more sophisticated controls, and values were higher for southern latitudes (occupants).

Sidebar: Quantified Value of NEBs for Controls

- Managers and decisionmakers from survey: average 11.4% of maintenance FTE
- Decisionmakers in utility programs: average 130% of energy savings
- Occupants: average 7.8% of FTE for each employee in treated workspace – a large "adder" to ROI calculations
- Of this, a minimum 2% FTE in self-reported "productivity" effects per employee

[1] "NEBs" is the original term coined by the initial inventors of the topic. Later researchers objected to the use of "benefits," since both positive and negative effects are relevant and included. A host of terms – some that do not address the core issue with the term – have been used (co-benefits, multiple benefits, non-energy effects). The term "NEIs" is perhaps a preferred term, and used fairly widely; however, we also note NEBs is original and easier to say in conversation. We use mostly "NEBs" here because the RFP was initially stated as requesting NEB work.

Implications for Marketing

The results also provide advice to vendors about those features that are most attractive to market to businesses considering purchasing controls. Managers and decisionmakers recognized and valued most highly the NEBs listed in **Table 2.2** (refer to **Section 2.1 NEB Valuations**). Decisionmakers referred by utility energy efficiency programs who had participated in equipment decisions tended to list cost and/or value effects; managers in general focused on productivity and safety. Negative impacts were also reported, with decisionmakers focused on intensity (i.e., quantity of illumination), color, maintenance, and user interface, and occupants focused on disruptive on/off cycles when they did not move around enough, and eye strain from the cycling. However, the impacts were strongly net positive. The most highly valued NEBs by each stakeholder group are shown below.

Most important NEBs by stakeholder group		
Decisionmakers from utility sample	**Decisionmakers from survey**	**Occupants**
• *Extending the life of lighting equipment* • *Look and ambiance of the space* • *Control over energy use* • *Maintenance and associated labor costs* • *Carbon emissions or goodwill from being green* • *Flexibility of the space/usage; value/ease of renting the space*	• *Internal and external building safety and security* • *Productivity from the automation of the lighting and equipment* • *Quality of lighting in the space* • *Ability to perform work more efficiently and effectively*	• *Feeling of safety/security within the building* • *Feeling of safety/security outside the building* • *Improvement of quality of light in the workspace* • *Ability to do their job more efficiently and effectively* • *Productivity from having high quality light in the workspace*

2. Executive Summary

The study was focused on developing an approach for quantifying non-energy benefits (NEBs), also called non-energy impacts (NEIs), for lighting controls and, if possible, developing monetized or monetizable estimates for the two primary stakeholders in commercial buildings: decisionmakers or managers, and occupants. The results could help illuminate the value of the omitted effects of controls in the commercial sector, potentially improve benefit-cost ratios for this equipment, and increase uptake of the measures in utility programs and the general marketplace.

The study conducted interviews or surveys with four groups of stakeholders:

- Professionals (subject matter experts, or SMEs) in lighting controls, such as vendors, distributors, and contractors. The goal was to conduct in-depth interviews (fewer than a dozen) with this group. They were interviewed to obtain additional background on common equipment options and relevant NEBs, and to discuss alternatives on approaches to make the study more feasible, attractive, and relevant to end users.
- Decisionmakers referred by utility energy efficiency programs, with contacts made by the utilities. Only a few responded to this survey, but their input was especially valuable because they tended to be decisionmakers who were familiar with the equipment installed, its promised performance factors, costs, and savings. These knowledgeable respondents were asked to value the NEBs relative to energy savings for the measures, the most common method of approaching NEBs that are not directly financial.
- Occupants, whose results were derived from responses from two combined sources: a small number (10) of completed surveys from utility programs and a larger group from a purchased sample of commercial workers, with quotas established on the four business sectors of interest (offices, healthcare facilities, schools, and warehouses). They were used to provide feedback on the value of non-energy benefits from controls based on their assessment of the equipment's effects on the occupants' net increases in productive time compared to a workspace without controls. SERA translated the average minutes to the percentage of an employee FTE.
- Managers or decisionmakers, included in the purchased sample for the commercial worker survey and separated by job title or function. This larger sample of decisionmakers provided responses of the value of the non-energy benefits for line managers and decisionmakers. Their responses were also expressed in minutes of productive time, which were averaged and then translated into the percentage of an employee FTE.

The groups and their sample sizes are shown in **Table 2.1**.

Table 2.1. Sample Completions by Group

Group	Goal Sample Size	Achieved Sample Size	Means of Acquisition	Notes
SMEs	0	10	Cold calls to firms in lighting, plus referrals	For background on NEBs, categories
Managers, Decisionmakers	5 each of 4 business types = 20 total	12	From utility program web link	68 total, exceeding project goal
		56	Managers taking occupant survey	
Occupants	15 each of 4 business types = 60 total	127	127 from purchased sample, 4 business types	137 total, exceeding project goal
		10	10 utility program manager forwarding	

Generally, the building managers and decisionmakers represent purchasers and users of lighting controls, who gain positive effects from energy savings but also direct financial benefits from potential operational savings and productivity benefits (and other effects) that may come from staff working in an environment with automated lighting controls.

Building workers and other occupants do not make decisions about the equipment or benefit from the energy savings, but the study explored the degree to which they recognize positive or negative effects that controls technologies have on their environmental, productivity, and workplace experience.

The decisionmakers were asked about 14 different NEBs relevant to their perspective, and occupants were asked about 15 NEBs.[2] The estimated net NEBs for both groups were positive; that is, the positive effects outweighed negative effects from the technologies.

The quantitative estimates of NEBs developed by the project team are explained in **Sections 2.1** through **2.5.** The results are presented for multiple groups of respondents.

2.1 NEB Valuations

Decisionmakers and Managers Overall

The following overall results were identified for decisionmakers:

- **NEBs worth 11.4% of one maintenance worker FTE: Table 2.2, Figure 2.1, and Figure 2.2** show that decisionmakers from the occupant survey reported an average of 11.4% of a full-time equivalent (FTE) maintenance or facility staff member would be needed to provide similar impacts on the workplace as provided by the advanced lighting controls (ALC), over a space

[2] The NEB categories are listed in a table in **Section 3.3 Study Design as Implemented.** Note that two additional NEBs were asked about for school respondents, and one additional was asked about for respondents in the health sector. All respondents were asked whether they had difficulty separating NEB effects, or whether there was overlap. If there was, then to be conservative, the effect was reduced by spreading the largest value across all overlapping effects and deleting the lower values.

without these types of controls.[3] The 90% confidence interval (CI) associated with this estimate is 9.9% to 12.9% of an FTE. This is multiplied by the pay scale for this job title, and the resulting dollar value is then added to the energy savings to provide a more complete benefit-cost computation related to the purchase and installation of advanced controls.

- **NEBs value of 130% of energy savings**: Using the small-sample survey of decisionmakers that participated in utility programs (see **Figure 2.3**), the net value in the associated features and performance was 130% times the energy savings, or 30% more valuable than the energy savings from the advanced controls installed.[4] This implies the return on investment (ROI) is 2.3 times higher than the ROI calculated using only energy savings. The 80% confidence interval associated with this value is 112% to 148% of the measure's energy savings. It is important to note that this smaller sample size group is included in the reported results because they were directly involved in decision-making regarding the installation of the lighting control measures, and the other, larger sample of decisionmakers are self-reported managers or decisionmakers at the commercial establishment, but were not always directly involved in lighting decisions.[5,6]
- **Conservative assumptions**: The approach used in this study used conservative assumptions in the calculations.[7]
- **NEBs significantly higher for warehouses, lower for schools**: Warehouses showed higher total NEB value (average 13.6% of an FTE) than did schools (6.4% of an FTE), with the difference significant at the 90% confidence level. However, there were only six school responses, so the results should be applied with caution.
- **Higher NEB value for basic controls systems**: There is also some evidence of variation by lighting control system; however, these differences do not show up at the 90% confidence level. At the 80% confidence level, the NEBs associated with Level 1 lighting controls (see "Preparing the Data" in **Section 3.3 Study Design as Implemented**) without outdoor lighting have higher

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[3] The individuals in this sample did not necessarily know the costs or savings associated with the advanced controls measures.

[4] This individuals in this sample were aware of the cost and the estimated energy savings expected for the measures, and could be asked questions using this reference point.

[5] For this sample, the results were estimated two ways: using in-sample-derived label weights, and published, or "academic," weights. The mean for the in-sample weights was 130%, with a 90% confidence band of ±24%, and an 80% confidence band of ±18%. The mean using academic values for this small sample decisionmaker group was 147%. The more conservative value is presented in this report. It should also be noted that more detail on differences between in-sample vs. published weights is presented at the end of **Appendix B.**

[6] It is important to note that lighting controls receive additional incentives in some state programs. In several states, the utility can include a NEB "adder" for commercial and industrial (C&I) measures and programs in the benefit-cost screener tests, with the adder based on energy savings. This may encourage additional incentives for these measures in programs in these states. These adders are discussed in **Appendix A**, including the states in which various adders are in place (see **Table A.6**).

[7] For example, when customers reported that some NEB categories overlapped, the NEB values were re-apportioned out between the value given for just *one* of the overlapping NEBs, not both, thus reducing the NEB value. Estimates were derived using in-sample values for "label" weights to check for differences. Confidence intervals are presented to allow use of conservative values. Finally, one last conservative calculation was carried out. The research team estimated the NEBs based only on the minutes associated with the top four NEB categories for each respondent, information that was gathered earlier in the survey. For decisionmakers taking the occupant survey, the top four NEBs represented 85% of the total reported NEBs, and for (combined) occupants, 76.4% of the total NEBs were associated with the top four NEBs. If users wanted even more conservative estimates, these percentages could be applied. However, use of the lower confidence interval bounds is the traditional application.

NEBs than do Level 1 lights with outdoor lighting. Sample sizes are small, and the confidence level is lower than the traditional 90% threshold.

Table 2.2. Average (Mean) Total NEB Value: Overall and by Strata, and Statistical Differences for Decisionmakers and Occupants

Column Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Decision-Maker Respondents	All	Office	Hospital	School	Ware-house	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Number of Obs.	56	22	5	6	23	4	6	10	3	17	14	18	38	18	16
%FTE-Mean	11.38%	10.03%	13.08%	6.35%	13.61%	9.13%	10.26%	10.81%	17.31%	11.58%	12.50%	11.88%	11.14%	9.94%	11.18%
Signif. Differences 90%	No	No	No	Yes, 5	Yes, 4	No	No	No	No	No	No	No	No	No	No
Signif. Differences 80%	Yes, 4, 5	No	No	Yes, 5	Yes, 4	Yes, 9	No	No	Yes, 1, 6	No	No	No	No	No	No

Column Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Occupant Respondents	All	Office	Hospital	School	Ware-house	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Number of Obs.	137	32	30	43	32	3	9	8	23	79	13	66	68	73	34
%FTE-Mean	7.78%	8.28%	8.92%	6.55%	7.87%	8.21%	7.65%	10.34%	4.90%	7.27%	15.15%	7.70%	7.95%	6.41%	10.71%
Signif. Diffs 90%	No	No	No	No	No	No	Near, 11	No	Yes, 11, 9	Yes, 11	es, 1,9,10,~7	No	No	Yes, 15	Yes, 14
Signif. Diffs 80%	No	No	No	No	No	Near, 11	Yes, 11	Yes, 9	Yes, 11, 9, 8	Yes, 11	1,9,10,7, ~6	No	No	Yes, 15	s, 14, 1, 15

Table notes:

- The last two rows of each table note whether there are significant differences between the value for the specific column and any other column numbers. For example, if column 14 says it is different from column 15 (numbers at the top of the table), then the northern and southern latitude values are significantly different from each other, at the statistical significance level identified in the far left-hand column.
- More detailed versions of this table are provided in **Section 4.3, Section 4.4,** and **Appendix B.**

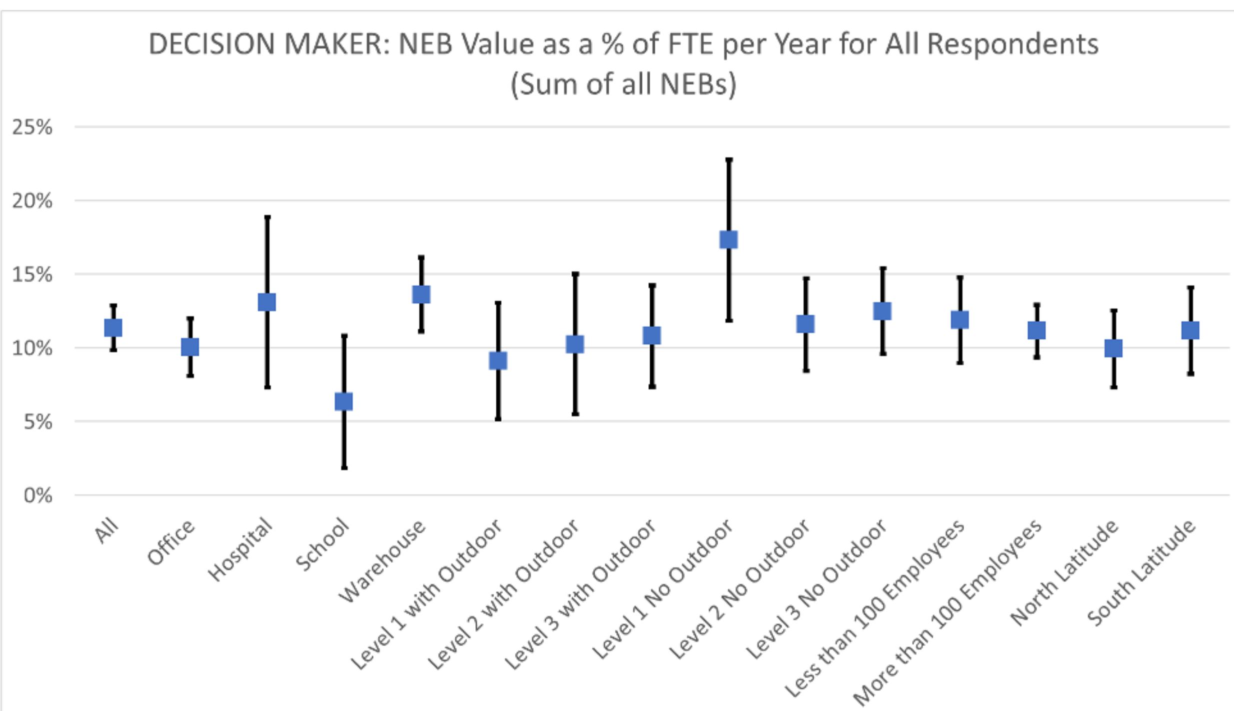

Figure 2.1. Decisionmakers: Total NEB value expressed as a percentage of an FTE – overall and by strata. (Box represents average (mean) value; "whiskers" identify the 90% confidence interval.)

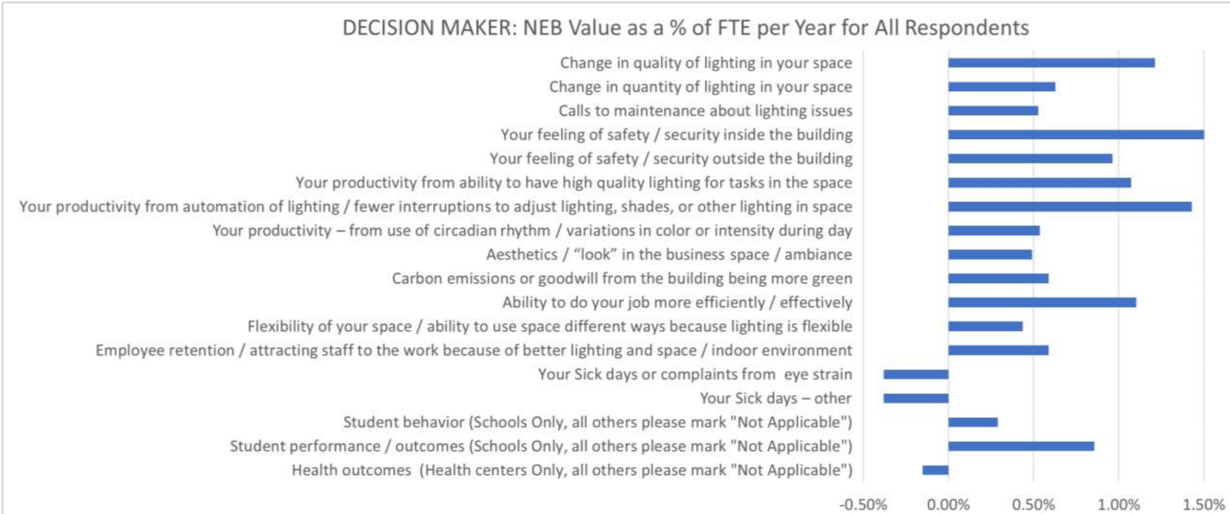

Figure 2.2. Decisionmakers: Value of individual NEB categories expressed as a percentage of an FTE – overall.

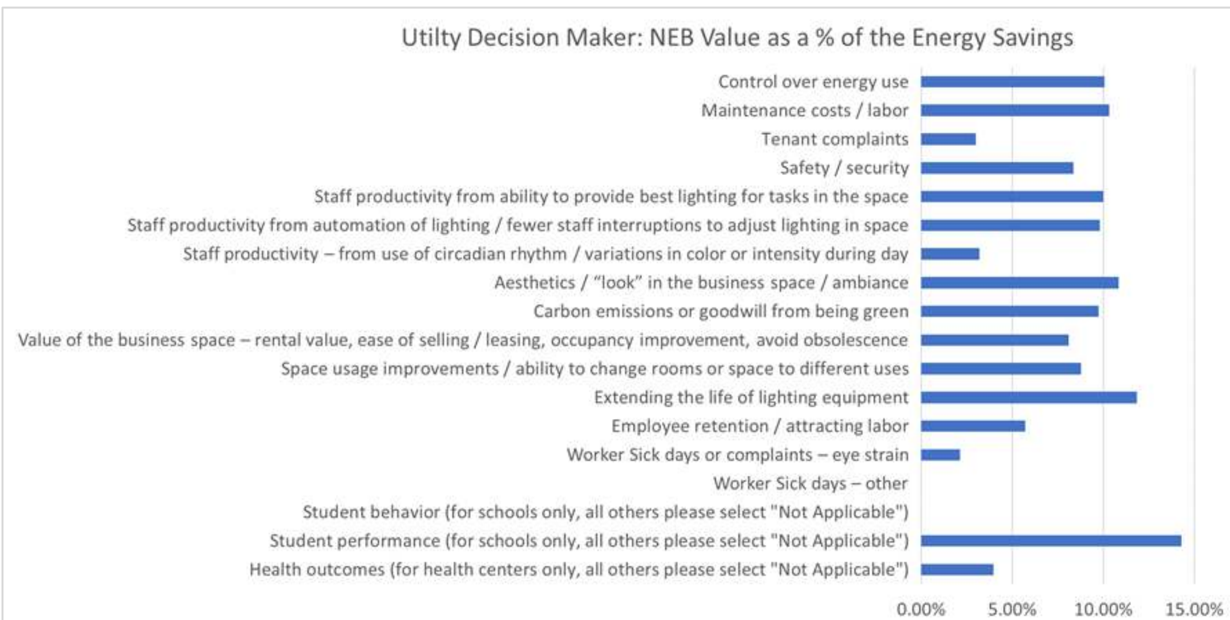

Figure 2.3. Decisionmakers from utility sample: Value of individual NEB categories expressed as a percentage of energy savings (small sample). Total NEB value = 130% of energy savings.

Occupants, Staff, Employees

The occupant values were expressed in terms of minutes of greater productivity or avoided minutes spent adjusting their work environment, compared to a similar workspace without advanced controls. These "minutes" results were then translated into a percentage of the full-time equivalent hours for the employee. The reported results are as follows:

- **7.8% of FTE NEB value for average employee**: The bottom of **Table 2.2** and **Figure 2.4** show that occupants reported an average of 7.8% of FTE-equivalent staff time per employee in self-reported net *increases in productive time from the operation of the controls equipment*. The 90% confidence interval for this value is 6.6% to 8.9% of the value of an FTE. The most appropriate and conservative methodology for translating this to a dollar value would use marginal worker take-home pay to reflect value to each of the workers. However, the value to the company is calculated as the percentage of an FTE per employee times the marginal fully loaded pay times the number of employees working in the improved workspace – *a potentially very large number and large "adder" that improves the cost-effectiveness and ROI of the advanced controls to the company*.
- **Minimum 2% FTE in productivity effects per employee**: If an owner, developer, or manager considering purchasing an advanced controls system wishes to be especially conservative, the portion of improvements pertaining to "productivity" that are attributable to NEBs is about one-quarter of the reported total value, or about 2% of an FTE, *for each employee affected by the system*. This was calculated using the information on individual NEB values shown in **Figure 2.5**. An adder equal to 2% - 8% of labor costs, attributable to the lighting controls system (in addition to energy savings) is likely a very significant factor in improving the cost effectiveness of a controls system.[8]
- **Conservative assumptions**: Conservative assumptions were used in deriving these results.[9]
- **Occupant NEBs higher for southern latitudes**: The NEB value is higher for the southern latitudes[10] (10.7% FTE), than for northern latitudes (6.4%) at the 90% confidence level, and both are different from the overall average at the 80% confidence level.
- **Highest NEBs from most sophisticated controls**: Occupant NEB estimates for Level 3 lighting controls (without outdoor lighting) were significantly higher (15.2%) than those for Level 2 (7.3%) or Level 1 (4.9%) systems at the 90% confidence level. Significant results did not carry through to different control levels *with* outdoor systems included, as these outdoor options had very small sample sizes.

[8] If sample sizes had been higher for Level 2 or 3 advanced controls systems, more refined estimates might have been possible.

[9] For example, when customers reported that some NEB categories overlapped, the NEB values were re-apportioned out between the value given for just *one* of the overlapping NEBs, not both, thus reducing the NEB value. Estimates were derived using in-sample values for "label" weights to check for differences. Confidence intervals are presented to allow use of conservative values. Finally, one last conservative calculation was carried out. The research team estimated the NEBs based only on the minutes associated with the top four NEB categories for each respondent, information that was gathered earlier in the survey. For decisionmakers taking the occupant survey, the top four NEBs represented 85% of the total reported NEBs, and for (combined) occupants, 76.4% of the total NEBs were associated with the top four NEBs. If users wanted even more conservative estimates, these percentages could be applied. However, use of the lower confidence interval bounds is the traditional application.

[10] Respondents were assigned to the southern latitude if the state was on or south of the 35th latitude, and to the northern latitude group if the state was on or north of the 40th latitude. The middle of the country was omitted from the comparison.

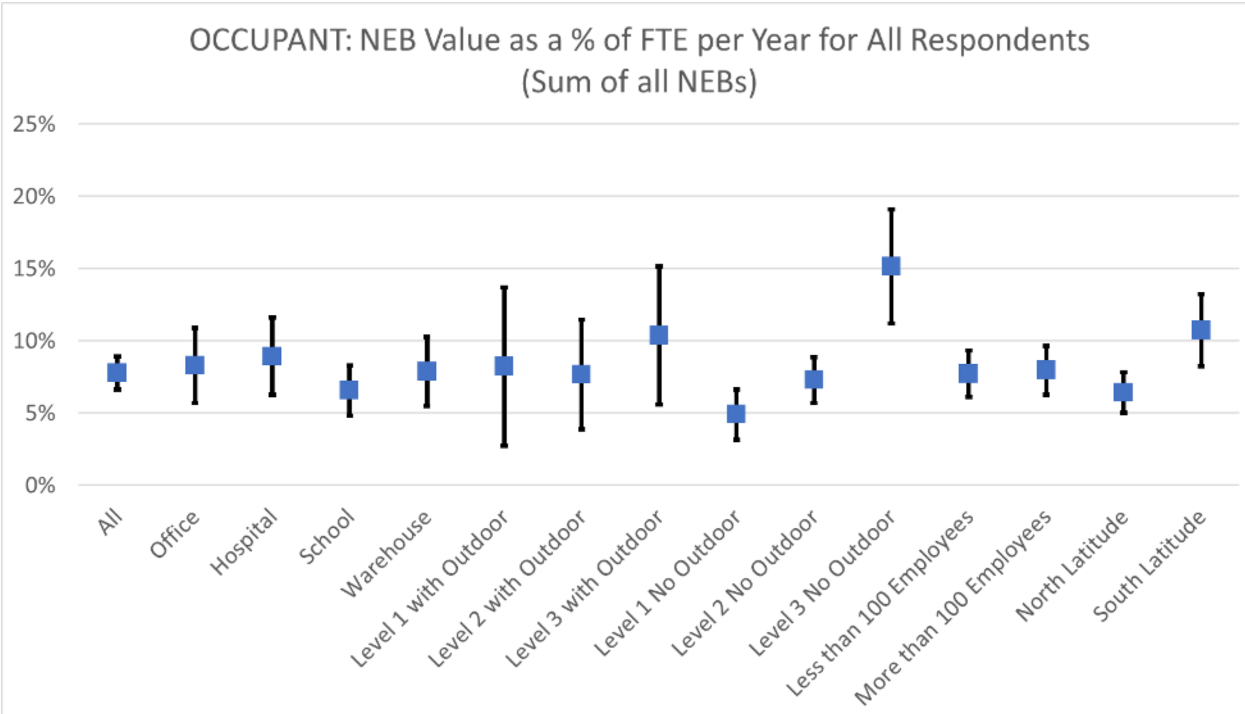

Figure 2.4. Occupants: Total NEB value expressed as a percentage of an FTE, overall and by strata. (Box represents average (mean) value; "whiskers" identify the 90% confidence interval.)

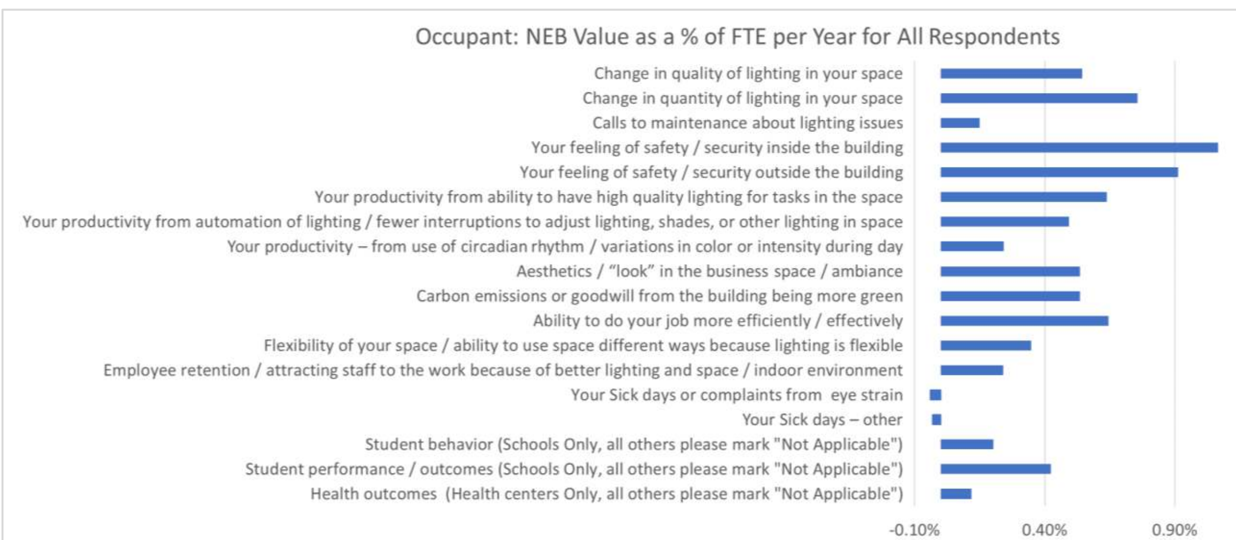

Figure 2.5. Occupants: Value of individual NEB categories expressed as a percentage of an FTE, overall.

Substantial Adder to Benefit-Cost and Payback Calculations

These NEB estimates are significant, with a value of 11.4% of a facility maintenance FTE, or 130% of energy savings in direct benefits recognized by decisionmakers, and potentially 7.8% of an FTE's time *for every employee in a workplace with the systems*. Even if only the most conservative subset of occupant

NEBs are considered valuable to businesses by managers or decisionmakers (including only those NEBs specifically mentioning "productivity"), it appears that businesses could add at least 2% of labor costs to the benefits in a benefit-cost analysis (BCA) or ROI calculation for controls measures. If recognized, this combination of valuations – energy savings plus direct decisionmaker benefits plus 2% - 7.8% of labor costs – could make investment in these measures substantially more attractive to businesses.

2.2 Most Valued NEBs

Marketing Emphasis

The results of the survey can be informative to vendors regarding those features that will be most attractive to businesses considering purchasing controls. Managers and decisionmakers recognize and value the NEBs listed in **Table 2.3** most highly.

Table 2.3. Highest Valued NEBs by Respondent Group

Decisionmakers from utility sample	Decisionmakers from survey	Occupants
• Extending the life of lighting equipment • Look and ambiance of the space • Control over energy use • maintenance and associated labor costs • Carbon emissions or goodwill from being green • Flexibility of the space or its usage • Value and/or ease of renting the space	• Internal building safety and security • Productivity from the automation of the lighting and equipment • The quality of lighting in the space • Ability to perform work more efficiently and effectively • Safety and/or security outside the building	• Feeling of safety and/or security within the building • Feeling of safety and/or security outside the building • Improvement of quality of light in the workspace • Ability to do their job more efficiently and effectively • Productivity from having high quality light in the workspace

2.3 Negative Impacts

Although overall, NEBs were net positive for the controls systems, some share of respondents from both decisionmakers and occupants did note negative effects as part of the array of non-energy effects. Review of these negative effects provides useful feedback on barriers and concerns about aspects of the controls technologies.[11] The study reviewed the negative impacts reported by individual category, as well as patterns by various strata. Negative impacts were lowest in warehouses, and relatively high for the respondents with Level 1 controls systems (e.g., simple, non-integrated occupancy sensors). Decisionmaker responses included a higher share of negative values in the individual NEB categories than did those from occupants, and although negative responses were scattered across most of the

[11] With large sample surveys, the negative NEBs can be powerful signals of barriers to a measure or program that should be considered in research and development (R&D) in the longer run, or program incentives or remedies in the short run that can offset the negative effects.

categories, the two or three NEBs that showed values that were net negative or nearly so were related to eye strain, general health, and sick days.

Negative effects associated with eye strain, sick days, and general health may seem contrary for measures that are focused on trying to adjust light to be responsive to perceived occupant needs (and save energy). When asked to identify what is helpful and not helpful about the advanced lighting controls, the majority of both respondent groups (just over 60%) stated "None," or "They are all helpful."[12] However, the responses from the remaining respondents show[13]:

- Decisionmakers statements were not numerous but focused on light intensity (i.e., quantity of illumination) and color as well as and possible maintenance issues, such as flickering and strange sounds. Decisionmakers also made comments about the user interface and alarm redundancy.[14]
- The majority of occupant-worker complaints focused on the timer on the occupancy sensor. There were multiple comments about the lights turning off while they were working, in the restrooms, or during online meetings, and they commented on negative productivity effects when they needed to interrupt work to stand up or move around to turn the lights back on. Others noted eye-strain effects from lights turning on and off in the space, some noting that it happened "suddenly."

Addressing proper timers and motion sensitivity settings (for less sophisticated systems) would appear likely to bring significant payback in reducing dissatisfaction among those occupants expressing negative NEBs, and the study shows the specific reduction in expressed "costs" that could be reduced from these efforts. In addition, the results on negative effects may suggest to manufacturers areas for R&D focus that can reduce the costliest barriers and bring the biggest payback in future generations of controls systems.

2.4 Study Conclusions and Caveats

The study demonstrated that estimates of NEBs could be developed for lighting controls, and the study provides monetized or monetizable values for both decisionmakers and occupants. The study used conservative assumptions in deriving the results. The key results were:

- Decisionmaker NEBs: 11.4% of a custodial FTE.
- NEBs for decisionmakers from utility sample: 130% of energy savings from the measures, or a value that is 30% *greater* than the dollar value of the energy savings from the measures.
- Occupant NEBs: 7.8% of an FTE for each occupant in the workspace with the advanced lighting control measures. Alternatively, if a very conservative BCA is needed for decisionmakers, a value

[12] Helpful effects included statements that motion activated lights are helpful, an energy saver, and a big time saver in warehouses. Positive notes included statements like "I don't have to think about it," fewer janitors having to walk around turning off switches, safety walking to vehicles, and feeling safe inside. Positive comments about more sophisticated systems lauded the ability to control lighting in patient rooms remotely, daylight harvesting, automatic dimming on bright days, and the positive changes from bright white for paperwork to soft light that is better for online meetings (e.g., with Zoom).

[13] The full list of verbatim responses is provided in **Appendix B** .

[14] Decisionmaker positive effects focused on the savings in labor from automated changes and safety effects, and there were multiple comments about more sophisticated systems including remote control, and more nuanced effects of changes in color and brightness and positive effects on productivity.

of 2% of an FTE for occupants may be used, which subsets the occupant NEBs to include only those directly mentioning productivity benefits.

These values are appropriate to add to a benefit-cost assessment, payback analysis, or ROI computations to provide a more complete assessment of the benefits compared to the costs.

Results on leading NEBs for the various subgroups were also developed. It will be useful to take steps to help make sure that vendors, programs, and others in the chain of recommending and installing controls equipment understand and communicate both: 1) the monetizable NEB values to businesses (directly *and* through occupant-reported productivity improvements), and to occupant satisfaction; and 2) the array of NEBs that are valued by decisionmakers and occupants (see **Figure 2.5**, in **Section 2.1 NEB Valuations**). This information is crucial to making sure all relevant stakeholders can speak about the most important features of controls from the purchaser's point of view and conduct a dialogue that will likely be more successful in expanding adoption of building and lighting controls in commercial buildings.

The main caveats associated with these results are noted in **Table 2.4**.

Table 2.4. Strengths and Caveats Associated with the Estimates

Strengths and Features of the Estimates	Caveats
• The project achieved more than the study's initial sample goals (60 occupants, 20 decisionmakers). • This study achieved sufficient sample size to meet statistical thresholds and develop statistically defensible estimates. A total of 68 responses from decisionmakers (in two groups) and 137 responses from occupants were analyzed. • The NEB survey and analytical approach were adapted from methods with two decades of applications for energy efficiency programs, and extensive foundation in the literature. • The study was able to exceed project goals. Rather than positing and validating or pre-testing a method, the study developed quantitative results with statistically significant sample sizes for each of two main groups. • The overall sample size was sufficient to meet basic statistical thresholds and provide quantitative results that can be used to indicate that NEBs for these measures are significant and indicate benefit-cost analyses (BCA) using energy only are understating the benefits of controls measures.	• Obtaining respondents for the needed groups was far more complicated than anticipated and did not achieve the desired number of respondents for each business type, thus hampering the ability to detect differences between these strata. • Because respondents were recruited from open samples, most respondents (and all occupant respondents) were unaware of which specific types of advanced lighting technologies were installed in the building. Also, utility samples would have provided more knowledgeable decisionmaker respondents. • Very few respondents indicated the presence of any controls affecting more than lighting. • Granularity by controls type was not possible. • Sample sizes were not large enough to provide statistical reliability for most of the substrata. Where results are significantly different, they are reported.

2.5 Remainder of the Report

The remainder of this report includes:

- **Section 3: Study Design and Development**
- **Section 4: Study Results and Recommendations**
- **Appendices**:
    - More detailed information on the status of commercial NEB estimates in the literature, and the NEB adders incorporated by states for commercial energy efficiency measures **(Appendix A)**
    - More detailed results tables from the NEB estimation work and verbatim responses **(Appendix B)**
    - The survey instruments used in the study (**Appendix C**, under separate cover)

3. Study Design and Development

Advanced lighting controls in the commercial and industrial sector provide a wide array of benefits to building managers and building occupants. These measures are also becoming more and more important to energy efficiency programs, as LED market advances have shrunk the energy savings available from lighting. Estimates of energy savings attributable controls are generally available; however, the DLC and its members are aware that these estimates likely represent only a fraction of the value provided by ALCs.

3.1 Original Study Expectations

In this document, the terms “NEBs” and “NEIs” refer to the positive and negative effects, beyond energy savings, that accompany energy efficiency equipment. These effects can be experienced by the utility (e.g., reduced electric load, better bill payment behavior), society and non-participants (e.g., job creation, lower emissions and associated effects), and purchasers. It is particularly this last group that the DLC was interested in because if the extra effects associated with the ALCs are net positive, the purchasers of the equipment will experience a net improvement in the payback or return on investment (ROI) from choosing and installing ALCs. However, this relies on the NEBs being: 1) effects that are actually recognized by and valued by purchasers; and 2) credibly quantified.

The project goal was initially focused on developing a feasible NEBs measurement method that could be used by DLC members to explore NEBs, and then validating the method using small samples of interviews. However, the consultants (SERA) worked with the DLC team to identify ways to leverage efforts and increase the sample size, within the study’s original budget, so the study could develop estimates based on samples sizes that met traditional 90/10 statistical thresholds. This raised the possibility of being able to provide valuations of the NEBs with known statistical properties and increased the direct usefulness of the study to DLC members.

With defensible, monetizable valuations of these additional non-energy impacts, DLC members can use them to:

- Provide monetized estimates of total and specific benefits that can improve estimates of benefit-cost, payback, and ROI estimates for ABC equipment by reducing the current downward bias in these metrics. This information is valuable for better informing specifiers, owners, and other stakeholders (potentially real estate professionals, appraisers, property managers, and others) in investment decision making regarding these technologies
- Identify additional, attractive, prioritized “selling” points for ABCs for marketing to various decisionmakers and stakeholders
- Identify variations in the NEB categories and their relative total and individual variations for four key business sectors
- Help owners and decisionmakers understand the key benefits of ABCs to occupants that may aid with employee retention and satisfaction

- Help identify barriers and problems with ABCs that may be the focus of equipment or implementation improvements, better outreach or training, or R&D efforts, with barriers represented by any negative NEBs that are identified and/or estimated[15]
- Potentially improve the benefit-cost analysis for measures and programs for utility energy efficiency programs, leading to increases in measures included and their utility incentives, as well as associated information dissemination by utilities, updates of the measures in the C&I sector, and other uses

The RFP identified the four main project activities as:

- Conduct background research on C&I NEB estimation work and literature (see **Appendix A**)
- Review existing state and utility NEBs and adders for C&I NEBs (included in **Appendix A**)
- Develop a methodology that can be used to monetize NEBs (see **Section 3.2 Planning the Study Approach** and **Appendix B**, **Sections B.4** and **B.5**)
- Validate the method (Chapter 4)

Results are summarized in **Section 1 Introduction** and **Section 2 Executive Summary**.

The RFP noted that the study was interested in four main business types:

- Offices
- Health and hospital facilities
- Schools and other educational facilities
- Warehouses

Also from the RFP, the following equipment was included in the definition of advanced building and lighting controls for this project[16]:

- Networked (lighting) control systems
- Building IoT that provides data about conditions within the building (IAQ, occupancy levels, comfort levels) and, potentially, wayfinding and asset tracing
- Analysis applications that collect information from building systems (space utilization, heat mapping, energy use visualization, exception reporting, fault detection, and other advanced analytics that advise building management on building operation or automatically issue corrective commands to building systems)
- Light sensors
- Control of lighting in outdoor spaces including motion sensors and advanced scheduling

[15] Negative NEBs are not uncommonly estimated for certain advanced C&I technologies, usually represented by advanced HVAC systems that owners fear existing building custodial and/or engineering staff or local HVAC contractors will not be able to adequately operate or maintain. The value of a negative NEB provides an estimate of the dollars needed to "get potential purchasers to neutral," or make them willing to purchase the equipment. This incentive may be in the form of additional contractor visits, enhanced warranties, incentives, or other remedies with an estimate of the specific value needed. SERA estimated the first negative NEBs, and pioneered this research and these interpretations and applications of negative NEBs.

[16] From the RFP, page 3.

- Integration of building systems – between networked lighting controls and other building systems including heating, ventilation, and air conditioning (HVAC), shade or window controls, access control, energy metering, onsite energy generation, and grid response (inkling system configurations that make the building more responsive to occupants)

Similarly, a preliminary list of NEBs of interest from the RFP included changes in[17]:

- Occupant productivity
- Occupant comfort
- Maintenance
- Space utilization
- Carbon emissions

3.2 Planning the Study Approach

The results summarized in **Sections 1** and **2** and described in detail in **Section 4** are the product of several analytical steps. The first step involved a review of the literature on commercial NEB estimation work and measurement methods. The results of this work are presented in **Appendix A**.

Review of Previous C&I NEB Studies

This research found that NEBs estimates for C&I controls measures had been investigated in about half a dozen previous studies (1999 through 2018), and the work focused mainly on occupancy sensors and HVAC controls, with a few focused on lighting controls, energy monitoring, and energy management systems. These studies focused on estimating operations and maintenance (O&M) NEBs, with a few also estimating emission effects. The value of these O&M NEBs varied from 3% to 5% of energy savings for lighting controls in Massachusetts, to estimates of "all NEBs" that ranged from 64% of savings for EMS systems to 129% of savings from occupancy sensors. Several studies also provided dollar values. C&I NEB estimation methods and results were provided in about a dozen studies (1999 through 2020). The estimation methods used when primary data were collected included quantification of expert interviews or stakeholder in-depth interviews coupled with engineering calculations (of O&M); participant surveys asking about NEB value relative to measures' energy savings with relative words or scales, or percentages or ratio estimates about increases or decreases in value; or conjoint and contingent value approaches.

Preferred Measurement Approach – Labeled Scaling

The most frequent approach used was participant interviews, using a "labeled scaling" phrasing. This approach takes account of the fact that many respondents cannot easily answer traditional "willingness to pay" or "willingness to accept" (WTP/WTA) questions asking how much the respondent would be willing to pay (in dollars) for individual or total NEB effects. Instead, this method uses the fact that respondents can fairly readily rate whether a particular NEB effect is more valuable or less valuable than

[17] Additional NEBs are mentioned later in the RFP.

some other factor whose (dollar) value is known. In most energy efficiency work, respondents are asked whether the NEB is more valuable or less valuable to them than the energy savings for the measure, with phrasing asking, for example, whether it is much more valuable, somewhat less valuable, or another similar "verbally scaled" or "label scaled" assessment. Published literature has found that these phrases translate fairly systematically to numeric multipliers that can be applied to the known dollar value "factor" (energy savings value) to provide a dollar value for the NEB. These multipliers have been checked against in-sample numeric multipliers in multiple previous energy efficiency NEB studies,[18] and found to be 1) consistent and increased or decreased as expected, and 2) have values quite similar to published literature values.[19] This approach was selected for the controls study because it provided the advantages of: being accepted in journals and other literature; being demonstrated as relatively easy for respondents to answer (increasing the trust in the responses provided, allowing faster surveys and therefore larger samples sizes for the budget); being able to be asked using a web survey approach (based on multiple previous studies); and having been used for similar types of energy efficiency NEB studies for nearly 20 years.[20]

Identifying a Suitable Comparison Factor

One of the most complex issues was finding a factor of known value that decisionmakers and occupants could relate to, so respondents could be asked if the NEB was more or less valuable than "X." Decisionmakers gathered from utility records could be asked the question relative to energy savings, using the decisionmakers approach used commonly for NEB studies on energy efficiency measures. However, occupants could not be expected to have any idea of energy savings, nor would they be able to relate to or likely care about energy savings, and so the value of energy savings to them would not be known or consistent. The consultant team conducted interviews with a number of lighting contractors, retailers, and vendors to ask questions around the study's design. They suggested that one option might be to ask about savings in occupant work time. Given no better options, and finding reasonable performance from the first few surveys, a variation of this approach was adopted – asking about minutes of time saved, which were later translated to percentage of full-time equivalent (FTE) staff time.

Identifying Survey Respondent Sources (Populations)

The DLC was interested in results for four business types – office, health, education, and warehouse sectors – and for a variety of advanced lighting controls. The study needed a population of decisionmakers who implemented these technologies and were familiar with controls technologies, and ideally, were familiar with the costs and savings and had operational experience with the systems. The study also needed a population of occupants in buildings with these advanced controls. In developing the proposal, the consultant team recognized several difficulties associated with assembling these populations.

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[18] Derived from asking respondents to provide percentage multipliers for a subsample of NEBs within the labeled scaling survey.

[19] For example: Skumatz LA, D'Souza D. NEB values for next generation LEDs: Residential, commercial, and street lighting. Proc ACEEE Summer Study on Buildings; American Council for an Energy Efficient Economy. Washington, DC; 2020.

[20] In addition, the approach is easier to construct and understand than conjoint and contingent valuation approaches, leads to shorter surveys, and can therefore ask about many more NEBs than some of these alternate approaches.

Decisionmakers: The hierarchy of possible sources included the following, with strong preference for sources 1 or 2.

1. **Utilities**: Utilities would have the ideal sample of decisionmakers, but the study was being conducted for the DLC and not a utility, so utilities might not want to participate, and participants might not be available for the four business types of interest.
2. **Vendors**: Populations of decisionmakers who purchased systems might be available from vendors, but they might not want to participate; in addition, sufficient samples might not be available for the four business types of interest.
3. **Purchased contact info**: Populations could potentially be purchased from vendors that specialize in selling contact information for any desired NAICS[21] codes (business types). Selection by certain job titles can be obtained to focus on potential decisionmakers. The difficulty with this sample source is that the percentage of respondents who would have purchased an advanced building or lighting controls system would be tiny, and combined with the low response rates commonly found in surveys over the last several years, hundreds or thousands of surveys would need to be solicited for each response, so costs would likely exceed the budget.
4. **Purchased panels with screeners**: Similar to the previous option, panels of survey respondents are maintained by various vendors. The advantages are that the contract can specify screening questions (e.g., have specific types of controls at the site, and specific business types and, potentially, decisionmakers), and the firm quotes a price per completed survey based on their estimate of incidence, which is in turn based on the screeners. The negative aspects of this source include: a possibly insufficient sample if screeners are very limiting (especially with job titles); and that during the COVID-19 pandemic,[22] increasing numbers of panel participants lie about their eligibility or “click through” the survey, leading to poor-quality data.

Occupants: The hierarchy of possible sources included the following, with strong preference for source 1.

1. **Forwarded by utility or vendor decisionmaker respondents**: Occupants were not available directly from utilities or vendor sources. However, decisionmaker respondents from utilities or vendor sources could be asked to forward a link to an occupant survey to a sample of their employees. These respondents might be asked for the name of their employer, so decisionmaker and occupant surveys could be linked and responses about specific systems analyzed from both sides.
2. **Purchased contact info**: As with decisionmakers, populations could potentially be purchased from vendors that specialize in selling contact information for any desired NAICS codes (business types). No selection by job title would be needed, or selecting “out” management titles might be appropriate. However, again, the difficulty with this sample source is that the percent of respondents who would realize they work in a building with an advanced building or lighting controls system would be tiny. Combined with the low response rates commonly found in

[21] North American Industry Classification System.

[22] Respondents are paid for completing surveys, and the survey firms indicate that respondents have more time (are unemployed or at home) and may need the income.

surveys over the last several years, hundreds or thousands of surveys would need to be solicited for each response, so costs would likely exceed the budget. Furthermore, employees solicited in this way may not be aware of the systems and would be unlikely to know much about what type of system was installed, recognizing only some of the effects of those systems (lights turn on and off "automatically, somehow.")

3. **Purchased panels with screeners**: Similar to this option under the decisionmaker list, panels of survey respondents are maintained by various vendors and screeners. The advantages are that the contract can specify screening questions (e.g., have specific types of controls at the site and specific business types), and the firm quotes a price per completed survey based on their estimate of incidence, which is in turn based on the screeners. Again, the negative side of this source is that some of the panel participants lie about their eligibility or "click through" the survey, leading to poor quality data. Furthermore, employees solicited in this way may not be aware of the systems, and would be unlikely to know much about what type of system was installed, only some of the effects of those systems (lights turn on and off "automatically, somehow."

Pre-interviews to Inform and Adapt Project Approach

The consultant team held discussions with the DLC team and reached out to more than 50 industry professionals, including contractors, lighting vendors or distributors, manufacturers, and others. The consultant team successfully connected with about 10 respondents, and gathered information on a variety of topics, including additional information on control measures, the types of language participants would be familiar and unfamiliar with, NEBs that might be experienced in each of the four key business sectors, possible comparison factors (since the most common NEB comparison factor, energy savings, would not be relevant to occupants), frequency of types of lighting controls, and other discussions. SERA also approached each to see if they were interested in participating in the project and in supplying customers that purchased equipment. Several promised leads, but these were not ultimately delivered.

Survey Approach

Although phone, mail, and web approaches are all available and have been used for NEB-type surveys, phone pre-interviews, and web surveys were selected for budget reasons and because these approaches have been successful in the past.

3.3 Study Design as Implemented

The study's actual implementation experienced some changes from the preferred plan. These obstacles are outlined below.

Decisionmaker Population

The consultants reached out to multiple utility and utility association contacts. Several utilities agreed to participate up front, but a couple found they had nearly zero participants who had actually selected and installed any controls measures. In addition, several utilities expressed reluctance to participate because of existing utility confidentiality requirements regarding customer privacy. After numerous meetings and discussions of NDAs and data transfer, the consultant team realized that it was unnecessary for the consultants to conduct the mailing or ever gather or touch any customer information. Instead, the utilities could send email requests with links to the survey, and the survey could be crafted to avoid collecting any customer information.[23]

The consultants crafted a "packet" of the email that utilities could send out to decisionmakers, including the decisionmaker link and a follow-on email that decisionmakers could send to their employees with an occupant survey link.[24] That helped for a few utilities; others did not wish to participate in a study that was not part of their regular Evaluation Plan or did not include existing contractors. Some checked records and found very few participants in programs who had installed the controls measures of interest.

The participating utilities were vital in obtaining real decisionmaker responses. These utilities sent out two rounds of emails to their eligible participants.[25] It became clear that utilities could not be the only (or even primary) source of decisionmaker data. Both the DLC and SERA reached out to vendor contacts, and the DLC reached out to vendor associations. One vendor association sent out a solicitation to their membership (vendors and some utilities) with the packet. After extensive effort and scores of contacts and outreach, a *total of 12 decisionmakers and 10 occupants completed surveys via this route.*

The consultant team then turned to purchased contacts for an additional decisionmaker sample with job titles, emailed out 2,250 emails, and obtained five responses, with two usable decisionmaker responses. Finally, SERA engaged a purchased panel survey for the occupant sample, but asked for job title within the survey. The survey provided responses that were true occupants, but also a significant number of respondents who were managers or decisionmakers. These decisionmakers have some of the perspectives of management, but most were not responsible for purchasing any of the controls equipment that was in place in the workplace. *This survey, after data cleaning, resulted in 127 useable occupant surveys, and 56 useable decisionmaker surveys*.

With the various sidetracks and recontacts, this process unexpectedly took several months to complete.

Survey Instrument

SERA used a review of their own in-house NEBs database; literature review; discussions with DLC staff; and interviews with subject matter experts (SMEs), including vendors, contractors, and designers to refine the list of NEBs that would be relevant for each group – decisionmakers and occupants. This list is included in **Table 3.1**. The objective was to provide a list that did not have redundancies, and that would enable assignment of each NEB to key features or aspects of the controls, where possible.

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[23] The agreed-upon exception was that customers could willingly provide their name and email address to receive a gift card as an incentive for completing the survey. Within the survey, only state, business type, and business size information were collected with the permission of the utilities.

[24] The solicitation offered $50 for each decisionmaker survey completed, and $15 for each occupant survey completed. All respondents completing the survey were also entered into a drawing for a $250 gift card.

[25] Many thanks to: Eversource, NYSERDA, Pacific Power, and the Integrated Lighting Campaign (ILC) for reaching out to their participants who had installed controls measures.

Table 3.1. NEBs Relevant to Decisionmakers and to Occupants

NEBs List for Decisionmakers	NEBs List for Occupants
1. Control over energy use 2. Maintenance costs/labor 3. Tenant complaints 4. Safety/security 5. Staff productivity from ability to provide best lighting for tasks in the space 6. Staff productivity – from use of circadian rhythm/variations in color or intensity during day 7. Aesthetics/“look” in the business space/ambiance 8. Carbon emissions or goodwill from being green 9. Value of the business space – rental value, ease of selling/leasing, occupancy improvement, avoid obsolescence 10. Space usage improvements/ability to change rooms or space to different uses 11. Extending the life of lighting equipment 12. Employee retention/attracting labor 13. Worker sick days or complaints – eye strain 14. Worker sick days – other 15. Student behavior (for schools only, all others please select "Not Applicable") 16. Student performance (for schools only, all others please select "Not Applicable") 17. Health outcomes (for health centers only, all others please select "Not Applicable")	1. Change in quality of lighting in your space 2. Change in quantity of lighting in your space 3. Calls to maintenance about lighting issues 4. Your feeling of safety/security inside the building 5. Your feeling of safety/security outside the building 6. Your productivity from ability to have high quality lighting for tasks in the space 7. Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space 8. Your productivity – from use of circadian rhythm/variations in color or intensity during day 9. Aesthetics/“look” in the business space/ambiance 10. Carbon emissions or goodwill from the building being more green 11. Ability to do your job more efficiently/effectively 12. Flexibility of your space/ability to use space different ways because lighting is flexible 13. Employee retention/attracting staff to the work because of better lighting and space/indoor environment 14. Your sick days or complaints from eye strain 15. Your sick days – other 16. Student behavior (schools only, all others please mark "Not Applicable") 17. Student performance/outcomes (schools only, all others please mark "Not Applicable") 18. Health outcomes (health centers only, all others please mark "Not Applicable")

The list of 14 to 18 NEBs was thorough, but also too long to reasonably ask of every respondent. The standard survey design would ask about each NEB. The consultant team considered sub-setting, asking subsets of NEBs to subsets of respondents, and combining the results. However, sample size was an issue and the team elected not to use this option. Instead, the questionnaire asked an initial question about the relative importance of each NEB, but then asked valuation questions about each respondent’s top four NEBs in detail, and then the value for the remainder.

Given that different NEBs would be important to different respondents, the hope was that values could be assigned across all the NEBs. Then the wording on comparison factors was crafted (see **Appendix B** for the specific survey instruments). The utility decisionmaker group was asked about value relative to energy savings using labeled scaling. All the other groups were asked about values in terms of minutes of time daily, and the SERA team later translated minutes to percentage of an FTE. The occupants from the purchased panel were asked about the number of minutes of extra productive time they realized from the top four NEBs (compared to a workspace without the controls), and how much more or less valuable the top four NEBs were, relative to each other. The value of “all the other NEBs” in terms of minutes was also asked, and the responses were attributed to individual NEBs based on the initial importance factors provided in the first round. The decisionmakers were asked about the amount of a facility manager’s or custodian’s time it would take to accomplish a similar effect, and the relative importance of various NEB effects. Respondents were also asked to provide the best-fit percentages associated with specific labeled values (e.g., much more valuable). A question about the total value of the NEBs was also asked.

Preparing the Data

Data needed to be cleaned, checked, and kept or deleted as it was coming in, to allow the consultant team to alert the panel survey supplier when the quotas were met. Cleaning involved eliminating click-throughs and unusable responses (e.g., too fast to complete, nonsensical responses in open ends, not passing logic checks). The verbal responses on in-sample multipliers were translated to numbers using averages within each sample group. Overlapping responses were shared out among the overlapping NEBs. The subgroups and strata were also identified and classified for analytical purposes, including latitude, business size, and lighting group:

- *Level 1 controls:* On/off/dim controlled by separate sensor on wall or ceiling.
- *Level 2 controls:* On/off/dim controlled by sensors integrated into the lighting equipment, or controllable by computer or phone app. Includes sequential lighting in, for example, halls.
- *Level 3 controls:* Shades or blinds automatically open and close based on occupancy or weather, or heating and cooling are integrated.
- *Level 4 controls:* Broader integration of functions and data monitoring.
- *Outdoor:* External or parking lighting turns on as a person approaches a car or leaves the facility.
- *Latitude:* Southern latitude if the state was on or south of the 35th latitude, and in the northern latitude group if the state was on or north of the 40th latitude; the middle of the country was omitted from the comparison.
- *Business size:* Small business if less than 100 employees; large if 100 employees or more.
- *Office:* Office category.
- *Hospital/health:* Hospitals, health clinics, nursing homes, care facilities, or similar.
- *School:* Schools, including any for grades K-12, colleges, universities.
- *Warehouse:* Small warehouses, large warehouses, small industrial buildings.

Analyzing the Results

A number of analyses were conducted, including: determining percentage positive and negative for each NEB overall and by strata; using numeric averages for labeled response categories to compute weighted averages for population-wide estimates; calculating normalized responses for each NEB for those experiencing (positive or negative) effects; computing sample-wide NEB estimates accounting for those not experiencing specific NEB effects; calculating NEBs for negative responses; and preparing results including multipliers, minutes as a percentage of an FTE, confidence intervals, and other results overall and by strata using tables and graphics. The occupant responses also required assigning multipliers to the top four ranked NEBs, and to "all remaining" based on initial 1 – 7 scaling in survey.

Results

Numerous tables of detailed results are presented in **Appendix C** (included separately). A summary of important results is included in **Section 4 Study Results and Recommendations** and in **Section 2 Executive Summary**.

4. Study Results and Recommendations

4.1 Summary of Quantitative Results

The results are presented for multiple groups of respondents. The groups and their sample sizes are shown in **Table 4.1**.

Table 4.1. Sample Completions by Group

Group	Goal Sample Size	Achieved Sample Size	Means of Acquisition	Notes
SMEs	0	10	Cold calls to firms in lighting, plus referrals	For background on NEBs, categories
Managers, Decisionmakers	5 each of 4 business types = 20 total	12	From utility program web link	68 total, exceeding project goal
		56	Managers taking occupant survey	
Occupants	15 each of 4 business types = 60 total	127	127 from purchased sample, 4 business types	137 total, exceeding project goal
		10	10 utility program manager forwarding	

Table Note: Table is identical to **Table 2.1** in **Section 2 Executive Summary.**

Respondent Groups

Each group brings an important perspective to the analysis. The building managers and decisionmakers represent purchasers and users of lighting controls, who gain positive effects from energy savings, but also direct financial benefits from potential operational savings and productivity benefits (and other effects) that may come from staff working in an environment with automated lighting controls. Building workers ("occupants") were also interviewed. Although they do not make decisions about the equipment or benefit from the energy savings, the study explored the degree to which they recognize positive or negative effects that controls technologies have on their environmental, productivity, and workplace experiences. The decisionmakers were asked about 14 different NEBs relevant to their perspective, and occupants were asked about 15 NEBs.[26] The estimated net effects for both groups were positive; that is, the positive effects outweighed negative effects from the technologies.

Positive and Negative Effects

The respondents were first asked to identify whether the lighting controls in their building caused them to experience any positive, negative, or no effects from the list of NEBs. **Figure 4.1** presents results for the decisionmakers, and **Figure 4.2** presents overall results for the occupant respondents. The figures

[26] The NEB categories are listed in tables in **Sections 4.3** and **4.4**. Two additional NEBs were asked about for school respondents, and one additional was asked about for respondents in the health sector. All respondents were asked whether they had difficulty separating NEB effects, or whether there was overlap. If there was, then to be conservative, the effect was reduced by spreading the largest value across all overlapping effects and deleting the lower values.

show that 60% to 80% or more of the respondents attribute positive impacts to the majority of the NEBs mentioned, and in most cases, 10% or fewer attribute any negative results to the controls. The highest positive results for decisionmakers related to safety, security, and productivity. The most negative items are related to sick days. For occupants, the highest positive values are safety, security, aesthetics, goodwill, quality of light, and carbon issues.

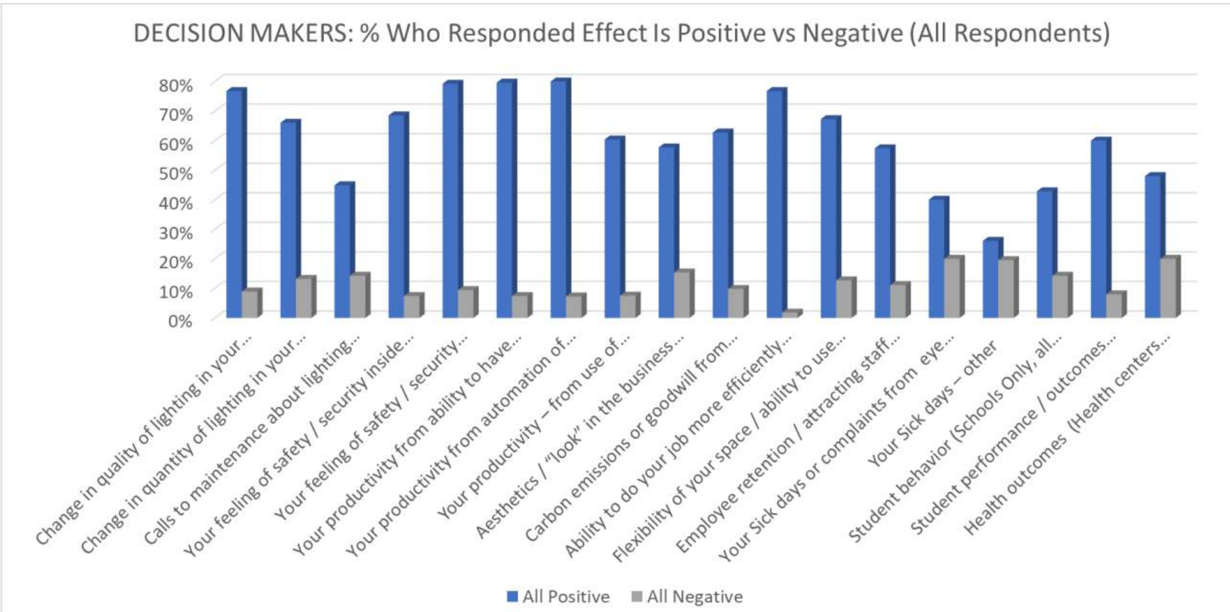

Figure 4.1. Share of positive and negative NEBs overall by decisionmakers from survey (*n* = 56).

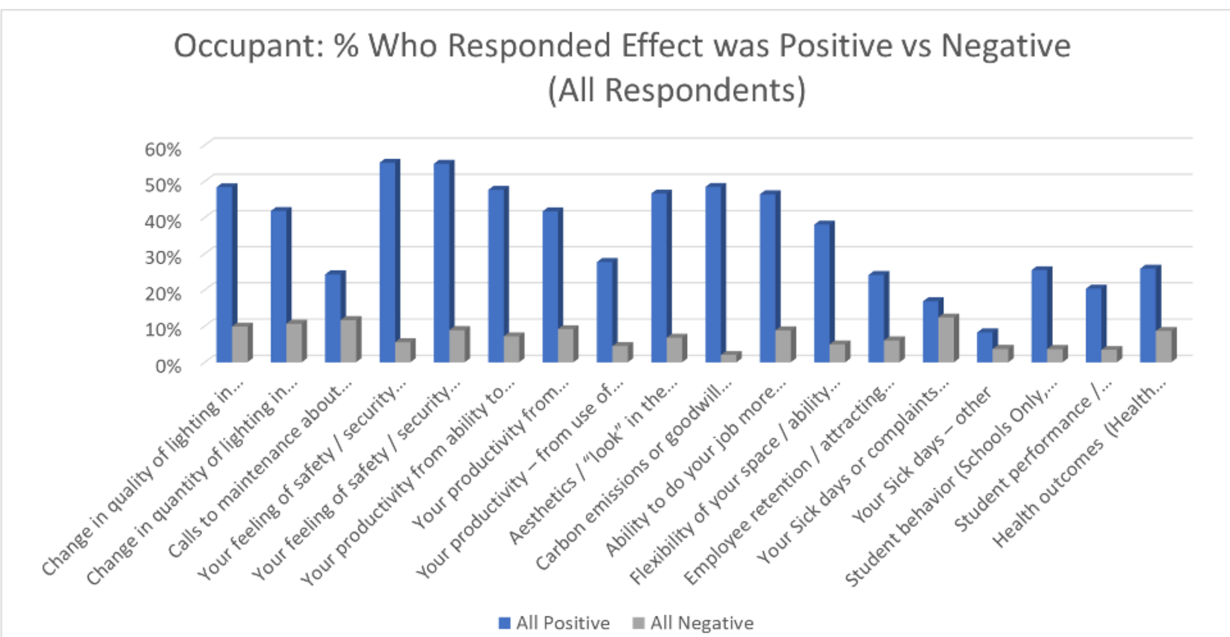

Figure 4.2. Share of positive and negative NEBs overall by occupants from survey (*n* = 137).

4.2 Quantifying the NEBs

The first step in quantifying the NEBs requires developing the means to convert words into numeric multipliers. The survey asked respondents about the relative value of specific NEBs using "labeled" phrases, for instance, "much more valuable," or "somewhat less valuable." The survey also asked the percentage more valuable that the respondent meant when they said "much more valuable" or "somewhat less valuable." These percentages were only asked for a minority of the responses, but when combined across all respondents, percentage multipliers could be associated with each of the valuing labeled phrases.

SERA staff used survey responses from each group of interviewees to develop relevant in-sample multipliers to use for that sample's estimation work. As a check, SERA staff compared the values for these multipliers across subgroups, and to values found in published literature (sometimes referred to as "academic" values in this report). **Figure 4.3** indicates that the multipliers are relatively consistent between groups and with the literature, even though some of the groups have very small sample sizes. This comparison gives some confidence that the survey responses are reasonably reliable, that surveys that are "click throughs" have been appropriately removed, and that the estimation work can continue, using the estimated multiplier values. The greatest variation occurs at extreme values, and for smaller samples (e.g., utility decisionmakers). These multipliers were used to develop weighted average NEB values for each of the survey groups.[27]

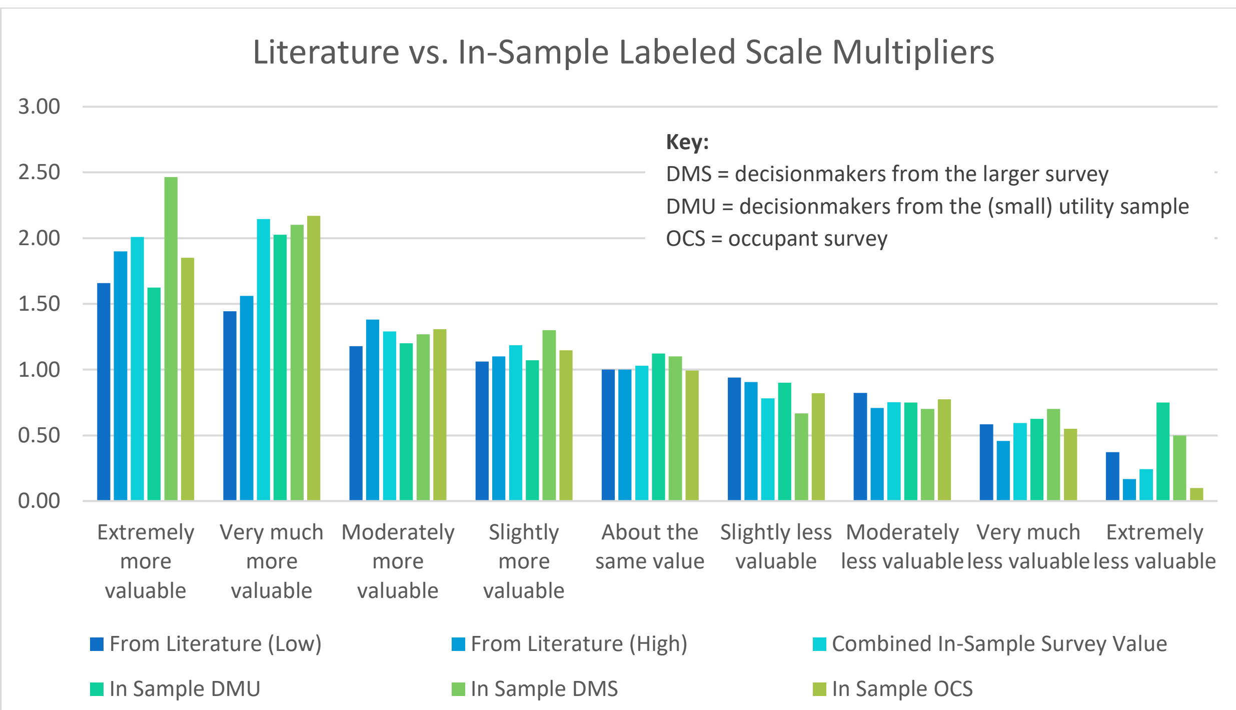

Figure 4.3. Comparison of in-sample estimated multipliers among samples and to published values.

[27] Additional detail on the differences in results calculated using in-sample weights vs. published weights is presented at the end of **Appendix B.**

4.3 Decisionmaker Results – NEB Estimates and Most Important NEBs

The estimation work for decisionmakers and managers as a group found several quantitative estimates for the NEBs, discussed below. Each value is easily translated into dollars using either the measure's savings or average labor costs per FTE.

Decisionmaker NEB Quantifications

Table 4.2 and **Figure 4.4** show that decisionmakers reported an average of *11.4% of a full-time equivalent (FTE) maintenance or facility staff member* would be needed to provide similar impacts on the workplace as provided by the advanced lighting controls over a space without these types of controls.[28] The 90% confidence interval (CI) associated with this estimate is 9.9% to 12.9% of an FTE. Multiplied by the pay scale for this job title, the dollar value can be added to the energy savings to provide a more complete benefit-cost computation related to the purchase and installation of advanced controls.

Table 4.2. Decisionmakers: Values, Ranges, Confidence Intervals, and Statistical Differences for Total NEB Value, Overall and by Strata

Column Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Decision-Maker Respondents	All	Office	Hospital	School	Ware-house	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Number of Obs.	56	22	5	6	23	4	6	10	3	17	14	18	38	18	16
Maximum Minutes	61	60	60	45	61	30	60	61	60	61	61	61	61	61	61
Minimum Minutes	0	0	5	0	10	5	10	10	30	0	4	4	0	4	0
Average Minutes	29.59	26.09	34.00	16.50	35.39	23.75	26.67	28.10	45.00	30.12	32.50	30.89	28.97	25.83	29.06
Median Minutes	30	30	30	10	30	30	22.5	22.5	45	30	30	30	30	22.5	30
25th Percentile	15	15	30	5.5	15	23.75	15	15	37.5	10	18.75	15	15	11.25	15
75th Percentile	45	30	45	25	52.5	30	30	41.25	52.5	45	45	45	41.25	30	45
%FTE-Mean	11.38%	10.03%	13.08%	6.35%	13.61%	9.13%	10.26%	10.81%	17.31%	11.58%	12.50%	11.88%	11.14%	9.94%	11.18%
% FTE - Upper CI 90%	12.90%	11.99%	18.86%	10.83%	16.12%	13.09%	15.00%	14.26%	22.79%	14.73%	15.39%	14.79%	12.93%	12.54%	14.11%
% FTE - Lower CI 90%	9.86%	8.08%	7.30%	1.86%	11.10%	5.18%	5.52%	7.36%	11.83%	8.44%	9.61%	8.97%	9.36%	7.33%	8.24%
% FTE - Upper CI 80%	12.56%	11.55%	17.58%	9.84%	15.57%	12.22%	13.95%	13.49%	21.58%	14.03%	14.75%	14.15%	12.53%	11.96%	13.47%
% FTE - Lower CI 80%	10.20%	8.52%	8.57%	2.85%	11.66%	6.05%	6.56%	8.12%	13.04%	9.13%	10.25%	9.61%	9.75%	7.91%	8.89%
Signif. Differences 90%	No	No	No	Yes, 5	Yes, 4	No	No	No	No	No	No	No	No	No	No
Signif. Differences 80%	Yes, 4, 5	No	No	Yes, 5	Yes, 4	Yes, 9	No	No	Yes, 1, 6	No	No	No	No	No	No

Table note: The last two rows of the table note whether there are significant differences between the value for the specific column and any other column numbers. For example, if column 14 says it is different from column 15 (numbers at the top of the table), then the northern and southern latitude values are significantly different from each other, at the statistical significance level identified in the far left-hand column.

[28] The respondents in this sample did not necessarily know the costs or the savings associated with the controls measures.

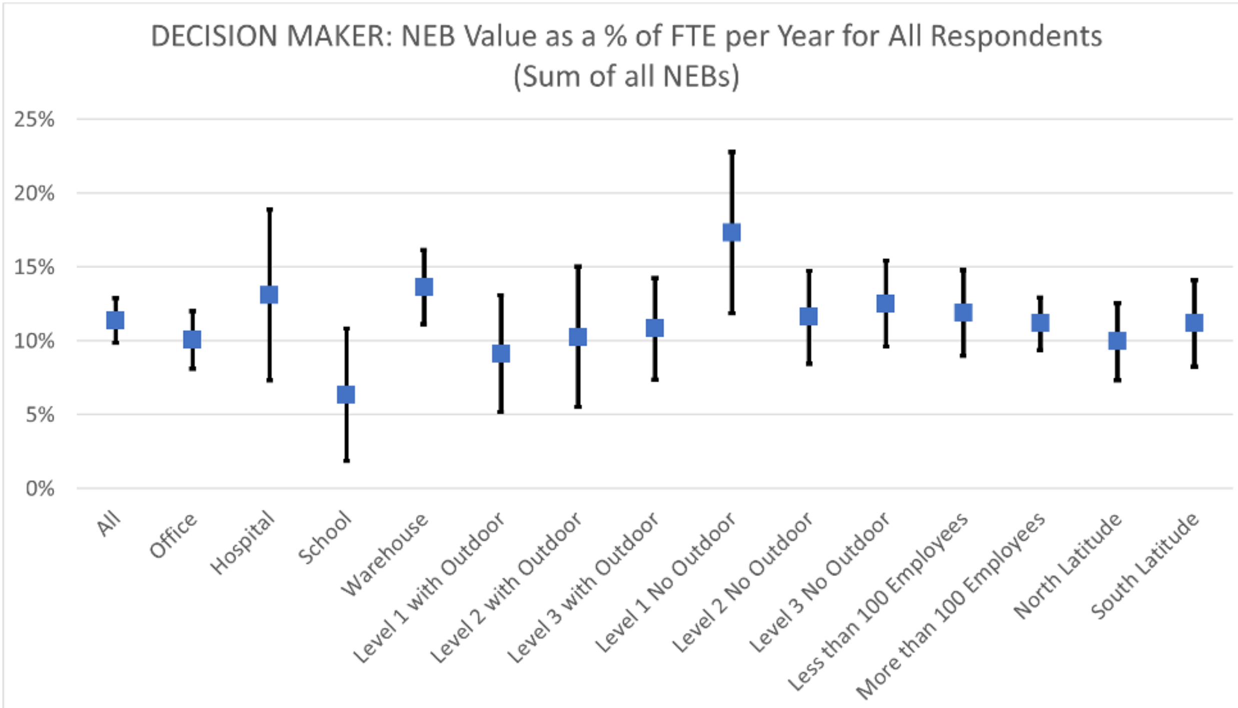

Figure 4.4. Decisionmakers: Total NEB value expressed as a percentage of FTEs – overall and by strata. (Box represents average (mean) value; "whiskers" identify the 90% confidence interval.) (*Note:* This figure is identical to Figure 2.1.)

Using the small-sample survey of decisionmakers who participated in utility programs (see **Figure 4.5**), the net value in the associated features and performance was *130% of the energy savings*, or 30% more valuable than the energy savings from the advanced controls measures installed.[29] This implies that the ROI is 2.3 times higher than the ROI calculated using only energy savings. The 80% confidence interval associated with this value is 112% to 148% of the measure's energy savings.[30] It is important to note that this smaller sample-size group is included in the reported results because they were directly involved in decision making regarding the installation of the lighting control measures, and the other, larger sample of decisionmakers are self-reported managers or decisionmakers at the commercial establishment, but were not always directly involved in lighting decisions.[31]

[29] The respondents in this sample were aware of the cost and the estimated energy savings expected for the measures and could be asked questions using this reference point.

[30] The 90% confidence interval associated with this value is 106% to 154%.

[31] For this sample, the results were estimated two ways: using in-sample-derived label weights, and using published, or "academic" weights. The mean for the in-sample weights was 130%, with a 90% confidence band of ±24%, and an 80% confidence band of ±18%. The mean using academic values for this small sample decisionmaker group was 147%. The more conservative value is presented in this report.

As mentioned before, all assumptions in this study tend toward the conservative side, to provide a downward, rather than over-enthusiastic valuation, for the NEBs.[32]

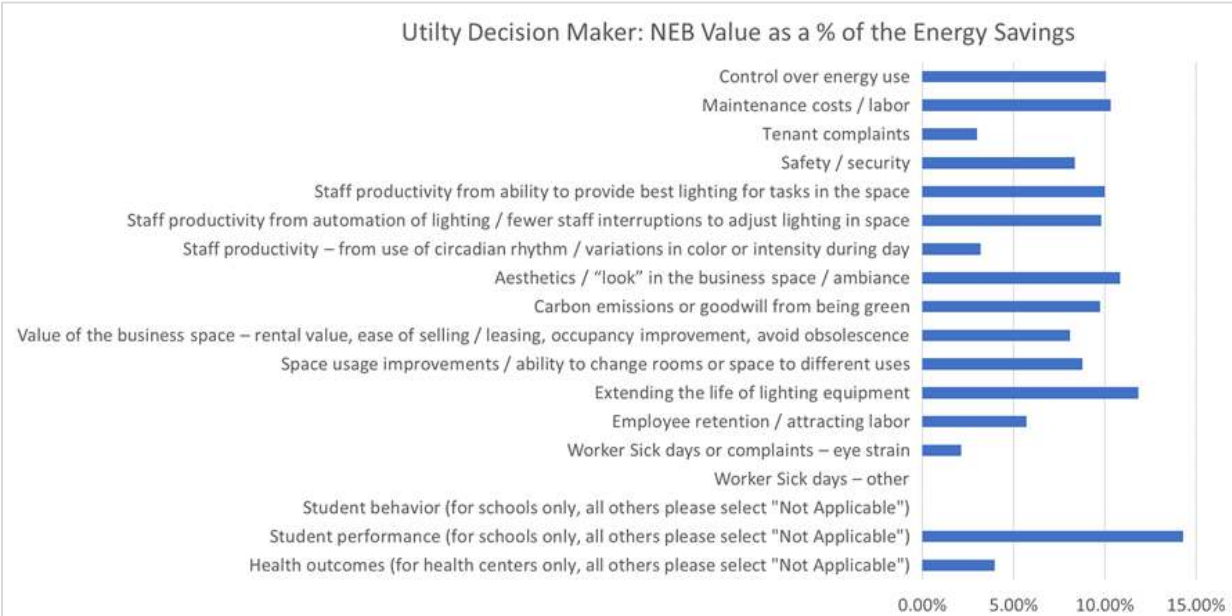

Figure 4.5. Decisionmakers from utility sample: value of individual NEB categories expressed as a percentage of energy savings (small sample). Total NEB value = 130% of energy savings. (*Note:* This figure is identical to Figure 2.3.)

Decisionmakers – Most Important NEBs

Figure 4.6 shows that the most valuable NEBs identified by building decisionmakers were:

- Internal building safety and security
- Productivity resulting from the automation of the lighting and equipment
- The quality of lighting in the space
- Ability to perform work more efficiently and effectively
- Safety and security outside the building

Although most NEBs were positive, some negative effects were identified, associated with sick days and eye strain. The total multipliers identified above represent the net of these effects.

[32] For example, when customers reported that some NEB categories overlapped, the NEB values were re-apportioned out between the value given for just *one* of the overlapping NEBs, not both, thus reducing the NEB value. Estimates were derived using in-sample values for "label" weights to check for differences. Confidence intervals are presented to allow use of conservative values. Finally, one last conservative calculation was carried out. The research team estimated the NEBs based only on the minutes associated with the top four NEB categories for each respondent, information that was gathered earlier in the survey. For decisionmakers taking the occupant survey, the top four NEBs represented 85% of the total reported NEBs, and for (combined) occupants, 76.4% of the total NEBs were associated with the top four NEBs. If users wanted even more conservative estimates, these percentages could be applied. However, use of the lower confidence interval bounds is the traditional application.

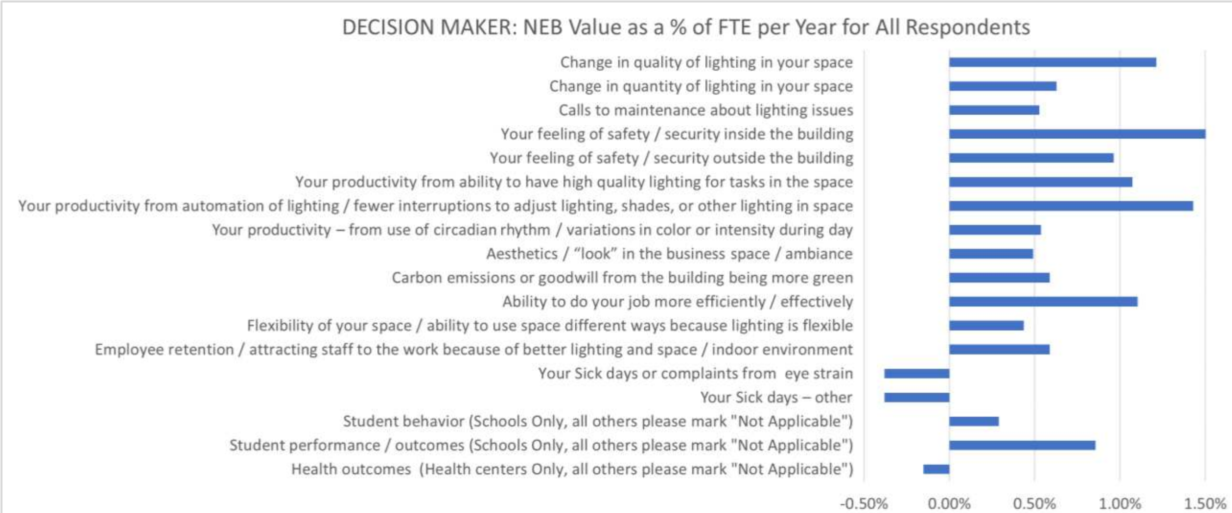

Figure 4.6. Decisionmakers: value of individual NEB categories expressed as a percentage of FTEs – overall. (*Note:* This figure is identical to Figure 2.2 in Section 2.1 NEB Valuations.)

Figure 4.5 shows that the smaller sample of decisionmakers who had participated in utility programs for the installation of the advanced controls equipment valued somewhat different NEBs most highly (*n* = 12). They concurred on staff productivity from quality task lighting and automation, but their perspective was more focused on energy use, costs, carbon, and rental value. They valued the following most highly:

- Extending the life of lighting equipment
- Look and ambiance of the space
- Control over energy use
- Maintenance and associated labor costs
- Carbon emissions, or goodwill from being green
- Flexibility of the space or its usage
- Value or ease of renting the space

No change, and no value, was noted for changes in sick days for this group of respondents.

Decisionmaker Quantitative Differences by Strata

Table 4.2 (earlier in this section) provides the total NEB results compared across several strata that the consultant team thought might affect patterns in NEBs, specifically: building type, which could increase sophistication of the controls installed (i.e., Level 1, 2, and 3)[33]; size of the business; and northern vs. southern latitudes, with the expectation that buildings in northern climates might exhibit more use of controls, given their shorter daylight hours in the winter. Although sample sizes for individual strata were relatively small, some significant differences were identified.

Warehouses showed higher total NEB value (average 13.61% of an FTE) than schools (6.35% of an FTE), with the difference significant at the 90% confidence level. At 80% confidence, both these business types differ from the overall average as well. However, there were only six school responses, so the results should be applied with caution.

There is also some evidence of variations by lighting control system. At the 80% confidence level, the NEBs associated with Level 1 lighting controls without outdoor lighting have higher NEBs than Level 1 controls with outdoor lighting. Sample sizes were small, and the confidence level is lower than the traditional 90% threshold.

No other patterns were detected for decisionmakers.

4.4 Occupant Results – NEB Estimates and Most Important NEBs

Quantitative NEB Estimates – Occupants

The occupant values were expressed in terms of minutes of greater productivity or avoided minutes spent adjusting their work environment, as compared to a similar workspace without advanced controls. These "minutes" results were then translated into a percentage of the full-time equivalent hours for the employee.

Table 4.3 and **Figure 4.7** show that occupants reported an average of 7.8% of FTE staff time per employee in self-reported net *increases in productive time from the operation of the controls equipment*. The 90% confidence interval for this value is 6.6% to 8.9% of the value of an FTE. The most appropriate and conservative methodology for translating this to a dollar value would use marginal worker take-home pay to reflect the value to each of the workers). However, the value to the company is calculated as the percentage of an FTE per employee times the marginal fully loaded pay times the number of employees working in the improved workspace – *a potentially very large number and large "adder" that improves the cost-effectiveness and ROI of the advanced controls to the company*.

If an owner, developer, or manager considering purchasing an ALC system wishes to be especially conservative, the portion of improvements pertaining to "productivity" that are attributable to NEBs is about one-quarter of the reported total value, or about 2% of an FTE, *for each employee affected by the system*. This was calculated using the information on individual NEB values shown in **Figure 4.8**. An

[33] Levels were developed by the consultant team to classify types of equipment, with a higher number representing more sophisticated controls. Generally, Level 1 means individual or groups of lights that are controlled by external occupancy or daylight sensors or manual controls. Level 2 includes on/off/dimming via occupancy or other controls integrated into the lighting, or allows control via computer or phone app. Level 3 incudes more sophisticated systems with automated shades or blinds controlled based on occupancy or weather, or heating/cooling integration. Outdoor controls are external or parking lights that turn on based on approaching an area or car. A more detailed list is provided in **Appendix B Section B.1 Description of Sample.**

adder equal to 2% - 8% of labor costs, attributable to the lighting controls system (in addition to energy savings) is likely a very significant factor in improving the cost-effectiveness of a controls system.[34]

As noted previously, conservative assumptions were used in deriving these results. [35]

Table 4.3. Occupants: Values, Ranges, Confidence Intervals, and Statistical Differences for Total NEB Value, Overall and by Strata

Column Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Occupant Respondents	All	Office	Hospital	School	Ware-house	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Number of Obs.	137	32	30	43	32	3	9	8	23	79	13	66	68	73	34
Maximum Minutes	61	61	61	61	61	30	45	60	45	61	61	61	61	61	61
Minimum Minutes	0	0	0	0	0	4	0	10	0	0	5	0	0	0	0
Average Minutes	20.23	21.53	23.20	17.02	20.47	21.33	19.89	26.88	12.74	18.91	39.38	20.02	20.68	16.66	27.85
Median Minutes	10	10	15	10	12.5	30	15	15	5	5	45	10	12.5	10	30
25th Percentile	4	4	4.25	2	4	17	5	13.75	4	0	15	4	4	4	5
75th Percentile	30	30	41.25	30	30	30	30	37.5	22.5	30	60	30	33.75	30	45
%FTE-Mean	7.78%	8.28%	8.92%	6.55%	7.87%	8.21%	7.65%	10.34%	4.90%	7.27%	15.15%	7.70%	7.95%	6.41%	10.71%
% FTE - Upper CI 90%	8.93%	10.89%	11.58%	8.30%	10.27%	13.69%	11.44%	15.12%	6.64%	8.84%	19.10%	9.30%	9.65%	7.81%	13.22%
% FTE - Lower CI 90%	6.64%	5.68%	6.26%	4.80%	5.47%	2.72%	3.86%	5.56%	3.16%	5.71%	11.20%	6.09%	6.25%	5.01%	8.21%
% FTE - Upper CI 80%	8.67%	10.31%	10.99%	7.91%	9.74%	12.48%	10.60%	14.06%	6.25%	8.50%	18.22%	8.95%	9.28%	7.50%	12.67%
% FTE - Lower CI 80%	6.89%	6.25%	6.85%	5.18%	6.00%	3.93%	4.70%	6.61%	3.54%	6.05%	12.07%	6.45%	6.63%	5.32%	8.76%
Signif. Diffs 90%	No	No	No	No	No	No	Near, 11	No	Yes, 11, 9	Yes, 11	es, 1,9,10,~7	No	No	Yes, 15	Yes, 14
Signif. Diffs 80%	No	No	No	No	No	Near, 11	Yes, 11	Yes, 9	Yes, 11, 9, 8	Yes, 11	1,9,10,7, ~6	No	No	Yes, 15	s, 14, 1, 15

Table note: The last two rows of the table note whether there are significant differences between the value for the specific column and any other column numbers. For example, if column 14 says it is different from column 15 (numbers at the top of the table), then the northern and southern latitude values are significantly different from each other, at the statistical significance level identified in the far left-hand column.

[34] If sample sizes could have been higher for Level 2 or 3 advanced controls systems, more refined estimates might have been possible.

[35] For example, when customers reported that some NEB categories overlapped, the NEB values were re-apportioned out between the value given for just *one* of the overlapping NEBs, not both, thus reducing the NEB value. Estimates were derived using in-sample values for "label" weights to check for differences. Confidence intervals are presented to allow use of conservative values. Finally, one last conservative calculation was carried out. The research team estimated the NEBs based only on the minutes associated with the top four NEB categories for each respondent, information that was gathered earlier in the survey. For decisionmakers taking the occupant survey, the top four NEBs represented 85% of the total reported NEBs, and for (combined) occupants, 76.4% of the total NEBs were associated with the top four NEBs. If users wanted even more conservative estimates, these percentages could be applied. However, use of the lower confidence interval bounds is the traditional application.

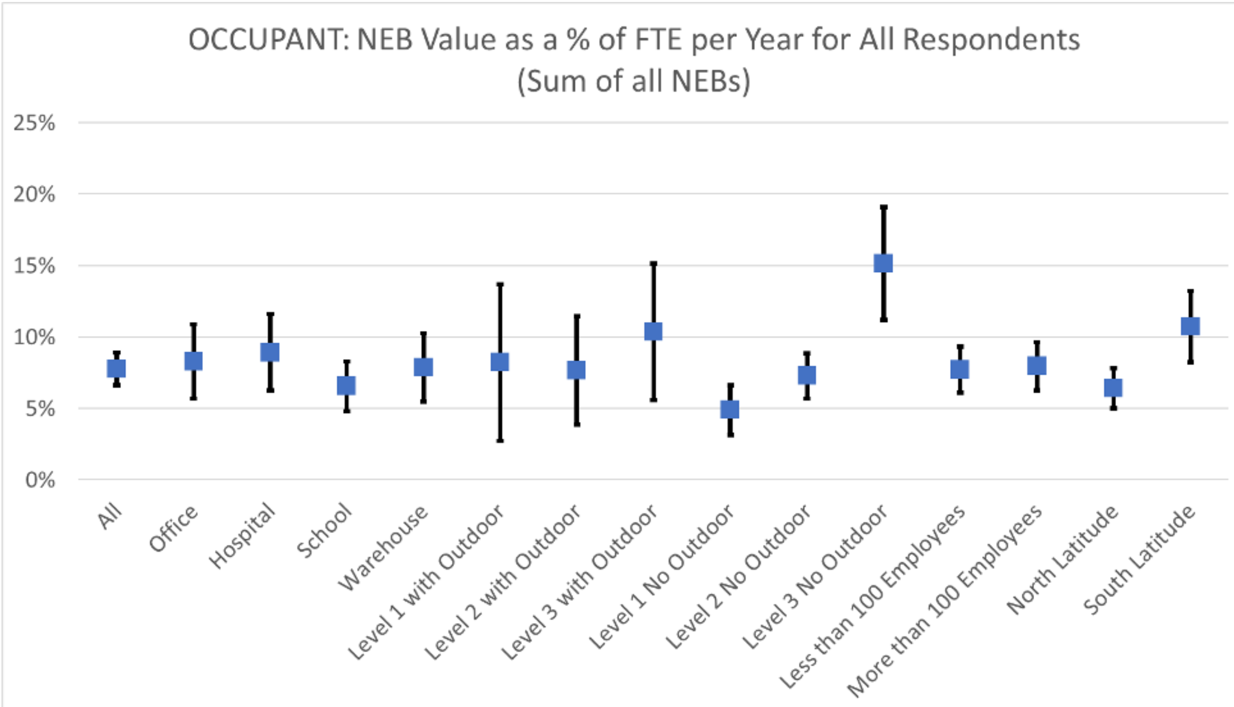

Figure 4.7. Occupants: Total NEB value expressed as a percentage of an FTE, overall and by strata. (Box represents average (mean) value; "whiskers" identify the 90% confidence interval.) (*Note:* This figure is identical to Figure 2.4.)

Most Valued Individual NEB Categories – Occupants

The most valuable NEBs identified by occupants i.e., workers (see **Figure 4.8**), included:

- Feeling of safety and/or security within the building
- Feeling of safety and/or security outside the building
- Improvement of quality of light in the workspace
- Ability to do the job more efficiently and effectively
- Productivity improvement arising from having high quality light in the workspace

The next tier of valued benefits includes aesthetics of the systems; reduced carbon emissions, and associated company goodwill; quantity of light in the space; and improved productivity resulting from greater automation and fewer interruptions.

The lowest-valued NEBs include sick days and eye strain, with a slight negative effect associated with the controls. The total multipliers identified above represent the net of these effects.

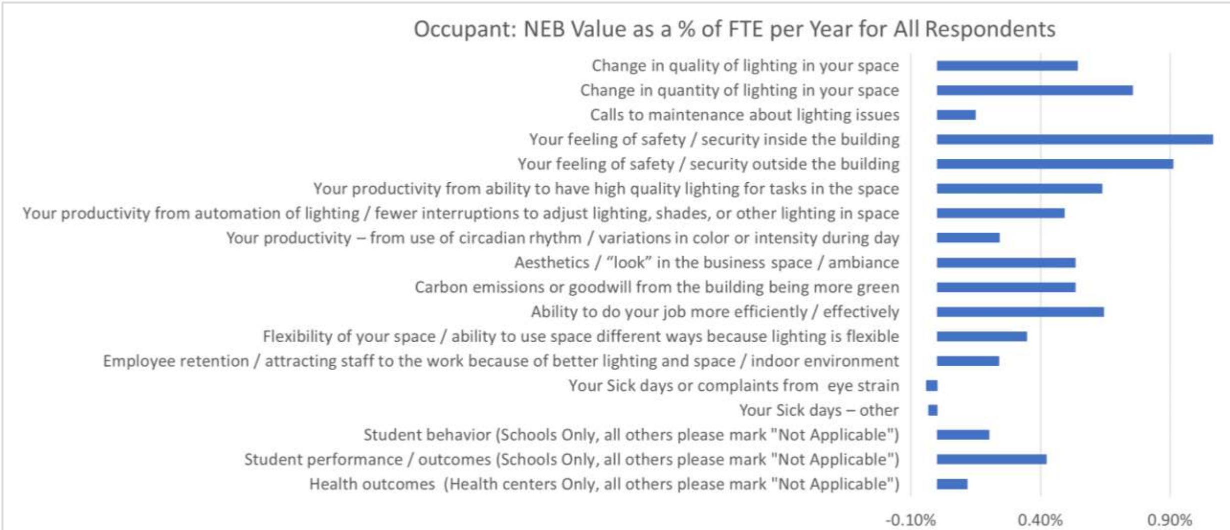

Figure 4.8. Occupants: value of individual NEB categories expressed as a percentage of an FTE, overall. (*Note:* This figure is identical to Figure 2.5.)

Estimated Differences in Quantitative Results, by Strata

Table 4.3 shows total NEB values from occupant responses compared across several strata. Although sample sizes for individual strata were relatively small, some significant differences were identified.

There are higher NEB values estimated for the southern latitudes[36] (10.7% of an FTE), than in northern latitudes (6.4%) at the 90% confidence level. Both values are different from the overall average at the 80% confidence level. In addition, occupant NEB estimates for Level 3 lighting controls (without outdoor lighting) were significantly higher (15.15%) than those for Level 2 (7.27%) and Level 1 (4.90%) systems at the 90% confidence level. Significant results did not carry through to different control levels *with* outdoor systems included, as these outdoor options had very small sample sizes.

4.5 Negative NEBs/NEIs

The analysis of NEBs associated with the controls measures found that the NEB values were overall positive in total, and for the strata. However, individual respondents did report negative NEBs, even if the averages were net positive. Review of these negative effects provides useful feedback on barriers and concerns about aspects of the controls technologies.

The surveys asked respondents to identify and rate both positive and negative impacts from each of the individual effects; for instance, positive or negative effects related to lighting quality, work productivity, or health and safety. Some percentage of negative effects were reported for nearly every NEB,[37] and **Figure 4.9** and **Figure 4.10** illustrate the computed value of the positive (green bar), negative (red bar), and net NEB values (blue squares) for each NEB category for both decisionmakers who responded to the

[36] Respondents were assigned to the southern latitude if the state was on or south of the 35th latitude, and in the northern latitude group if the state was on or north of the 40th latitude. The middle of the country was omitted from the comparison.

[37] Graphs of simple shares of the percentage positive and negative responses are provided in **Appendix B.**

occupant survey and occupants. A review of the figures shows that the red bars vary in size, and comparison of largest and smallest negative effects reveals that they are not generally consistent across the two groups; quantity and quality of light have low negative reports for decisionmakers, but relatively higher negative reports for occupants. Carbon effects are not reported as very negative for either group. However, for both groups, non-energy effects related to eye strain complaints, sick days, and health outcomes are relatively high, and these specific NEBs are net negative.

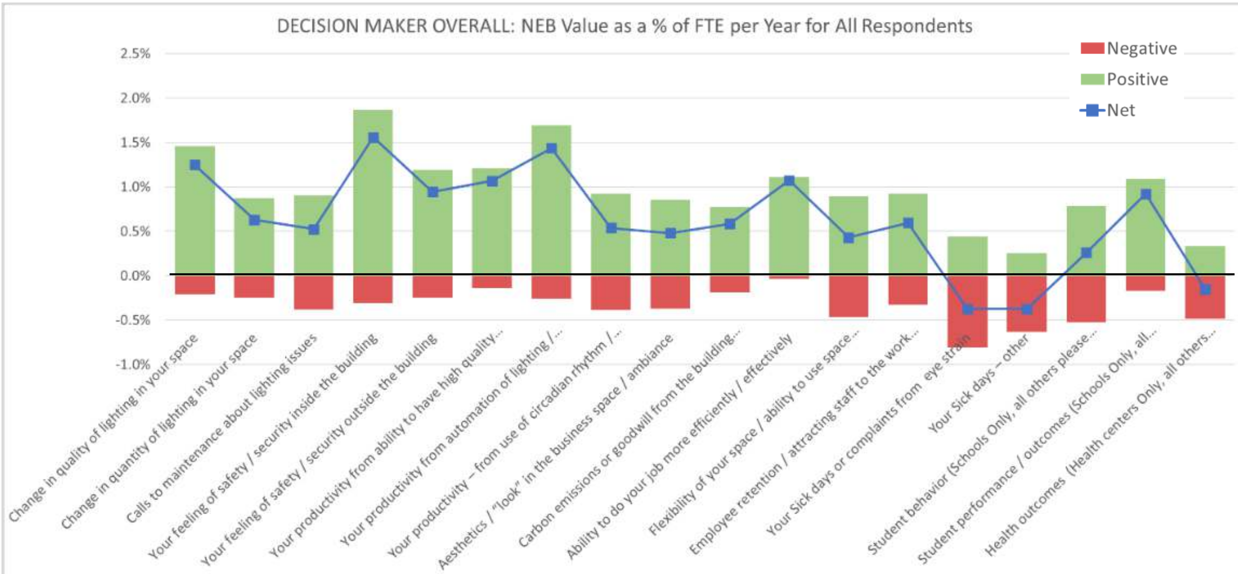

Figure 4.9. Decisionmakers overall. Positive, negative, and net value of NEBs as a percentage of an FTE, by NEB (overall sample). (*n* = 56).

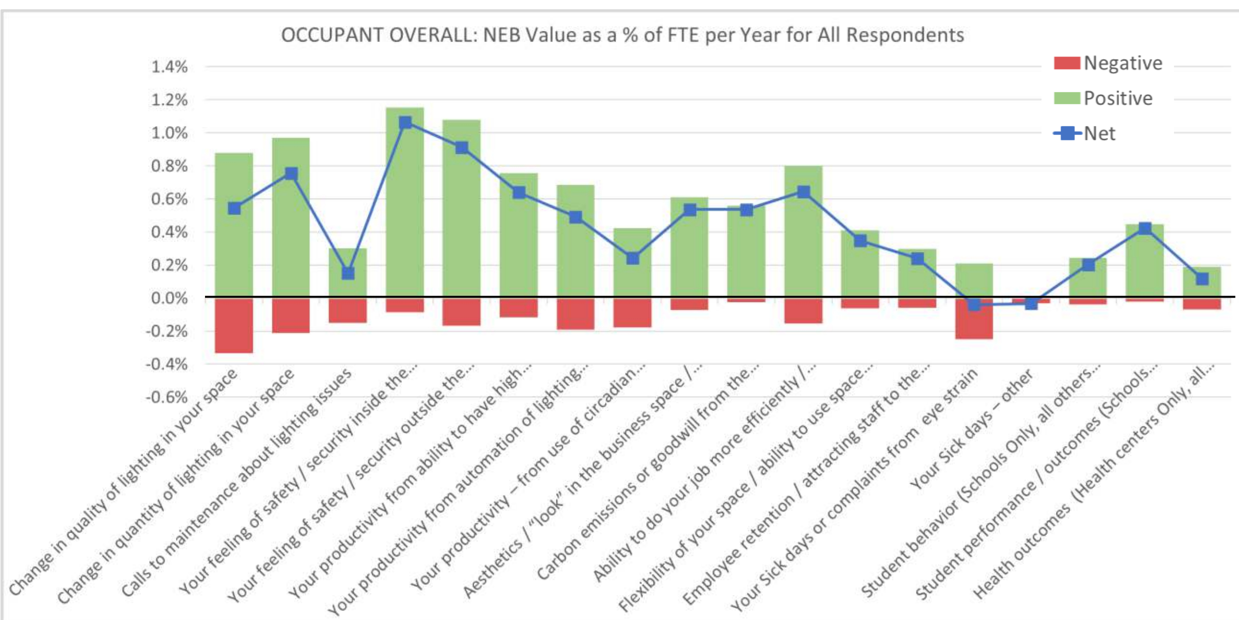

Figure 4.10. Occupants from survey. Positive, negative, and net value of NEBs as a percentage of an FTE, by NEB (overall sample). (*n* = 137).

Figures 4.11 and **4.12** show the positive and negative NEB categories[38] overall and for each of the strata. The stacked bars represent the different NEBs as a percentage of an FTE. The positive valued NEBs extend above the 0% line (marked in black), and the negative NEBs extend below the line. The stacked bar shows the cumulative saved percentage of an FTE. These two figures show that the value of the positive NEBs is higher than the cost of the negative NEBs, leading to an overall net NEB value that is positive. The figures show relatively high shares of negative results for Level 1 controls (but not for Level 2 or Level 3), indicating more negative effects from the simpler forms of lighting controls (e.g., basic, non-integrated occupancy sensors). Schools, offices, and health facilities also showed relatively higher levels of negative effects. Almost no patterns in negative effects were shown that varied for the different occupant strata.

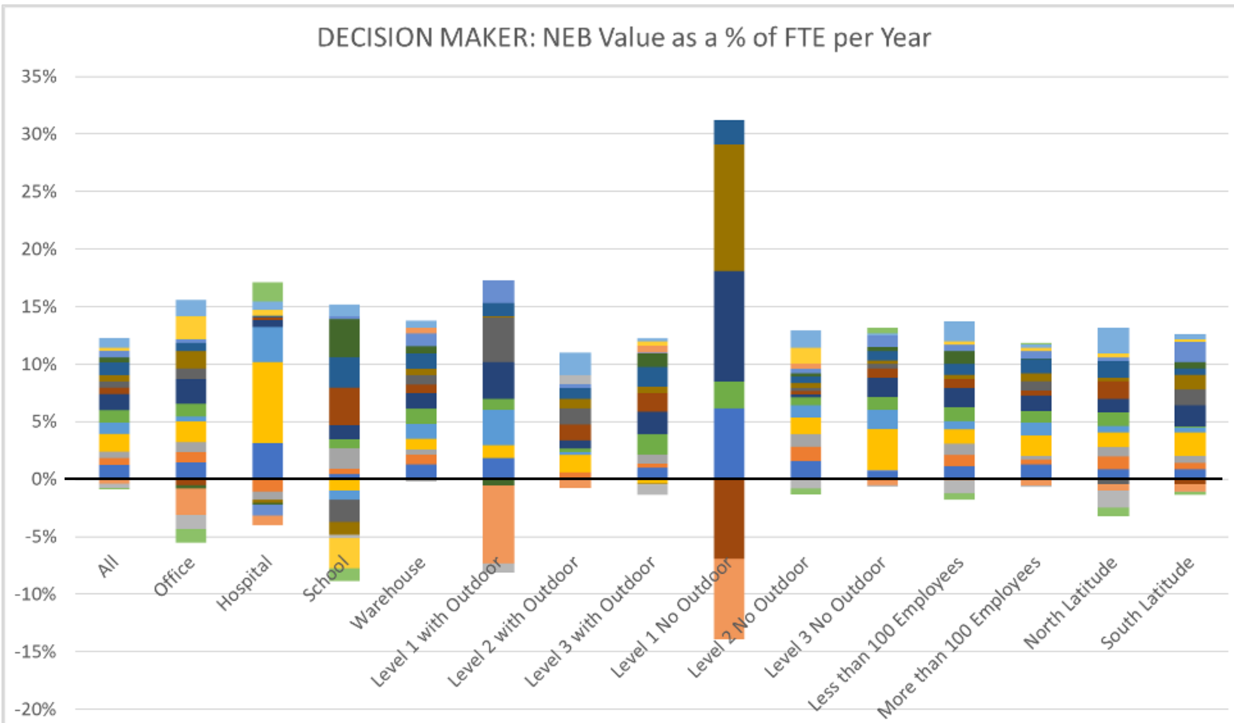

Figure 4.11. Decisionmakers overall: NEBs overall and by individual NEB by strata, as percentage of an FTE (*n* = 56).

[38] The key for the individual NEB categories is provided in **Appendix B** (Figures **B.21** and **B.27**). For the purposes of this discussion, it is the pattern of negative effects by strata that is of interest; the previous two figures illustrate the specific NEBs with more negative reports and values.

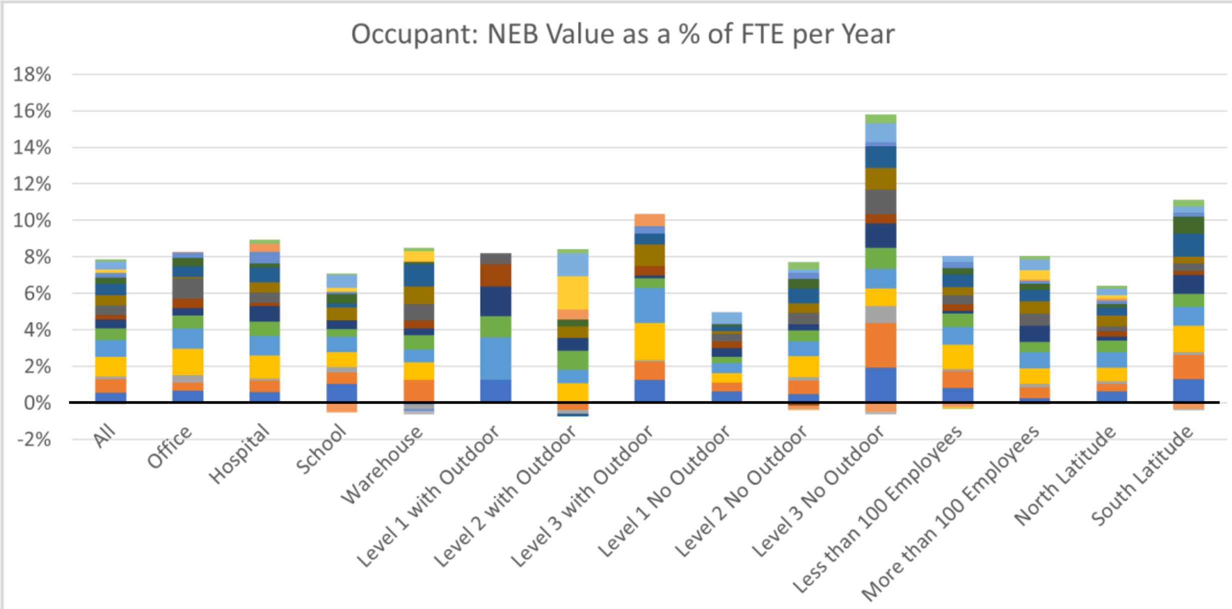

Figure 4.12. Occupants: value of NEBs overall and by individual NEB by strata, as percentage of an FTE (*n* = 137).

Negative effects associated with eye strain, sick days, and general health may be hard to understand for measures that are focused on adjusting the lighting to be responsive to perceived occupant needs – and of course, energy reduction as well. To help understand why these negative effects occurred, respondents were asked the open-ended question of what was not helpful about the advanced lighting controls. The majority of respondents, 61% of decisionmakers and 62% of occupant workers stated "None," or "They are all helpful."[39] The responses from the remaining 39% and 38% of respondents, respectively, show[40]:

- Decisionmakers statements were not numerous, but they focused on light intensity (i.e., quantity of illumination) and color, as well as possible maintenance issues, such as flickering and strange sounds. Decisionmakers also made comments about the user interface and alarm redundancy.[41]
- The majority of occupant-worker complaints focused on the timer on the occupancy sensor. There were multiple comments about the lights turning off while they were working, during

[39] Helpful effects included: motion activated lights being helpful, energy savings, and are a big time saver in warehouses. Positive notes included comments like "I don't have to think about it," fewer janitors having to walk around turning off switches, safety when walking to vehicles, and feeling safe inside. One respondent said, "I don't have to think about it." Positive comments about more sophisticated systems lauded the ability to control lighting in patient rooms remotely, daylight harvesting, automatic dimming on bright days, and the positive changes from bright white light for paperwork to soft light that is better for online meetings, e.g., using Zoom.

[40] The full list of verbatim responses is provided in **Appendix B**.

[41] Decisionmaker positive effects focused on safety effects and the savings in labor from automated changes, and there were multiple comments about more sophisticated systems, including remote control, as well as more nuanced effects of changes in color and brightness and positive effects on productivity.

online meetings (e.g., using Zoom), and even while in the restroom.[42] Some respondents commented on negative productivity effects when they need to interrupt work to stand up or move around to turn the lights back on. One noted, “Lights cut off while I’m under a truck working. I have to stop everything and move in front of the sensor. It wastes a lot of time.” A few comments specifically noted eye strain effects due to the lights turning on and off in the space, some noting that it happened “suddenly.”

This issue of timers and sensitivity settings (for less sophisticated systems) seems to be the main source of dissatisfaction among occupants, and the negative associated “cost” reduces the overall positive NEBs from the technology. The NEB analysis identifies the specific value of these negative effects, which can be easily monetized using staff wage rates. These values are useful in identifying how much negative cost (i.e., productivity time) is lost from ill-adjusted timers, and the payback from keeping these well-set. The overall analysis of negative effects may suggest to manufacturers those areas in which additional R&D might focus to reduce barriers that are potentially preventing the biggest payback in the value of advanced controls systems.

4.6 Benefit-Cost Ratios and Marketing Applications for the Results

These NEB estimates are significant, with a value of 11.4% of a facility maintenance FTE, or 130% of energy savings in direct benefits recognized by decisionmakers, and potentially 7.8% of an FTE’s time *for every employee in a workplace with the systems*. Even if only the most conservative subset of occupant NEBs are considered valuable to businesses by managers or decisionmakers (including only those NEBs specifically mentioning “productivity”), it appears that businesses could add at least 2% reduction in labor costs to the benefits in a benefit-cost analysis (BCA) or ROI calculation for controls measures. If recognized, this combination of valuations – energy savings plus direct decisionmaker benefits plus 2% to 7.8% reduction in labor costs – could make investment in these measures substantially more attractive to businesses.

The results also provide advice to vendors about those features that are most attractive to market to businesses considering purchasing advanced controls. Managers and decisionmakers recognize and value:

- Internal and external safety and security improvements
- Productivity improvements arising from the quality of lighting and automation of the lighting and equipment
- Ability of workers to perform their work more efficiently and effectively
- Extending the life of lighting equipment
- Control over energy costs
- Reduction in maintenance and associated labor costs
- Carbon reductions, and associated goodwill

[42] One noted “automatic lighting sounds like a great idea on paper, but NO when people actually use it due to safety issues.” Others noted that lights turning on and off was distracting, particularly during online meetings.

- Aesthetics, space usage flexibility, and the associated value of a rental space

Some additional research may also be needed to understand and address some of the negatives, including perceptions of some health and eye strain worries resulting from the systems, which may be partly related to the small samples. However, these factors were much smaller than the positive effects, and the associated NEB values were not positive.[43]

When associated with lighting and building controls the NEBs listed above have large and significant values that have been recognized as net positive additions beyond energy savings.

The main caveats associated with these results are provided in **Section 2 Executive Summary**.

4.7 Study Recommendations, Implications, and Lessons

The study demonstrated that estimates of NEBs could be developed for lighting controls, and the study provides monetized or monetizable values for both decisionmakers and occupants. The study used conservative assumptions in deriving the results. Key results include:

- Decisionmaker NEBs: 11.4% of a custodial FTE.
- NEBs for decisionmakers from the utility sample: 130% of energy savings from the measures, or a value that is 30% *greater* than the dollar value of the energy savings from the measures.
- Occupant NEBs: 7.8% of an FTE for each occupant in a workspace with the advanced lighting control measures. Alternatively, if a very conservative BCA is needed for decisionmakers, a value of 2% of an FTE for occupants may be used, which subsets the occupant NEBs to include only those directly mentioning productivity benefits.

These values are appropriate to add to a BCA, payback analysis, or ROI computations to provide a more complete assessment of the benefits compared to costs.

Results on leading NEBs for the various subgroups were also developed. It will be useful to take steps to help make sure that vendors, utility programs, and others in the chain of recommending and installing controls equipment understand and communicate both 1) the monetizable NEB values to businesses (directly *and* through occupant-reported productivity improvements) and to occupant satisfaction; and 2) the array of NEBs that are valued by decisionmakers and occupants. This information is crucial to making sure all of the relevant stakeholders can speak about the most important features of controls from the purchaser's point of view, and conduct a dialogue that will likely be more successful in expanding adoption of building and lighting controls in commercial buildings.

Lessons for Future Research

A few lessons were also learned during conduction of the study:

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[43] The verbatim responses (provided in **Appendix B**) indicate that some of these comments relate to having eye strain from the lighting turning on and off in their space or as they walk down halls; concerns about lights turning off too quickly in bathrooms or in rooms in which they are working but not moving around; and similar kinds of concerns. With larger sample surveys, the negative effects can be important signals of barriers to a measure or program that should be considered in R&D in the longer run, or in program incentives or remedies in the short run that can offset the negative effects.

- Some kinds of NEB studies (including this one) can conduct surveys without confidential customer data. As utilities and others become increasingly sensitive about divulging customer information or sharing confidential data, this may be an increasingly useful approach to evaluation and NEB estimation.
- Different comparison factors, beyond energy savings, can work. The wording and valuation methodology needs to be carefully thought out in advance. Speaking to subject matter experts (i.e., industry stakeholders) was useful in exploring options.
- It is important to stick to basics in questionnaire design. The approaches used to shorten the survey complicated the analysis. Future studies should try to avoid the design that requested separate ranking and scoring of a subset of NEBs. Instead, the results of this study can be used to reduce the number of NEBs that may need to be included in future studies.
- The study would have been more robust if there had been more survey respondents who had employed controls measures beyond basic occupancy sensors. It would be useful to have the opportunity to explore datasets with a preference for more advanced measures. To the extent possible, it would be useful to work with utilities up front, but whatever the source, follow-up work should look hard for buildings with installed measures more sophisticated than occupancy sensors to explore whether higher NEB values would be associated with such measures.

Appendix A: Review of Quantitative NEB/NEI Estimates and State Incentives for Commercial Efficiency Measures

This appendix is adapted from a task memo prepared by Lisa Skumatz, Ann Vander Vliet, and Dana D'Souza of SERA, provided to the DLC/Efficiency Forward on May 7, 2021, summarizing the results of Tasks 1 and 2 for the project.

There were three tasks that the DLC asked SERA to undertake:

- Task 1 focused on reviewing the literature on commercial NEBs and identifying measurement methods used.
- Task 2 identified states that have NEB adders or other incentives that are relevant to controls measures, so DLC members may be made aware of states with extra incentives to add to the economics of controls measures.
- Task 3, to be provided in the next deliverable, will use information from Task 1 to inform the development of a recommended approach for measuring the various types of NEBs of interest to the project.

A.1 Commercial NEBs/NEIs and Measurement Methods Used (Task 1)

The authors reviewed SERA's "NEB-It" database to summarize the current literature of commercial NEBs. This proprietary database summarizes all quantitative NEB values and inputs from about 600 of the most useful NEB/NEI literature that has been conducted from the late 1990s to 2021. The database includes nearly 50,000 entries and information on 160 NEBs.

Number of C&I NEB Studies

The database review indicated there are just over 100 studies from the past 25 years that have addressed or measured NEBs in the commercial sector. Of these 100 studies, only about 35 value NEBs for specific measures. The number of measures for which NEB values are reported is limited, with most reports only valuing benefits from HVAC and lighting. Other measures include appliances, building envelope, and water measures.

Of the three categories of NEBs that are distinguished by beneficiaries (Participant, Utility, and Societal), almost all commercial studies report solely values for Participant NEBs, and most of these studies focus on calculating operations and maintenance (O&M) benefits using engineering or secondary-data-based calculations. Several studies used data from respondent surveys to develop estimates of water savings, comfort, and productivity. A few estimated longer lists of NEBs, but estimated them program-wide, not attributing shares of the values to individual NEBs; a few others estimated "all NEBs" for individual measures.

NEBs for C&I Controls Measures

The "NEB-It" database identified studies that estimated NEBs for seven[44] measures that could be broadly estimated as control-related. Five of these measures were identified by the DLC as of interest to this study. These measures are:

- Occupancy sensors
- Lighting controls
- Energy monitoring
- HVAC controls
- Energy management system (EMS)

Table A.1 shows the number of studies that estimated NEBs for each of these controls measures, the years the studies were conducted, and the NEB categories that were estimated. The literature shows that NEBs estimated for these measures are limited to O&M, "All NEBs," and greenhouse gas emissions. The majority of these estimates were published in 2014, with some as recent as 2018, while others date back to 1999. **Table A.2** presents the data sorted by NEB category.

Table A.1. Commercial Controls Measures with NEB Estimates in the Literature

C&I Measure[1]	Count of NEB Values	2018-2020	2010-2017	2000-2009	1999 and earlier	NEB	Studies
Occupancy Sensor	4	0	3	1	0	O&M, ALL NEBs	379, 1242, 1890
Lighting Controls	2	2	0	0	0	O&M	1140
Energy Monitoring[2]	3	0	0	0	3	O&M, Emissions	453
HVAC Controls	1	0	1	0	0	O&M	1242, 1890
Energy Management (EMS)	1	0	0	1	0	ALL NEBs	1890
Total	11	2	4	2	3		

[1] Measures requested in the RFP that have not been estimated in the literature are Shade & Window Controls, Access Controls, and Grid Response

[2] This measure includes site energy management systems for optimal energy recovery and distribution between various processes and plants for Iron and Steel production.

Table A.2. NEBs Measured for Commercial Controls Equipment in the Literature

C&I NEB[3]	Count of NEB Values	2018-2020	2010-2017	2000-2009	1999 and earlier	Controls Measure	Studies
O&M	7	2	4	0	1	Occupancy Sensor, Controls, Energy Monitoring, HVAC	379, 453, 1140, 1242
Emissions	2	0	0	0	2	Energy Monitoring	453
ALL NEBs	2	0	0	2	0	Occupancy Sensor, EMS	1890
Light Quality[4]	9	0	0	9	0	Lighting (Not Controls)	1140
Total	20	2	4	11	3		

[3] NEBs requested in the RFP that have not been estimated in the literature for Control measures are Light Quality, Productivity, Comfort, Footprint, Indoor Air Quality, Health & Safety

[4] Light Quality was included in this table as a DLC request from an e-mail on 4-27-2021

[44] Excluded controls measures are motors or drivers and process controls.

Table A.3 shows the actual values and business sector (if available) for these NEBs for specific controls measures. The NEB Value column uses dollar or percentage terms, and the following column indicates the associated units for the value (e.g., net present value (NPV) for the measure over its lifetime, or percent multiplier to be applied to annual energy savings). The assortment of results shows modest but potentially significant values for most of the NEBs.

Table A.3. Values and Sectors for Commercial Controls Equipment in the Literature

Specific End Use	Measure Name	NEB	Year	Region	NEB Value	Units	Program / Sector	Study ID
Occupancy Sensor	Occupancy Sensor	O&M (Labor)	2014	CT	$ 185.51	NPV$/measure	Prescriptive	379
Occupancy Sensor	Occupancy Sensor	O&M (Labor)	2014	CT	$ 185.51	NPV$/measure	Small Business Direct Insall	379
Occupancy Sensor	New construction control/sensor O&M	O&M	2015	RI	$ 6.69	$/unit/yr	New Construction	1242
Occupancy Sensor	Occupancy Sensors	ALL NEBs	2005	BC	129%	% of energy savings/business/year		1890
Lighting Controls	Controls	O&M	2018	MA	5%	% of energy savings/yr		1140
Lighting Controls	Controls	O&M	2018	MA	3%	% of energy savings/yr		1140
HVAC Controls	Retrofit boiler, reset controls, retrofit thermostat	O&M	2015	RI	$ 0.14	$/kWh saved/yr		1242
Energy Management System (EMS)	EMS	ALL NEBs	2005	BC	64%	% of energy savings/business/year		1890
Energy Monitoring	General - Energy monitoring and management system	Emissions	1999	USA	2.6	kgC/t	Iron & Steel	453
Energy Monitoring	General technologies - Energy monitoring & management system	O&M	1999	USA	$ -	US$/ton crude steel	Iron & Steel	453
Energy Monitoring	General technologies - Energy monitoring & management system	Emissions	1999	USA	1.02	kgC/t	Iron & Steel	453

Comparing, Transferring, and Normalizing Values

It should be noted that most of the NEBs presented represent only values for a small portion of the range of NEBs provided by some of the measures. For instance, occupancy sensors likely deliver more than O&M benefits, including, potentially, safety benefits. Unfortunately, the aggregate occupancy sensor NEB values ("ALL NEBs") are in different units than the O&M values, so the extra value contributed by other occupancy sensor NEBs beyond O&M would require translations, and consideration of differences in location and/or climate, sector (business types) and other factors. This is the difficulty of applying NEBs beyond the original study (i.e., "transferability"), but this can be facilitated somewhat if normalizing factors are included in studies (amount of savings per measure[45] or other information). This type of normalization can also support comparing values across studies.

[45] Studies with multipliers need to be very clear about whether the savings being discussed are measured savings or program savings. Finally, program-wide measures are especially difficult to compare because they depend on the number or percentage of program participants who received each measure. Measure-based estimates avoid this problem and can increase transferability.

For interested readers, **Table A.4** provides the citations for the studies with NEB results for the commercial controls equipment of interest to the study.

Table A.4. "NEB-It" Reference Study Numbers and Sources for Commercial Control Equipment NEBs

Study ID	Study
379	Itron, Inc., 2014. "Development and Application of Select Non-Energy Benefits for the EmPOWER Maryland Energy Efficiency Programs," August 5, 2014
453	Worrell, Ernst, Lynn Price, and Nathan Martin, 1999. "Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector." Energy 26.5: 513-536.
1140	Tetra Tech, NMR, DNV GL, 2018, "Program Administrators of Massachusetts Non-Energy Impact Framework Study Report," Prepared for the Massachusetts Program Administrators and Energy Efficiency Advisory Council (EEAC) by Tetra Tech, January 23, 2018.
1242	National Grid, 2014. "Rhode Island Technical Reference Manual, For Estimating Savings from Energy Efficiency Measures, 2015 Program Year," Produced by Sean Murphy, November 2014.
1890	Skumatz, Lisa, SERA, Inc., to Carmelina Sorace, Shari, Elliott, Sol Friedman, BCHydro, 2005. "Non-Energy Benefits Information for BCHydro Programs: Revised Memo," January 11, 2005.

NEI Measurement Methods Used:

The annotated bibliography in **Section A.3** provides descriptions of the measurement methods used in 16 of the C&I studies, not limiting the list to just those addressing controls measures. **Table A.5** provides a brief summary of the measurement methods used and the general conclusions reached. Citations are provided in the bibliography.

Table A.5. Summary of Measurement Methods Used for C&I Studies with Strong Methodology Sections

Study	Topic	Method Summary, Conclusion – C&I
Vaidya… 2013 *In Apprise (2018)*	Economics, job impacts, program-wide	• **Method: Expert Interviews and Program Data – Direct Calculations** • Description: Used in-depth interviews (IDIs) with subject matter experts (SMEs), followed up with data from program databases, agencies, and community-based organizations. Used to calculate FTEs created by program. • Pros: specific to program. Cons: labor intensive, difficult to replicate.
Johnston… 2013 *In Apprise (2018)*	Economics, program-wide	• **Method: Model-Based (IMPLAN™)** • Description: Reviewed program documents to estimate (job or spending) amount spent on specific business (NAICS) sectors, and these dollar impacts were introduced into a third-party input-output model (IMPLAN) that was populated with the regional NY business mix. Model computed direct, induced, and total economic impacts on regional economy. • Pros: vetted model, localized data, replicable and/or transferable method. Cons: N/A.

Study	Topic	Method Summary, Conclusion – C&I
Coates… 2000 *In Apprise (2018)*	Water from measures; O&M (lighting, HVAC, refrigeration); C&I joint audit program	• **Method: Water – Secondary Data Calculation** • **Method: O&M – Participant Survey of % Value Relative to Savings** • Description: Water measured as used gallons saved per measure times number of measures installed per business times water rates. O&M used survey; participants were asked to estimate value of NEBs (change) relative to expected energy savings for measure in percentage terms. Expressed as a percentage; easily translated to dollars. • Water pros: simple, defensible, transferable. Cons: none. • O&M pros: relative valuation is easier to answer than direct dollars; asked respondents who were realizing the impacts; perceptions may be most appropriate metric; cheaper than detailed engineering calculations. Cons: –may not work for new construction (no direct comparison).
DNVGL 2016 *In Apprise (2018)*	Maintenance, repair, replacement, and other NEBs for 10 measures	• **Method: Stakeholder IDIs, Engineering Approach for 4 NEBs** • Description: The study used four steps to organize the analysis: 1) select a sample of true new construction (NC) measures; 2) define the baseline technology for each measure; 3) use engineering calculations to identify the difference in life-cycle cost between the baseline and energy efficient (EE) measure; and 4) estimate the resulting NEI per unit energy savings in dollar terms using appropriate planning horizons, discount rates, and capital replacement and/or amortization assumptions. Ten measures were investigated: boilers, comprehensive design, compressed air, food service, hot water, processes, lighting, motors, other gas heating, and refrigeration. The study used in-depth interviews (IDIs) with the most relevant stakeholder, broken into four main categories (maintenance, repair, replacement, and other NEBs (including production increases). • Pros: appropriate for NC including baseline; variety of measures. Cons: very limited set of NEBs, complicated survey instrument, needs up-front work on baseline (pro and con).
Tetra Tech… 2012 *In Apprise (2018)*	O&M	• **Method: Expert Interviews and Estimated Resulting Labor Impacts** • Description: Semi-structured IDIs were conducted with energy industry experts regarding an array of components of operations (O&M; administration; supplies or transportation; other labor; water usage; product spoilage and/or defects, fees for disposal, insurance, and permits; and revenue from sales, rent, or other sources. Computation used was the difference in hours per year for old vs. new equipment times the wage per hour (adjusted for load factor). Adjustments were made for equipment that would have been replaced anyway (i.e., due to failure or replacement). • Pros: simpler than asking participants or industry, easily calculated, may provide "industry" accepted values. Cons: does not vary, does not reflect actual buildings or participants.

Study	Topic	Method Summary, Conclusion – C&I
Itron 2014 *In Apprise (2018)*	O&M from avoided lamp replacement due to occupancy sensors	• **Method: Deemed or Assumed Occupancy Sensor Savings Applied to All Lighting Measures** • Description: Labor savings were assumed to be 1 minute per day of maintenance staff time per sensor (5 hours/year), multiplied by maintenance wage rate, summed over lifetime of occupancy sensor, and discounted. Multiplied by number of program occupancy sensors. • Pros: very simple. Cons: difficult assumption or logic to justify, ignores many NEBs, does not seem to include effects on lighting in a defensible way.
Shelter 2016 *In Apprise (2018)*	O&M due to lighting replacement (deferred equip. replacement)	• **Method: Technical Resource Manual (TRM)-Based Computations** • Description: Annual replacement costs = Number of replacement lamps, leading to component costs (lamp plus labor costs). Calculate difference between replacement costs for baseline minus EE measure, and discount at 5% for NPV. Lighting removal savings = baseline lamp cost/baseline lamp life (years) • Pros: Uses industry or TRM data, defensible, logical, simple, used in residential. Cons: none.
Tetra Tech… 2018	ALL NEBs for lighting controls, lighting quality from lighting system	• **Method: Controls – Not Described. Light Quality From Surveys** • Description: Two survey methods were used to estimate the dollar value of light quality: willingness to pay (WTP) surveys, and conjoint survey methods. Reported as dollar per project. • Pros: defensible methods from literature, uses information from occupants, relatively direct valuation. Cons: two most difficult survey methods, requiring complicated instruments and responses.
ERS 2018	6 categories of NEBs for 3 programs; using primary interviews	• **Method: Monetizing NEIs for Business Programs Using Multiple Normalized Methods** • Description: Study interviewed individual business projects asking about NEB effects in a variety of units (e.g., unregulated fuel energy saved, water gallons saved, labor hours saved), and these were converted into dollar values. Several key NEIs were not estimated, biasing results downward (waste generation, productivity). Categories included: fuel, water or wastewater, waste, labor, O&M, supply needs, productivity (not well estimated), spoilage, transportation cost, rent, insurance, and other (health, emissions). Total NEBs for each of the main programs were provided (Prime, O&M, and RCx programs), and the NEB values were expressed in dollars per source MMBtu savings, $/MWh savings, and percentage of avoided costs. • Pros: provided NEB totals for major C&I programs in CT, based on specific projects from participants. Cons: labor intensive, complicated with multiple units to translate.

Study	Topic	Method Summary, Conclusion – C&I
Stevens… 2016	O&M overall and by several industries (education, health, manufacturing, offices)	• **Method: Retrofit – Surveys and Expert IDIs Using Ratio Estimates, or Increases or Decreases in Value. For New Construction (NC) – Engineering or Secondary Calculations** • Description: Retrofit asked relative increases or decreases in value (pre- or post-retrofit) relative to savings. New construction (NC) attempted to estimate values using tracking data, dodge data, tax assessor data, TRM, and CostLab software. Internal and external labor are associated with measures (using labor, old vs. new, hourly wage, services visits per year). Reported in average annual dollars per measure, and dollars per kilowatt-hour (kWh) or therm. Reports for retrofit or new construction, electric or gas, prescriptive or custom. Interview probes were tailored for or matched to the specific effects and programs, and valued. For NC, the steps included: Identify true NC measures and sample; define baseline through TRM and CostLab; estimate cost differences for high efficiency vs. baseline using manufacturer and project documentation sources; and extrapolate the information to the population. Results include average NEI/kWh saved for multiple industries (ranging from $100/kWh - $5,500/kWh). • Pros: reflects that NC cannot be answered well by occupants without pre- or post- evaluation, NC attempts direct valuation (but not strongly O&M). Survey approach appropriate for retrofits. Cons: NC is complicated and data intensive.
Summit Blue… 2006	HVAC and lighting in CIPP, small commercial, and new-construction programs; multiple NEBs	• **Method: Conjoint Surveys Translated to WTP Dollars; Also, Relative Value Questions** • Description: By measure and NEB, conjoint combined with 5-point scale (e.g., much worse, somewhat better) with 25% increments, asked about program influence on decision to upgrade, and conjoint on two hypothetical buildings that varied in building cost, O&M, comfort, satisfaction with lighting, productivity, and marketability. Estimated comfort, productivity, lighting quality, O&M, marketability, indoor air quality (IAQ), noise, and doing good for environment for HVAC and lighting measures. Expressed as $/sf, annual dollars, and percent on a 5-point scale. • Pros: gathered data from those experiencing effects, survey approaches are defensible. Cons: some arbitrary scoring (25% increment), conjoint complicated to set up and to answer; multiple questions to get to answers and estimates. Found WTP difficult to answer; relative NEIs are easier, less problematic (demonstrated in 2002 Skumatz study).

Study	Topic	Method Summary, Conclusion – C&I
Skumatz 2005	Overall NEBs for lighting occupancy sensors, chillers, HVAC, refrigeration, traffic lights, other; also, economics & emissions	• **Method: Comparative Valuation Surveys and Models** • Description: Study discusses 4 survey approaches (WTP, comparative, direct computations, ordered logit). Uses comparative valuation for better properties and less volatility, but uses multiple methods for comparison and exploration for some measures. Net NEBs for variety of measures as ratio of energy savings for indoor lighting, occupancy sensors, HVAC, chillers, refrigeration, LED traffic lights, and others (total NEBs). Most important NEBs also asked about. Results presented in $/1,000 kWh saved and multiple of energy savings. Economic (using model) and emissions benefits (emissions from generation mix and age times carbon value) also reported program wide. Uses of NEBs were also reported. • Pros: survey approach performed better than others, easier to answer, good statistical properties, models defensible. Cons: none.
Skumatz 2004	NEBs for multiple C&I programs using relative survey approach (CIPP, SCLP, and others)	• **Method: Comparative Valuation Surveys and WTP** • Description: Comparative valuations (CV) were used for individual NEBs, and both CV (relative to bill savings) and WTP were used for total NEB estimates. Specific causal categories were queried, asking positive or negative, and relative values from slightly to very. Sum of the individual NEBs exceeded the total, and were rescaled. Overall NEBs were reported in the official reports; supporting memos provided individual categories. Overall NEBs were substantial compared to energy savings. • Pros: consistent performance of CV checked by WTP, feasible for large-scale samples, worked across multiple programs, strong results. Cons: should consider revised approach for new construction.
Skumatz 2002	Exploring and/or evaluating survey methods	• **Method: Comparison of Performance for Multiple NEB Survey Methods – WTP, Comparison, and Labeled (Magnitude or Hedonic) Scaling (LMS)** • Description: Very detailed direct comparison of performance characteristics for WTP, comparison valuations, and labeled or scaled valuations, and finds: 1) WTP is difficult for respondents, confusing, and leads to more inconsistent or volatile answers than other approaches; 2) comparative or relative valuations (higher or lower with dollar or multiplier follow-up), and this method produces similar results between comparable programs; and 3) scaled or labeled magnitude scaling asks values based on relative verbal scores and does not require the follow-up of numeric multipliers because the words translate directly to multipliers based on academic studies. Also, in-sample estimates can be developed, but do not require follow-up to every question. This method shows answers very close to comparative valuation. • Pros: direct comparison of performance shows LMS is strong, consistent, not volatile, and simplest to ask. Cons: tradeoffs with primary options, but they are less practical. Recommendation: Use two approaches for the total NEBs.

Study	Topic	Method Summary, Conclusion – C&I
Skumatz 2005	Exploring and/or evaluating survey methods	• **Method: Best Practices for Measuring NEBs** • Description: Notes key elements of measurement must include: 1) positive and negative NEBs; 2) appropriate baseline, e.g., comparison to standard efficiency equipment rather than equipment replaced (in most cases); and 3) resulting net-to-gross evaluation, counting only NEBs that are attributable to the program's efforts and incentives (free ridership and spillover). • Pros: important to include attributable effects. Cons: many studies have not followed the recommendations relative to standard efficiency equipment.
Wobus… 2007	Exploring and/or evaluating survey methods	• **Method: Comparison of WTP and Contingent Valuation Labeled Scaling, and Conjoint Surveys for NEBs** • Description: Noted WTPs (open end or suggested values) are hard to answer and lead to inconsistent answers. Scaling approaches (citing Skumatz 2002 and 2006) – authors feel scaling is close to WTP, and range of values is influenced by parameters set by researchers. However, although they are concerned benchmark bias may exist, there are benefits to providing a consistent reference, and customers are more comfortable answering scaling. Conjoint approaches[46] ask respondents to compare or rank hypothetical situations in which one situation has a known dollar value, and statistical analysis is used to assign dollar values to the situation without dollar values, and a WTP can then be assigned. Approach can be constructed to learn about values of multiple situations simultaneously with each comparison question, reducing number of responses needed; however, complexity of questions limits researchers to 6 or fewer attributes. This approach experiences the same benchmarking effects as scaling. Estimation work showed values from conjoint were lower than from direct query (WTP or scaling), but same general range. NEBs estimated for even light distribution, lighting quality, and lamp life as a percentage of energy saving and annual dollar values. • Pros: direct comparison of performance shows LMS and conjoint are strong, consistent, and less volatile and confusing than WTP. Cons: some limitations in number of attributes that can be asked using conjoint, conjoint approach cannot ask about more than 6 attributes without questions getting too complicated.

Task 1 Results and Implications

The key results found from Task 1 were:

1. NEBs for control measures have not often been estimated. The literature shows five published studies, which provide 1 to 3 NEBs for each of a total of five commercial control measures of interest.

[46] Approach recommended by Skumatz to study authors in trainings.

    a. Additional research is needed to fill gaps, both on NEB categories for the measures already examined, and potentially for more of the list of controls measures identified by the DLC in order to meet the DLC's objectives to provide information or tools to members to aid in understanding NEB values, and the potential impacts on ROI of controls equipment. The information that exists includes very few NEB categories, potentially biasing NEB values downward. In addition, many of the data are not normalized, limiting the ability to transfer data between jurisdictions or compare results for consistency and patterns by climate zone, target business types, and other factors.
2. Evaluation of alternative methods of estimating participant NEBs has been explored. For those NEBs based purely on survey inputs, four main approaches have been examined: willingness to pay (WTP), comparative valuation, scaled or labeled valuation (e.g., labeled magnitude or hedonic scaling), and conjoint analysis.
    a. Based on the findings to date, labeled scaling and hedonic techniques have shown consistent performance. However, where surveys will not become cumbersome, a second method will be employed to make the estimates more robust and triangulate the values.
    b. These survey methods will be relevant for both pure participant-survey-based NEBs (changes in comfort, noise) and for the "incidence" portion of NEBs that are estimated as "change in incidence" times value (e.g., change in number of employee safety incidences times the average cost per avoided safety incident).
3. Recognition of the appropriate baselines is vital, especially for new construction measures, representing conditions for which participants may not be expected to be familiar with baseline or "pre" conditions.
    a. An in-depth exploration of whether some priority measures are nearly purely "new construction" vs. "retrofit" (where occupants may experience pre- and post-conditions)[47] will be needed to provide accurate and useful measurements.
4. The literature includes calculations of several participant benefits that used inputs from stakeholder or expert in-depth interviews rather than participant or occupant feedback. This included certain O&M calculations and some new construction measures.
    a. We will explore if and where, and for which NEBs, measures, or baseline conditions, these sources of data may be most appropriate for estimating NEBs or inputs to NEBs of interest.
5. Some of the participant NEB estimation work included "all participant NEBs aggregated."
    a. The focus should be on estimating NEBs by measure and for multiple individual NEB categories. Total NEBs help refine and augment ROI calculations that underlie decision making about controls measures. However, individual categories of NEBs are also important factors.

[47] Or other conditions, like replace on failure, early replacement, and other conditions or "events."

        i. The work can identify valued features of a controls measure, and can identify those features that may be especially desirable and useful for advertising and marketing generally or to specific customers.
        ii. Estimating the constituent NEBs can help identify whether there are some "negative" impacts that would otherwise be masked when "net" NEBs are estimated. These negative impacts, or barriers, may be useful in refining the design of next generation of measures (or product warranties), may help inform refinements in program incentives, or may help reassure potential buyers that feared negative impacts are not (or are) costly, based on those with experience with the measure.

6. Few NEBs beyond participant NEBs were examined in the literature.
    a. Many utility NEBs, such as avoided generation and line losses, or societal NEBs, including health effects based on emissions, can be calculated based on kWh savings and are not program-, sector-, or measure-specific. Therefore, values for these NEBs can be readily calculated and attributed to controls measures using the measure's energy savings and the relevant factors from the literature or models. No sector-specific measurement method is needed for these NEBs. It is expected that some of these NEBs will be prioritized.
    b. Prioritization of NEBs to be estimated will be informed by:
        i. Important NEBs from the literature
        ii. NEBs identified by pre-interviews with occupants and managers
        iii. Discussion with the DLC and members
        iv. NEBs that are included in the list of incentives included for state cost-effectiveness tests, to the extent that will advantage controls measures
        v. Those that are straightforward to estimate
        vi. Other sources

A.2 NEB Incentives and Adders for Commercial Programs or Controls Measures at the State Level (Task 2)

SERA reviewed and updated its ongoing tracking of state NEB incentives and adders for use in measure, program, or portfolio benefit-cost tests. In addition, interviews or email outreach were conducted to understand the state of adders and the types of criteria applied to the NEBs work. Two tables summarize this information. **Table A.6** provides the adder values in place that affect commercial programs, and thus provide an added incentive for commercial controls measures. It should be noted that low-income NEB incentives, if they are available in addition to C&I NEB incentives, are provide within brackets (< >).

The table shows that 17 states have adders that can benefit commercial programs by enhancing the value of their savings. The table also shows that when adders are in place that cover C&I programs or measures, they are commonly in the 7.5% to 15% range. Fossil fuel adders for emissions range from about $15/ton (T) to $40/T. A few states actively encourage estimation of NEBs (e.g., MD, MA).

Table A.6. Incentives for NEBs in State Cost Tests* – All Inclusive

State	% Adder**	$ Adder**	Primary Test	Possible C&I NEB Implications from Primary Test*	NEBs allowed or included***
AK			None		None
AL			None		None
AR			TRC	U, P	TRC accounts for water, other fuels, participant equipment replacement costs, participant measure costs, low-income NEBs.
AZ			SCT	U, P, S	SCT accounts for NEIs, including productivity (system ops), H&S, participant satisfaction (customer service), water, environment, public health impacts from fossil fuels. NEIs not required to be included, but allowed if presented to them (especially emissions).
CA		$30/T attrib. GHG reductions	TRC	U, P	TRC accounts for AvC emissions compliance; state also calculates and includes LI NEBs in some applications.
CO	10% electric, 5% gas <25% low income>		TRC	U, P	TRC accounts for AvC compliance with emission regulations, public health, participant health, and environmental benefits. Additional NEBs may be included in 10% adder as determined by Commission. Recommended values exist from a study, including arrearages, emissions, economics, comfort or noise, H&S, home improvement, water, and total values.
CT		<Low-income NEBs in TRM used; other Residential and C&I NEBs not used>	UCT		DEEP is re-examining C/E tests and NEI inclusion.
DC	10% adder, 10% risk, 10% environment, + NEIs in goals or measured		SCT	U, P, S	2008 Clean and Affordable Energy Act, establishing sustainable energy utility and SCT as test. Risk adder applied as proxy for risk benefits, mostly for improved health and reduced environmental degradation.

State	% Adder**	$ Adder**	Primary Test	Possible C&I NEB Implications from Primary Test*	NEBs allowed or included***
DE		<Quantified LI NEIs>; Values for carbon and water available.	TRC	U, P	Quantifiable NEIs; Table includes LI NEIs ($164/LI to $182/LI home weatherized, plus 2% for arrearages and $35.35/home shell measures). Air emissions of $0.002/kWh or $0.009/kWh annual. Plus "other benefits," including water savings ($5/1,000 gal) and O&M as specified in DE TRM.
FL			RIM		None
GA			TRC	U, P	TRC accounts for additional fuel and water to include environmental externalities. NEIs do not need to be reported for regulatory evaluations.
HI			TRC	U, P	The TRC accounts for avoided participant costs.
IA	10% electric, 7.5% gas		SCT	U, P, S	SCT accounts for asset value, natural gas savings, appliance water savings, and AvC environmental costs. Cost-effectiveness not required for LI.
ID			UCT		State is reviewing whether to add NEIs and adders.
IL	10% electric, 7.5% gas (Ameren) DCEO 10% adder; ComEd NA + emissions $0.0139/kWh reduction		TRC	U, P	TRC accounts for AvC of environmental compliance and environmental impacts, and costs and/or benefits of participant productivity (reduced O&M), other fuel (natural gas), and water savings.
IN			TRC	U, P	
KS			TRC	U, P	
KY			TRC	U, P	<One source indicates the California Public Purpose Test (PPT) is used for a range of NEBs; not reported elsewhere.>
LA			TRC	U, P	
MA		Reliably measured and with real economic value.	TRC	U, P	Include values for utility, property, H&S, comfort, low income, equipment, costs of complying with environmental regulations. TRC (and TRM) accounts for values including asset value, productivity, economic well-being (arrearages, terminations and reconnects), comfort, other fuels, and water.
MD		1.115 cents/kWh; + measured per Order 87082	TRC	U, P	Calculated values include: productivity, comfort, water, alternative fuel benefit, AvC emissions. Ruling encourages other measured values.

State	% Adder**	$ Adder**	Primary Test	Possible C&I NEB Implications from Primary Test*	NEBs allowed or included***
ME			State-specific TRC	U, P*	TRC accounts for AvC fossil fuel, supply water and wastewater. Economic development, job creation, productivity, environmental benefits allowed *if* they can be quantified and valued. Also target 10% of program funds for LI.
MI			UCT		
MN			SCT	U, P, S	SCT includes asset value, productivity.
MO			TRC	U, P	NEBs may be included if they result in avoided utility costs that can be calculated with confidence. May also include participant economic well-being (property value), O&M, water. Utility well-being may be included: payment behavior (arrearage, terminations or reconnections, collections or notices). LI programs do not have to pass C/E test.
MS			TRC	U, P	
MT	10% environmental adder		TRC	U, P	10% adder intended to account for NEBs; utility avoided costs.
NC			TRC	U, P	
ND			None		
NE			UCT		
NH		Granite State Test, NEBs only in secondary test; <10% adder recently removed>	TRC	U, P	TRC historically accounted for AvC environmental compliance, and benefits from public health, participant health, environmental benefits. TRC accounted for impacts of other fuels, job creation, water savings.
NJ			TRC, PCT	U, P	TRC accounts for other fuel savings, water; but values are not incorporated in practice. LI programs do not need to pass C/E.
NM	15% adder; <low-income weatherization has multiplier of 1.25 for benefits>		UCT		
NV	10% non-low income, 25% low income, 15% combined programs.		TRC	U, P	NTRC (NEB-TRC) accounts for AvC environmental compliance, alternative fuel, water, economic development, and jobs from programs. NEBs include customer asset value, productivity, economic well-being, comfort, H&S, satisfaction. Proxy NEB for LI.

State	% Adder**	$ Adder**	Primary Test	Possible C&I NEB Implications from Primary Test*	NEBs allowed or included***
NY		$15/ton adder for carbon	SCT	U, P, S	SCT accounts for AvC enviro compliance, environmental benefits from emissions. NEBs include water. For regulatory cost-effectiveness for LI programs, NEBs include comfort, safety, air quality, productivity, and other NEBs. Previous studies measured NEBs for array of programs, including C&I.
OH			TRC	U, P	TRC accounts for participant productivity, and includes water and fossil fuel savings. State can run programs if they do not pass test but demonstrate high NEBs, including potentially: participant asset value, economic well-being, comfort, H&S, satisfaction, environment, public health, economic development/jobs, energy. LI programs do not need to pass C/E.
OK			TRC	U, P	TRC accounts for net participant measure costs. Also, in theory, NEBs from non-resource benefits may be included but are not included in practice. The low-income weatherization program has a lower TRC threshold.
OR	10% adder plus "easily measured"	$15/ton carbon	TRC, UCT	U, P	TRC accounts for AvC emissions compliance. Adder represents efficiency over supply-side and accounts for NEBs through direct utility calculations where value is significant and quantifiable (water, O&M).
PA			TRC	U, P	TRC accounts for participant productivity and AvC water, fuel; also includes environmental public health, economic development, jobs, energy security. Specifically, state does not include or allow participant asset, economic well-being, comfort, H&S, satisfaction; or societal environmental, public health, economic development or jobs, or energy security in TRC. One source says "low income only."
RI		TRM includes estimated values. Appendix includes residential values. Individual measure writeups of some C&I measures in TRM includes limited NEI values.	State-specific	Special	State test accounts for AvC emission regulations and compliance, participant health, and environmental benefits from emissions. Test accounts for NEBs, including economic well-being, comfort, H&S, other fuels, water, the portion of the social cost of carbon (SCC) of energy that is not embedded in energy market prices, economic development, energy security from reduced fuel oil.
SC			UCT		No NEBs with UCT.
SD			TRC	U, P	

State	% Adder**	$ Adder**	Primary Test	Possible C&I NEB Implications from Primary Test*	NEBs allowed or included***
TN			TRC	U, P	
TX			UCT		TX uses different test for low income.
UT	<Low-income environmental adder of 10% if regulators allow>		UCT		For low income or societal: 10% adder to benefits to account for non-quantified environmental and non-energy benefits of conservation resources over supply-side alternatives. PacifiCorp performs TRC test with and without adder.
VA			TRC, UCT, PCT, RIM	U, P	Savings-oriented. Programs are in the public interest if they provide measurable and/or verifiable savings for LI or elderly.
VT	15% adder, 10% cost reduction for risk and flexibility <+15% low income>		SCT	U, P, S	SCT accounts for AvC other fuel, water, emission regulations, renewables requirements. SCT also allows NEB adder of 15% that includes public health, participant health, environmental benefits, participant comfort, economic development and jobs, and energy security in adder.
WA	10% adder		TRC	U, P	TRC accounts for AvC emission regulations, participant health benefits. TRC may also account for safety, water, other fuels. For natural gas, may request UCT where NEBs are known but unquantified (biasing TRC against conservation).
WI		$30/ton carbon. Participant: water conservation, property values. Societal: economic, emission, water, purchase deferral, property values	TRC	U, P	TRC includes environmental benefits. State has estimated NEBs in past reports; not included.
WV			None		
WY	<10% Enviro adder for low-income C/E if regulators allow>		TRC	U, P	Rules for benefit-cost tests are not specified.
Total states with percent or dollar adders relevant to any programs/measures:					**20**

Table notes:

* Full Societal Cost Test (SCT) uses Utility(U), Participant (P), and Societal (S) NEBs. Total Resource Cost Test (TRC) uses U and P NEBs; Participant Cost Test (PCT) uses P NEBs.

** Highlighted if applicable to C&I.

*** AvC = avoided cost; H&S = health and safety; C/E = cost effectiveness; LI = low income.

Sources: SERA (2014), NEEP 2017, NESP 2018, Filings 2020-21.

Table A.7 identifies those states for which the type of benefit-cost test they use would theoretically accommodate some types of commercial sector NEBs, but for which the regulators or utilities have not adopted values or yet allowed NEBs to be incorporated.

Table A.7. States Without Current NEI Incentives for C&I, but Primary C/E Test Implies Potential*

Primary Test	Relevant NEB Categories	Number of States	States
Uses SCT	U, P, S	2	AZ, MN
Uses TRC	U, P	20	AR, GA, HI, IN, KS, KY, LA, (ME), MO, MS, NC, (NH), NJ, OH, OK, PA, SD, TN, VA, WY
Uses PCT	P	(2)	NJ (with TRC), VA (with PCT)
Uses UCT or RIM	None	6	CT, FL, MI, NE, (NM)**, SC, TX, (UT)**
No test	None	4	AK, AL, ND, WV

Table notes:

* Full Societal Cost Test (SCT) uses Utility(U), Participant (P), and Societal (S) NEBs. Total Resource Cost Test (TRC) uses U and P NEBs; Participant Cost Test (PCT) uses P NEBs.

** Despite the primary test, NM and UT have adders; not included in total here.

Sources: SERA (2014), NEEP 2017, NESP 2018, Filings 2020-21

In addition, **Table A.8** shows that some states have estimated NEBs over the years, and NEB values are available in the Program Savings Document (PSD) or Technical Resource Manual (TRM) that is used for planning and evaluating the Energy Efficiency Plan for the covered utilities. The three leading TRMs with NEBs include MA and RI.

Table A.8. Commercial Measures and NEBs included in 2020 State Technical Reference Manuals (TRM)

Measure (Not Controls)	NEB	TRM
Boilers	ALL NEBs	MA, RI
Building Envelope	ALL NEBs	MA
CHP Systems	O&M	RI
Commercial Kitchen	ALL NEBs	MA, RI
Comprehensive Design	ALL NEBs	MA
Compressed Air	O&M, ALL NEBs	MA, RI
HVAC	O&M, ALL NEBs	MA, RI
Lighting	O&M, ALL NEBs	MA, RI
Other	ALL NEBs	MA
Other Gas Heating	ALL NEBs	MA, RI
Process	O&M, ALL NEBs	MA
Program Wide	O&M, ALL NEBs	CT
Refrigeration	O&M, ALL NEBs	MA

Table Note: RI TRM includes Residential and C&I Multi-family Gas Program NEBs of thermal comfort, noise reduction, home durability, and health (colds, viruses, indoor air quality) for measures of insulation, thermostat, and air sealing.

The last element of Task 2 asked for information regarding criteria that were used or applied for the development of NEB incentives at the state level. The primary criteria that are mentioned in association with NEBs are that, in several states, they must be meaningful and “easily measured.” For most other states, there are NEB adder values negotiated via collaboratives, or specific estimated NEBs that are produced by evaluation studies using best practices and managed by utilities or third-party evaluation oversight staff, or the criteria for use of a NEB value are that it is in the TRM or PSD and had to go through a review process to be added to the TRM.

A.3 Annotated Bibliography of Studies Addressing Estimation of Commercial NEBs (Task 1)

APPRISE, 2018. Connecticut Non-Energy Impacts Literature Review: R1709 Final Report. Prep for Connecticut Energy Efficiency Board (CTEEB); 2018 Dec.

This study was a literature review by APPRISE for the Connecticut Energy Efficiency Board. This study was written to assist the board in incorporating NEIs into their cost-effectiveness analyses. The report reviews residential and commercial studies. Seven commercial studies were reviewed. These are separated by Economic Benefits, reported as Job Creation; and Operations & Maintenance Benefits, reported as O&M and Water Usage. The economic benefits are not measure specific, but are reported as program wide. The O&M benefits are reported for lighting, HVAC, water, and appliance (i.e., refrigeration) measures.

Benefits: Economic (two reports reviewed)
Measures: Program wide
Methods:

Johnston E, Garcia F, Daniel Vickery D. Economic Impacts of Green Jobs Green New York (GJGNY) Program Report. Prep for NYSERDA by ICF International, Inc.; 2013 Nov.

This study used an engineering and financial approach from job and wage data, from prior research, to input into the IMPLAN Version 3.0 input-output model. These results were also listed as residential benefits. APPRISE reported job creation as C&I, since the programs included residential and C&I.

Vaidya R, Poulin B. Assessment of Job Impacts of the Green Jobs – Green New York Program, Final Report. Prep for NYSERDA by NMR Group, Inc.; 2013 Nov.

Data was collected first from in-depth interviews with stakeholders and followed up with data from program databases, state agencies, and community-based organizations. These results were listed as the benefits of the residential program. Results are listed for FTE creation for 2013 and 2015. APPRISE included these results in the C&I section.

Benefits: O&M, Water Usage (five reports reviewed)

Measures: Lighting, HVAC, water, refrigeration

Methods:

Coates B, Pearson D, Skumatz L, Operations Resource Assessment Service: Process and Impact Evaluation. Prep by Seattle City Light Evaluation Unit, Energy Mgmt. Services Division; and Skumatz Economic Research Associates; 2000 May.

The estimation of water savings was based on secondary literature, using water savings per measure, and the number of measures installed under the program. The following equation was used:

$$Benefit\ (Program\ Total = \Sigma(water\ savings\ estimate\ per\ year\ for\ measure \times \%\ measure\ installed) \times water\ rates$$

For O&M NEBs, a survey asked respondents to estimate how much more or less valuable the NEBs were relative to expected energy savings. O&M was estimated for lighting, HVAC, and refrigeration. The results for each end-use were stated as a percentage of the energy savings.

DNV GL. Stage 2 Results – Commercial and Industrial New Construction Non-Energy Impacts Study– Final Report. Prep by DNV GL for the Mass. Electric and Gas Program Admin.; 2016 Mar 24.

To estimate NEIs, baseline conditions were set for randomly selected new construction measures using in-depth interviews with stakeholders. An engineering and life-cycle cost analysis was used to compare the set baseline measures and the energy efficiency measures. The authors compared the energy savings between the baseline and energy efficiency measures and used planning horizons, discount rates, and capital replacement or amortization.

Ten measures, including boilers, compressed air, hot water, lighting, and refrigeration, were measured for maintenance and productivity.

Results are reported in $/kWh and as electric, or gas and custom or prescriptive measures. Significance at the 90% confidence interval was reported for the measures. DNV GL recommend the installation of multiple measures, including some that were not statistically significant.

Itron, Inc. Development and Application of Select Non-Energy Benefits for the EmPOWER Maryland Energy Efficiency Programs; 2014 Aug 5.

This study specifically looked at O&M benefits from avoided lamp replacement from the installation of occupancy sensors. Benefits were reported in net present value (NPV) dollars for a nine-year period and were broken down between prescriptive vs. small business direct install (SBDI), and including vs. excluding labor. The measures were reported as CFL, Fixture, Interior LED, Exterior LED, and Occupancy Sensor.

The savings were calculated with the following formulas:

$$Replacement\ costs\ per\ year = (Number\ of\ replacement\ lamps \times (component\ cost),$$

where:

$$Component\ cost = (lamp\ cost) + (labor\ cost\ to\ replace)$$

Next:

$$Avoided\ replacement\ costs\ per\ yr = (replacement\ costs\ per\ yr\ for\ baseline\ measure) - (replacement\ costs\ per\ yr\ for\ EE\ measure)$$

The NPV of the avoided replacement costs is calculated at a 5% discount rate.

This APPRISE literature review did not include the specific calculation used to estimate the savings due to occupancy sensors. However, the study itself notes:

"Occupancy sensor cost savings result from reduced labor costs. We assumed one minute per day of maintenance staff time per sensor. We then assumed that one minute would be saved 300 days per year, thus totaling five hours per year. We then multiplied by the maintenance wage rate to get annual labor cost. The annual labor cost per sensor was summed over the estimate useful life of an occupancy measure and discounted to calculate the discounted lifetime benefit per sensor. The discounted lifetime benefit per sensor was multiplied by the number of program occupancy sensors installed in each utility program to arrive at the discounted program benefit."

Shelter Analytics. Mid-Atlantic Technical Reference Manual Version 6.0. Prep for Northeast Energy Efficiency Partnerships, Inc. (NEEP) by Shelter Analytics; 2016 May.

This study estimates the O&M savings from lighting replacement with energy efficient bulbs and fixtures, and light removal. Results are presented as dollars per year for lamp removal and NPV dollars for lamp replacement. The following calculations are based on information from the TRM:

$$Light\ Removal\ Savings = (Baseline\ lamp\ cost)/(baseline\ lamp\ life, in\ years)$$

Light replacement:

$$Replacement\ costs\ (baseline\ and\ energy\ efficiency\ measure)\ per\ year = (Number\ of\ replacement\ lamps) \times (component\ cost),$$

where:

$$Component\ cost = (lamp\ cost\ + (labor\ cost\ to\ replace), both\ of\ which\ vary\ by\ type\ of\ measure$$

Next:

$$Avoided\ replacement\ costs\ per\ yr = (replacement\ costs\ per\ yr\ for\ baseline\ measure)\ - (replacement\ costs\ per\ yr\ for\ EE\ measure)$$

The NPV of the avoided replacement costs is calculated at a 5% discount rate.

Tetra Tech and DNV GL. Final Report – Commercial and Industrial Non-Energy Impacts Study. Prep by Tetra Tech and DNV GL for Mass. Program Admin.; 2012 June 29.

APPRISE reports the methods used as "semi-structured in-depth interviews … conducted by energy industry experts." The interviews asked about O&M; Administration; Supplies and Transportation of Materials; Other Labor; Water Usage; Product Spoilage or Defects; Fees for Disposal, Insurance, and/or Permits; and Revenue from Sales, Rent, and/or Other.

Results from these interviews were then used in the following equation:

$$O\&M\ NEI = [(Hours\ per\ year\ due\ to\ Old\ Equipment)\ - (Hours\ per\ year\ due\ to\ New\ Equipment)] \times (Unloaded\ wage\ per\ hour) \times (Loaded\ Factor)$$

The authors of the study adjusted their results to remove the individual measures that would have been replaced without the program due to failure or already scheduled replacement.

Energy & Resource Solutions. C1641: Impact Evaluation of the Business and Energy Sustainability Program. Prepared for Connecticut Energy Efficiency Board (CTEEB); 2018 Sep 5.

This report is a review of multiple projects in the Business & Energy Sustainability Program. Part of the review involved evaluating NEBs from these projects. The authors provide in-depth details on their methods, including the installation of lighting status loggers for lighting O&M and the survey questions used to interview facility managers and owners. This survey information included evaluating factors that could affect run time, including seasonal changes and holidays. Questions included impacts on unregulated fuel savings, water savings, and labor hours reduced.

The study reported multiple NEBs in its Table 4-19, including water, O&M, and productivity. The values are reported in dollars saved, percentage increases, or pounds reduced. These results are program wide and not specific to a measure. Results are presented as dollars per source MMBtu savings, $/MWh, and percent of avoided costs. The survey template is provided in Appendix F of the report.

Skumatz, Lisa, SERA, Inc., to BCHydro. Non-Energy Benefits Information for BCHydro Programs: Revised Memo; 2005 Jan 11.

In a memo to BCHydro in 2005, Dr. Skumatz details the methods used to evaluate NEBs for select commercial measures.

Dr. Skumatz outlines four techniques for evaluating NEBs: willingness to pay (WTP), two comparative valuations (two methods), direct computations of value to owner, and other approaches, including ordered logit. From this list, Dr. Skumatz cites findings that the comparative valuation method is preferred, based on over 10 years of research. Prior research has shown that respondents are often confused by WTP questions and find it difficult to estimate a dollar amount. The comparative valuation method reduces the volatility of WTP responses by providing a starting point.

Using the comparative valuation method, net NEBs are reported as a value of the energy savings for a variety of commercial measures, including indoor lighting, occupancy sensors, HVAC, chillers, refrigeration, LED traffic lights, air compressors, variable speed drives, premium efficiency motors, transformers, and several others. Only overall NEB values are reported in the memo. The underlying research estimates 14 NEB categories: non-energy operating cost, equipment maintenance, equipment performance, equipment lifetimes, productivity, tenant satisfaction, comfort, aesthetics, light quality, noise, safety, ease of selling building, product loss, labor requirements, and environmental effects (i.e., doing good for the environment).

Results are presented as a multiple of energy savings and as $CAN/1,000 kWh saved. The survey also asked respondents which measures had the greatest impact on NEB categories. Economic benefits and emission benefits were reported program wide.

Dr. Skumatz concludes that NEBs are valuable for program design, for selecting which measures to include, and marketing. For commercial buildings, the energy savings can be a “wash out”; that is, business operations change throughout the year and across years, and owners are not confident the promised savings actually occur, or that they become less important as other costs change over time. Thus, it is important to market non-energy benefits to this sector in order to help them recognize other valued changes that are associated with the efficiency measures and be able to use them to help increase program participation and measure adoption.

Skumatz, Lisa, A. Commercial/Industrial Performance Program (CIPP) Market Characterization, Market Assessment, and Causality Evaluation Report: Non-Energy Benefits. Prep for NYSERDA by Skumatz Economic Research Associates, Inc. (SERA); 2004. (One of a series of NEB studies of four commercial programs for NYSERDA.)

Two methods were used for valuing commercial NEBs, WTP and a comparison approach. WTP was only used for valuing the Overall NEB value, not individual categories, and was phrased as, "If all the extra effects were taken away, what would [the respondent] be willing to pay to gain back the benefits?"

For individual NEB categories, Dr. Skumatz used a comparative valuation and modified labeled magnitude scaling (LMS) for assigning a dollar value to the NEB benefits. To do this, a list of NEBs that might be relevant to the program, based on past research, was assembled. For each NEB, respondents were asked if the energy efficient equipment had a positive, negative, or no effect compared to if the standard equipment had been installed. For those categories with a change, either positive or negative, the respondents were asked how valuable (or costly) the effect was, based on a ranked scale of slightly valuable to very valuable. These questions were also asked for overall or total NEBs.

Respondents were then asked to compare the overall NEB savings to the energy bill savings by asking if the NEBs were more, less, or the same value as the energy savings. This question was followed up by asking by what percentage the NEBs were more or less valuable. The "relative" values are translated into multipliers that were applied to the energy savings. This produced a dollar value for each NEB.

The sum of the individual NEB categories was greater than the value that respondents assigned to "overall NEB." The individual NEB categories are scaled down proportionally to equal the stated overall value.

Individual measures were not reported. NEB categories include O&M, Productivity, Comfort, Aesthetics, Lighting, Noise, Health and Safety, and Doing Good for the Environment.

Based on the Overall NEB value, a NEB multiplier is reported as a percentage of the energy bill savings. Individual categories are reported as a percentage of the Overall NEB value. These results are reported separately for owners and for contractors. Dr. Skumatz found that the multipliers from this study were consistent with estimates from other commercial programs. The report also states that 45% of owners and 74% of contractors report that NEBs are important for marketing and the installation of energy efficient measures. Both of these groups state that maintenance is the most important NEB for marketing, but also list lighting, air quality, and comfort. These net NEB benefits are used in the overall benefit-cost analysis for the NYSERDA programs.

Stevens N, Caron N, Chan C, Rathbun P. Innovative tools for estimating robust non-energy impacts that enhance cost-effectiveness testing and marketing of energy efficiency programs. Proc 2016 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, Calif. 2016.

Stevens et al. sought to provide estimates for energy efficient upgrades in the commercial sector from measures installed by a retrofit program and measures installed in new construction. Results are reported by end-use and by industry. The goal of the NEI estimates is to provide marketing tools for program implementors and participants.

The categories of NEI benefits were O&M, admin, materials handling and movement, other labor, spoilage and defects, water usage, waste disposal, fees, other costs, sales, rent revenues, and other revenues. NEI sub-categories included internal labor, external labor, and parts and supplies.

The authors used two methods to estimate NEI values. First, for retrofit measures, a combination of self-reported responses and in-depth interviews were conducted. The questions for the respondents addressed ratio-estimations, perceived or measured increases or decreases (this was only used in the O&M calculations), and open- and closed-ended questions. Follow-up questions included estimates on labor, parts and materials, training, fuel, water, and fees and permits). Examples of the questions asked were not provided.

The second step, to estimate new-construction NEI values, was an engineering and statistical approach. The authors used input from tracking data, the Dodge Players database, tax assessors' data, TRM, and Cost Lab software. The formulas for calculating internal and external labor are provided in a table along with the number of measures that use each formula. The specific measures used in each formula were not included. The formulas included but were not exclusive to labor hours per year in old vs. new equipment, hourly wage, and number of service times per year.

Results were reported in average annual dollars per measure and dollar per kWh or therm. Ninety percent confidence intervals and significance were also reported. Results were reported as retrofit or new construction, electric or gas, and prescriptive or custom. The authors then revisited their data to report average NEI by industry, including education, health care, manufacturing, and office.

The authors conclude by stating that the NEIs should be included in benefit-cost tests for energy efficiency programs. They also caution that the results provided are specific to Massachusetts due to labor costs.

Summit Blue Consulting and Quantec, LLC. Non-Energy Impacts (NEI) Evaluation. Prep for NYSERDA, Project Number 7721; June 2006.

This report is an evaluation of the NEIs in the New York Energy $mart℠ programs, including the New Construction Program (NCP), Commercial/Industrial Performance Program (CIPP), and Small Commercial Lighting Program (SCLP). Two residential programs are also reported on. The results of this evaluation provide feedback to NYSERDA on energy efficiency measures for future programs and marketability strategies.

The study limited the results to two types of measures, HVAC and lighting, and evaluated the following NEIs: comfort, productivity, lighting quality, O&M, marketability, indoor air quality, noise, and doing good for the environment.

The authors used a conjoint analysis questionnaire and converted these answers to WTP dollars. The survey begins by asking questions that are broken down by measure and by NEI. The respondents are asked to answer on a 5-point scale (Much worse, Somewhat worse, Same, Somewhat better, Much better), with the specification that "much worse" and "much better" are based on a decrease or increase of 25%. The next part asked respondents about how much NEBs influence their decision to install or upgrade measures. For the final part of the survey, respondents were asked a series of questions comparing two hypothetical buildings. The buildings varied in building cost, O&M costs, occupant comfort, satisfaction with lighting, productivity, and marketability.

Results are reported as lifetime value ($/sf) or annual value ($), and percentage of respondent answers to each point on the 5-point scale. Interviewers established that respondents recognize NEIs and their positive values; however, it is difficult for respondents to come up with WTP values. Respondents were better able to value NEIs when given a value to compare to. The authors also suggest "pre-screening" respondents before the in-depth interview. This pre-screen establishes a rapport with the respondents and increases response rates.

Tetra Tech, NMR, DNV GL. Program Administrators of Massachusetts Non-Energy Impact Framework Study Report. Prepared for the Massachusetts Program Administrators and Energy Efficiency Advisory Council (EEAC) by Tetra Tech; 2018 Jan 23.

The authors used a variety of methods, including calculations, interviews, and a literature review. Of interest to this proposal are the values for Lighting Controls (reported for ALL NEBs) and for Lighting Quality (based on all lighting measures).

The value for Lighting Controls is reported as a percentage of energy savings for both 2011 and 2016. The study does not describe the methods involved for measuring NEBs for this measure, but cites a memo written for the 2012 Tetra Tech report, "Commercial and Industrial Existing Retrofit NEI," referenced above (Tetra Tech & DNV GL, 2012). However, in the 2012 report, the NEB value for Lighting Controls is not specifically stated.

Lighting Quality is referenced from Wobus 2008. The value is reported in a table as the dollar value per project. This study cites "Survey / WTP" as one method and "Survey / Conjoint Analysis" as a second method for the NEB savings. The technique described in Wobus 2008 references the 2006 Summit Blue and 2006 SERA NYSERDA studies, and the Wobus 2007 paper described below.

Detailed NEB Survey Methods for Commercial and Residential Studies:

Skumatz, Lisa. Comparing participant valuation results using three advanced survey measurement techniques: New non-energy benefits (NEB) computations of participant value. Proceedings of ACEEE 2002 Summer Study; 2002 Aug.

Dr. Skumatz details three survey methods for estimating NEBs, willingness to pay (WTP), comparative valuations, and scaled valuations (or labeled magnitude scaling, LMS).

Willingness to pay (WTP): This method is used in surveys or interviews for NEBs that are difficult to measure, such as comfort, illness, and noise. Interviewers ask respondents how much they would be willing to pay for the NEB through open-ended questions. This method alone is often difficult for respondents to answer. Respondents are either confused by the question or do not feel comfortable providing a number. The "total" NEB value is often valued much less than the sum of the individual NEBs. This suggests that respondents may be overlapping benefits from separate NEBs. Other difficulties with this method are that the respondents' estimated NEB values vary greatly and are many times greater than estimates from other methods.

Comparative or relative valuations: Rather than asking respondents to come up with a value for the NEB, this allows the respondent to compare the value of the NEB to a known benefit or value. A common approach is to ask whether the benefits have a higher or lower value compared to the energy savings. This is followed up with open or closed ended questions quantifying how much more or less the value is. This can be asked as a dollar amount, multiplier, or as a percentage. Surveys start by asking respondents if they experience negative, positive, or no change effect in the NEB. Then they were asked if the NEB was more, less, or the same value as the energy benefits and by how much. Percentages can be applied against the known energy savings to produce dollar value of the NEB. This method produces similar results between comparable programs.

Scaled valuations (or labeled magnitude scaling, LMS): This method is similar to the comparative valuation. Respondents are asked to rank the importance of energy savings, and then they are asked to rank each NEB. The respondents are asked if the NEBs are more valuable, much more valuable, less valuable, much less valuable, or of a similar value. Each response represents a dollar value based on established research. Values from this method have been found to estimate very closely to values from the comparative valuation method.

Skumatz L, Gardner J. Methods and results for measuring non-energy benefits in the commercial and industrial sectors. Proceedings of the 2005 ACEEE Summer Study, Panel 6: pp. 163-76.

When estimating NEB values to estimate savings from a program, or to calculate the cost-effectiveness of a program, three factors need to be considered to represent "Best Measurement Practices": the net value of the NEB, standard equipment comparison, and free ridership.

Net positive and negative: Non-energy benefits, or non-energy impacts, can have a positive or negative value. The NEB or NEI value refers to the net value. In surveys, this is asked in three parts. 1) Were any benefits experienced (open-ended), 2) Were the impacts of specific NEB categories positive, negative, or of no impact (closed-ended); and 3) What was the size of the impact?

Compare to standard equipment: For equipment-derived benefits, the new energy efficient equipment is compared to the equipment that it would have been replaced with if the energy efficient equipment had not been installed; it is not compared to the old equipment that was in place.

Free riders: A determination is made as to what would have been replaced regardless of the program. This value may still be incorporated as spillover into program savings.

Wobus N, Meissner J, Barkett B, Waldman D, Train K, Thacker J, Violette D. Exploring the application of conjoint analysis for estimating the value of non-energy impacts. In: 2007 International Energy Program Evaluation Conference; 2007.

The authors review multiple survey methods for valuing NEBs, including willingness to pay (contingent valuation), scaling, and conjoint analysis.

Willingness to pay (WTP, contingent valuation): WTP asks respondents open-ended questions, such as, "what are you will to pay," and "would you be willing to pay $X?" These questions can be difficult for respondents to answer and value and often lead to inconsistencies in responses.

Scaling approach:- This section cites Skumatz and Gardner (2006) (see Skumatz 2002), highlighting the benefits and challenges with this approach that are outlined in the referenced paper. Wobus et al. continues their review with concerns that scaling is too similar to WTP and that the range of values is influenced by parameters set by the researchers. For example, scaling often uses energy savings as a benchmark to rate other benefits against. The authors cite Gregory et al. (1995), who notes that if the benchmark is low, all resulting values will reflect to that lower value. If the benchmark is high, the values will reflect a higher value. Wobus et al. conclude that even though a benchmark bias exists, there are benefits to providing respondents with a consistent reference and that many respondents are more comfortable answering scaling questions vs. WTP questions.

Conjoint analysis: This approach asks respondents to compare or rank hypothetical situations in which one of the situations has a known dollar value. A statistical analysis is then performed to assign dollar values to the situations without known values. Through this statistical model a WTP value can be calculated. The paper states that some studies have found that this can be easier for respondents to answer than the WTP or scaling questions. The seeming randomness of the questions prevents respondents from realizing that they are providing WTP responses. The comparative nature of the questions allows researchers to learn about the value of multiple situations simultaneously with each new comparison question, and requires fewer responses for analysis overall. While multiple attributes can be measured with each question, attempting to measure too many attributes can create complicated questions. This limits the researchers to six or fewer attributes. Similar to the scaling approach, the resulting values will be dependent on the value of the benchmark attributes that are set by the researchers.

The paper then describes the methods used to estimate NEBs for NYSERDA: direct query (WTP or scaling) and conjoint analysis. The authors include limited sample questions used for each method and compare limited results between the two methods. The authors found that the values from the conjoint analysis were lower than those from the direct query, although values from both methods are in the same general range for individual attributes (1% to 20% of annual electric bill savings).

NEBs reported include Even Light Distribution, Lighting Quality, and Lamp Life. The values are presented as a percentage of annual energy savings and as annual dollar values.

Other Studies for Commercial or Control Measures That Do Not Include Detailed Methodology:

Mass Save. Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2019 Plan-Year Report Version. Prep Efficiency Program Administrators; 2020 May.

National Grid. Rhode Island Technical Reference Manual, For Estimating Savings from Energy Efficiency Measures, 2015 Program Year. Produced by Sean Murphy, 2014 Nov.

National Grid. Rhode Island Technical Reference Manual, For Estimating Savings from Energy Efficiency Measures, 2020 Program Year. 2019 Oct.

Worrell E, Price L, Martin N. Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector. Energy. 1999;26.5:513-36.

A.4. Template NEBs Questionnaire and Associated Analysis Method

Table A.9 is extracted and adapted from the document “2020 Cookbook for NEI Studies”.[48] It has been adapted here for use with advanced lighting controls (ALC). It is important to note that there are decisions as part of the first step, in preparation before the survey is written.

Preparation and Planning Steps

FIRST: Identify the comparison factor (CF): Decide which CF is appropriate for the sample being surveyed. The CF in most energy efficiency NEBs studies is “energy savings from the measure.” For an ALC study, for each occurrence of CF in **Table A.9**, make the appropriate substitution. Suggestions:

- If decisionmakers participated in a utility program or made the specific decision to purchase the equipment, then the CF may be “compared to the energy savings from the lighting control measure you would receive relative to not installing a lighting control measure.” After that you can use “compared to the energy savings from the control measure,” periodically reminding them of the “relative to no lighting” control measure.
- If the survey respondent did not make the purchase decision, or would not be familiar with the savings, then this study implies that both occupants and decisionmakers can respond in terms of minutes saved per day relative to a building or workspace without lighting controls. The minutes can be easily translated into percentage of an FTE.
- If the questions are to be used directly, the CF in minutes will need to be selected. Based on the results of this survey, a value of about 5 minutes a day is suggested as the comparison factor. (CF = 5 minutes per day)
- If desired, the questions may be revised to ask in a straightforward way, how many minutes each NEB is worth per day, and then again, how much the total of all the NEBs is worth in minutes per day.

SECOND: Phrase the ALC measures properly with a comparison measure (CM) (or baseline measure) in mind:

- In most NEB studies, the phrasing for the program, measure, or measure group is something like “a similar standard efficiency model of the same measure.” For the study of controls, the measure should be phrased as “the lighting control measure relative to a workspace without control measures.” For each occurrence of “CM” in the table below, make the appropriate substitution.

[48] Skumatz LA. 2020 Cookbook for NEI Studies, a SERA white paper, updated from 2014; Silverthorne, Colo.; 2020. Online: www.serainc.com

THIRD: Obtain the list of NEBs relevant to the measure.

- Use the list from this study, or augment or modify the list using only the largest values, or information you receive from up-front targeted interviews regarding specific ALC measures. Prepare a matrix that clearly identifies the NEBs associated with each measure for the study.

Table A.9. NEBs Questions for Standard Questionnaire – A simpler analysis approach than Surveys C1 - C3, attached under separate cover

<table>
<tr><th>Content</th></tr>
<tr><td>Preparation steps and decisions to be made before drafting the survey, described in Boxes A - E below.</td></tr>
<tr><td>A. INTRODUCTION ONCE AT TOP
Short intro on NEBs concept</td></tr>
<tr><td>B. For each ALC they are in the sample for:
Establish presence of ALC NEB list from matrix, or use sample design to accomplish same item)
For each ALC, ask about any positive or negative effects (or no effects) they received from the lighting control measure beyond what they would have experienced from a workspace without the control measure. Open ended, but do not wait a long time – move on. (If none mentioned, still go ahead because they sometimes do not understand the concept.)</td></tr>
<tr><td>C. For each NEB, this segment is repeated. Ask these questions for each NEB relevant to the measure:
Some people who received the same measures as you in the program say they experienced a change in <NEB1>. Thinking about < NEB1>, would you say you received a positive or negative change in <NEB1> from the ALC measure, or no impact or difference compared to what you would have experienced from a workspace without the control measure? (If no impact, go to next NEB). (+/-/0)
If a positive value: Was the NEB1 effect you received from the P/M/MG more or less valuable than energy savings you received from the (P/M/MG) beyond what you would have experienced from a workspace without the control measure? (Drop down or multiple choice: for level of value - <LABELED MAGNITUDES>[49])
Extremely more valuable than the <CF>.[50]
Much more valuable
Slightly more valuable (do not repeat the whole rest of the sentence above after 1st time)
About the same value
Slightly less valuable
Much less valuable
Extremely less valuable
(For negative or more complicated wording, use “costly” rather than “valuable.”)
Then repeat for other NEBs for the ALC they are sampled for. (Consider asking about any NEBs outside of your list that they mentioned in the open-ended question.)</td></tr>
</table>

[49] The rationale behind the labeled magnitude scaling (LMS) approach SERA developed (see SERA publications starting in 2001-2; summarized best in 2009 SERA paper for CPUC/CIEE) is that people can answer more quickly, which increases sample size and reduces guessing; and people cannot answer numbers well (and it is less volatile than WTP/WTA and other approaches.

[50] The five levels identified here can be abbreviated as EMV, MMV, SMV, SV, SLV, MLV, ELV. Cost or negative side wording noted below.

Content

D. Every third NEB, to get percentages from in-sample[51]:

- You mentioned <NEB3> was <much more valuable> than the <CF>. How much more value – in percentage terms – would you say it is to you?
  - Drop down ranges for percentages, plus open-ended other at bottom for outside range. Use fewer options for phone survey!)

E. ONCE, at the end (*partly to understand the total value, but also partly to get at the issue that the sum of the individual NEIs is commonly more than the value of the total NEIs)*[52]*:*

- You mentioned positive and negative effects or values from the following NEIs (XXX). (Or just say they mentioned several times to minimize the logic.) Thinking about all of them, would you say the total value of the effect was positive or negative or of no value or effect? (+/-/0)
- If positive, would you say the total of all these NEIs is more or less valuable than the <CF> you received from the ALC relative to a workspace without control measures?
  - LABELED MAGNITUDES - More or less valuable than <CF>?
  - Extremely more valuable
  - Much more valuable
  - Slightly more valuable
  - About the same value
  - Slightly less valuable
  - Much less valuable
  - Extremely less valuable

  <Reply to a negative response has similar wording but uses "costs" rather than "value.">
- What percentage more or less valuable? (Open end or drop downs similar to above, perhaps allowing for a higher high value)
- Did you have trouble separating any of the NEIs we asked about – did any overlap for you? If so, which ones? Y/N. Which ones _________
- Finally, how would you rank the various benefits[53]? (Have them rank 1 – 5, with 1 the highest and 5 the lowest value (randomize order of NEBs):
  - Comfort
  - Noise
  - Light
  - X
  - Y
  - Z
- For the NEI you ranked as highest value, what percentage more valuable is it than the <CF> from the ALC? (Use drop-down menu OR open end). (If there is space, ask about the lowest as well.)
- If there is space, consider asking how much <CF> they understand or think they get per day or month or year from the ALC.

Thank you to the respondent!!

Source: Adapted for DLC ALC survey approach from Skumatz, LA. 2020 Cookbook for NEI Studies," a SERA white paper, updated from 2014. Silverthorne, Colo.; 2020. Online: www.serainc.com.

[51] Ask roughly every third NEB for each person, giving enough observations for the PERCENTAGES to assign to each LABELED MAGNITUDE sample-wide (in-sample multiplier). Do *not* ask for their first NEB, or they may stop specifying they got a NEB.

[52] This estimates the total, and then the analysis can proportionally drop down the values for each of the NEBs accordingly, based on ratio of TOTAL to SUM. This question provides one more value for the percentage vs. the labeled magnitude.

[53] The ranking provides another chance to get nuance on which is truly highest value and how valuable (more info than label for top ranked).

A.5. Outline of Analysis Method for the NEBs Survey

For each NEB, the following steps should be taken:

- Calculate the average percentage across the sample assigned to each "LABELED MAGNITUDE LABEL." You may also compare with published SERA or other values for reasonableness. Review responses for 1 – 5 ranking questions also.
- Substitute those percentages for the LABEL for each respondent – (you can use full sample magnitude, or if you have enough, you can consider using a personal one – rarely possible).
- Check for overlap. For those reporting overlap, split the LABELED NEB multiplier among the 2/3/X overlapping NEBs into half, one-third, and so on for each of the NEBs reported as overlapping.
- Weight or identify the percentage responding with each labeled level, then average or sum up the individual NEBs.
- Compare to the multiplier for the TOTAL and decrease each INDIVIDUAL NEB multiplier proportionally to sum up to the total NEB multiplier.
- Compute the average NEB (and weight if needed); that is the CF or minutes (usually savings) multiplier for the NEB (report that in the first column).
- Multiply by the confirmed or measured savings (for each ALC, as relevant) to get the dollar value. That is NEB for those with the ALC. This goes in the second column of results. (You may wish to compare the perceived savings with verified, deemed, or estimated savings.)
- Report the percentage of the program participants with that ALC (third column), and use to calculate this NEB for the average program participant; enter in fourth column (obviously, more calculations are needed if different measure groups lead to or contribute to the same NEB).
- Sum up participants to get the program-wide NEB value for the NEB fifth column, and then total those for the grand total of all relevant NEBs.

Appendix B: Detailed Tables of Results from the Study

This appendix includes figures and graphics illustrating responses and results associated with the study. Each section focuses on specific types of results.

B.1 Description of Sample

Table B.1 lists the goal and achieved sample sizes. Subject matter experts (SMEs) were first interviewed to gain a better understanding of what effects can occur and might be noticed by those working in an environment where advanced lighting controls (ALCs) have been installed. Managers and occupants who were reached out to with known ALCs were generally unresponsive to requests to participate in the survey. Large numbers that exceeded initial sample size goals were achieved through a paid survey that sampled the general U.S. population.

Table B.1. Sample Completions by Group

Group	Goal Sample Size	Achieved Sample Size	Means of Acquisition	Notes
SMEs	0	10	Cold calls to firms in lighting, plus referrals	For background on NEBs, categories
Managers, Decisionmakers	5 each of 4 business types = 20 total	12	From utility program web link	68 total, exceeding project goal
		56	Managers taking occupant survey	
Occupants	15 each of 4 business types = 60 total	127	127 from purchased sample, 4 business types	137 total, exceeding project goal
		10	10 utility program manager forwarding	

Table B.2 shows the distribution of business types for decisionmakers and occupants for both the utility sample and the survey sample, as well as the combined distribution. Columns may not add to 100, due to rounding.

Table B.2. Percentage of Sample by Business Type

	Decision-makers from Utility Programs	Decision-makers from Survey	Occupants from Utility	Occupants from Survey	All Decision-makers	All Occupants
Office Building	71.4%	38.7%	10.0%	24.4%	44.7%	23.4%
Hospital	0.0%	0.0%	0.0%	12.6%	0.0%	11.7%
Health Clinic	0.0%	3.2%	0.0%	5.5%	2.6%	5.1%
Nursing home, care facility, or similar	7.1%	6.5%	0.0%	5.5%	6.6%	5.1%
School including any grades K-12	0.0%	1.6%	10.0%	20.5%	1.3%	19.7%
College or University	7.1%	9.7%	80.0%	6.3%	9.2%	11.7%
Small Warehouse	0.0%	8.1%	0.0%	3.9%	6.6%	3.6%
Large warehouse	0.0%	16.1%	0.0%	14.2%	13.2%	13.1%
Small industrial building	7.1%	16.1%	0.0%	7.1%	14.5%	6.6%
Other (please specify)	7.1%	0.0%	0.0%	0.0%	1.3%	0.0%
	N=14	N=62	N=10	N=127	N=76	N=137

In **Figure B.1**, the blue bars (on the left) represent decisionmakers, and the orange bars (on the right) represent occupants. The majority of decisionmakers are from office buildings, followed by warehouses and industrial buildings. The respondents for occupants are more evenly distributed between the four main business types (Office buildings, Healthcare facilities, Schools, Warehouses, and Small Industrial), with the most respondents from schools.

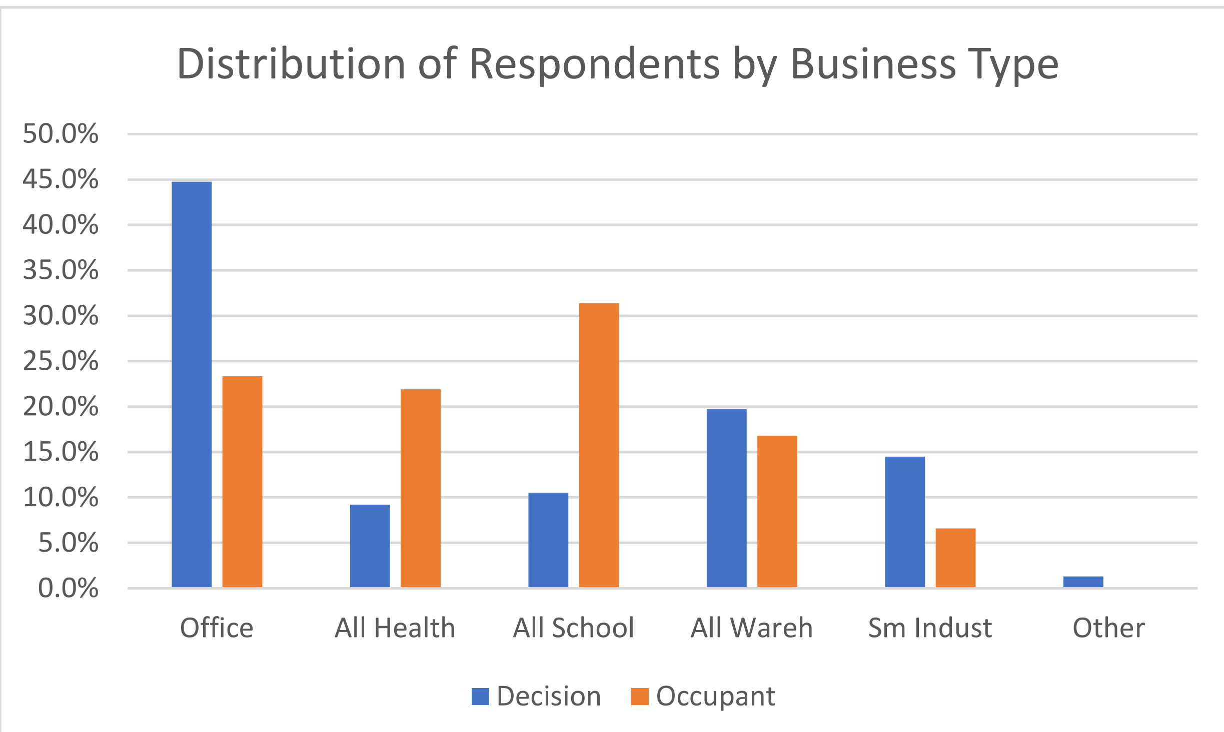

Figure B.1. Distribution of decisionmaker and occupant samples by business type.

Figure B.2 shows the distribution of each type of control, separated by groups of lighting control levels. Level 1 comprises basic control measures, such as occupancy sensors and dimming switches on the wall. Level 2 incorporates the sensors into the light fixtures and includes daylight sensors. Lights may also be controlled with a remote or mobile app at this level. Level 3 integrates the HVAC system into the lighting controls and can heat or cool a space based on occupancy, and can adjust the lights and shades to achieve proper temperature. Level 4 lighting controls are the most advanced and include central monitoring, alarms, and automatic light and HVAC schedules. The outdoor lighting controls shown in the figure refers to those installed outside of the building, such as occupancy sensors along walkways and parking lots, as well as alarm reporting. In this figure, turquoise indicates none installed, blue means a few are installed, and yellow means widespread installation. These graphs show that there is very little installation of lighting controls in Levels 3, 4, and Outdoor.

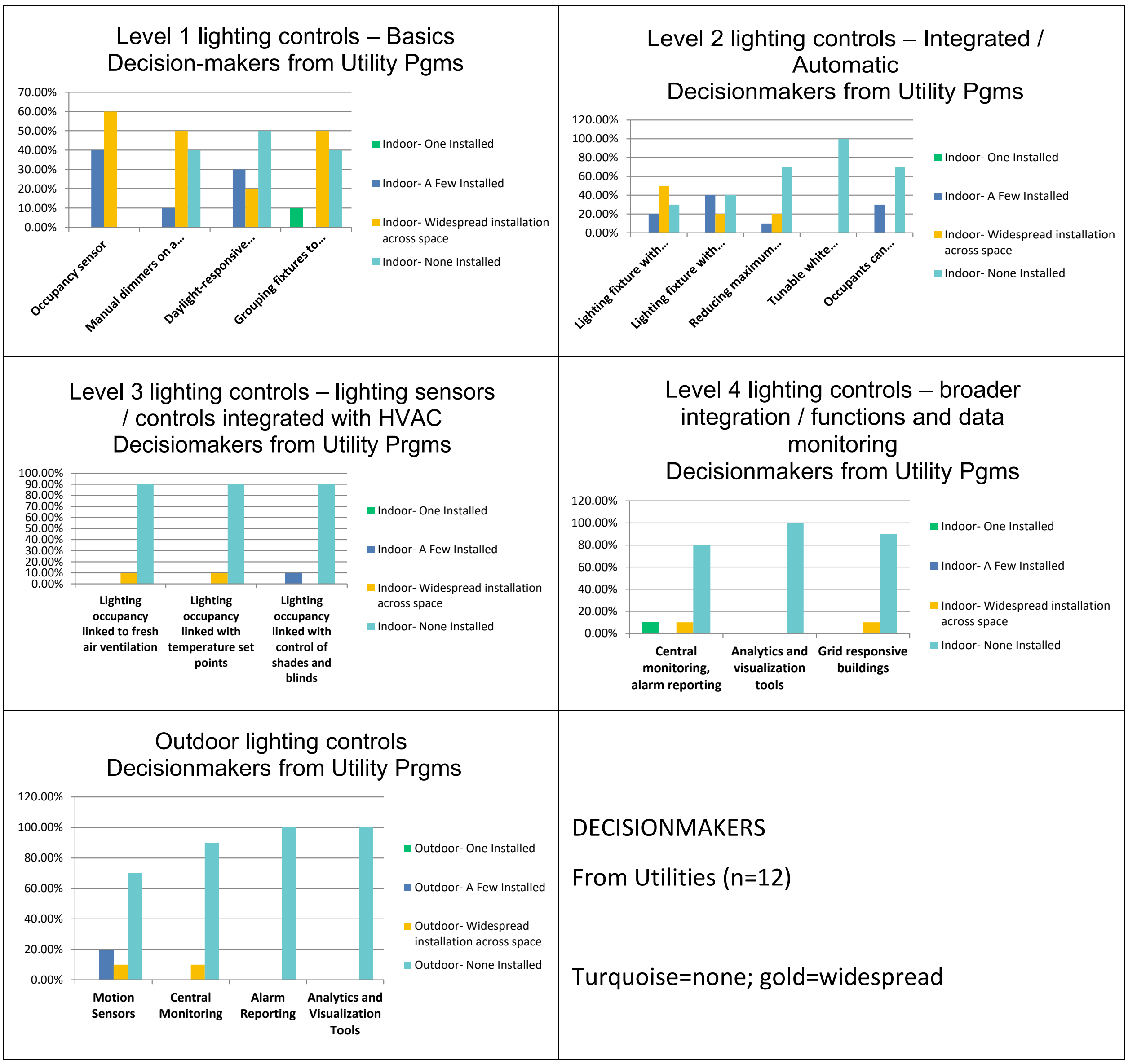

Figure B.2. Decisionmakers from utilities sample: reported installation of lighting levels.

Figure B.3 shows that decisionmakers most often noticed that their lights turn on and off from occupancy sensors on the wall or as they walk through a parking lot or garage. They also noticed that the lights turn on and off as they enter hallways, and many stated that they can control the lighting in their workspace from their computer or a phone app. The least noticed occurrences are related to daylight harvesting, such as the lights dimming with changing outdoor light, or shades or blinds automatically opening or closing. These results are similar to the utility decisionmaker responses from **Figure B.2**, which state that the most installed type of lighting controls is Level 1, such as occupancy sensors.

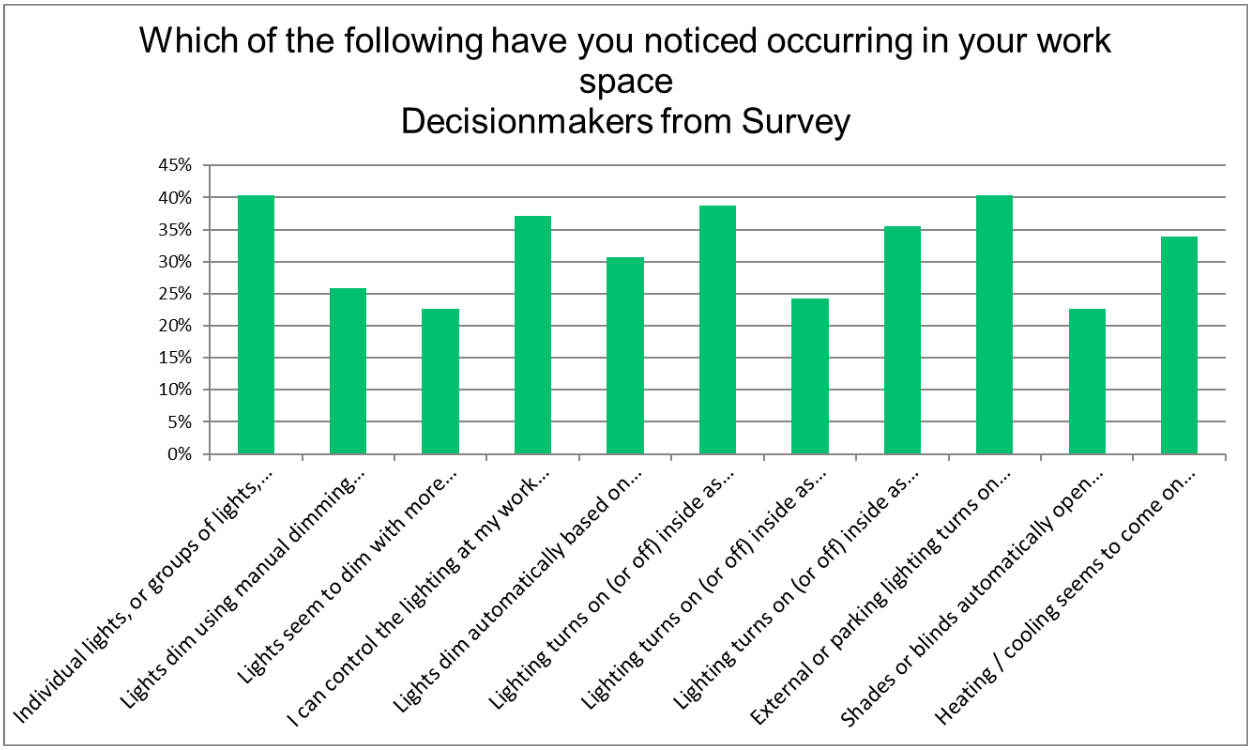

Figure B.3. Decisionmakers from larger survey: reported ALC or lighting types in facilities (*n* = 56).

Similar to decisionmakers, occupants also most often notice lights turning on and off due to occupancy sensors or as they enter or exit hallways (see **Figure B.4**). Occupants from the utility sample were unable to control their lighting from their computer or phone and did not notice the heating and cooling system responding to their presence.

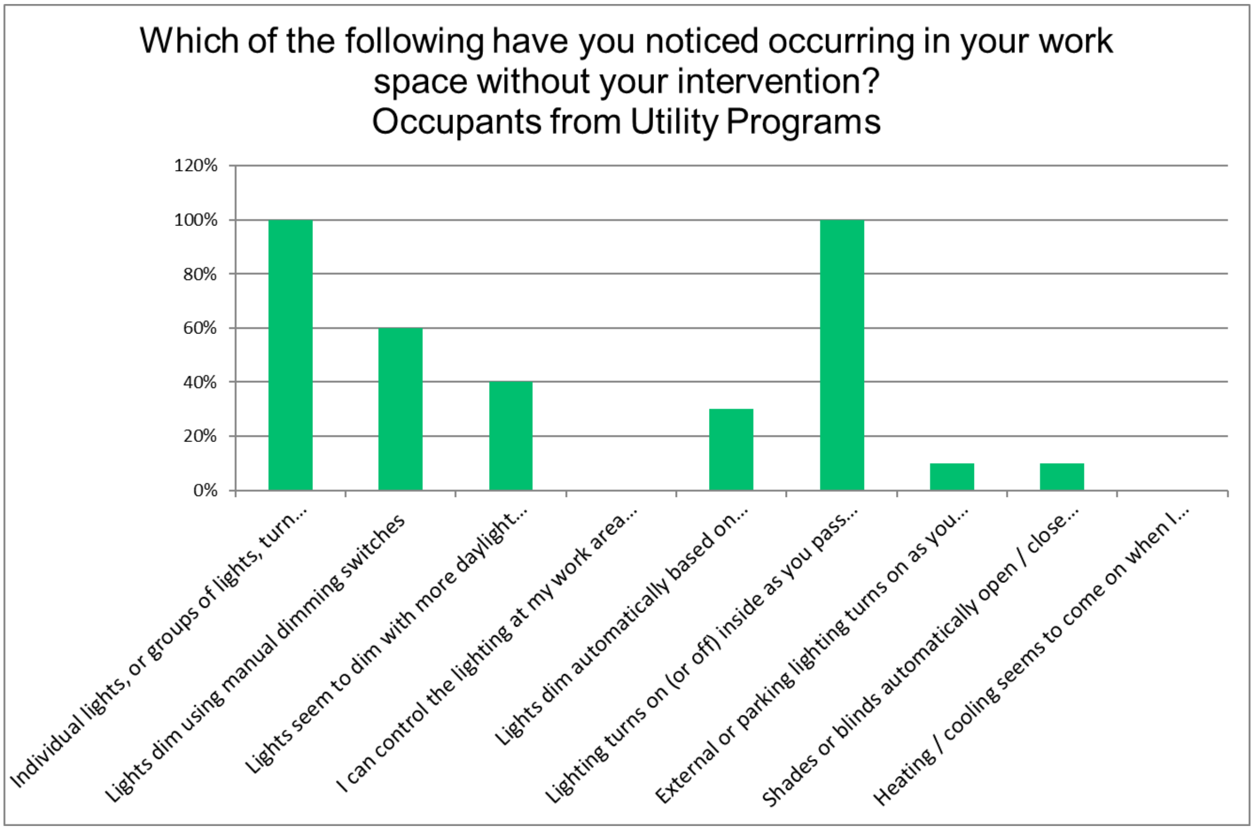

Figure B.4. Occupants from utility sample: reported ALC or lighting types in facilities (*n* = 10).

Again, occupant-workers most often noticed lights turning on and off from occupancy sensors and when they pass through hallways (see **Figure B.5**). The least noticed effect was shades and blinds automatically opening and closing.

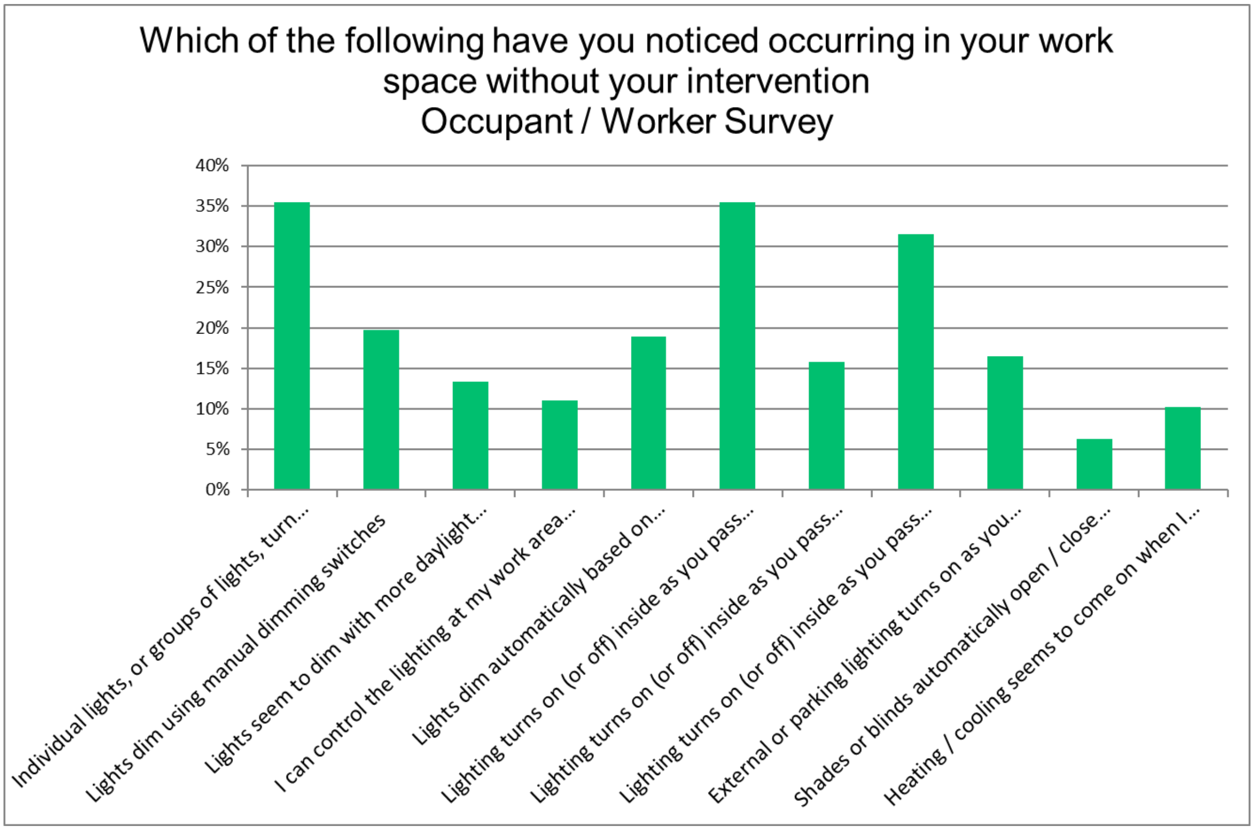

Figure B.5. Occupant-workers from survey: reported ALC or lighting types in facilities (*n* = 127).

B.2 Positive and Negative Responses Overall and by Strata – Decisionmakers

The major findings with respect to decisionmakers were:

- The largest positive NEBs included: A feeling of safety and/or security outside the building; productivity improvements; high quality lighting; and automation of lighting which resulted in fewer interruptions to adjust lighting, shades, or other lighting-related devices in a space
- Negative NEBs include those related to sick days, eye strain, and other health issues

In **Figure B.6**, each blue bar (left) indicates the percentage of decisionmaker respondents who answered that they experienced a positive effect from that NEB. Each gray bar (right) indicates the percentage who experienced a negative effect. Decisionmakers experienced improvements in safety inside the building and in productivity from higher quality light and fewer interruptions. They also had positive experiences in other areas of quality of light and job efficiency. They experienced the highest percentage of negative effects in sick days from eye strain and other ailments and health outcomes.

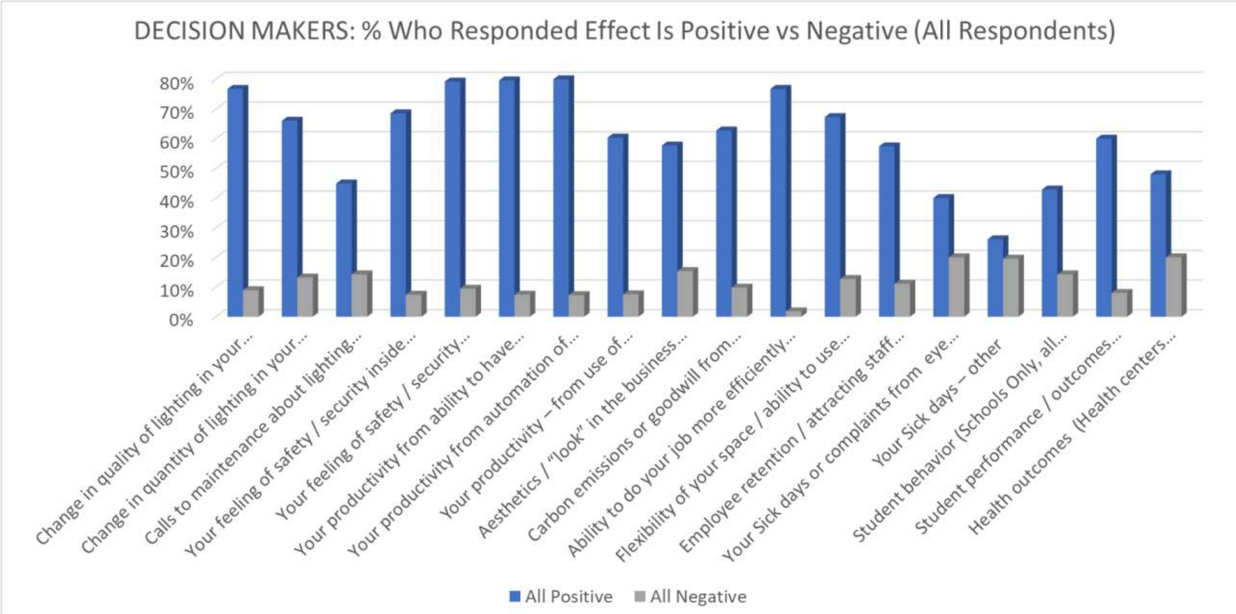

Figure B.6. Share of positive and negative NEBs overall by decisionmakers from survey (*n* = 56).

Figure B.7 shows the percentage of decisionmaker respondents who answered that they experienced a positive effect or a negative from each NEB. The results are presented by business type. The highest-ranked Office Positive effect was "Your productivity from the ability to have high-quality lighting for tasks in the space," and the highest ranked Office Negative effect was "Health outcomes." Respondents indicated the highest Hospital Positive effect as "Your feeling of safety/security inside the building," and the highest Hospital Negative effect as "Change in quantity of lighting in your space." Respondents indicated the highest School Positive effects were "Your productivity – from use of circadian rhythm/variations in color or intensity during the day," and the highest Schools Negative effect was "Student behavior." Participants responded that the highest Warehouse Positive effect was "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space" and the highest Warehouse Negative effect was "Your Sick days or complaints from eye strain." The overall highest indicated positive responses by business type were for the School Positive effect "Your productivity – from use of circadian rhythm/variations in color or intensity during the day" and the Hospital Positive effect "Your feeling of safety/security inside the building." Overall, the highest negative response was for the Warehouse Negative effect "Change in quantity of lighting in your space."

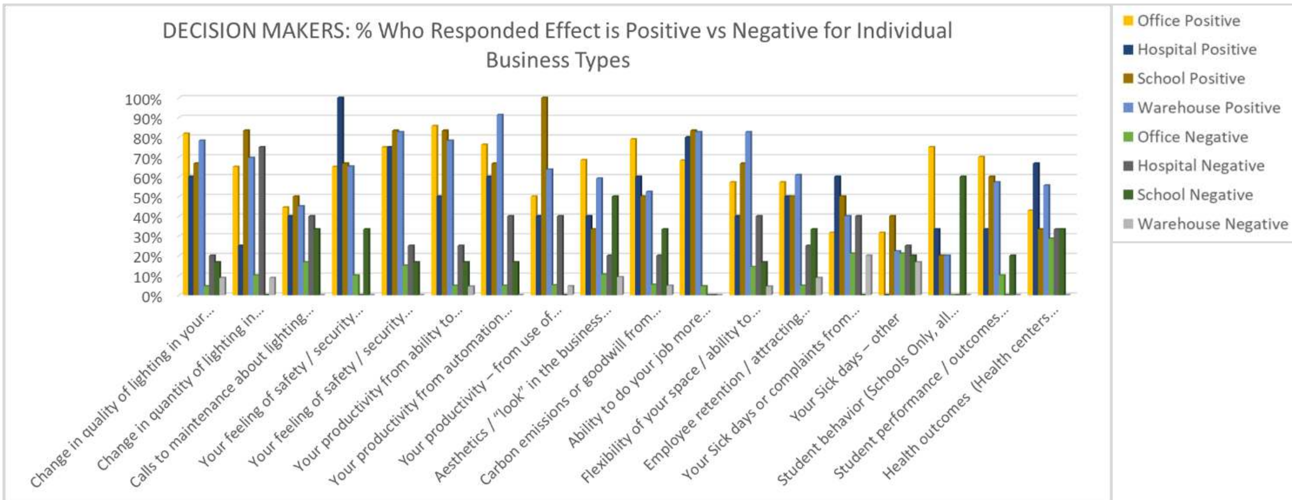

Figure B.7. Decisionmakers: percentage of positive and negative NEB effects by business type (*n* = 56).

Figure B.8 shows the percentage of decisionmaker respondents who answered that they experienced a positive effect or a negative from each NEB when consideration of outdoor lighting was included. The results are presented by controls type (i.e., Level 1, 2, or 3) *with* outdoor lighting. (**Figure B.2** shows the various levels of lighting controls.)

The highest indicated responses for Level 1 w/ Outdoor Positive effects were "Your feeling of safety/security outside the building," "Your productivity from the ability to have high quality lighting for tasks in the space," "Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space," and "Ability to do your job more efficiently / effectively." The highest indicated response for Level 1 w/Outdoor Negative effect was "Your Sick days or complaints from eye strain." The highest participant responses for Level 2 w/ Outdoor Positive effect were "Change in quality of lighting in your space," "Change in quantity of lighting in your space," "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," "Flexibility of your space/ability to use space different ways because lighting is flexible" and "Student performance/outcomes." The highest participant response for Level 2 w/ Outdoor Negative effect was "Your Sick days or complaints from eye strain." For Level 3 w/ Outdoor Positive effect, the highest indicated response was "Change in quantity of lighting in your space" and "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space." The highest response for Level 3 w/ Outdoor Negative effect was "Your Sick days – other."

Overall, the highest indicated positive effect responses were the Level 1 w/ Outdoor Positive effects "Your feeling of safety/security outside the building," "Your productivity from the ability to have high quality lighting for tasks in the space," "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," and "Ability to do your job more efficiently / effectively," as well as the Level 2 w/ Outdoor Positive effects "Change in quality of lighting in your space," "Change in quantity of lighting in your space," "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," "Flexibility of your space/ability to use space different ways because lighting is flexible," and "Student performance/outcomes." Overall, the highest indicated negative effect response was the Level 1 w/ Outdoor Negative effect "Your Sick days or complaints from eye strain."

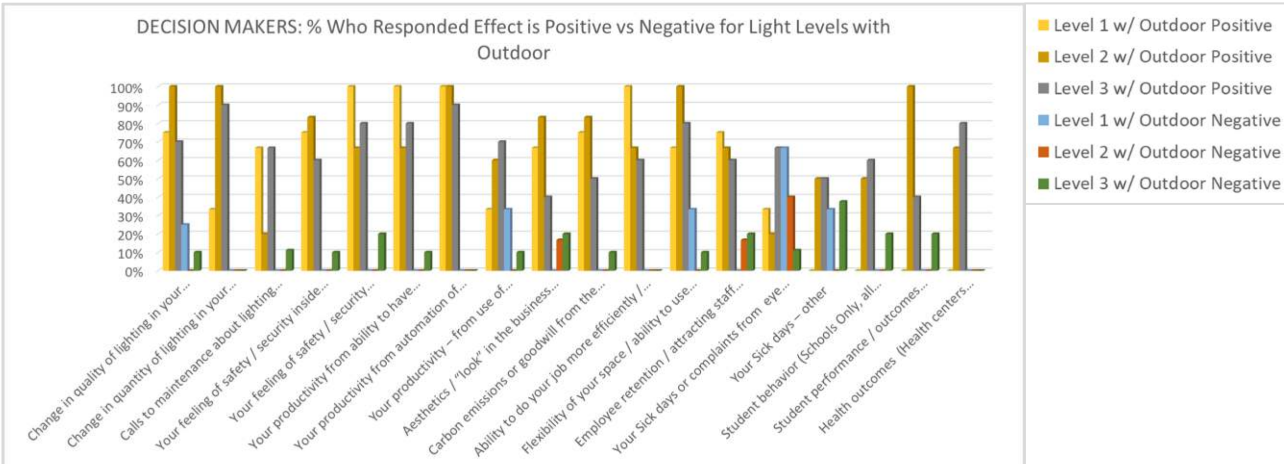

Figure B.8. Decisionmakers: percent positive and negative NEB effects by controls type, *with* outdoor lighting (*n* = 56).

Figure B.9 shows the percentage of decisionmaker respondents who answered that they experienced a positive effect or a negative from each NEB when consideration of outdoor lighting was *not* included. The results are presented by controls type (i.e., Level 1, 2, or 3) with *no* outdoor lighting. (**Figure B.2** shows the various levels of lighting controls.) The most responses for Level 1 No Outdoor Positive effects were "Your feeling of safety/security inside the building," "Your feeling of safety/security outside the building," "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," and "Carbon emissions or goodwill from the building being more green." The highest responses for Level 1 No Outdoor Negative were for "Your productivity – from use of circadian rhythm/variations in color or intensity during the day" and "Your Sick days or complaints from eye strain." Level 2 No Outdoor Positive had the highest response for "Change in quality of lighting in your space," and Level 2 No Outdoor Negative had the highest response for "Health outcomes." Respondents indicated the Level 3 No Outdoor Positive highest effect to be "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," and the highest Level 3 No Outdoor Negative effect was "Change in quantity of lighting in your space."

Overall, participants indicated the highest positive effects to be the Level 1 No Outdoor Positive "Your feeling of safety/security inside the building," "Your feeling of safety/security outside the building," "Your productivity from automation of lighting/fewer interruptions to adjust lighting, shades, or other lighting in space," and "Carbon emissions or goodwill from the building being more green." The highest negative effect participants indicated were the Level 2 No Outdoor Negative "Health outcomes" and the Level 3 No Outdoor Negative "Change in quantity of lighting in your space."

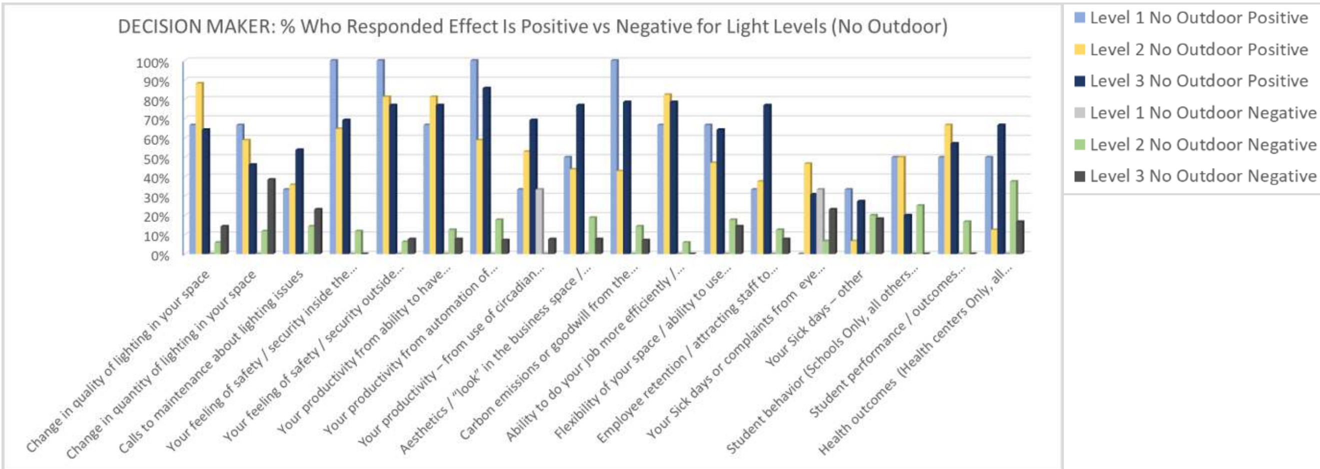

Figure B.9. Decisionmakers: percent positive and negative NEB effects by controls type, with *no* outdoor lighting (*n* = 56).

Figure B.10 shows the percentage of decisionmaker respondents who answered that they experienced a positive effect or a negative from each NEB. The results are presented by northern vs. southern U.S. latitudes. Respondents indicated the highest North Latitude Positive effect was "Ability to do your job more efficiently/effectively, "and the highest North Latitude Negative effect was "Student behavior." Respondents indicated the highest effect for South Latitude Positive was "Your productivity from the ability to have high quality lighting for tasks in the space," and the highest effect for South Latitude Negative was "Health outcomes." Overall, the highest positive effect for respondents was the South Latitude Positive "Your productivity from the ability to have high quality lighting for tasks in the space," and the highest negative effect for respondents was the North Latitude Negative "Student behavior."

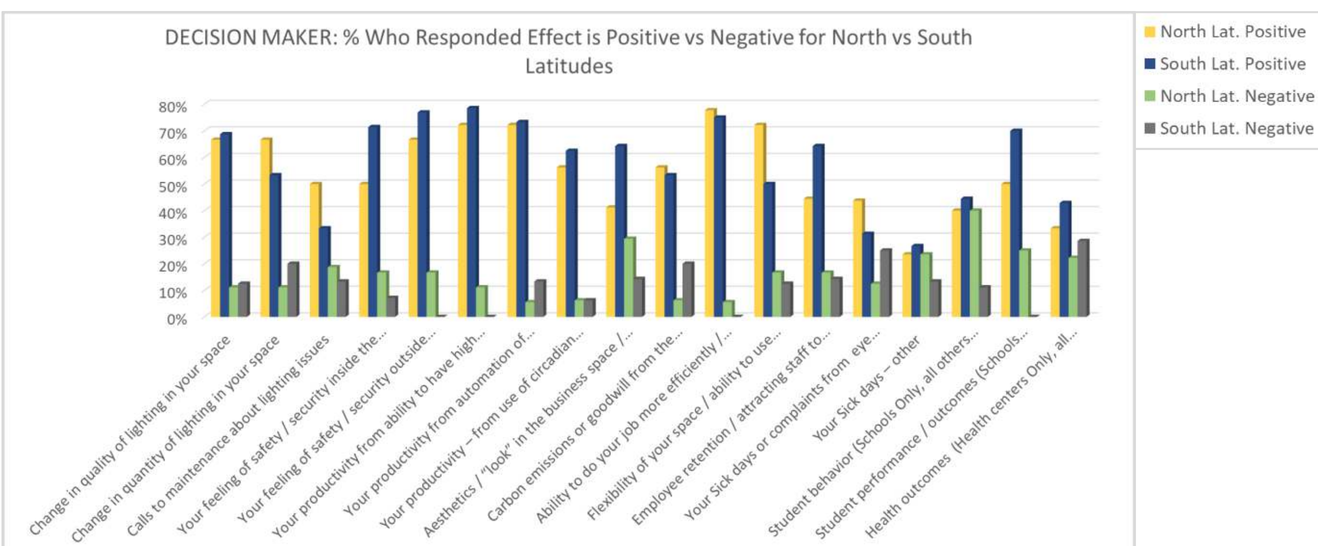

Figure B.10. Decisionmakers: percent positive and negative NEB effects by latitude (*n* = 56).

B.3 Positive and Negative Responses Overall and by Strata – Occupants

The number of respondents for the occupant survey was 137.

From the overall sample, the NEBs with the highest percentage positive response were related to "Safety/security." The NEBs reported most as negative effects included "Calls to Maintenance about lighting issues" and "Sick days from eye strain."

In **Figure B.11**, the blue bar (left) indicates the percentage of occupant respondents who answered that they experienced a positive effect from that NEB. The gray bar (right) indicates the percentage who experienced a negative effect. Occupants experienced improvements in safety inside and outside the building due to improvements in the quality of lighting. They also had positive experiences in productivity, aesthetics, carbon emission reduction, and job efficiency. They experienced the highest percentage of negative effects in sick days from eye strain calls to maintenance staff.

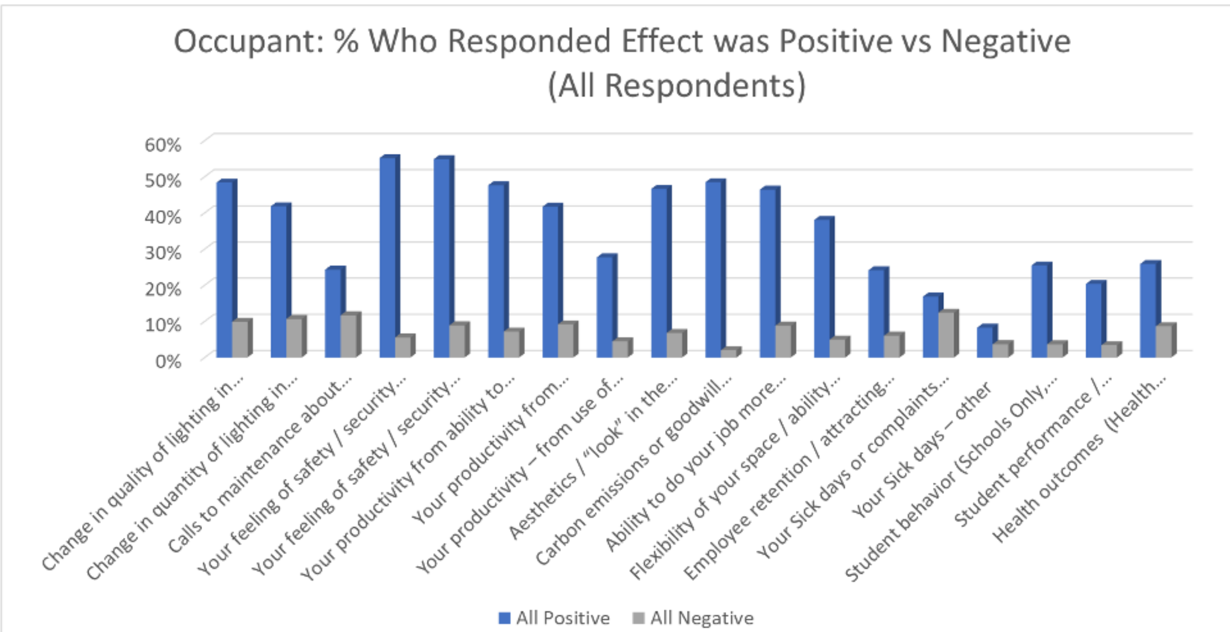

Figure B.11. Share of positive and negative NEBs overall for occupants from survey (*n* = 137).

Figure B.12 shows the percentage of occupant respondents who answered that they experienced a positive effect or a negative from each NEB. The results are presented by business type. Office occupants reported the most positive responses for "Your feeling of safety/security inside and outside of the buildings." The highest negative response from Office occupants was for "Call maintenance about lighting issues." Hospital occupants' highest positive responses were for "safety/security inside and outside the building" and "productivity from high quality lighting." Interestingly, the highest Hospital Negative effect was also for "safety/security outside the building." School occupants' most reported positive NEB was "Carbon emissions or goodwill from the building being more green," and their highest reported negative responses were for "change in the quality and quantity of lighting" and "Ability to do your job more efficiently/effectively." Warehouses reported the most positive responses from "safety/security inside the building" and "productivity from high quality lighting." Their highest negative responses were for "Your Sick days or complaints from eye strain" and "Health outcomes." Overall, the highest positive response was the Schools response for “Carbon emissions or goodwill from the building being more green.” I highest overall negative responses were the Warehouse responses for “Your Sick days or complaints from eye strain” and “Health outcomes.”

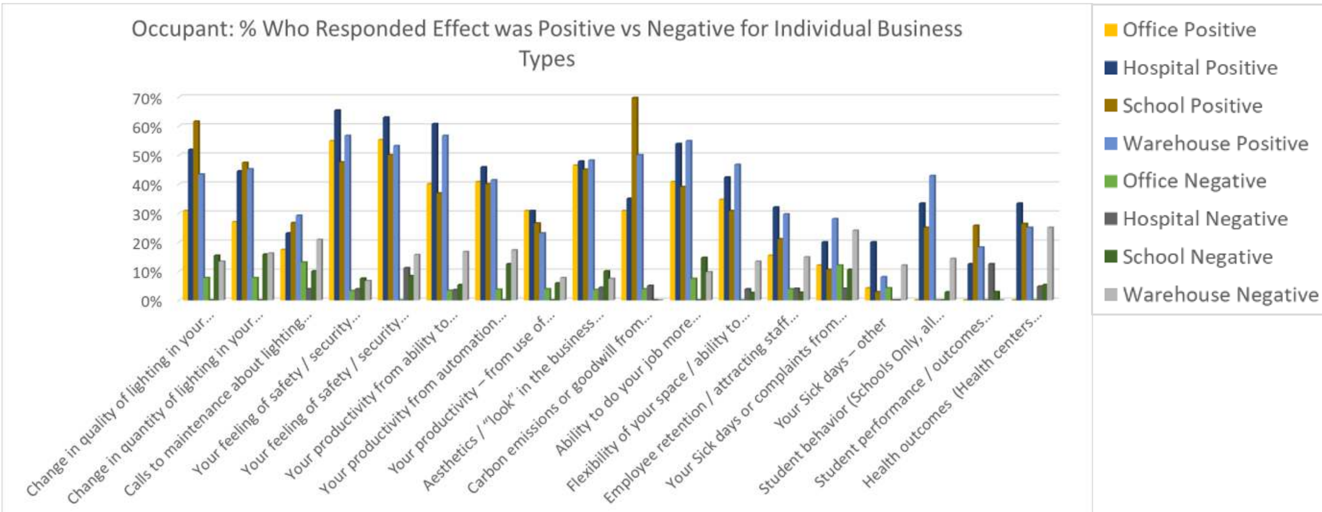

Figure B.12. Share of positive and negative NEBs overall for occupants by business type (*n* = 137).

Figure B.13 shows the percentage of occupant respondents who answered that they experienced a positive effect or a negative from each NEB when consideration of outdoor lighting was included. The results are presented by type of lighting controls (i.e., Levels 1, 2, or 3) *with* outdoor lighting. (**Figure B.2** shows the various levels of lighting controls.) “Your feeling of safety and security outside the building” was the highest selected option by participants for Level 1 w/ Outdoor Positive impact, and “Carbon emissions or goodwill from the building being greener” was the only option selected for Level 1 w/ Outdoor Negative impact. “Your feeling of safety and security inside the building,” “Your feeling of safety and security outside the building,” and “Carbon emissions or goodwill from the building being greener” were the top three options selected as Level 2 w/ Outdoor Positive impacts. “Change in quality of lighting in your space” and “Change in quantity of lighting in your space,” were the top two options selected as Level 2 w/ Outdoor Negative impacts. “Your feeling of safety and security inside the building” and “Your feeling of safety and security outside the building,” where the two highest options selected as Level 3 w/ Outdoor Positive impacts. “Your Sick days – other” was the highest selected Level 3 w/ Outdoor Negative impact. The most selected positive NEBs were Level 2 w/ Outdoor “Your feeling of safety and security inside the building,” “Your feeling of safety and security outside the building,” and “Carbon emissions or goodwill from the building being greener.” The most selected negative effect was Level 1 w/ Outdoor “Carbon emissions or goodwill from the building being greener.”

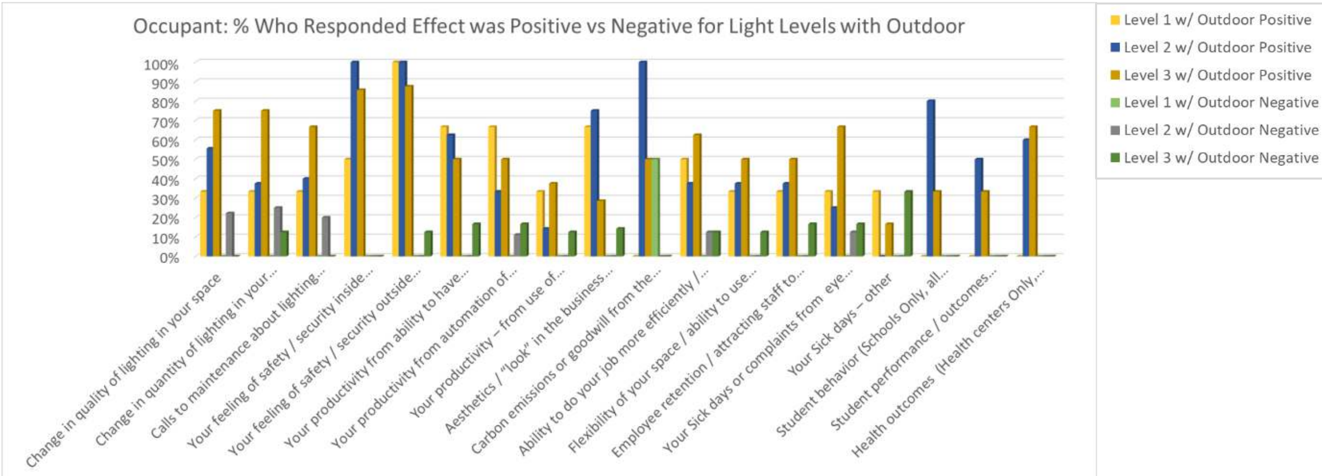

Figure B.13. Share of positive and negative NEBs overall for occupants by control level *with* outdoor lighting (*n* = 137).

Figure B.14 shows the percentage of occupant respondents who answered that they experienced a positive effect or a negative from each NEB when consideration of outdoor lighting was *not* included. The results are presented by controls type (i.e., Levels 1, 2, or 3) with *no* outdoor lighting. "Your productivity from ability to have high quality lighting for tasks in the space" was the highest selected option for Level 1 No Outdoor Positive impacts. "Change in quality of lighting in your space," "Change in quantity of lighting in your space," and "Your feeling of safety and security outside the building" were the top three options selected for Level 1 No Outdoor Negative impacts. "Your feeling of safety/security inside the building" and "Your feeling of safety/security outside the building" were the top two options selected by participants for Level 2 No Outdoor Positive impact. "Calls to maintenance about lighting issues" was the highest option selected by participants for Level 2 No Outdoor Negative impact. "Carbon emissions or goodwill from the building being greener" and "Ability to do your job more efficiently and effectively" were the top two options selected by participants for Level 3 No Outdoor Positive impact. "Your sick days or complaints from eye strain" and "Health outcomes" were the highest two options selected by participants for Level 3 No Outdoor Negative impact. The overall highest positives were Level 3 No Outdoor "Carbon emissions or goodwill from the building being greener" and "Ability to do your job more efficiently and effectively." The overall highest negative effect was Level 3 No Outdoor "Your sick days or complaints from eye strain" and "Health outcomes."

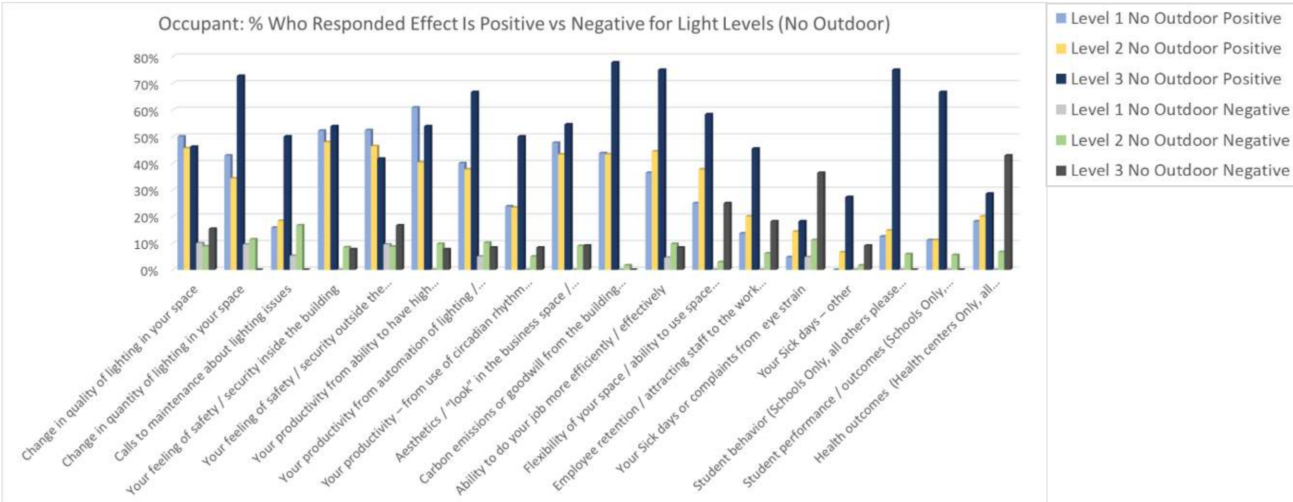

Figure B.14. Share of positive and negative NEBs overall for occupants by control level with *no* outdoor lighting (*n* = 137).

Figure B.15 shows the percentage of occupant respondents who answered that they experienced a positive effect or a negative from each NEBs. The results are presented by northern vs. southern U.S. latitudes. “Your feeling of safety and security inside the building” and “Your feeling of safety and security outside the building” were the top two options selected by participants in the northern latitude as positive impacts. “Change in quality of lighting in your space,” “Change in quantity of lighting in your space,” and “Calls to maintenance about lighting issues” were the top three options selected by participants in the northern latitude as negative impacts. “Change in quality of lighting in your space” and “Your feeling of safety/security outside the building” were the top two options selected by southern latitude as positive impacts. “Your feeling of safety/security outside the building” and “Your Sick days or complaints from eye strain” were the top two options selected by participants from the southern latitude as negative impacts. The overall highest positive NEBs were the northern latitude impacts “Your feeling of safety/security inside the building” and “Your feeling of safety/security outside the building.” The overall highest negative NEBs were the southern latitude impacts “Your feeling of safety/security outside the building” and “Your Sick days or complaints from eye strain."

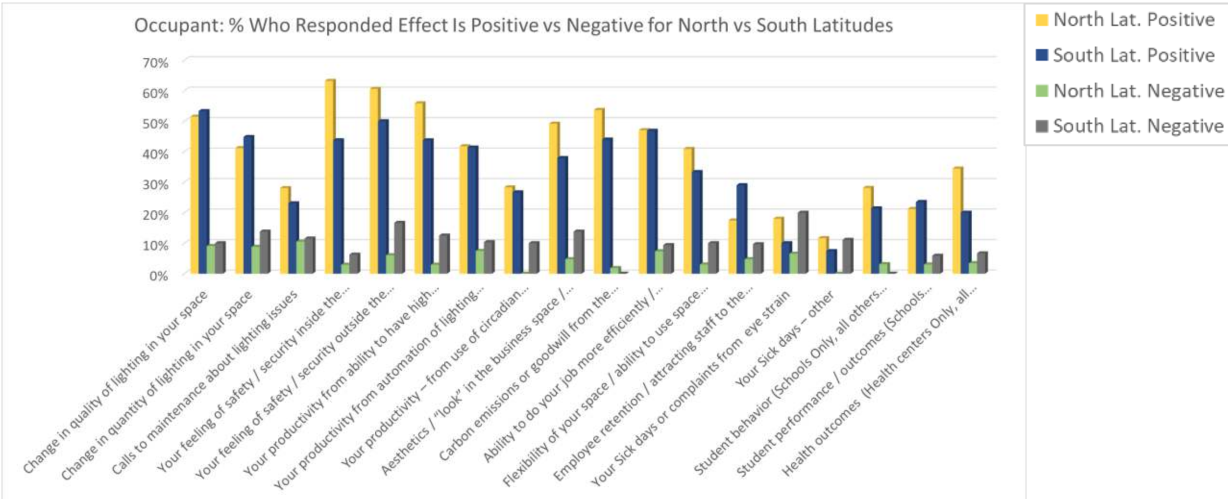

Figure B.15. Share of positive and negative NEBs overall for occupants by latitude (*n* = 137).

B.4 Individual NEB Valuations Overall and by Strata – Decisionmakers

The number of respondents for the decisionmakers survey was 56. The total net average FTE was 11.4%.

Figure B.16 shows the average percentage of an FTE for each stratum for all combined NEBs. Black lines represent confidence intervals for each strata group. The average FTE is 11.4%. In addition:

- Highest value NEBs included Safety/security inside building, and Productivity
- Lowest value NEBs included Sick days from eye strain, and Health

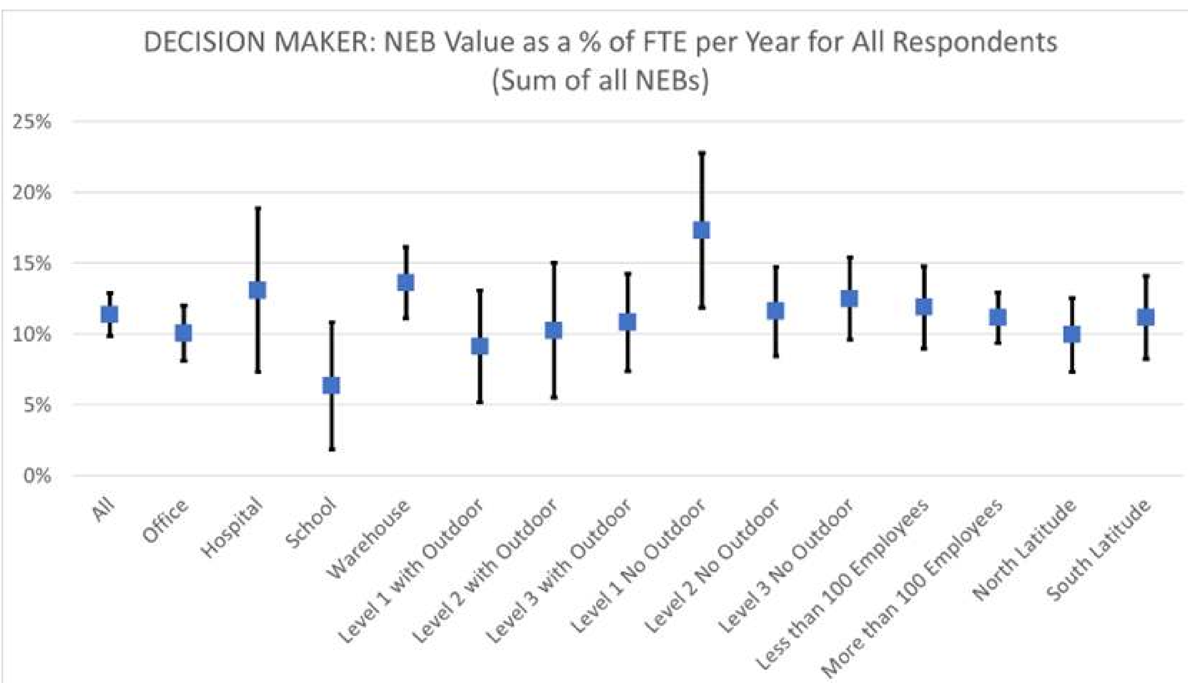

Figure B.16. Decisionmakers: average value of total net NEBs as a percentage of an FTE, by strata (*n* = 56). "Whiskers" represent 90% confidence intervals.

For decisionmakers overall, **Figure B.17** shows the average value of each NEB, expressed as a percentage of an FTE. “Feelings of safety inside the building,” “Productivity due to fewer interruptions,” and “Quality of lighting” were ranked highest by decisionmakers as improvements from the lighting controls. “Sick days due to eye strain and other factors” and “Health outcomes” for patients were ranked as costly, meaning that more sick days and more eye strain occurred due to the lighting controls.

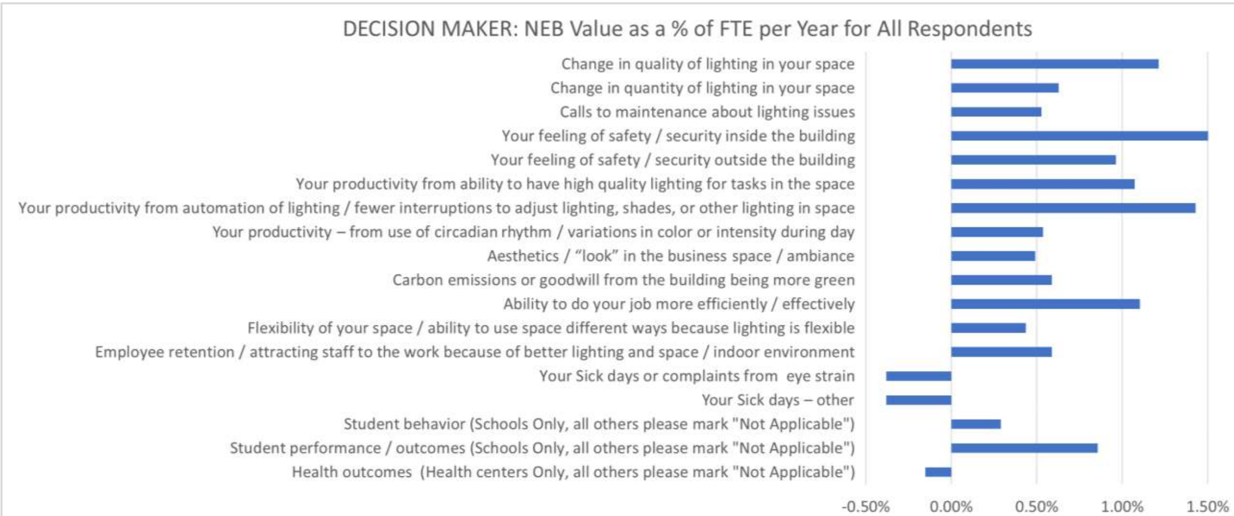

Figure B.17. Decisionmakers overall: average value of each NEB category as a percentage of an FTE (*n* = 56).

Figure B.18 shows the positive, negative, and net value of each individual NEB as a percentage of an FTE. The green bars above the black line (0%) indicate the positive values of the NEB. The red bars below the black line indicate the negative values. The blue squares connected by the blue line indicate the net value of each NEB. As shown in **Figure B.17**, “safety inside the building” and “productivity from fewer interruptions” were the highest net valued NEBs. “Sick days and complaints due to eye strain,” Sick days – other factors” and “Health outcomes” were each valued as a net negative effect.

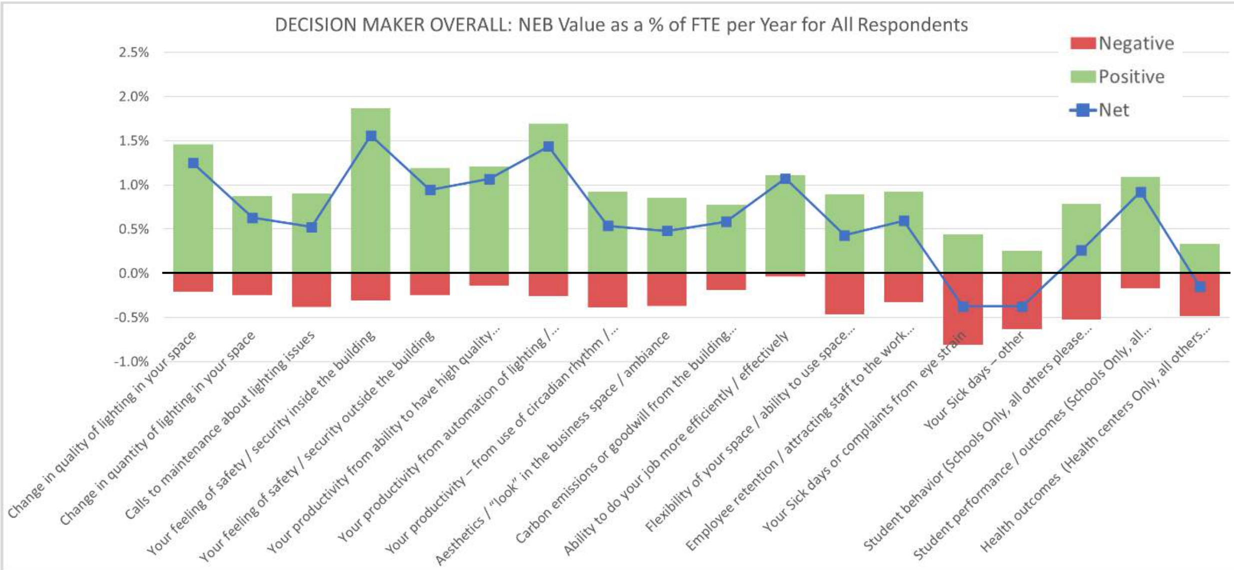

Figure B.18. Decisionmakers overall. Positive, negative, and net value of NEBs as a percentage of an FTE, by NEB (overall sample). (*n* = 56).

Figure B.19 shows positive and negative effects. Overall total average FTE: 11.4%.

The business type with the highest positive combined NEBs was Warehouses, while the one with the worst combined negative effects was Schools. The controls type with the highest positive combined NEBs was Level 1 No Outdoor, while the one with the worst combined negative effects was Level 1 with Outdoor.

The stacked bars represent the different NEBs as a percentage of an FTE. The positive valued NEBs extend above the 0% line (marked in bold), and the negative effects extend below that line. The "All" stacked bar shows the cumulative saved FTE percentage by each stratum. It also shows that, overall, the value of the positive effects is higher than the value of the negative effects, leading to an overall NEB value that is positive.

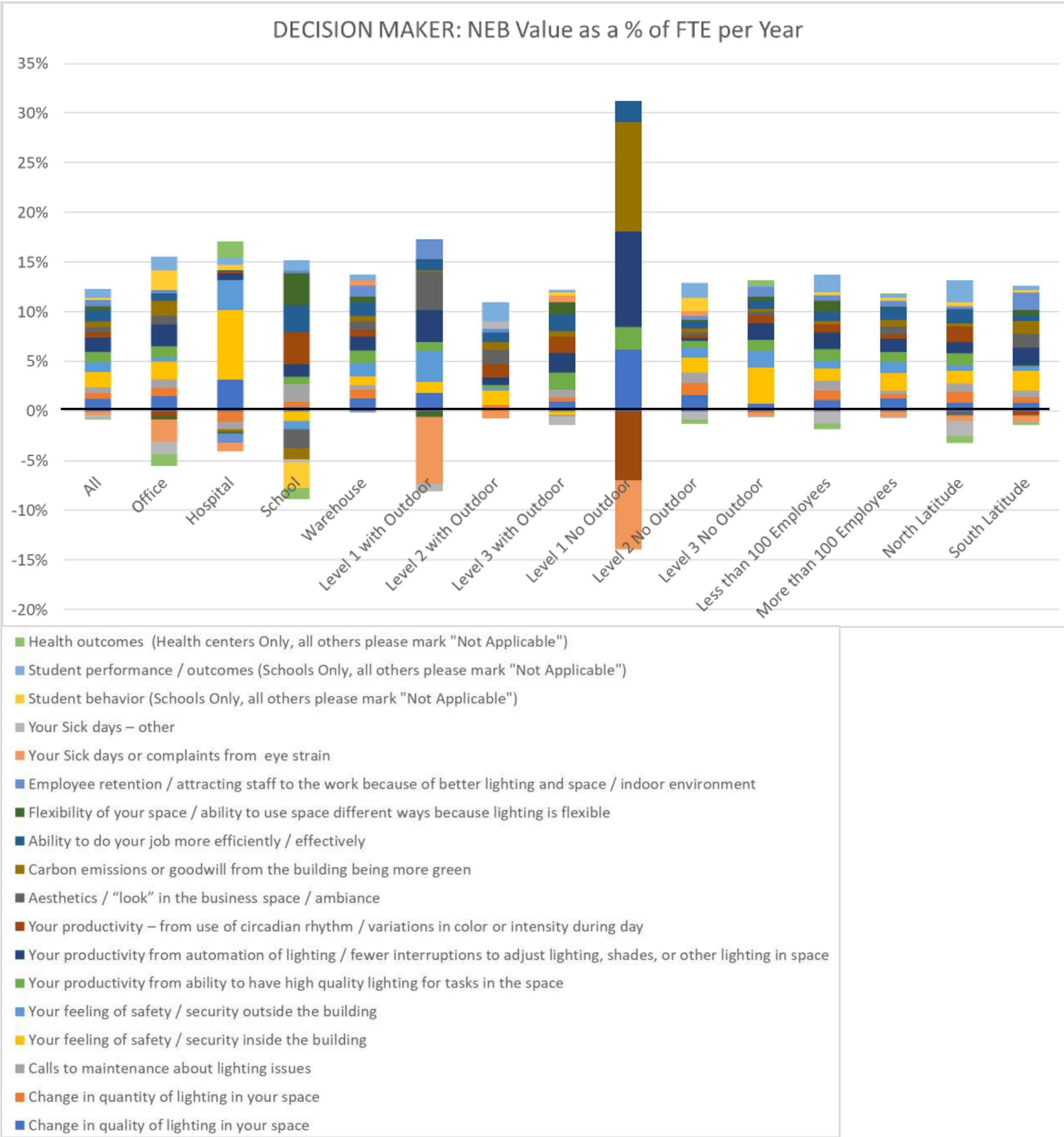

Figure B.19. Decisionmakers overall: NEBs overall and individual NEB by strata, as a percentage of an FTE (*n* = 56).

B.5 Individual NEB Valuations Overall and by Strata – Decisionmakers from Utility Participant Respondents

The number of respondents from this study was 10.

Table B.3 lists each NEB and its reported value as a percentage of the energy savings from the advanced controls. These multipliers of the energy savings are results from the utility sample of decisionmakers.

These values include the positive and negative values that result in a net positive. All NEBs combined are valued at 130% of the energy savings.

Table B.3. Decisionmakers From Utility Sample: Value of Each NEB and Total NEBs as a Percentage of Each Measure's Energy Savings

How much more or less valuable is this effect than the energy savings?	
Control over energy use	10%
Maintenance costs / labor	10%
Tenant complaints	3%
Safety / security	8%
Staff productivity from ability to provide best lighting for tasks in the space	10%
Staff productivity from automation of lighting / fewer staff interruptions to adjust lighting in space	10%
Staff productivity – from use of circadian rhythm / variations in color or intensity during day	3%
Aesthetics / "look" in the business space / ambiance	11%
Carbon emissions or goodwill from being green	10%
Value of the business space – rental value, ease of selling / leasing, occupancy improvement, avoid obsolescence	8%
Space usage improvements / ability to change rooms or space to different uses	9%
Extending the life of lighting equipment	12%
Employee retention / attracting labor	6%
Worker Sick days or complaints – eye strain	2%
Worker Sick days – other	0%
Student behavior (for schools only, all others please select "Not Applicable")	0%
Student performance (for schools only, all others please select "Not Applicable")	14%
Health outcomes (for health centers only, all others please select "Not Applicable")	4%
Total	130%

Table notes:

- Using in-sample multipliers
- *n* = 10

Decisionmakers from the utility sample were asked how the performance of advanced lighting controls compares to the projected savings. Most stated that they did not know if the project met the projections. Some answered that the project met or had exceeded expectations, and none answered that the project had not met savings expectations. (See **Figure B.20**.)

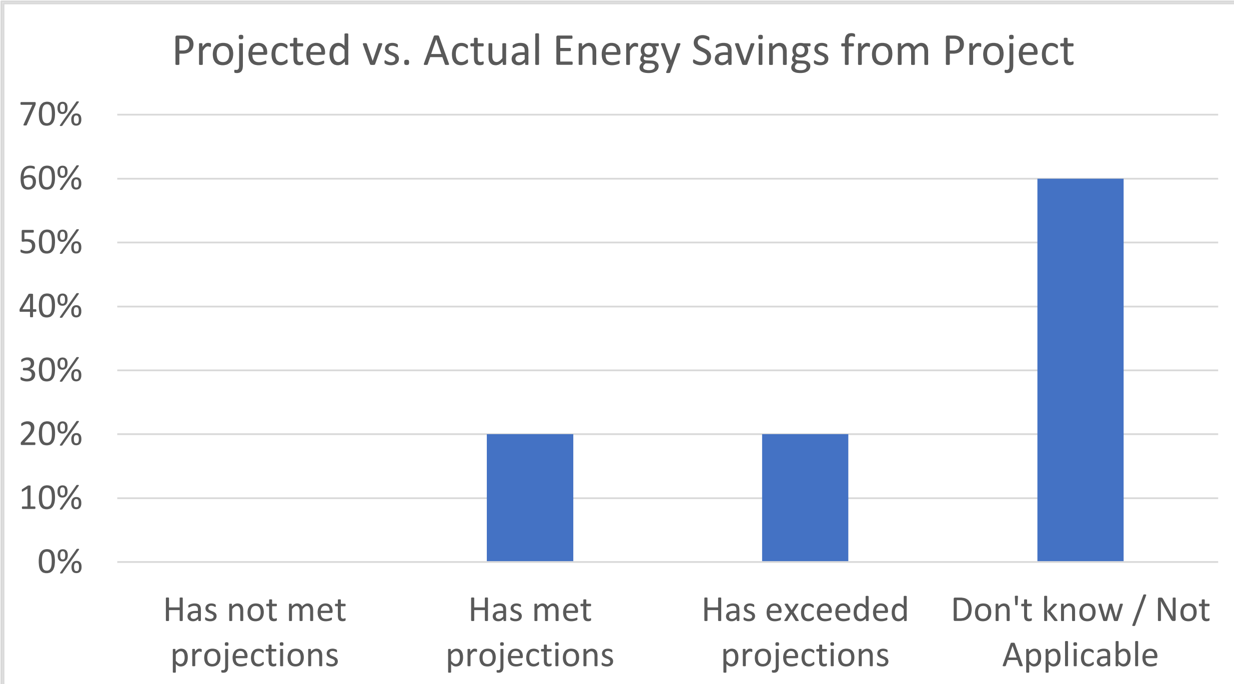

Figure B.20. Decisionmakers from utility sample: project performance relative to expectations (*n* = 12). Respondents were asked, "Thinking about all the control measures that were installed, how does the project compare to the projected energy savings and payback projections?"

B.6 Individual NEB Valuations Overall and by Strata – Occupants

The number of occupant survey respondents was 137. The total net NEB average in FTE was 7.8%.

Figure B.21 shows the average percentage of an FTE for each stratum, for all combined NEBs. Black lines represent confidence intervals for each strata group. The average FTE for this group was 7.8%. Most of the strata stay close to the overall average.

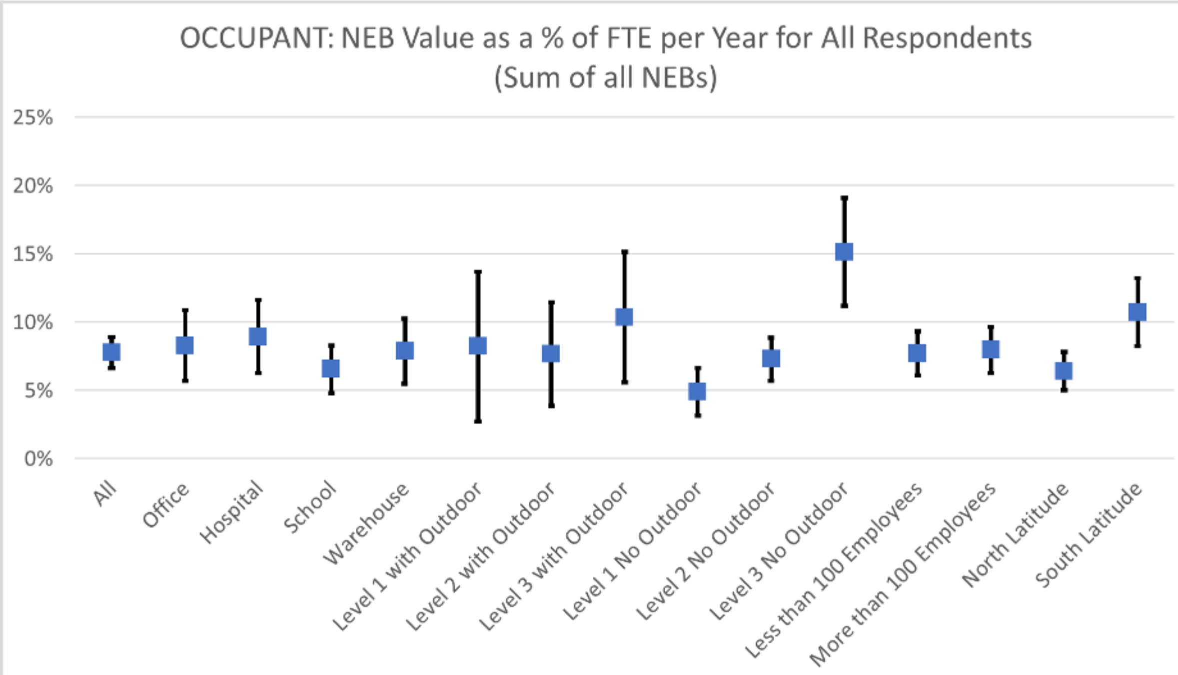

Figure B.21. Occupants from survey: value of total NEBs as a percentage of an FTE, overall and by strata (*n* = 137). "Whiskers" represent 90% confidence intervals.

Overall, occupants rated the highest valued NEB as "Safety/security inside & outside building." The lowest-valued NEB related to "Sick days from eye strain."

Figure B.22 shows the net value of each NEB, expressed as percentage of an FTE. "Feelings of safety inside and outside the building" and "Quantity of lighting" were ranked highest by occupants as improvements arising from the lighting controls. "Sick days due to eye strain" and "Sick days – other" were ranked as costly, meaning that more sick days and eye strain occurred due to the lighting controls.

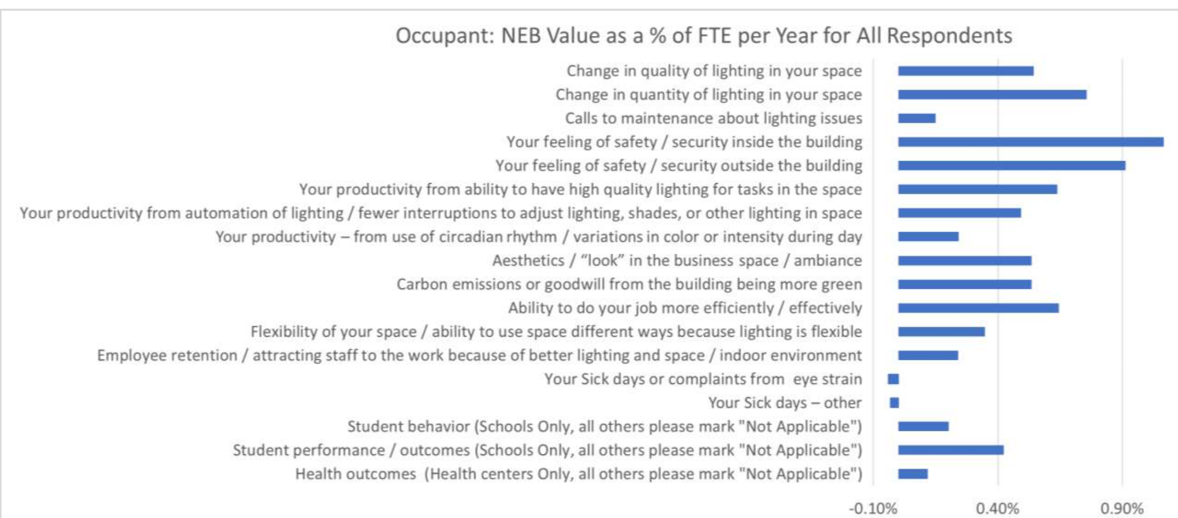

Figure B.22. Occupants from survey: *net* value of individual NEBs as a percentage of an FTE (overall sample). (*n* = 137).

Figure B.23 shows the positive, negative, and net value of each individual NEB as a percentage of an FTE. The green bars above the black line (0%) indicate the positive values of the NEBs. The red bars below the black line indicate the negative values. The blue squares connected by the blue line indicate the net value of each NEB. Again, “feelings of safety/security inside and outside the building” were the highest valued net NEBs. The two NEBs with net negative values were “Sick days and complaints from eye strain” and “Sick days – other.” While “Sick days and complaints from eye strain” was valued as a net negative, the figure shows that some respondents experienced improvement in eyestrain.

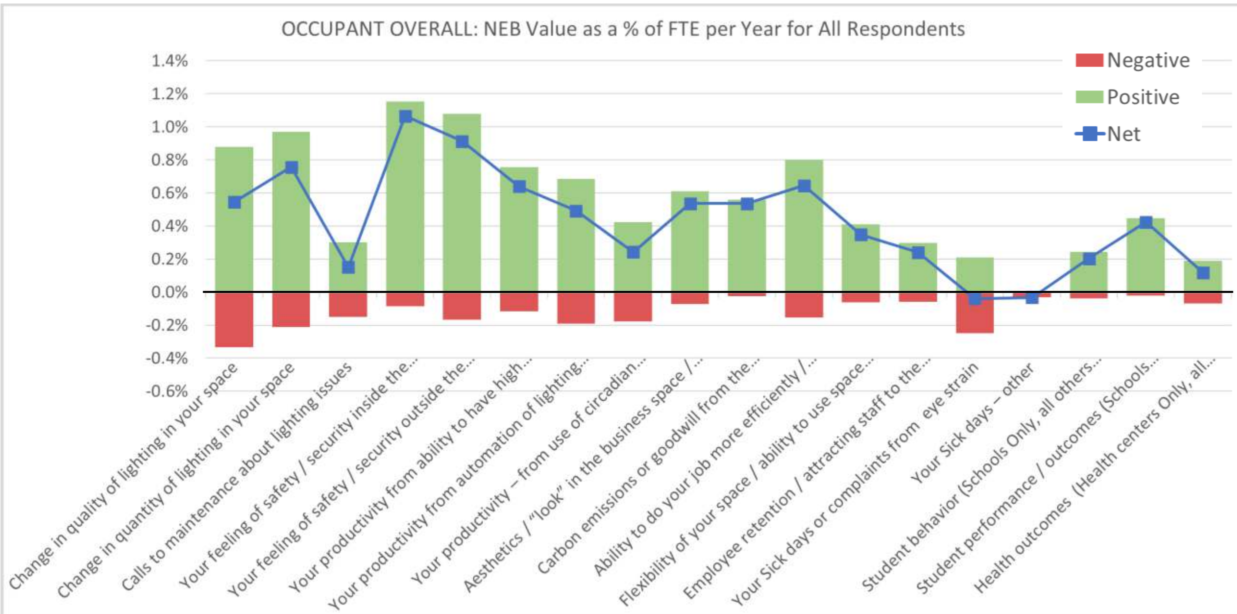

Figure B.23. Occupants from survey: positive, negative, and net value of NEBs as a percentage of an FTE, by NEB (overall sample). (*n* = 137).

Figure B.24 shows positive and negative overall effects for occupants surveyed. The average value for the total of all NEB effects from this group, expressed as a percentage of an FTE is 7.8%.

The business type with the highest positive combined NEBs was Hospitals, while the one with the worst combined negative effects was Schools. The controls type with the highest positive combined NEBs was Level 3 No Outdoor, while the one with the worst combined negative effects was Level 1 No Outdoor.

The stacked bars represent the different NEBs as a percentage of an FTE. The positive valued NEBs extend above the 0% line (marked in bold), and the negative impacts extend below that line. The overall stacked bars show the cumulative saved FTE percentage for each stratum. They also show that, overall, the value of the positive NEBs is higher than the value of the negative impacts, leading to an overall NEB value that is positive. Compared to the decisionmakers, occupants placed a smaller value on the negative impacts.

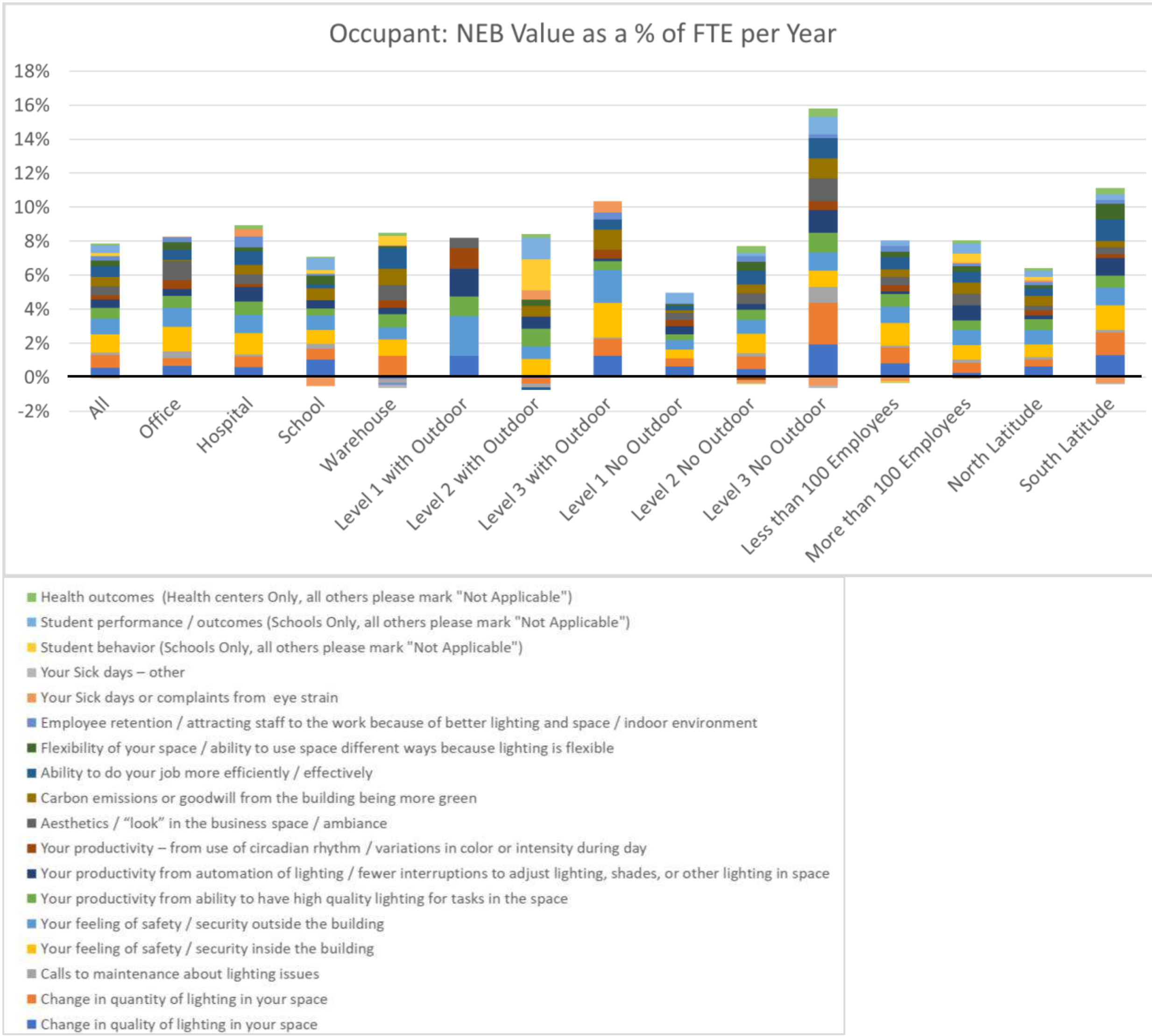

Figure B.24. Occupants: value of NEBs overall and individual NEB by strata, as a percentage of an FTE (*n* = 137).

B.7 Verbatim Responses – Occupants

This section shows the responses occupants provided to open-ended survey questions. The intent is to provide information as to the respondents' underlying reasons about positive and negative impacts experienced due to the controls systems.

Respondents were asked the open-ended question "Which lighting control features do you think work well, or are especially helpful?" Of the 158 comments, 23% were some version of "All of them," "None," or "No comment." There were 122 comments, or 77%, that provided a quote or listed one or two controls that they found helpful, such as dimmers and occupancy sensors.

Figure B.25 provides the more detailed quotes. Many of the quotes focus on the benefit of occupancy sensors, with specific mentions of the energy savings related to lights turning off while no one is present. Other respondents stated that the ability to manually control the lights or the ability to control the timer on the sensors was helpful. Safety while walking to a vehicle was also mentioned and correlates with the high ranking that safety received from respondents.

Which lighting control features do you think work well, or are especially helpful?
"Turn off when not in the room and can control how long it should remain on."
"Motion activated lights are a time saver in a big warehouse."
"All are helpfull u dont have to take extra time to turn anything on."
"I thinks lights turning off after no motion is a great energy savings."
"The fact that they go on and off... great energy saver!"
"When you can control lighting and not have it automatic due to motion."
"Lights turning off when rooms are vacant."
"Automatic turning on the lights when someone enters the room."
"Manual on/off switches with janitors making the rounds to maintain lighting."
"Changing from soft white to bright white. Bright white helps with paperwork. Soft white looks better for zooming."
"Can control lighting in patients rooms remotely."
"Daylight Harvesting"
"They are all great as I don't even need to think about them as they are automatically doing what they need to do thru sensors."
"Safety walking to vehicle."
"Feeling safe inside."
"Saves the personal energy of walking across the warehouse to turn off the lights on my way out."
"Real-time variable lighting intensity in different areas of the work space."
"Sensor that slowly dims the lights on bright days."

Figure B.25. Occupant-workers: notable quotes from survey respondents about what they found helpful about the advanced controls.

Table B.4 provides a count of the most common controls that respondents answered as being helpful. Occupancy sensors received the most mentions, followed by the ability to dim or change the quantity of light. The next-most helpful control was the ability to remotely control the lights inside and the lights outside of the building. Daylight harvesting and the automatic control of the lights received the fewest mentions.

Table B.4. Occupant-Workers: Controls Most Commonly Mentioned as Positive or Helpful

Control	Count	% of Responses
Occupancy Sensor	57	47%
Dimmer	29	24%
Remote Control	8	7%
Outdoor lights	7	6%
Light Switch	4	3%
Daylight Harvesting	3	2%
Automatic Settings	2	2%

To follow explore the reason that some NEBs were marked as a negative effect by respondents, the survey asked the open-ended question "Which lighting control features are not helpful or do not work well?" Of the 146 comments, 62% were "None," "No comment," or "They are all helpful." The most common complaints from the remaining 55 comments, or 38% of responses, were about the timer on the occupancy sensor, with many stating that their productivity was interrupted when the lights in the room turned off and the respondent had to move around in order to resume working. At least 2% of respondents specifically stated that the lights go out while they are in the restroom. **Figure B.26** provides the more detailed quotes.

Which lighting control features are not helpful or do not work well?
"Turns off suddenly."
"Timing of sensors."
"The color change."
"The color Of the light itself."
"Manual on/off switch, people often switch off lights for area not intended."
"Sometimes there is a problem keeping the light off when people walk around."
"Light sensors in classrooms, turn off when people are still in there."
"Lights switch off if no one moves enough."
"Turning on and off every time someone walks in forcing your eyes to adjust to the constant on and off."
"Shutting off when I don't move around in the room."
"Automatic Lighting sounds like a great idea "on paper" but NOT when people actually us it due to safety issues."
"Lights going off in restrooms (timer needs longer function)."
"Auto off when not enough movement even though I'm working in the room."
"Again, the lights turning off when I'm too still is annoying, and particularly distracting when I'm in a Zoom meeting."
"Hurts my eyes"
"Having to get up and get the lights to turn back on kinda makes me cranky."
"Lights cut off while im under a truck working. I have to stop everything and move in front of the sensor. It wastes a lot of time."

Figure B.26. Occupant-workers: Notable quotes from survey respondents regarding what they did not find helpful about the controls system.

Table B.5 shows the controls that were most often described as not helpful. The most often mentioned response was that the timer on the occupancy sensors turned the lights off too soon and disrupted productivity. Occupancy sensors and the control of multiple lights by one switch were the next-most mentioned controls issues. Remote controls and daylight harvesting were each mentioned once.

Table B.5. Occupant-Workers: Controls Most Commonly Mentioned as Negative or Not Helpful

Control	Count	% of Responses
Timer	23	42%
Occupancy Sensor	8	15%
Light Switch	5	9%
Dimming	4	7%
Remote Control	1	2%
Daylight Harvesting	1	2%

Many respondents also mentioned both positive and negative effects associated with some controls, as shown in **Table B.6**. The most common positive effect is comfort, followed by energy and greenhouse gas savings and time saved. The most common negative effect is eye strain.

Table B.6. Occupant-Workers: The Most Common Effects from Controls Considered Both Helpful and Not Helpful

Effect	Positive	% of Responses	Negative	% of Responses
Comfort	8	7%		
Eye Strain			7	13%
Energy / GHG Savings	5	4%		
Time Saved	3	2%		
Safety	2	2%	1	2%
Color			2	4%

B.8 Verbatim Responses – Decisionmakers

This section shows the responses by decisionmakers provided to open-ended survey questions. The intent is to provide information as to the respondents' underlying reasons about positive and negative impacts experienced due to the controls systems.

Respondents were also asked the open-ended question "Which lighting control features do you think work well, or are especially helpful?" Of the 74 responses, 18% were some version of "All of them," "None," or "No comment." There were 61 comments, or 82%, that provided a more in-depth answer or listed one or two controls that they found helpful, such as dimmers and occupancy sensors. **Figure B.27** provides those more detailed quotes.

Which lighting control features do you think work well, or are especially helpful?
"The timers that are in place when there is no one there."
"Chromatic light and changes of color."
"The safety lights, also the on/off controls and variable lighting."
"Automatic shut off in some rooms."
"Remote control feature."
"The remote app is convenient."
"Adjusting brightness."
"Outside lights."
"The ability to set the sensitivity on the sensor is great."
"Dimming lights on desk."
"Dimmer and automatic shade adjustment. Also the motion sensor gives added security when working late."
"Automatic shutting down, and turning on as people respectively exit or enter."
"Being able to turn the lights off and on with a remote."
"The bright lights seem to put people in a good mood."
"Saves manipulation time."
"Awareness of surroundings."
"Less migraine headaches because of the right lighting."
"Easier to stay awake."
"Positive effect from lightening located in safety, security and performance."
"Proper lighting helps the environment, makes working more productive."
"It's amazing how technology involving something as simple as lighting can lead to higher productivity and better security in the office."

Figure B.27. Decisionmakers: notable quotes from survey respondents regarding what they found helpful about the controls system.

Table B.7 shows a count of the most common controls that decisionmakers answered as being helpful. As with the occupant-workers' responses, occupancy sensors received the most mentions. Decisionmakers mentioned the ability to control the lights remotely as helpful more often than the dimmers, which is the opposite of the occupant-workers' responses. The next-most helpful control was the ability to remotely control the lights inside and the lights outside of the building. Daylight harvesting and automatic control of the lights received the fewest mentions. Light switches, daylight harvesting, and outdoor lights were each only mentioned once.

Table B.7. Decisionmakers: The Controls Most Commonly Mentioned as Positive or Helpful

Control	Count	% of Responses
Occupancy Sensor	17	28%
Remote Control	12	20%
Dimmer	8	13%
Light Switch	1	2%
Daylight Harvesting	1	2%
Outdoor lights	1	2%
Automatic Settings	0	0%

Respondents were also asked the open-ended question “Which lighting control features are not helpful or do not work well?” Of the 64 comments, 61% were “They all work well,” “None,” or “No comment.” There were 25 comments, or 39%, from decisionmakers that provided feedback regarding which features they were concerned about, such as how well the lights were functioning and the sensitivity of the occupancy sensor. **Figure B.28** provides those more detailed quotes.

Which lighting control features are not helpful or do not work well?
"Group lighting."
"Extreme light intensity."
"The user interface."
"Nothing really stands out although there's been a few times the dimmer isn't exactly spot on but i'm nit picking here."
"Manual are not good, automatic are preferrable."
"Flickering"
"Cold lighting."
"Unusual sounds from the light fixtures."
"Some alerts are redundant."

Figure B.28. Decisionmakers: Notable quotes from survey respondents regarding what they did not find helpful about the control system.

Table B.8 shows the controls that were most often described as not helpful. The one mentioned most often was the dimmer, followed by occupancy sensors and ability to control the lights remotely.

Table B.8. Decisionmakers: The Controls Most Commonly Mentioned as Negative or Not Helpful

Control	**Count**	**% of Responses**
Dimmer	4	16%
Occupancy Sensor	2	8%
Remote Control	2	8%
Light Switch	1	4%
Outside Lights	1	4%
Daylight Harvesting	1	4%

Many respondents also mentioned both positive and negative effects associated with some controls. **Table B.9** shows that the most common positive effect was safety, followed by energy, cost, and greenhouse gas savings. Decisionmakers also valued increased productivity, comfort, and time saved. The most common negative effects was flicker.

Table B.9. Decisionmakers: The Most Common Effects from Controls Considered Both Helpful and Not Helpful

Effect	Positive	% of Responses	Negative	% of Responses
Safety	5	8%		
Energy / Cost / GHG Savings	5	8%		
Inc. Productivity	4	7%		
Comfort	3	5%		
Flicker			3	12%
Time Saved	2	3%		
Light Color	2	3%		

B.9 Results Calculated Using In-Sample vs. Published Multipliers for Labeled Categories

The six tables in this section present the results for the decisionmaker and occupant NEBs, in total and by strata, using in-sample vs. published multipliers for the labeled categories. As a reminder: the respondents were asked to state the relative value of NEBs using word labels, for instance, "much more valuable," or "slightly less valuable." The respondents were also asked to state what they meant by some of those labels in percentage terms. Each respondent was only asked for a few percentages, but when taken in total across the entire sample, average multiplier values for each of the labeled phrases could be estimated from the within-sample responses ("in-sample"). The basis for using this labeled scaling approach is that the literature has demonstrated that these percentage values are meaningful, and the estimated multipliers are quite consistent across different population groups. This finding has also been borne out by multiple previous published NEBs studies by the authors. Therefore, this study examined the results using the multipliers derived from both sources – in-sample and published values.

Tables B.10, **B.11**, and **B.12** cover decisionmaker results, while **Tables B.13**, **B.14**, and **B.15** cover the occupant results. Within each set of three tables:

- The first table shows the value of the individual NEBs using in-sample multipliers for sharing out the total percentage of FTEs among individual NEBs.
- The second table shows the values using the published multipliers.
- The third table calculates the percentage difference between the values in the second table and those in the first, to identify variations. Each of these tables highlights the largest five values and the smallest five values. It should be noted that blanks in the tables represent division by zero.

The totals at the bottom of each set of three tables remain the same because the respondents provided specific totals of minutes for the total of all NEBs in terms of increased productivity relative to a workspace without the lighting controls.

Decisionmaker Results

Table B.12 shows the decisionmaker results from the occupant survey. The only variation greater than 10% in the "All" column was for the small response category of school-related effects. There were variations outside the thresholds noted in 35 of the 270 values, or about 13% of the values. Some varied a great deal. Beyond the student-related NEBs categories, the category with the most values exceeding the threshold was the "Carbon emissions or goodwill" category. Three numbers varied by more than 100%, with two of them in the student categories.

For the group of decisionmakers assembled from utility program sources, the results were also calculated two ways, using in-sample-derived label weights, and published, or "academic," weights. Unlike the occupant survey, which asked for specific "minutes" values and used labeled values for sharing out the resulting totals, in this group, the total values of the NEBs were dependent on the multiplier translations assigned for "much more valuable" or "slightly less valuable." For this group:

- The mean for the in-sample weights was 130%, with a 90% confidence band of ±24 percentage points (106% to 154% confidence band), and an 80% confidence band of ±18 percentage points (112% to 148%).
- The mean using academic values for this small sample decisionmaker group was 147%.
- This is a difference of 13% for this very small sample group. The mean from the published values fell within the confidence bands for the in-sample weights.

The more conservative value, from the in-sample weights, is used in this report.

Occupant Results

Table B.15 shows there was less variation in this group, which had a higher number of respondents. Only six of the values varied by more than 10% (a total of 2% of total cells). The NEB category related to flexibility of a space had the most values outside the 10% threshold, and the category with the single largest variation was in aesthetics/ambiance of the workspace. None in this category exceeded 100%, and the pattern of larger variations in student categories was not repeated.

Table B.10. Decisionmakers From Occupant Survey: Detailed NEB Results by NEB and Strata Using In-Sample Multipliers*

Decision-Makers: Using In-Sample Multipliers to Apportion Minutes															
% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	1.25%	1.50%	3.01%	0.39%	1.35%	2.02%	0.00%	0.98%	6.19%	1.65%	0.74%	1.14%	1.31%	0.91%	0.76%
Change in quantity of lighting in your space	0.63%	0.88%	-1.08%	0.48%	0.84%	0.00%	0.55%	0.38%	0.00%	1.20%	-0.14%	0.96%	0.43%	1.06%	0.62%
Calls to maintenance about lighting issues	0.52%	0.80%	-0.73%	1.91%	0.42%	0.00%	0.00%	0.81%	0.00%	1.05%	0.03%	1.01%	0.31%	0.82%	0.58%
Your feeling of safety / security inside the building	1.56%	1.77%	6.98%	-1.04%	0.98%	1.07%	1.36%	-0.38%	0.00%	1.43%	3.64%	1.29%	1.71%	1.33%	1.95%
Your feeling of safety / security outside the building	0.94%	0.43%	3.05%	-0.77%	1.21%	3.03%	0.31%	0.03%	0.00%	1.07%	1.60%	0.72%	1.09%	0.47%	0.43%
Your productivity from ability to have high quality lighting for tasks in the space	1.07%	1.10%	0.00%	0.69%	1.33%	0.94%	0.33%	1.84%	2.06%	0.69%	0.99%	1.23%	0.98%	1.03%	0.10%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	1.43%	2.22%	0.61%	1.23%	1.32%	3.04%	0.77%	1.89%	9.84%	0.24%	1.77%	1.58%	1.39%	1.19%	1.91%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	0.54%	-0.50%	0.27%	3.20%	0.80%	0.00%	1.40%	1.56%	-6.78%	0.33%	0.81%	0.81%	0.46%	1.59%	-0.45%
Aesthetics / “look” in the business space / ambiance	0.48%	0.92%	0.00%	-1.96%	0.74%	3.87%	1.30%	-0.07%	0.00%	0.25%	0.39%	0.00%	0.74%	-0.41%	1.36%
Carbon emissions or goodwill from the building being more green	0.58%	1.58%	-0.23%	-1.08%	0.56%	0.10%	0.75%	0.48%	11.15%	0.46%	0.30%	0.29%	0.75%	0.23%	1.31%
Ability to do your job more efficiently / effectively	1.07%	0.73%	0.12%	2.33%	1.35%	1.18%	0.96%	1.69%	1.64%	0.59%	0.90%	0.95%	1.17%	1.46%	0.59%
Flexibility of your space / ability to use space different ways because lighting is flexible	0.43%	-0.36%	-0.22%	3.51%	0.57%	-0.61%	0.00%	1.19%	0.00%	0.23%	0.36%	1.06%	0.06%	-0.02%	0.48%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	0.59%	0.34%	-0.92%	0.39%	1.06%	2.03%	0.29%	0.13%	0.00%	0.34%	0.98%	0.58%	0.61%	0.33%	1.77%
Your Sick days or complaints from eye strain	-0.38%	-2.30%	-0.88%	0.00%	0.52%	-6.73%	-0.72%	0.64%	-6.78%	0.52%	-0.37%	-0.05%	-0.56%	-0.52%	-0.58%
Your Sick days – other	-0.38%	-1.24%	0.00%	-0.33%	-0.18%	-0.80%	0.77%	-0.93%	0.00%	-0.82%	-0.14%	-1.19%	-0.12%	-1.48%	-0.09%
Student behavior (Schools Only, all others please mark "Not Applicable")	0.26%	1.80%	0.60%	-2.62%	0.00%	0.00%	0.00%	0.35%	0.00%	1.22%	0.00%	0.12%	0.38%	0.17%	0.30%
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	0.92%	1.52%	0.80%	1.09%	0.75%	0.00%	2.19%	0.21%	0.00%	1.64%	0.10%	1.96%	0.33%	2.52%	0.43%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	-0.15%	-1.15%	1.69%	-1.08%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.50%	0.53%	-0.59%	0.09%	-0.74%	-0.27%
Sum	11.38%	10.03%	13.08%	6.35%	13.61%	9.13%	10.26%	10.81%	17.31%	11.58%	12.50%	11.88%	11.14%	9.94%	11.18%

* ***Table note:*** Results are calculated value of NEB as a percentage of an FTE.

Table B.11. Decisionmakers From Occupant Survey: Detailed NEB Results by NEB and Strata Using Published Multipliers*

Decision-Makers: Using Academic Multipliers to Apportion Minutes

% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	1.21%	1.44%	3.12%	0.43%	1.31%	1.81%	0.00%	0.96%	6.19%	1.61%	0.72%	1.08%	1.29%	0.85%	0.82%
Change in quantity of lighting in your space	0.63%	0.90%	-1.08%	0.46%	0.83%	0.00%	0.60%	0.38%	0.00%	1.19%	-0.14%	0.98%	0.42%	1.11%	0.59%
Calls to maintenance about lighting issues	0.53%	0.83%	-0.73%	1.82%	0.43%	0.00%	0.00%	0.78%	0.00%	1.06%	0.05%	0.99%	0.32%	0.83%	0.61%
Your feeling of safety / security inside the building	1.58%	1.82%	7.05%	-1.04%	0.96%	1.13%	1.45%	-0.38%	0.00%	1.48%	3.57%	1.26%	1.76%	1.28%	2.02%
Your feeling of safety / security outside the building	0.96%	0.40%	3.04%	-0.76%	1.25%	3.08%	0.29%	0.04%	0.00%	1.05%	1.69%	0.71%	1.13%	0.56%	0.44%
Your productivity from ability to have high quality lighting for tasks in the space	1.07%	1.15%	0.00%	0.70%	1.31%	0.95%	0.32%	1.71%	2.25%	0.68%	1.10%	1.22%	0.99%	1.15%	0.09%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	1.43%	2.14%	0.60%	1.27%	1.34%	3.21%	0.71%	1.98%	9.65%	0.26%	1.69%	1.63%	1.35%	1.22%	1.82%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	0.54%	-0.51%	0.29%	3.30%	0.78%	0.00%	1.37%	1.61%	-6.96%	0.34%	0.76%	0.83%	0.45%	1.52%	-0.45%
Aesthetics / "look" in the business space / ambiance	0.49%	0.91%	0.00%	-1.95%	0.77%	3.83%	1.40%	-0.07%	0.00%	0.23%	0.40%	-0.01%	0.77%	-0.43%	1.37%
Carbon emissions or goodwill from the building being more green	0.59%	1.50%	-0.22%	-1.08%	0.60%	0.14%	0.81%	0.54%	11.00%	0.41%	0.31%	0.33%	0.73%	0.28%	1.30%
Ability to do your job more efficiently / effectively	1.10%	0.76%	0.11%	2.62%	1.35%	1.19%	0.97%	1.78%	2.14%	0.64%	0.81%	0.98%	1.20%	1.45%	0.58%
Flexibility of your space / ability to use space different ways because lighting is flexible	0.44%	-0.34%	-0.21%	3.28%	0.61%	-0.60%	0.00%	1.14%	0.00%	0.26%	0.38%	1.07%	0.06%	-0.04%	0.52%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	0.59%	0.32%	-0.92%	0.25%	1.08%	1.94%	0.36%	0.09%	0.00%	0.33%	1.01%	0.57%	0.61%	0.27%	1.74%
Your Sick days or complaints from eye strain	-0.38%	-2.29%	-0.88%	0.00%	0.52%	-6.74%	-0.74%	0.62%	-6.96%	0.53%	-0.37%	-0.04%	-0.57%	-0.52%	-0.59%
Your Sick days – other	-0.38%	-1.24%	0.00%	-0.33%	-0.18%	-0.80%	0.75%	-0.93%	0.00%	-0.82%	-0.14%	-1.19%	-0.12%	-1.48%	-0.09%
Student behavior (Schools Only, all others please mark "Not Applicable")	0.29%	1.95%	0.49%	-2.61%	0.00%	0.00%	0.00%	0.32%	0.00%	1.36%	0.00%	0.29%	0.33%	0.37%	0.25%
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	0.86%	1.43%	0.76%	1.06%	0.65%	0.00%	1.96%	0.24%	0.00%	1.48%	0.13%	1.77%	0.34%	2.25%	0.43%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	-0.15%	-1.15%	1.66%	-1.08%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.50%	0.52%	-0.59%	0.09%	-0.74%	-0.27%
Sum	11.38%	10.03%	13.08%	6.35%	13.61%	9.13%	10.26%	10.81%	17.31%	11.58%	12.50%	11.88%	11.14%	9.94%	11.18%

* ***Table note:*** Results are calculated value of NEB as a percentage of an FTE.

Table B.12. Decisionmakers From Occupant Survey: Percentage Difference in Individual NEB Category Results Between In-Sample and Published Multipliers*

Decision-makers taking occupants survey: Percent difference in NEB values between in-sample vs. published weights; top 5 and bottom 5 values (red) and >10% (green)

% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	-2.8%	-3.9%	3.5%	8.6%	-3.3%	-10.3%		-2.0%	0.0%	-2.3%	-2.7%	-5.3%	-1.4%	-6.3%	8.5%
Change in quantity of lighting in your space	-0.1%	3.2%	-0.3%	-3.5%	-1.5%		9.5%	-2.0%		-0.8%	4.2%	1.9%	-2.5%	4.9%	-4.2%
Calls to maintenance about lighting issues	1.0%	3.5%	-0.3%	-4.3%	1.5%			-3.9%		1.2%	86.9%	-2.2%	5.2%	0.6%	5.9%
Your feeling of safety / security inside the building	1.1%	2.8%	1.0%	-0.4%	-1.3%	6.3%	6.8%	0.1%		3.5%	-1.7%	-2.0%	2.4%	-3.6%	3.4%
Your feeling of safety / security outside the building	1.8%	-7.0%	-0.3%	-0.4%	3.7%	1.6%	-6.4%	41.3%		-1.6%	6.1%	-2.7%	3.8%	19.8%	4.1%
Your productivity from ability to have high quality lighting for tasks in the space	0.4%	4.8%		1.1%	-1.5%	1.5%	-2.0%	-7.2%	9.3%	-1.0%	10.9%	-0.8%	1.2%	11.6%	-10.8%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	-0.5%	-3.7%	-3.1%	3.5%	1.4%	5.6%	-7.8%	4.9%	-1.9%	7.0%	-4.7%	3.2%	-3.2%	2.4%	-4.6%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	0.0%	2.0%	7.0%	3.1%	-1.5%		-2.5%	3.4%	2.6%	3.2%	-5.8%	3.0%	-2.4%	-4.3%	0.0%
Aesthetics / “look” in the business space / ambiance	1.9%	-1.4%		-0.6%	3.0%	-1.1%	7.6%	5.0%		-5.2%	2.0%	-495.5%	2.9%	3.5%	0.8%
Carbon emissions or goodwill from the building being more green	0.7%	-4.9%	-5.9%	-0.4%	7.3%	30.7%	6.9%	12.5%	-1.3%	-10.9%	0.9%	16.3%	-2.3%	19.6%	-0.3%
Ability to do your job more efficiently / effectively	2.8%	3.9%	-12.5%	12.2%	0.5%	0.9%	1.5%	5.1%	30.3%	7.7%	-10.3%	3.1%	2.6%	-0.7%	-1.7%
Flexibility of your space / ability to use space different ways because lighting is flexible	1.7%	-4.8%	-2.7%	-6.6%	7.3%	-1.8%		-3.9%		14.2%	3.3%	1.3%	1.3%	74.2%	8.5%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	-0.8%	-4.2%	-0.3%	-35.3%	1.9%	-4.3%	27.5%	-30.4%		-5.4%	3.3%	-2.1%	-0.2%	-17.3%	-1.4%
Your Sick days or complaints from eye strain	1.3%	-0.7%	-0.3%		-1.2%	0.2%	2.8%	-4.0%	2.6%	0.8%	-0.2%	-6.2%	1.5%	0.7%	2.2%
Your Sick days – other	1.2%	0.3%		-0.4%	0.5%	0.2%	-2.5%	0.1%		-0.1%	-3.2%	-0.2%	5.3%	0.1%	-3.1%
Student behavior (Schools Only, all others please mark "Not Applicable")	11.3%	8.6%	-19.0%	-0.4%				-8.5%		11.5%		138.3%	-13.1%	116.9%	-18.1%
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	-7.0%	-6.3%	-4.9%	-3.6%	-12.4%		-10.4%	15.8%		-9.8%	30.1%	-9.9%	2.5%	-10.4%	-1.4%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	1.6%	-0.7%	-1.4%	-0.4%						-0.1%	-2.0%	-0.2%	-3.8%	0.1%	0.0%
Sum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table note: The top and bottom five values are highlighted red; absolute values >5% are highlighted green.

Table B.13. Occupants: Detailed NEB Results by NEB and Strata Using In-Sample Multipliers*

Occupants: In-Sample Multipliers Used to Apportion Individual NEBs

% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	0.54%	0.65%	0.59%	1.03%	-0.11%	1.25%	-0.03%	1.23%	0.63%	0.48%	1.79%	0.79%	0.25%	0.61%	1.29%
Change in quantity of lighting in your space	0.76%	0.46%	0.63%	0.66%	1.26%	0.00%	-0.35%	0.97%	0.49%	0.75%	2.52%	0.96%	0.59%	0.42%	1.34%
Calls to maintenance about lighting issues	0.15%	0.39%	0.10%	0.30%	-0.25%	0.00%	-0.19%	0.10%	0.00%	0.17%	0.96%	0.11%	0.19%	0.14%	0.15%
Your feeling of safety / security inside the building	1.08%	1.45%	1.28%	0.80%	0.98%	0.00%	1.06%	2.05%	0.52%	1.18%	1.04%	1.34%	0.88%	0.76%	1.46%
Your feeling of safety / security outside the building	0.92%	1.09%	1.09%	0.86%	0.73%	2.50%	0.76%	1.92%	0.53%	0.82%	1.01%	0.97%	0.88%	0.87%	1.05%
Your productivity from ability to have high quality lighting for tasks in the space	0.64%	0.71%	0.78%	0.43%	0.77%	1.09%	1.01%	0.53%	0.36%	0.60%	1.18%	0.74%	0.56%	0.64%	0.70%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	0.49%	0.43%	0.85%	0.45%	0.38%	1.71%	0.70%	0.17%	0.49%	0.33%	1.35%	0.17%	0.90%	0.22%	1.04%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	0.24%	0.50%	0.20%	-0.02%	0.42%	1.17%	0.00%	0.53%	0.35%	-0.16%	0.54%	0.35%	-0.04%	0.27%	0.24%
Aesthetics / “look” in the business space / ambiance	0.54%	1.12%	0.55%	0.00%	0.90%	0.48%	0.00%	0.00%	0.42%	0.62%	1.30%	0.48%	0.64%	0.27%	0.41%
Carbon emissions or goodwill from the building being more green	0.53%	0.07%	0.55%	0.71%	0.97%	0.00%	0.60%	1.23%	0.16%	0.54%	1.18%	0.44%	0.68%	0.57%	0.37%
Ability to do your job more efficiently / effectively	0.64%	0.62%	0.82%	0.22%	1.23%	0.00%	-0.17%	0.59%	0.25%	0.82%	1.21%	0.73%	0.60%	0.45%	1.27%
Flexibility of your space / ability to use space different ways because lighting is flexible	0.34%	0.43%	0.22%	0.51%	0.08%	0.00%	0.35%	0.00%	0.09%	0.50%	0.02%	0.33%	0.36%	0.17%	0.91%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	0.24%	0.31%	0.62%	0.12%	-0.12%	0.00%	0.00%	0.41%	0.03%	0.34%	0.22%	0.31%	0.13%	0.19%	0.19%
Your Sick days or complaints from eye strain	-0.04%	0.03%	0.44%	-0.50%	0.04%	0.00%	0.57%	0.61%	-0.06%	-0.19%	-0.49%	-0.22%	0.08%	0.12%	-0.35%
Your Sick days – other	-0.03%	0.00%	0.00%	0.00%	-0.16%	0.00%	0.00%	0.00%	0.00%	-0.04%	-0.17%	-0.03%	-0.04%	0.00%	-0.07%
Student behavior (Schools Only, all others please mark "Not Applicable")	0.20%	0.00%	0.00%	0.20%	0.58%	0.00%	1.81%	0.00%	0.00%	-0.05%	0.00%	-0.06%	0.52%	0.18%	0.00%
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	0.43%	0.00%	0.00%	0.70%	0.00%	0.00%	1.28%	0.00%	0.64%	0.19%	1.03%	0.33%	0.58%	0.38%	0.34%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	0.12%	0.00%	0.21%	0.08%	0.18%	0.00%	0.24%	0.00%	0.00%	0.38%	0.47%	-0.04%	0.19%	0.15%	0.37%
Sum	7.78%	8.28%	8.92%	6.55%	7.87%	8.21%	7.65%	10.34%	4.90%	7.27%	15.15%	7.70%	7.95%	6.41%	10.71%

Table note: Results are calculated value of NEB as a percentage of an FTE.

Table B.14. Occupants: Detailed NEB Results by NEB and Strata Using Published Multipliers

Occupants: Academic Multipliers Used to Apportion Individual NEBs

% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	0.54%	0.66%	0.58%	1.02%	-0.09%	1.24%	-0.04%	1.26%	0.63%	0.47%	1.92%	0.80%	0.25%	0.61%	1.30%
Change in quantity of lighting in your space	0.76%	0.46%	0.63%	0.65%	1.24%	0.00%	-0.35%	0.98%	0.48%	0.75%	2.45%	0.96%	0.58%	0.42%	1.32%
Calls to maintenance about lighting issues	0.15%	0.40%	0.10%	0.29%	-0.25%	0.00%	-0.20%	0.10%	0.00%	0.17%	0.92%	0.11%	0.19%	0.14%	0.15%
Your feeling of safety / security inside the building	1.07%	1.45%	1.26%	0.79%	0.96%	0.00%	1.07%	2.01%	0.53%	1.16%	0.99%	1.32%	0.88%	0.74%	1.45%
Your feeling of safety / security outside the building	0.91%	1.10%	1.09%	0.85%	0.72%	2.33%	0.76%	1.93%	0.53%	0.81%	1.05%	0.97%	0.87%	0.86%	1.05%
Your productivity from ability to have high quality lighting for tasks in the space	0.64%	0.71%	0.77%	0.43%	0.79%	1.16%	1.04%	0.52%	0.35%	0.60%	1.14%	0.75%	0.56%	0.64%	0.70%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	0.49%	0.42%	0.84%	0.46%	0.37%	1.66%	0.70%	0.16%	0.48%	0.33%	1.36%	0.16%	0.90%	0.22%	1.03%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	0.24%	0.50%	0.20%	-0.02%	0.42%	1.21%	0.00%	0.53%	0.35%	-0.15%	0.53%	0.35%	-0.04%	0.28%	0.24%
Aesthetics / "look" in the business space / ambiance	0.54%	1.12%	0.56%	0.00%	0.90%	0.61%	0.00%	0.00%	0.42%	0.62%	1.31%	0.48%	0.65%	0.27%	0.42%
Carbon emissions or goodwill from the building being more green	0.54%	0.07%	0.54%	0.72%	0.98%	0.00%	0.62%	1.19%	0.16%	0.54%	1.22%	0.44%	0.69%	0.58%	0.36%
Ability to do your job more efficiently / effectively	0.64%	0.61%	0.83%	0.23%	1.23%	0.00%	-0.17%	0.58%	0.24%	0.83%	1.17%	0.73%	0.60%	0.46%	1.26%
Flexibility of your space / ability to use space different ways because lighting is flexible	0.35%	0.44%	0.24%	0.52%	0.08%	0.00%	0.36%	0.00%	0.11%	0.50%	0.02%	0.34%	0.36%	0.18%	0.93%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	0.24%	0.32%	0.62%	0.12%	-0.12%	0.00%	0.00%	0.41%	0.03%	0.35%	0.21%	0.31%	0.13%	0.18%	0.19%
Your Sick days or complaints from eye strain	-0.04%	0.03%	0.45%	-0.50%	0.04%	0.00%	0.56%	0.65%	-0.06%	-0.19%	-0.47%	-0.22%	0.08%	0.12%	-0.34%
Your Sick days – other	-0.03%	0.00%	0.00%	0.00%	-0.16%	0.00%	0.00%	0.00%	0.00%	-0.04%	-0.17%	-0.03%	-0.04%	0.00%	-0.07%
Student behavior (Schools Only, all others please mark "Not Applicable")	0.20%	0.00%	0.00%	0.21%	0.57%	0.00%	1.84%	0.00%	0.00%	-0.05%	0.00%	-0.06%	0.53%	0.18%	0.00%
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	0.42%	0.00%	0.00%	0.69%	0.00%	0.00%	1.23%	0.00%	0.64%	0.19%	1.05%	0.34%	0.57%	0.37%	0.35%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	0.12%	0.00%	0.21%	0.07%	0.19%	0.00%	0.24%	0.00%	0.00%	0.39%	0.46%	-0.04%	0.19%	0.15%	0.36%
Sum	7.78%	8.28%	8.92%	6.55%	7.87%	8.21%	7.65%	10.34%	4.90%	7.27%	15.15%	7.70%	7.95%	6.41%	10.71%

**** Table note:*** Results are calculated value of NEB as a percentage of an FTE.

Table B.15. Occupants: Percentage Difference in Individual NEB Category Results Between In-Sample and Published Multipliers

Occupants: Percentage difference in NEB values between in-sample vs. published weights, with top 5 and bottom 5 values highlighted (red) and >10% (green).

% FTE / year	All	Office	Hospital	School	Warehouse	Level 1 with Outdoor	Level 2 with Outdoor	Level 3 with Outdoor	Level 1 No Outdoor	Level 2 No Outdoor	Level 3 No Outdoor	Less than 100 Employees	More than 100 Employees	North Latitude	South Latitude
Change in quality of lighting in your space	0.1%	2.3%	-0.4%	-1.0%	-12.4%	-0.4%	58.2%	2.5%	0.6%	-1.0%	7.4%	0.2%	-0.6%	-0.8%	1.1%
Change in quantity of lighting in your space	-1.0%	-1.9%	0.3%	-1.2%	-1.4%		0.1%	0.8%	-1.9%	-0.7%	-2.7%	-0.5%	-1.9%	-0.5%	-1.5%
Calls to maintenance about lighting issues	-0.2%	1.3%	-0.6%	-0.9%	0.5%		6.5%	5.8%		1.8%	-3.5%	-2.7%	1.0%	0.9%	1.1%
Your feeling of safety / security inside the building	-1.0%	-0.3%	-1.3%	-1.0%	-2.0%		1.1%	-2.0%	1.6%	-1.4%	-5.0%	-1.5%	-0.3%	-1.8%	-0.8%
Your feeling of safety / security outside the building	-0.3%	0.4%	0.0%	-0.9%	-1.1%	-6.7%	-0.4%	0.4%	0.7%	-1.4%	4.4%	0.2%	-0.9%	-0.5%	-0.2%
Your productivity from ability to have high quality lighting for tasks in the space	0.5%	-0.6%	-0.7%	0.3%	3.2%	6.1%	2.7%	-1.1%	-1.6%	1.2%	-3.1%	0.8%	-0.1%	0.5%	0.5%
Your productivity from automation of lighting / fewer interruptions to adjust lighting, shades, or other lighting in space	-0.1%	-0.8%	-1.1%	1.8%	-0.6%	-3.3%	0.0%	-0.4%	-0.8%	0.0%	0.2%	-1.5%	0.2%	-0.2%	-1.0%
Your productivity – from use of circadian rhythm / variations in color or intensity during day	-0.2%	-0.3%	1.5%	0.0%	-0.6%	3.3%		-0.9%	-0.5%	-0.8%	-1.7%	-0.4%	-0.9%	0.4%	-2.2%
Aesthetics / “look” in the business space / ambiance	0.3%	-0.5%	0.8%	-91.1%	0.2%	25.8%			-0.8%	-0.3%	0.2%	0.0%	0.5%	1.3%	0.5%
Carbon emissions or goodwill from the building being more green	0.7%	-9.2%	-0.5%	1.7%	1.0%		3.1%	-2.6%	-0.7%	0.3%	2.6%	0.0%	1.1%	1.7%	-1.8%
Ability to do your job more efficiently / effectively	0.3%	-0.9%	0.7%	2.7%	-0.3%		0.1%	-0.8%	-4.2%	1.6%	-3.1%	-0.2%	1.0%	2.2%	-0.6%
Flexibility of your space / ability to use space different ways because lighting is flexible	2.8%	1.4%	9.3%	1.8%	1.6%		2.5%		23.2%	1.4%	23.2%	4.4%	1.5%	2.5%	2.5%
Employee retention / attracting staff to the work because of better lighting and space / indoor environment	0.8%	3.1%	-0.1%	-0.4%	1.1%			0.0%	-2.6%	1.3%	-4.2%	0.3%	-0.1%	-0.5%	0.5%
Your Sick days or complaints from eye strain	-4.2%	2.5%	1.2%	-0.1%	1.3%		-2.1%	6.1%	-0.1%	1.1%	-3.6%	-1.6%	4.0%	-2.8%	-3.7%
Your Sick days – other	0.0%				-0.1%					-0.1%	-0.6%	-0.1%	0.0%		0.0%
Student behavior (Schools Only, all others please mark "Not Applicable")	1.6%			3.4%	-1.3%		1.5%			-0.1%		-0.1%	1.4%	-0.9%	
Student performance / outcomes (Schools Only, all others please mark "Not Applicable")	-1.0%			-1.1%			-3.7%		-0.1%	-1.6%	1.8%	1.3%	-2.2%	-0.7%	2.7%
Health outcomes (Health centers Only, all others please mark "Not Applicable")	0.2%		-0.9%	-1.4%	6.8%		-1.4%			2.0%	-2.3%	-0.1%	0.3%	1.2%	-1.0%
Sum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table note: The top and bottom five values are highlighted red.