Work Statement #1627

Sponsoring TC: 2.8 Building Environmental Impacts and Sustainability
Co-sponsoring TC/TG/MTG/SSPCs: Advanced Energy Design Guide Steering Committee

Title: An Evaluation of the Actual Energy Performance of Small Office and K-12 School Buildings Designed in Accordance with the 30% ASHRAE *Advanced Energy Design Guides*

Executive Summary:

An Energy Center of Wisconsin study recently estimated that the use of ASHRAE's *30% Advanced Energy Design Guides* (AEDGs) for K-12 schools and small office buildings has resulted in energy savings of approximately 25% with respect to ASHRAE Standard 90.1-1999. That estimate is based on the number and types of measures implemented, as reported by building designers. This project will quantify energy savings based on actual utility data, and will investigate whether above-average energy performance compromises indoor environmental quality through building surveys. This study will support the development of the 70% AEDG series and guides for achieving cost-effective net-zero-energy buildings. From a broader perspective, this study will promote continuous improvement within ASHRAE, providing critical feedback to help focus the Society's efforts on those activities and strategies that have greatest impact in real buildings.

Applicability to the ASHRAE Research Strategic Plan:

This project will support the following goals outlined in the ASHRAE Research Strategic Plan 2010 – 2015: Navigation for a Sustainable Future:

Goal No. 1: Maximize the actual operational energy performance of buildings and facilities.

By documenting the actual performance of a representative sample of buildings designed in accordance with two AEDGs (K-12 schools and small office buildings), we will gain an understanding of how well the real world results measure up to the AEDG goal of achieving 30% less energy consumption than buildings designed to meet ASHRAE Standard 90.1-1999. This project will also investigate success factors for well-performing buildings and why some buildings fall short of the goal. This knowledge will help ASHRAE determine ways to guide building designers and operators toward achieving improved energy performance in future AEDGs.

Goal No. 2: Progress toward Advanced Energy Design Guides (AEDG) and cost-effective net-zero-energy (NZE) buildings.

Documenting the actual energy performance of buildings designed in accordance with two of the first AEDGs, determining critical success factors, and determining why some buildings fall short will help ASHRAE develop future, more aggressive AEDGs that will enable designers and operators to achieve stringent energy performance goals. As stated in the current Research Strategic Plan, the AEDGs are laying the groundwork for achieving cost-effective NZE buildings after 2015.

Goal No. 7: Support development of tools, procedures and methods suitable for designing low-energy buildings.

As stated previously, this research project will support the development of future, more aggressive AEDGs, leading up to guides for achieving cost-effective NZE buildings.

Application of Results:

The results of this project will relate directly to the following two special publications:

1. *30% Advanced Energy Design Guide for K-12 School Buildings*
2. *30% Advanced Energy Design Guide for Small Office Buildings*

The results of this project will relate indirectly to the following two special publications:

1. *50% Advanced Energy Design Guide for K-12 School Buildings*
2. *50% Advanced Energy Design Guide for Small to Medium Office Buildings*

The above four guides have already been published. The results of this project are expected to directly affect and strengthen the content of the following two special publications, which are slated to appear by 2015:

1. *70% Advanced Energy Design Guide for K-12 School Buildings*
2. *70% Advanced Energy Design Guide for Small to Medium Office Buildings*

Additionally, the results of this project will indirectly affect and strengthen the content of 70% AEDGs for other building types.

Results will be disseminated through a technical paper to be submitted for peer review and publication in ASHRAE *Transactions*. Additionally, TC 2.8 intends to sponsor a conference paper session at a national ASHRAE meeting based on the results of this project. The intended benefits of this research are a) more effective use by ASHRAE members and others of the already-published AEDGs, and b) more effectively developed and written 70% AEDGs.

State-of-the-Art (Background):

As a leader in the realm of building energy and sustainability in the built environment, ASHRAE took the initiative to develop the *30% Advanced Energy Design Guide* series for several typical building types that typically don't get the amount of attention in the design phase received by "mega-projects", such as large office buildings and large hospitals. These smaller buildings represent the bulk of the projects built today. These projects are constructed on tight budgets and even tighter schedules. As a result, they often do not get the type of advanced energy modeling that is typical of larger scale or more complex projects. The AEDGs attempt to take some of the findings of analysis programs employed on the mega-projects and scale them to reasonable applications on smaller projects. This is a vital and important contribution.

Practitioners in the industry have come to depend upon ASHRAE for leadership and guidance in the design and selection of building systems and the AEDGs have taken a lead position in the industry. Documenting the effectiveness of those recommendations and determining how to improve them are both important to maintaining that leadership role.

A 2010 report published by the Energy Center of Wisconsin estimated energy use by small offices and K-12 schools designed in accordance with the AEDGs to be 24% and 26% lower, respectively, than would be expected if the buildings had been designed in accordance with ASHRAE Standard 90.1-1999. It is important to note that these estimates were based on the number and type of building improvements adopted by design professionals responding to a survey.

It appears that no research has been conducted to date that attempts to evaluate the effectiveness of the 30% AEDGs based on utility data and building surveys. This project will address that gap.

Advancement to State-of-the-Art:

According to the second goal of the current ASHRAE Research Strategic Plan, the next step in developing AEDGs is a 70% reduction in annual energy consumption relative to Standard 90.1-2007 (or other baseline). Beyond that, ASHRAE intends to work toward developing design guidelines for "cost-effective net-zero-energy buildings." In order to accomplish these two goals, it is critical for engineers, designers, and contractors to understand how effective earlier efforts to achieve significant reductions in building energy consumption have been, and to derive lessons from those earlier experiences.

Justification and Value to ASHRAE:

As described above, this project supports goals #1, 2, and 7 in ASHRAE's Research Strategic Plan 2010 – 2015. The project will help ASHRAE maintain its leadership position in the effort to help engineers, designers, and contractors build progressively more energy-efficient buildings that deliver acceptable indoor environmental quality.

Objectives

The three objectives of this research project are to:

1. Compare Energy Utilization Indices (EUIs; site energy use per unit area per year), normalized based on standard hours of operation and plug load energy use, for a sample of small office and K-12 school buildings designed in accordance with the first (30%) ASHRAE AEDGs to the modeled EUIs of small office and K-12 school buildings in the same climate zone that meet the requirements of ASHRAE Standard 90.1-1999.
2. Determine the factors common to relatively well-performing buildings, as well as the factors common to relatively poorly-performing buildings, based on building surveys.
3. Provide recommendations for how future AEDGs for small office and K-12 school buildings could be made more effective in achieving better energy performance than required by ASHRAE Standard 90.1 while providing acceptable indoor environmental quality.

Scope/Technical Approach

In support of Objective 1 described above, the research team will:

1. Develop a list of as many K-12 and small office buildings that have been constructed in accordance with the applicable 30% AEDG as feasible. The contractor will identify criteria for determining whether or not a building qualifies as having been so constructed. The minimum number of buildings on this list must be submitted to the Project Monitoring Subcommittee (PMS) for approval before the research team proceeds with the project. The work statement authors have contact information for 54 people who participated in interviews for the 2010 Energy Center of Wisconsin Study referenced above. These people all said they had used the AEDGs in some way: either as a general reference or in a more systematic way on specific buildings. The work statement authors also have the names and addresses of 273 buildings that obtained a LEED Platinum rating from the U.S. Green Building Council between 2004 and 2011. Some of these are likely to have used recommendations from the 30% K-12 and small office building AEDGs. We believe that it should be possible to construct a list of several dozen buildings that have been constructed using a significant number of 30% AEDG recommendations with a reasonable level of effort. The research team shall then select a statistically valid representative sample of that group of buildings based on the notions of confidence and precision, and obtain approval from the PMS before proceeding with the project. This representative sample will be known as "Study Group 1."
2. Gather a limited amount of information, including utility data for a period of at least 24 months, gross square footages, operating hour data, plug load data (e.g. equipment type, power draw, estimated usage), and general programmatic data for the buildings in Study Group 1. The research team shall develop a questionnaire for the building owner/operator to facilitate gathering this data, which shall be submitted to the PMS for approval before the researchers proceed with the project. It should not be necessary to conduct site visits to gather these data.
3. Determine the "raw" EUIs for each Study Group 1 building by dividing site energy use in BTUs by gross square footage.
4. Based on detailed information concerning hours of occupancy, plug loads, and energy end use data by climate zone for "low energy" K-12 and small office buildings modeled during the development of the 30% AEDGs, determine the "normalized" EUI for each building in Study Group 1. The low energy K-12 and small office model data is available in the applicable AEDG Technical Support Document, and (in the case of end use data for small office buildings) directly from the Technical Support Document authors. The normalization methodology shall be submitted to the PMS for approval before the research team proceeds with the project.
5. Compare the normalized EUIs for Study Group 1 to the baseline model building EUIs in a table to determine how many buildings meet the AEDG goal of 30% lower energy use than a "baseline" building designed to meet the requirements of ASHRAE Standard 90.1-1999. Baseline model building EUIs are available in the K-12 AEDG Technical Support Document and directly from the small office AEDG Technical Support Document authors. This table shall be submitted to the PMS.

In support of Objective 2 described above, the research team will:

1. Select at least five of the buildings with the best energy performance (i.e. those with the lowest normalized EUIs relative to those of the reference building models) and at least five of the buildings with the worst energy performance in Study Group 1 on which to perform building surveys. This set of at least ten buildings will be known as "Study

Group 2." Study Group 2 shall be selected in consultation with the PMS, and its approval must be obtained before the researchers proceed with the project. The work statement authors hope to see a mix of schools and small office buildings in both the best- and worst-performing subgroups.

2. Interview members of the construction team for each Study Group 2 building to determine the contracting method used during the construction process (e.g. design/bid/build, design/build, etc.), and the level of commissioning performed during or immediately after the construction process.
3. Perform ASHRAE Level I energy audits on the Study Group 2 buildings. The Level I audits are intended to provide insights into the success of design strategies employed to reduce energy consumption with respect to buildings designed to meet ASHRAE Standard 90.1-1999 requirements only. These audits should include qualitative evaluations of the impact of O&M procedures and occupant behaviors on building energy performance. ASHRAE Level I energy audits are described in Chapter 36 of the *2011 ASHRAE Handbook* and in *Procedures for Commercial Building Energy Audits* published in 2011 (see "Key References").
4. Acquire "basic level" performance data in the areas of indoor air quality, thermal comfort, and lighting for the Study Group 2 buildings at the same time the ASHRAE Level 1 energy audits are conducted. Researchers will follow the methodologies outlined in *Performance Measurement Protocols for Commercial Buildings* published in 2010 and the accompanying *Best Practices Guide* published in 2012 (see "Key References"). Site visits will be required for all Study Group 2 buildings.
5. Prepare combined Level I energy audit and indoor environmental quality reports for each Study Group 2 building based on audits. These reports should include information concerning contracting method and commissioning. The audit reports shall be delivered to the PMS.
6. Analyze the combined Level I energy audit and indoor environmental quality reports to determine factors common to relatively well-performing buildings, as well as the factors common to relatively poorly-performing buildings. These factors shall be summarized and delivered to the PMS.

In support of Objective 3 described above, the research team will:

1. Evaluate the factors common to relatively well-performing buildings and the factors common to relatively poorly performing buildings, in order to develop recommendations for how the AEDGs for small office and K-12 school buildings might be made more effective in achieving better energy performance than required by ASHRAE Standard 90.1 while providing acceptable indoor environmental quality. These recommendations shall be summarized and delivered to the PMS.

Deliverables/Where Results Will be Published:

1. Progress and Financial Reports must be sent to the PMS at quarterly intervals, no later than January 1st, April 1st, July 1st, and October 1st of the contract period. Reports may be transmitted electronically or on ASHRAE-approved electronic media.
2. The Principal Investigator shall report in person to TC 2.8 at the annual (summer) and winter meetings, and be prepared to answer any questions regarding the research that may arise.

3. Criteria for determining whether or not a building qualifies as having been constructed in accordance with the applicable 30% AEDG, the total number of buildings found for this list, and the number of buildings selected for Study Group 1, as described under Task 1 in support of Objective 1.
4. Questionnaire for gathering information for the buildings in Study Group 1, as described under Task 2 in support of Objective 1.
5. Methodology for determining normalized EUIs for Study Group 1 buildings, as described under Task 4 in support of Objective 1.
6. Table comparing the normalized EUIs for Study Group 1 to the baseline building EUIs, as described under Task 5 in support of Objective 1.
7. Audit reports for Study Group 2 buildings, as described under Task 5 in support of Objective 2.
8. Summary report or table of factors common to relatively well-performing buildings, as well as the factors common to relatively poorly-performing buildings, as described under Task 6 in support of Objective 2.
9. List of recommendations for how the AEDGs for small office and K-12 school buildings might be improved, as described under Task 1 in support of Objective 3.
10. A Final Report shall be prepared and submitted to ASHRAE by the end of the contract period covering complete details of all research carried out on the project. The Final Report shall include, at a minimum:
    a. An executive summary suitable for wide distribution to the industry and to the public
    b. A table comparing the normalized EUIs for Study Group 1 to the baseline building EUIs
    c. A discussion of what factors contribute to the success of relatively well-performing buildings and what factors contribute to the failure of relatively poorly-performing buildings, based on the data obtained via the Level I energy audits and application of the performance measurement protocols
    d. Recommendations for how the AEDGs for small office and K-12 school buildings can be made more effective in reducing energy consumption while providing acceptable indoor environmental quality
    e. An appendix containing:
        i. Actual utility data and other information used to determine normalized EUIs for the buildings in Study Group 1
        ii. Audit reports for Study Group 2 buildings
    f. The Final Report shall be furnished in the following manner:
        i. Two bound copies
        ii. One unbound copy, printed on one side only, suitable for reproduction
        iii. Two copies on ASHRAE-approved digital media; one in PDF format and one in Microsoft Word.
11. One or more papers based on the research project. These shall be submitted to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Paper(s) for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value. ASHRAE Conference papers are not

acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research paper. The paper title shall contain the research project number (XXXX-RP) at the end of the title in parentheses, e.g., (XXXX-RP).

a. Note: A research or technical paper describing the research project must be submitted after TC 2.8 has approved the Final Report. Research or technical papers may also be prepared before the project's completion, if it is desired to disseminate interim results of the project. Contractor shall submit any interim papers to MORTS and the PMS for review and approval before the papers are submitted to ASHRAE Manuscript Central for review.

Level of Effort:

The level of effort is expected to include approximately 134 hours (3/4 of a full-time month) for the principal investigator and 760 hours (4.3 full-time months) for a research assistant or assistants. The estimated cost is $130,000, and the project is expected to take eight months to a year to complete.

Other Information for Bidders:

None.

Proposal Evaluation Criteria and Weighting Factors

1. Contractor's understanding of work statement as expressed in proposal 20%
   a. Technical issues
   b. Logistical issues
2. Qualifications of personnel included in proposal 30%
   a. Principal investigator
   b. Research assistant(s)/junior engineer(s)
3. Institutional or corporate capabilities 30%
   a. Performance on prior, similar projects demonstrated via references
   b. Administrative support capabilities
4. Probability that proposed research plan will meet work statement objectives 20%
   a. Detailed and logical work plan with major tasks and key milestones, including number of buildings assumed to be in Study Group 1
   b. All technical and logistical factors considered
   c. Reasonableness of project schedule

References

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ASHRAE. 2011. 2011 ASHRAE Handbook: Heating, Ventilating, and Air Conditioning Applications, Chapter 36: Energy Use and Management.

ASHRAE. 2011. *Procedures for Commercial Energy Building Audits*, Second Edition.

ASHRAE. 2010. *Performance Measurement Protocols for Commercial Buildings*.

ASHRAE. 2007. *Advanced Energy Design Guide for K-12 School Buildings Achieving 30% Energy Savings Toward a Net Zero Energy Building*.

ASHRAE. 2004. *Advanced Energy Design Guide for Small Office Buildings Achieving 30% Energy Savings over ANSI/ASHRAE/IESNA Standard 90.1*-1999.

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NREL. 2007. Technical Support Document: Development of the Advanced Energy Design Guide for K-12 Schools—30% Energy Savings.

PNNL. 2006. Technical Support Document: Development of the Advanced Energy Design Guide for Small Office Buildings

Authors:

1. Kevin Cross, P.E., C.E.M., LEED AP, Member ASHRAE
2. E. Mitchell Swann, P.E., LEED AP, Member ASHRAE