INDOOR AIR QUALITY AND PERFORMANCE CONTRACTING IN SCHOOLS IN THE U.S.

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) in partnership with the National Association of Energy Service Companies (NAESCO) is demonstrating an approach which integrates indoor air quality (IAQ) improvements into energy efficiency upgrades provided to schools using "performance contracts". Capital costs of energy-related improvements are financed, then repaid from utility and maintenance savings realized as a result of new equipment, systems, and controls. In five public schools in various climate zones across the U.S., baseline IAQ measurements and heating, ventilation and air conditioning (HVAC) system characterization was conducted prior to energy-related upgrades performed by energy service companies. This paper describes the performance contracting approach, the schools in the study, and presents some initial baseline (pre-intervention) measurements. In the study schools, minimum outside air ventilation is being adjusted to meet the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) 62-1989 recommendations, energy savings are projected to average 407,200 KWH per school, and project costs averaged $535,300 per school.

INTRODUCTION

In 1995 the General Accounting Office (GAO) reported that 63% of students in the United States attend schools where one or more building feature(s) is in need of extensive repair, overhaul, replacement or that contain environmentally unsatisfactory conditions [1]. These declining facility factors also result in higher energy consumption in schools [2].

The purpose of the EPA / NAESCO project, in progress 1996-1999, is to demonstrate performance contracting as a viable approach for simultaneously improving IAQ and energy efficiency in U.S. schools. The demonstration project is conducted by the EPA in partnership with NAESCO, the trade association which represents energy service companies (ESCOs). ESCOs offer a range of energy related services utilizing an innovative procurement method known as "performance contracting", in which payment is linked to performance. Future energy savings are guaranteed by the ESCO. Typical contracts include an energy audit, design, financing, installation, training and maintenance for the life of the contract. These contracts can result in significant dollar savings, reduced energy consumption and upgraded physical facilities, as well as safer, healthier, more comfortable indoor environments. School performance contracts that include ventilation upgrades, on average, last 10 years.

The primary method for achieving IAQ improvements was to achieve 8 L/second/person (L/s/p) minimum outdoor air ventilation as recommended in ASHRAE Standard 62-1989 for schools [4]. In addition, other specific measures, such as point source exhaust ventilation and moisture control were included in school upgrades. EPA staff also made recommendations for maintenance and building management practices consistent with EPA's "IAQ Tools for Schools" guidance [3].

The demonstration project has several goals: (1) to address and integrate IAQ into the assessment, design and performance contracting process, (2) to demonstrate that IAQ improvements could be successfully achieved and sustained through a performance contract, and (3) to develop a sustainable approach to IAQ assessment and facility improvements that the energy services industry could eventually adopt as part of its routine package of benefits offered to school customers. Following completion of the demonstrations, EPA and NAESCO will develop national guidance and provide training to school officials about the benefits and uses of performance contracts for air quality and energy improvements.

METHODS

Selection of buildings

Schools selected for the demonstration study are representative of typical public schools (kindergarten - twelfth grades) in various U.S. climate zones [5]. None of the schools were selected because of known, serious IAQ problems. Schools were initially identified from candidates that had already begun consideration of energy-related performance contracts with NAESCO-member firms. Potential for a performance contract was determined by either a facility energy audit or analysis of utility bills before EPA involvement in the school. Performance contracts of selected schools also indicated potential for improving IAQ, because of planned upgrades, which included HVAC upgrades, or energy upgrades such as improved control systems. Candidate schools were also evaluated based upon climate zone, building construction type, size, age; existing mechanical/HVAC systems and control strategies; and maintenance programs. Site visits were conducted to verify criteria before final selection.

Four fixed sampling locations were selected in each school to include various ventilation conditions, differing construction, and typical classroom occupancy and use. An outdoor monitoring station was also included at each school. The characteristics of the study schools are summarized in Table 1.

Monitoring Protocols

Baseline IAQ measurements and HVAC characterization were completed before upgrades of the energy systems were performed by the ESCO. IAQ and ventilation measurements were conducted in accordance with the Building Assessment Survey and Evaluation (BASE) protocol [6], modified for use in schools [7]. Baseline and post-intervention IAQ monitoring was scheduled, to the extent possible, to occur during the same one week period in two consecutive years, and (when possible) to coincide with seasonal effects that would minimize outdoor air percentage during measurements. Actual dates were adjusted to accommodate finalization of performance contract agreements, school vacation schedules, and scheduling of school upgrades. Each school was monitored over a three day (Tuesday through Thursday) period during normal school (occupied) hours.

Table 1. Building Characteristics

	A Minnesota	B New Jersey	C Colorado	D California	E Texas
School Grade Level	Elementary	High	Middle	Elementary	Elementary
Climate	S: Humid W: Severe	S: Humid W: Moderate	S: Dry W: Severe	S: Mild W: Mild	S: Hot,Humid W: Moderate
Floor Area (m^2)	7,989	26,987	11,278	3,716	4,116
Classrooms	39	103	56	25	42
Occupancy	910	1,900	900	560	700
Building Age (years)	IS: 31 A: 7	IS: 72 A: 26	IS: 67 A1: 51 A2: 38 A3: 7	IS: 27	IS: 51 A1: 43 A2: 10
HVAC	4 cAHUs	8 cAHUs 85 ccCUVs	100 ccCUVs 14 cAHUs	6 cRTUs	25 ccRTUs
Total Air Handlers	4	93	114	6	38

Abbreviations:
S = Summer W = Winter
IS = Initial Structure; A = Addition c = Centralized/Distributed cc = Classroom Controlled
AHUs = Air Handling Units CUVs = Classroom Unit Ventilators RTUs = Rooftop Units

According to the school BASE protocol, monitoring instrumentation was deployed on a small cart at each of the four indoor sampling locations, and at one outdoor location, near the outdoor air intake, where possible. A duplicate set of integrated measurements was taken at one indoor and the outdoor location. Continuous measurements were made throughout the three day monitoring period. Continuous IAQ and comfort parameters included: air temperature, relative humidity, carbon dioxide (CO_2), carbon monoxide (CO), illuminance, and noise. Integrated measurements were performed during occupied hours on Wednesday of the monitoring week. Integrated measurements included: inhaleable and respirable particles (PM 10 and PM 2.5), volatile organic compounds, formaldehyde, radon, and bioaerosols.

Concurrent with the continuous IAQ measurements, the heating, ventilation and air-conditioning systems were characterized in normal operation. This included supply and return air flow rates, temperatures, and relative humidity; outdoor air intake rates; exhaust fan airflow rates; supply diffuser air flow rates; supply diffuser temperatures; supply diffuser relative humidity; and supply diffuser CO_2 levels; percent outdoor air intake; and percent outdoor supply, and return air. In addition to measurements and HVAC characterization, engineers noted baseline conditions and operational performance that related to IAQ and energy consumption, such as inoperable exhaust fans and moisture incursion.

RESULTS

Baseline temperature, CO_2, and outdoor air measurements are summarized in Table 2. Current ventilation standards established by ASHRAE standard 62-1989 recommend 8 Liters per second outdoor air per person. This standard also correlates with CO_2 levels of 1000 parts per million under an equilibrium steady state condition. CO_2 levels have been widely used as an indicator of overall IAQ [4]. There were examples in each school where inadequate outdoor air ventilation rates contributed to elevated CO_2 levels. Detailed pre- and post-intervention measurement results will be reported in future papers.

Table 2. Baseline Temperature, Carbon Dioxide, and Outdoor Air Measurements for the Measurement Period, During Occupied Hours

	A Minnesota	B New Jersey	C Colorado	D California	E Texas
Indoor Temp. (C°)					
Average	23.4	22.2	23.0	21.7	23.4
Min	21.1	16.7	18.6	19.2	20.1
Max	27.1	24.7	26.2	23.6	27.3
Avg. Outdoor Temp	17.7	21.9	2.9	16.6	20.9
Indoor CO_2 (ppm)					
Average	680	870	1020	770	1480
Max	980	2350	2290	1120	2870
Avg. Outdoor CO_2	370	480	380	420	390
Outdoor Air (range) L/s/p	2-32	N/A*	2-13	3-11	1-4

* System not operating during measurement week

Benefits of the performance contracts are summarized in Table 3. For each school, a performance contract agreement was attained, and each included planned ventilation improvements that are designed to adjust outside air ventilation rates to meet ASHRAE 62-89 recommendations. Examples of methods used for ensuring adequate ventilation include CO_2 sensors for demand control, minimum outdoor air damper positions, air balancing, and repair of exhaust fans. Each demonstration school realized significant benefits in capital facility improvements and energy savings. In addition, performance contracts for four of the five schools included system maintenance for the term of the contract, which ensures sustainability of IAQ improvements, as well as energy conservation measures.

Table 3. Summary of Performance Contract Benefits

	A Minnesota	B New Jersey	C Colorado	D California	E Texas
Value of Improvements ($)	412,000	841,000	250,000	435,000	738,500
Projected Savings					
KWH / year	247,769	1,289,000	146,863	146,877	205,605
$ / year (energy & maint.)	27,400	142,500	46,000*	29,150	246,150**
Length of Contract (years)	15	10	10	10	3
Estimated Payback (years)	15***	6	10	15***	3
Maintenance Included?	Yes	No	Yes	Yes	Yes

* Includes operational savings and capital avoidance; ** Includes capital cost avoidance;
*** Project subsidized by measures at other schools in the district under the contract

DISCUSSION

In the five study schools, EPA has successfully demonstrated that ventilation improvements can be incorporated into energy performance contracts. Designs for the five schools in various climatic regions across the U.S. call for minimum outside air ventilation to meet ASHRAE 62-1989 recommendations of 8 L/s/person. Future papers will report actual outdoor air ventilation rates and pollutant levels in the retrofitted schools.

Based upon planned upgrades, and estimated costs, the study schools will realize capital improvements to facilities ranging in value from $250,000 - $841,000, an average of $535,300 per school. Also based upon projections, annual KWH savings will range from 146,863 KWH - 1,289,000 KWH, an average of 407,200 KWH per school, and annual combined energy and maintenance savings for these schools will range between $27,400 - $246,150 . Most HVAC-related problems associated with deferred maintenance in each school were corrected as a result of facility upgrades, and provisions in four schools have been made to include maintenance of new equipment for the life of the performance contract. The impact of regular maintenance will guarantee energy and ventilation performance, and will prevent premature deterioration of new systems.

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