Public Health Concerns and Opportunities for Energy Efficiency Upgrades in Subsidized Housing

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ABSTRACT

Public health officials and the general public often associate efforts to reduce energy consumption with an increased risk of indoor environment problems. Taking this public health concern into consideration, what should subsidized housing energy efficiency practitioners, residents, and managers do to address potential health problems associated with energy and water efficiency upgrades in their buildings?

In this paper the authors summarize five critical stakeholder perspectives and our collective research regarding the potential resident health ramifications of major energy and water efficiency investments proposed for the Boston Housing Authority's (BHA) 68 developments and 15,000 apartments. Our research includes analysis of indoor environment conditions in two public housing developments, an extensive literature review of housing and health relationships, and first person interviews with subsidized housing residents, housing management, public health officials, medical practitioners, and researchers. The findings from our research indicate that some existing conditions in BHA's housing portfolio could be associated with specific resident health and safety concerns. In addition, our findings indicate that the proposed energy and water efficiency measures at BHA can potentially exacerbate or improve poor indoor environment conditions. Sound scientific data on this subject, however, is limited and insufficient to link specific energy and health upgrades directly to improved or degraded resident health. In lieu of this important scientific evidence the authors suggest appropriate target indoor environment conditions for BHA's energy and water efficiency investments based on current medical best practices and the limited scientific data that is available.

Introduction

Similar to other large urban housing authorities, energy and water costs at the Boston Housing Authority (BHA) are high -$ 1,666/ apartment/ year (Bennett 2000). As part of US DOE's Rebuild America program, The Northeast Energy Efficiency Council (NEEC) has partnered with the Boston Housing Authority to identify energy and water efficiency upgrades for BHA's developments. The Boston Housing Authority is an important target for energy and water efficiency upgrades because they have high utility costs - $ 25 million per year and an aging utility infrastructure. Preliminary energy and efficiency retrofits valued at

about $ 16 million are under construction in 7 of BHA's 68 developments and more investments are under consideration[1] (Agro 2000).

Figure 1. West Broadway Apartments

At the same time, however, the housing authority is concerned that some energy and water efficiency measures might cause or exacerbate chronic health problems in their developments. Similar heating system upgrades at the Lawrence Housing Authority, for example, exacerbated chronic moisture problems in their apartments (Lstiburek 1993). In addition recent surveys of targeted BHA family developments indicate that medically diagnosed asthma rates are as high as 25% for adults (Hynes et al. 1998) and 50% for children (Brugge et al. 2000). These asthma levels are 4-8 times greater than the national average of 6.4% (CDC 1998). Following is a summary of the authors' current knowledge of existing energy and health conditions at BHA's Veterans era[2] family developments and our recommendations for health considerations for future energy and water investments.

Background

The closest example to the proposed heating system retrofits under construction and proposed at BHA is a $ 2.7 million energy performance contract completed in 1990 at the Lawrence Housing Authority's Merrimack Courts housing development. Merrimack Courts is a three-story 1940's Veterans Era housing development with 14 buildings and 292

[1] BHA has initiated a portfolio-wide master plan analysis to assess opportunities for short-term and long-term energy and water efficiency investments to reduce their utility bill. The $ 230,000 Master Plan (funded by the Housing Authority's utility companies through system benefit charges) includes 30 detailed audits, extensive documentation of existing conditions, and 3 year, 10 year, and 20 year recommendations for future energy and water efficiency investments. BHA has formed an Energy and Water Efficiency Advisory Council that includes the funding partners and other key energy stakeholders to oversee the master plan development and facilitate follow up interventions. Work on the master plan will be complete October 2000.

[2] Veterans Era Housing was constructed throughout the United States in the 1940's and 1950's as temporary housing for returning war veterans.

apartments. The energy services contractor converted the old central steam heating and domestic hot water system to distributed (one system per building) forced hot water distribution systems for each building, replaced the cast iron radiators with commercial baseboard heating elements, installed non-electric fail-closed thermostats in each room, and condensing gas-fired boilers with indirect domestic hot water (DHW) storage tanks. The energy savings were dramatic – 68% every year for the past 10 years (CCC 2000).

In addition to energy savings, however, the energy efficiency retrofit increased humidity levels in the apartments. The high humidity levels caused tenants complaints about a sensation of dampness, condensation on windows, and excessive mold growth. A formal study (Lstiburek 1993) concluded that lower apartment temperatures, high occupancy rates, and lack of ventilation all contributed to an indoor environment with high relative humidity (65% at 70 Deg F indoor temperature and 40 Deg F. outdoor temperature). In 1997 the Lawrence Housing Authority increased the upper temperature limit of the apartment thermostats (70 Deg F to 75) and installed mechanical ventilation in the bathrooms, basements, and crawlspaces. (Pettit & Snell 2000). According to housing management these measures have solved most of the moisture problems associated with the energy retrofit.

In 1999, the Boston Housing Authority signed two energy performance contracts valued at about $ 16 million for energy saving measures in seven of their 68 developments and 2,500 of their 15,000 apartments. Two of the developments are similar design and vintage as the Lawrence Housing Authority with central steam heating and DHW systems. The first development, West Broadway (484 apartments), will be converted from central steam heating and DHW to distributed forced hot water heating and direct-fired DHW systems. The second development, Mary Ellen McCormack (1,016 apartments), will be converted from central steam heating to distributed steam heating and direct-fired DHW systems. Neither development has mechanical ventilation in the apartments, nor is mechanical ventilation included in the energy performance contract specifications. In addition, similar investments are being investigated for the rest of BHA's 12,000 family housing apartments. Given the experience of moisture problems associated with the energy retrofits at the Lawrence Housing Authority and indications of high asthma rates among BHA's residents, what are appropriate apartment indoor environment and associated resident health conditions for BHA to consider? Following is the authors' collective answer to this question.

Scope

Methodology

The authors of this paper represent a diverse group of stakeholders who are either shaping or will be directly or indirectly affected by the energy and water efficiency measures under consideration at BHA. In order to answer these questions the authors reviewed temperature and humidity conditions recorded in two BHA housing developments and performed extensive literature searches and direct interviews with experts in our respective fields. In addition, we collected housing and health-related medical and legal patient case histories.

Results

Existing conditions. By the nature of their design Veterans Era public housing is very tight[3]. The historic source of moisture control has been to overheat the apartments and leave windows open. When apartment temperatures decrease, residents leave their windows closed for longer periods of time and apartment humidity levels increase. Figure 2 documents the indoor temperature and percent humidity level measured in one of eight sample apartment at BHA's Franklin Hill development in December 1999 (Spengler & Valarino 2000). Figure 3 documents the temperature and humidity levels measured in one of five sample apartments at BHA's West Broadway development in April 2000 (Spengler and Valarino).

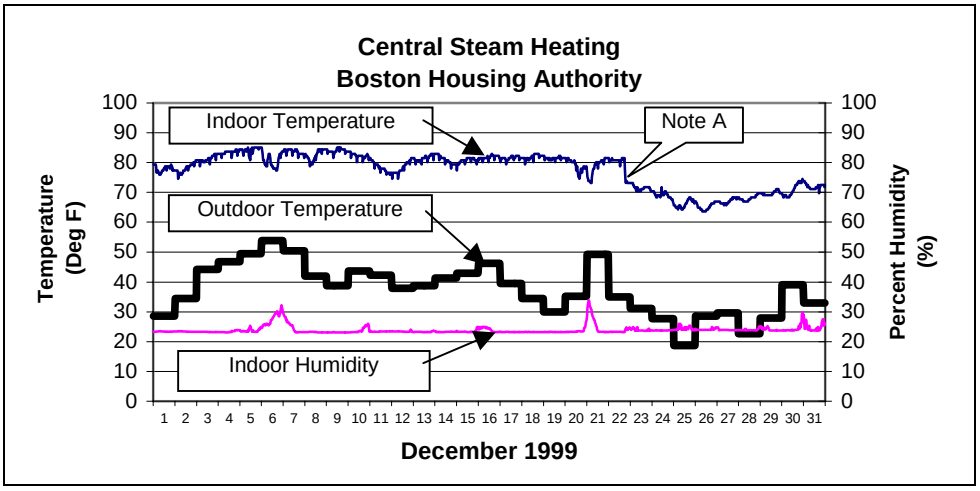

Figure 2. Temperature and Humidity Levels in Franklin Hill

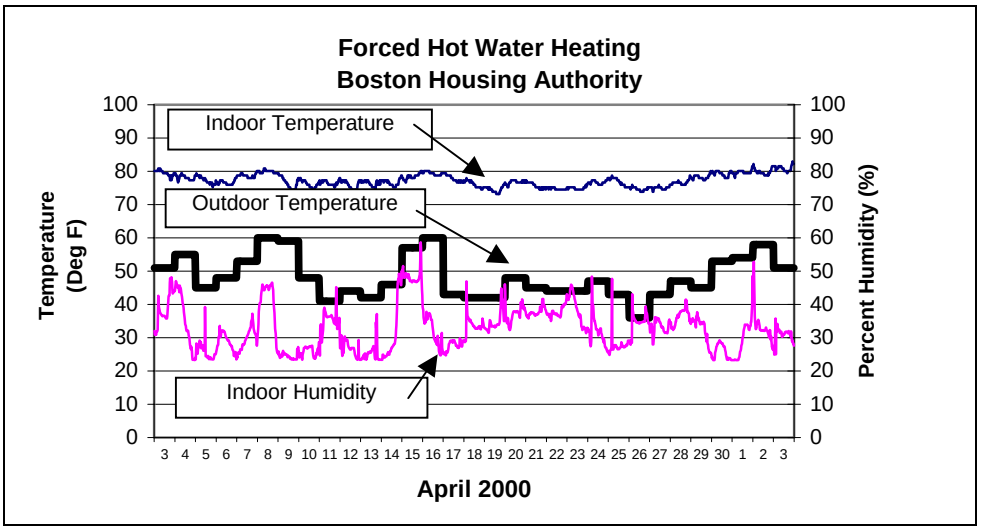

Figure 3. Temperature and Humidity Levels in West Broadway

[3] Measured fan pressurization levels were 3.8-5.4 ACH at 50 pascals in Lawrence (Lstiburek 1993) and 3.8 – 5.8 ACH at 50 pascals in Boston (Moriarta 2000). Typical AC/H values range from 8 to 12 AC/H for this type of construction and building envelope volume (Lstiburek 1993).

Franklin Hill is a Veteran's Era family housing development with central steam heating. Figure 2 documents high apartment temperatures (81 Deg F average indoor temperature at 5 feet) and very low humidity levels (< 24% average relative humidity) that are essentially off the recording scale of the measurement device during cold weather (41 Degree F average outdoor temperature)[4]. West Broadway is another Veterans Era family development, however, in this case the heating and domestic hot water system is being converted from central steam to forced hot water with boilers in the individual buildings. Figure 3 documents indoor environment conditions in one of four buildings that were converted from steam to forced hot water heating last fall. The graph indicates slightly lower apartment temperatures (77 Degree F average indoor temperature at 5 feet) during a period of slightly warmer weather (48 Deg F average outdoor temperature) and more reasonable humidity levels (33% average relative humidity) in the 25% to 60% range. Apartment temperature and humidity measurements in the other apartments measured at Franklin Hill and West Broadway documented similar apartment temperatures and humidity levels.

Health ramifications. What are the potential health ramifications of the energy and water efficiency measures currently under consideration by BHA for the next round of energy retrofits? Following are Dr. Sandel's comments regarding this question. From a medical perspective the results of Lawrence Housing Authority energy upgrade are disturbing. Though we do not have evidence that can definitively say the energy upgrades hurt health, it is suggestive that these energy improvements may have put people at risk for poorer health through increased humidity and mold growth. Clearly, the improvement helped conserve energy, but most likely created a very humid environment in the process, which encouraged mold growth. Residents of the housing development were not surveyed about their health conditions either before or after the energy upgrades, and therefore it is impossible to assume their health was worse. Many studies, however, have suggested mold as a respiratory irritant (Brunekreef 1989) and can make asthma worse (Williamson et al. 1997). Some molds have even been associated with pulmonary hemorrhage, or bleeding in the lungs, as a result of a toxin produced the mold[5] (American Academy of Pediatrics 1998).

There are many factors in the home that can impact health. Humidity, both high and low, can be detrimental to health. High humidity, generally classified as greater than 60%, can encourage mold growth, dust mites and cockroaches (Platts-Mills TAE et al. 1997). Dust mites, which are live organisms that live in pillows, mattresses, carpet, stuffed animals and some padded furniture, shed their skin to form dust into both fine and large particles. A known respiratory allergen (Murray et al. 1983), the only way to control dust mites and their dust is to maintain room temperatures below 77 Deg F, and humidity levels below 50% and clean bedding often in high temperature water above 131 Deg F (Jones 2000) and to encase bedding in plastic casing and preferably have no carpets (Murray et al. 1983).

Another respiratory allergen is cockroaches (Rosenstreich et al. 1997). Cockroaches also favor warm humid environments, and can shed their skin, like dust mites, as well. This

[4] Note A indicates a sudden drop in apartment temperature that occurred when the measuring device dropped for the shelf it was on down to the floor. The significantly lower floor temperature (10 Deg F. in five feet) was most likely caused by outside air rolling in from the open windows.

[5] This fungus is from the Stachybotrys family, both Stachybotrys Atra and Stachybotrys Chartarum, which has been shown to produce a toxin that can cause bleeding at as low a temperature as 37 Deg F. It is sometimes referred to as "toxic mold" (Vesper et al. 2000).

cockroach shedding, or cockroach allergen, can last long after buildings have been exterminated. It is important to avoid spraying pesticides since many pesticides themselves are respiratory irritants, and one of the most common used sprays, Chlorophryos, has been reported as a neuro-toxin (Chanda & Pope 1996). Generally, an integrated pest management approach of limiting access to food, sealing access to apartments through cracks, and limited traps and gels, is best.

Low humidity can compromise resident health through increased bacterial and viral infections. By low moisture content in the air breathed, nose and lung tissues are drier and more vulnerable to infectious particles entering the system. Since many housing units are overcrowded and have small children, residents can be at a higher risk for infections (Groothius et al. 1988). Also, drier, stagnant air can make some people more vulnerable to asthma attacks. Generally sudden changes temperatures are felt to be respiratory irritants, more than consistent high or low temperatures alone.

Injuries are the leading cause of death among children age 1-14 (Rudolph et al. 1987). Since almost half of all injuries are sustained at home, prevention in housing authorities becomes crucial. Window falls, an often deadly occurrence, are easily prevented by window guards (Stone et al. 2000). Keeping hot water boiler temperatures set to 120 degrees and using non-splash faucet heads in baths and showers can prevent scalding burns, especially common among young children (Sharp & Carter 1992).

Many trade-offs can exist between needed improvements and health consequences. Many housing authority buildings are in need of repair, and the substandard conditions that exist, such as leaking roofs, non-controlled temperatures and infestations already threaten health. However, if improvements do not include a health perspective, new upgrades may worsen an already unhealthy situation. Generally, ventilation and normal humidity (30-50%) are crucial to controlling many of the respiratory irritants, such as dust, cockroach allergen, mold and infections. Consistent control of temperature for each resident is important. New windows should be placed with window guards to avoid unnecessary tragedies. If renovations outside of specific energy improvements occur, removal of carpets and sealing of cockroach and other pest entry into homes is essential. Finally, health surveys before and after can track if housing or energy improvements have affected resident health positively or negatively.

Health costs. Medical costs to treat resident health problems noted in the resident surveys and medical literature are extraordinary both on a personal and economic perspective. In Boston, an asthma attack can cost $ 500 - $ 800 per emergency room visit and $ 1,000 - $ 2,000 per overnight stay to treat The average asthma patient stays in the hospital 3 ½ days thus resulting in $ 3,500 - $ 6,800 per hospital stay (Levy 1997)[6][7]. With appropriate health care, asthma can be managed. Boston, for example, has successfully reduced the number of asthma hospitalizations through aggressive medical management and community education

[6]The national health care costs for asthma amount to more than $ 6 billion a year (NIH 2000).Asthma is becoming more prevalent and more deadly. In the United States, asthma sufferers jumped from 6.7 million in 1980 to 17.3 million in 1998. Morbidity rates among 5-24 years nearly doubled from 1980 to 1993 (NIH 2000).

[7] Nationally an estimated 1.2 million U.S. households live in housing with severe or moderate physical problems. This corresponded to 17,849 childhood hospitalizations for asthma, 2.5 million lost I.Q. point dues to lead poisoning, and 187 child deaths due to fires attributable to electrical or heating problems (Doc4Kids 1998).

and interventions. Yet outpatient costs increased six-fold essentially negating any financial benefit from fewer emergency room visits (Steinbach 1999).

Health cost alternatives. As an alternative to expensive medical treatment, health care providers are increasingly turning to environmental interventions to improve the health of their patients and prevent disease. The hope is that reducing patient exposure to asthma triggers should reduce patient asthma attacks and associate medical costs. In order for this to work, health care providers need to understand potential housing interventions that can reduce their patients' exposures to potential environmental health hazards. In addition, they need appropriate mechanisms to "prescribe" housing interventions. Conversely, the building trades and housing management need to be made aware of the long-term health affects of their building design, construction management, and housing management decisions.

On an individual patient level, health clinicians need mechanisms that will assess a patient's environmental situation and provide proper indoor interventions. In the long term, the medical community and local, state and federal governments need to consider setting up an asthma surveillance and environmental intervention system. With a comprehensive and coordinated asthma monitoring and intervention, patients can receive, with a "prescription" from their doctor, a home inspection and environmental testing and referrals to agencies that will provide low or no cost home interventions. In addition, through tracking of these cases, the public health community will better understand the scope of the problem. Some countries, such as Sweden, have instituted such a system. In Sweden, a doctor can fill out a housing "certificate" that enables the patient to receive environmental testing of the home, inspections, and home interventions (Dahlgren 2000). Boston has begun to develop asthma inspections and environmental interventions; the process, however, is piecemeal and contingent on grant funding. While unusual, the medical community has funded indoor environmental interventions in the past. Rhode Island currently has a Medicaid waiver to use Medicaid dollars to replace windows that contain lead paint (Coplon-Neufield 2000). While such interventions are not traditionally medical, similar investments in health-related housing upgrades may reduce the overall cost of asthma care.

In addition, medical institutions should partner with housing authorities and other subsidized housing agencies to improve the indoor environment. This partnership can help spread the disproportionate cost burden that the medical establishment incurs in caring for asthma, lead poisoning, and injuries. Such a partnership may lead to creative funding mechanisms such as collaborative grants or using energy savings to improve the indoor environment and thus the health of the residents.

What are the ramifications of poor health for residents? Residents have the most at stake to find a solution to indoor-environment related health concerns. They confront these issues every day and often suffer the consequences of poor indoor environment conditions directly through their family's own poor health. Residents are also an important potential contributor (both positive and negative) to indoor environment conditions through their actions or inactions. In the worse case scenario, residents can override any effort by housing management or health care providers to improve indoor environment conditions and by association, resident health[8]. At the same time, residents have limited control over the

[8] Examples include smoking indoors and high humidity levels from apartment overcrowding.

structural environment of their apartments and the quality of their health care thus lacking control over some important health factors in their lives. Often, the only option for residents whose health is severely affected by their housing is to abandon their home. Following are Deborah George's comments regarding the health affects of poor housing conditions on residents.

From a residents' perspective, the affect of years of deferred capital investments of subsidized housing has changed from an aggravation to a legitimate and pressing health concern. Through personal interviews, home visits and community meetings with subsidized housing residents, community activists have identified several indoor environment issues. They are inadequate ventilation, excessive and/or inadequate heat, moisture problems, and use of low quality building materials such as sheet rock, particleboard, putty, plywood, and other cheap construction products.[9] Table 1 summarizes resident survey results that document these findings.

Table 1. Resident Survey Results from West Broadway (Hynes et al. 1988)

Air Quality Concerns	Response (Percent)
Air is stuffy	58%
No exhaust/ broken fan in bath	72%
Apartment too hot in the winter	66%
Leave windows open in winter	82%
Use oven to heat apartment	24%
Moisture Indicators and Sources	**Response (Percent)**
Mold growth	20%
Ceiling water leaks	38%
Wall water leaks	17%
Toilet, tub, sink leaks	24%
Radiator leaks	22%
Floor and/or ceiling condensation	17%
Health Factor	**Response (Percent)**
Asthma diagnosis	26%
Other respiratory symptoms	30%
Allergies	40%
Respondent smokes	49%
Symptoms within last month	
Headache	56%
Coughing	46%
Symptoms better outside apartment	40%

[9] Residents mention low quality building materials consistently, however, the authors are unaware of any scientific studies that have attempted to document the use of these building products.

These poor housing conditions (the lack of adequate ventilation, antiquated heating systems and low-grade construction materials) have direct consequences in the lives of residents. To date, the medical, building, and scientific communities have received the residents' experience as anecdotal evidence that require comprehensive and extensive scientific studies to validate. This perspective lends very little or no credibility to the individual statements of those affected by the problem. Residents cannot wait for the results of lengthy studies to have their environment changed. Asthma is a life threatening disease that affects them on a daily basis. Their personal experiences should be enough to depict, identify, define and help solve the problem.

Finally, despite their many obstacles, residents of subsidized housing have many riches and treasures. For instance, the diversity of the population is, in itself, a treasure. Residents are energetic, creative, ambitious, and talented, and they genuinely want to create healthier and safer homes. To accomplish this goal, they are willing to work with the appropriate groups of individuals to develop sound and effective strategies to solve their problems.

Housing Management Perspective. Following are Kate Bennett's comments regarding the housing management perspective. Housing management controls the day-to-day operations of subsidized housing and allocates available resources for ongoing maintenance and capital improvements. The challenge for subsidized housing management is to maintain safe healthy housing with limited resources. Since low-income residents cannot afford market rents, managers rely on federal and/or state subsidy to run the properties. These resources are inadequate. The BHA, for example, estimates roughly $ 600 million in deferred capital needs at BHA developments and this amount grows each year. Capital funding from state and federal resources currently averages less than $ 30 million per year. Thus, subsidized housing management will need new and innovative funding sources and significant technical support to correct the infrastructure health-related problems in their building portfolios.

Housing management solutions focus primarily on physical interventions that can maximize a positive health impact. Housing management's primary tool to solve health and safety infrastructure problems is direct capital investments. As lead and asbestos issues have been identified, for example, BHA has allocated capital investments to remediate these hazards. There are two considerations from BHA's planning perspective regarding indoor environment health upgrades. First, necessary health and safety investments often preclude other high-priority capital investments (BHA, for example, has deferred high priority kitchen and bath upgrades for lead removal investments). Second, both lead and asbestos have clear protocols, regulations, and laws for BHA to follow that have been developed over a period of years. Housing management lacks this level of guidance for other health issues such as asthma. Specific renovation strategies can be developed; however, it is important to acknowledge that similar to lead and asbestos abatement, targeted health-related building upgrade investments may occur at the expense of other high priority capital investments.

From housing management's perspective, the savings stream from energy and water efficiency measures and related energy efficiency financing and technical support services are attractive resources to augment BHA's health-related capital investment needs. As a first step to solve both energy and health priorities, BHA has agreed to participate in a Boston Edison-funded pilot program that will integrate health upgrades and energy-related

improvements at six high electric use developments for elderly and disabled residents. In addition, BHA has partnered in an aggressive collaborative research and implementation project headed by Boston's three schools of public health to identify and document appropriate health-related housing upgrade investments. Through research such as the Healthy Public Housing study, the BHA hopes to accumulate data that will support investments (BMC 2000) by the health industry and other financial stakeholders in health-related housing improvements.

Health and Housing Policy Ramifications. Consistent with BHA's housing management perspective City, State, and Federal health and housing agencies are under increased pressure to respond to the problem of poor housing conditions and poor resident health. Some of the pressure comes directly from resident initiated litigation (Harak 2000). The types of interventions needed to improve health outcomes, however, are not clearly understood yet. Therefore, the tools officials need to develop an appropriate long-term response to the health effects of poor housing do not exist because rigorous investigations of health-related housing problems and recommended solutions have not been completed (Matte & Jacobs 2000).

In the short term, legislators and government agencies have been limited to setting up committees to assess the problem(s) and wait for guidance on more aggressive measures and legislation. However, the current and immediate needs of the resident must be taken into consideration and some quick response is necessary. Integration of funding programs from the health, energy, and housing agencies is a critical component of an effective, holistic approach to solve the complicated issue of resident health and poor housing conditions. One possible solution is to give tax or other incentives to developers, housing managers, and energy service companies to build healthier housing and upgrade existing housing to higher standards such as DOE's Energy Star or American Lung Association's Health House building programs. Tax incentives, however, are only part of the solution as they often fall short of legislative expectations and can be challenging for end users to access and implement.

In order to develop appropriate long-term solutions to the housing-related chronic health problems, legislators and government agencies need to fund targeted, integrated health and housing research and technology transfer initiatives that will help shape appropriate legislative responses to these problems. The energy efficiency industry can play an important role in this process both from a services implementation and financing perspective. Based on the preliminary feedback from the West Broadway and similar energy efficiency projects in Boston, targeted energy efficiency initiatives can help solve many energy-related structural problems in subsidized housing.

Another important financial resource for integrated health and energy upgrades for the energy efficiency industry to pursue is the proper documentation of societal benefits from integrated energy and health upgrades that improve building indoor environments. Public health researchers have documented direct and indirect health costs associated with fossil-fueled electric generation exhaust emissions (Levy et al. 2000). The same process can be used to document the direct and indirect health costs associated with poor indoor environment conditions. The energy efficiency industry, however, cannot perform this work in a vacuum. Long-term solutions will require a collaborative effort with residents, housing management, health care providers, and Federal, State, and local government agencies beginning with systematic surveys of existing conditions and solid scientific data that links

specific energy and health related upgrades to improved resident health and lower long term health costs.

Health-related guidelines for proposed energy and water efficiency upgrades. In lieu of adequate scientific data that directly links indoor environment conditions and resident health the authors offer the following summary of medically based indoor environment conditions as target standards for BHA to consider during their energy and water efficiency master plan development. In particular, BHA should specify energy and water efficiency measures that:

1. Consider the health of the residents.
2. Provide consistent apartment temperature control that allows residents to maintain apartment temperatures above 65 Degree F and below 78 Deg F. [10]
3. Provide consistent apartment humidity control that allows residents to maintain all apartment room relative humidity levels between 30% and 50% relative humidity.[11]
4. If necessary, provide exhaust ventilation in bathrooms and kitchens.
5. Provide domestic hot water temperatures above 131 Degree F for laundry (Jones 2000) and 120 Degree F for bathing and washing.[12]
6. Cover or reduce the temperature of exposed heating and DHW systems' piping in apartments[13].
7. Include Energystar rated windows that can be equipped with child window guards.
8. Insulate all potable water piping to reduce condensation.

Conclusion

The challenges facing the Boston Housing Authority in their effort to upgrade their housing stock and reduce their utility costs are daunting. The existing conditions of high utility costs and in some cases unhealthy indoor environments are unacceptable. Equally unacceptable, however, are lower utility costs at the expense of worse (even if unintentional) indoor environment conditions. In order for BHA to reduce their utility costs and improve indoor environment conditions the authority will need to integrate long-term energy and health related investments in partnership with their key energy, health, housing, and resident stakeholders. The Northeast energy efficiency industry can play an important role in this effort through direct energy and water efficiency investments, construction management services, and ongoing monitoring and maintenance support services. An effective partnership between the Northeast energy efficiency industry, BHA, and related energy and health stakeholders will reduce BHA's operating costs through lower utility bills, leverage scarce capital improvement funds for other housing priorities, help maintain the long-term affordability of BHA's affordable housing apartments, improve the indoor environment of the apartments, and if preliminary scientific indications are correct, help improve resident health.

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[10] Massachusetts State Sanitary Code 105 CMR 410.201.

[11] See health ramifications section. In temperate climates this may require ventilation rates as high as 1.0 air change per hour during the winter (Jones 2000) and air conditioning during the summer.

[12] Massachusetts State Sanitary Code 105 CMR 410.190.

[13] The authors were unable to document specific radiator surface temperature recommendations. Exposed steam pipes, however, have caused 3rd degree burns on children and are significant potential health concern (Doc4Kids Project 1998).

References

American Academy of Pediatrics, 1998. Committee on Environmental Health. "Toxic effects of indoor molds". *Pediatrics*;101:712-714.

Bennett, K, 2000. BHA HUD Forms 52722 A&B 1998.

Brunekreef, B. 1989. "Home Dampness and Respiratory Morbidity in Children" *American Review of Respiratory Disease* 140: 1368-1367.

Agro, L. 2000. "Creative Financing Brings Boston Housing Authority $ 16 million for Energy Investment." *Housing Operations Manager* April, Vol. 9 No. 3: 20.

Brugge, D. Valarinno, J. Osgood, N. Spengler, J, 2000. *An asthma intervention pilot study in public housing: Lessons ands baseline data (In Press),* to be published in the Proceedings of the Air & Waste Management Association conference on Engineering Solutions to Indoor Air Quality, Salt Lake City, Utah. June 18-22.

CCC. 2000. *Citizens Conservation Corporation energy monitoring reports.* 1990-2000.

CDC 2000 Center for Disease Control. "Forecasted State-Specific Estimates of Self-Reported Asthma Prevalence -- United States", URL: http://www.cdc.gov/epo/mmwr/preview/mmwrhtml/00055803.htm.

Chanda, S. Pope, C. 1996 "Neurochemical and neurobehavioral effects of repeated gestational exposure to chlorpyrifos in maternal and developing rats". *Pharmocol Biochem Behav*.;53:771-776.

Coplon-Neufield, G. 2000 (Lead Action Collaborative). Personal communication. January.

Dahlgren, A. (Harvard School of Public Health). 2000. Personal communication. April.

The Doc4Kids 1998. *Not Safe at Home: How America's Housing Crisis Threatens the Health of its Children*. Boston: The Doc4Kids Project. Boston Medical Center.

Groothis JR,Gutierrez KM and Lauer BA.1988. "Respiratory Syncytial Virus infection in children with bronchopulmonary dysplasia". *Pediatrics* 82,199-203.

Harak, C. (Bernstein, Cushner & Kimmell). 2000. Personal communication.1997-2000.

Hynes, P. Brugge, D. Lally, Watts. 1998. "Public Health and Physical Environment in Boston Public Health." *Planning Practice and Research* (in press).

Jones, A.2000. "Asthma and the Home Environment" *Journal of Asthma* 37(2), 103-124.

Levy, E. (Neighborhood Health Plan) 1997. Personal communication to author.

Levy, J., Hammitt, J. Spengler, J., and Yanagisawa, Y. 2000 "Development of a New Damage Function Model for Power Plants: Methodology and Applications" *Environment, Science, & Technology* (in press).

Lstiburek, J. 1993. Building Science Corporation. *Building Science Evaluation Moisture Investigation for Lawrence Housing Authority*. December 17th, 1993.

Moriarta, C. 2000 (Conservation Services Group). Personal communication. May.

Matte, T. & Jacobs D. "Housing and Health – Current Issues and Implications for Research and Programs." *Journal of Urban Health* March: 77 (1) 7-13.

Murray, A. Ferguson, A."Dust-free bedrooms in treatment of asthmatic children with house dust and without dust allergy. A controlled trial". *Pediatrics*;71:418-422.

Pettit, B. & Snell, J. (1999) *Chronic Moisture Problems in Subsidized Housing (In Review).* Presented at the Bugs, Mold & Rot III Conference, Washington DC. June8-10.

Platts Mills, T. Verloet, D. Thomas, W. Aalbrese, R. Chapman, M.1997. "Indoor allergens and asthma: report of the third international workshop". *Am J Clin Immunol* 100:S2-S24.

Rosenstriech, D. Eggleston, P. Kattan, et al.1997. "The role of cockroach allergy and expeosure to cockroach allergen in causing morbidity among inner-city children with asthma". *N Engl J Med.*;336:1356-1363.

Rudolph, A. et al. 1987. *Pediatrics*, ed. 18. Norwalk, CT, Appleton and Lange, 706.

Sharp, G. Carter, M.1992. "Prevalence of smoke detectors and safe tap water temperatures among welfare recipients in Memphis Tennessee". *J Community Health.* 17:351-365.

Spengler, J. Valarino, J. (Harvard School of Public Health). 2000 Personal Correspondence with the author. May

Steinbach, S. (Boston Medical Center). 1999. Personal communication to author. December.

Stone, K. Lanphear, B. Pomerantz, W. Khoury J. 2000. "Childhood Injuries and Deaths due to Window Falls". *Journal of Urban Health: Bulletin of the New York Academy of Medicine*;77:26-33.

Vesper, S. Dearborn, D. Yike, I. Alan, T. Sobolewski, J. Hinkley, S. Jarvis, B. Haugland, R. 2000. "Evaluation of Stachybotrys Chartarum in the House of an infant with pulmonary hemorrhage: quantitative assessment before, during and after remediation". *Journal of Urban Health* March: 77;68-85.

Williamson, I. Martin, C. McGill, G. Monie, R. Fennerty, A. 1997. "Damp Housing and asthma: a case control study". *Thorax* Vol 52(3) March pp 229-234.