TRADEOFFS BETWEEN ENERGY AND INDOOR AIR QUALITY CONSIDERATIONS

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Abstract

The Northwest Power Planning and Conservation Act directed the Northwest Power Planning Council (Council) to develop Model Conservation Standards (MCS) for new buildings designed to produce energy savings that are both cost-effective to the regional power system and economically feasible for consumers. Implementing the MCS has proven to be a complex challenge for the Bonneville Power Administration (Bonneville) and the Pacific Northwest region of the United States. From the beginning, Bonneville has been faced with the need to deal with the tradeoffs between energy savings and indoor air quality. This paper will share Bonneville's experience from initial assumptions to revised analytical approaches and program designs based on an improved understanding of the relation among energy consumption, ventilation rates, and indoor air quality. This paper presents both technical and cultural risks of our experience.

Introduction

For the last 6 years the Pacific Northwest of the United States (encompassing the States of Washington, Oregon, Idaho, and Western Montana) has been experiencing a dramatic and exciting transformation in the way the region produces and consumes energy. Prompted by Federal legislation and local initiative, the region is promoting the conservation of energy as the primary new electrical energy resource. In the residential sector, energy efficiency standards [Model Conservation Standards (MCS)] for new construction were proposed. A demonstration program of approximately 800 homes [the Residential Standards Demonstration Program (RDSP)] was developed and implemented to demonstrate to the homebuilding industry what the MCS were, how to comply with them, and increase the industry's familiarity with them. Another objective of the RSDP was to document the cost effectiveness of the MCS by collecting energy use and cost data on the homes participating in the program. In addition, data regarding the characteristics of the homes [e.g., indoor air quality and operation of the air-to-air heat exchangers (AAHX)] were also collected.

In the United States, a Federal program of such magnitude cannot be conducted until environmental concerns are addressed. Before major actions are taken, an Environmental Impact Statement (EIS) must be prepared. Because the EIS was to utilize the results of the RSDP, interim environmental strategies were developed for that and other programs as the EIS was being prepared.

In this paper we examine the results of the RSDP indoor air quality monitoring, as well as the public's reactions received from the review and comment opportunities of the EIS process. We present the programmatic

changes made in response to both our increased technical knowledge and the public's sentiments.

Defining the Stage of the Model Conservation Standards

The Model Conservation Standards were perceived as a unique, innovative, and beneficial electrical energy resource by some, and as an undue risk by others. Thus, from the start, there was a cultural conflict on the MCS stage. Combine this with the fact that promoting the MCS throughout the Pacific Northwest was a new role for Bonneville. Instead of regulating rates, we found ourselves regulating energy-efficient new home construction, and the consequences thereof.

The Technical Risk?

A major problem faced by regulatory agencies today is establishing minimum exposure levels to known or potential carcinogens in the environment. For years the Environmental Protection Agency (EPA) has delved into the issue of radon as a human carcinogen based on high-dose epidemiological findings (e.g., radon in miners). However, only recently has EPA sought to address low-dose standards or action levels. High-dose carcinogenic results do not answer the question of how much risk from carcinogens may be present at low-dose levels commensurate with human environmental exposure. A considerable amount of work has gone into the problem of low-dose risk assessment in recent years, but the variables that affect health risk present a tremendous degree of scientific uncertainty.

The Cultural Risk?

As Bonneville started to plan MCS-related programs, we simultaneously initiated the preparation of a draft Environmental Impact Statement (EIS). Although an EIS is mandatory, the extent of Bonneville's efforts to seek public review and comment was self-imposed--our way of assessing the cultural risk factors. Public scoping meetings were conducted throughout the four Northwest States. At these meetings, it was no surprise to witness a high level of concern focused on the tradeoffs between energy and indoor air quality. Combine the aforementioned scientific uncertainty with the media. Their brief focusing of attention on crisis situations tended to be dysfunctional for rational public attitudes and behavior toward risks. A major media topic of the times was radon. (The Reading Prong, a geological area that encompassed highly populated areas of several Eastern States, had been identified as an area of very high natural levels of radon soil gas emissions.)

Thus, amid inflated levels of public concern created by the media, Bonneville embarked on the task at hand, as the entire region was asking the rhetorical question posed by Mary Douglas and Aaron Wildavsky in their 1982 publication, Risk and Culture: "Can We Know The Risks We Face?"

"The current consideration of risk has three peculiarities. The first is that disagreement about the problem is deep and widespread in the Western World. The second is that different people worry about different risks . . .. The third is that knowledge and action are out of sync: whatever programs are enacted to reduce risks, they conspicuously fail to follow the principle of doing the most to prevent the worst damage. In sum, substantial disagreement remains over what is risky, how risky is it, and what to do about it. . . . Are dangers really increasing or are we more afraid? And since no one can attend to everything, some sort of priority must be established among dangers; otherwise, merely counting risky objects would leave us defenseless."

Model Conservation Standards - First Generation (1983-1985)

The MCS were designed to make new, electrically heated residential homes more energy efficient by establishing "energy budgets" for space heating. The first generation MCS also offered a number of options to meet the energy budgets, such as insulation, glazing, heat pumps, and control of air leakage. This method of setting standards allowed homebuilders wide design flexibility.

However, air leakage control measures designed to improve the energy efficiency of new homes was an issue of public concern from the start. This concern was based on technological uncertainties as well as varied perceptions of public risk. Technological uncertainties regarding air leakage control have plagued energy efficiency for years. In essence, the question is: "How tight is too tight?" In order to pursue our activities, we needed to research the answer to "How tight are today's houses?" so that we could subsequently set a required rate of mechanical ventilation.

Air Leakage Control and Ventilation.

Ventilation standards for residential dwellings have, in general, not yet been established. Calculations of air exchange rates, based on fan pressurization (blower door) measurements of leakage area, suggested the average for current practice homes was between 0.5 ACH and 0.6 ACH. In order to minimize or eliminate adverse environmental impacts from programs designed to improve the energy efficiency of new homes, Bonneville required that MCS dwellings in RSDP have the same average infiltration rate as current practice homes. Consequently, it was decided to require that they incorporate an air-to-air heat exchanger (AAHX)*. In order to be consistent with the analysis used to develop the MCS, the average control dwelling (current practice) was assumed to be 0.6 ACH.

Preliminary Formaldehyde Testing Results for The RSDP.

"Measurements for winter formaldehyde concentrations in indoor air for 530 homes included 182 dwellings constructed to MCS and 348 control dwellings built over the last several years to current building codes (control homes). For the entire sample of homes, the median formaldehyde level was 0.092 parts per million (ppm). The median level in the MCS dwellings was 11 percent higher on the average than that in the control dwellings, and this difference was found to be statistically significant. The higher levels in the MCS homes was likely due principally to their younger age as compared to the control homes; one-half year as compared to 3 years at the time of the test." (1)

* MCS dwellings refer to all residential buildings, single-family and low-rise multifamily, built to MCS levels of energy efficiency.

Preliminary Radon Testing Results for The RSDP.

Measurements for heating season indoor radon concentrations were made in 289 homes, including 143 dwellings constructed to MCS and 146 control dwellings built over the last several years to current building codes. "For the entire sample of homes, the geometric mean radon concentration was 1.4 picoCuries per liter (pCi/l), and 16 percent of the homes exceeded 5 pCi/l. The mean level in the MCS dwellings was 8 percent higher than in the control dwellings, but the result was not statistically significant ($P<0.05$)."

"The results indicated that the location of the dwelling was a more important determinant of indoor radon concentration than was compliance with the MCS. This was not surprising considering that the MCS and control dwellings were thought to have similar air exchange rates (due to use of AAHX in the MCS dwellings). Previous studies have shown that radon levels in dwellings are only weakly correlated with air exchange rates, and that control of radon sources is a more practical and effective method of reducing indoor concentrations." (2)

Additional Formaldehyde and Radon Testing Results for The RSDP.

By September 1986 an additional year's worth of indoor air quality data had been collected on approximately 400 MCS and 400 control homes. Assessed at a 99 percent confidence level, both radon and formaldehyde test results showed no statistically significant difference in pollutant concentrations between MCS and control homes.

Model Conservation Standards - Second Generation (1986)

RSDP's preliminary results seemed to indicate that MCS home construction was not contributing to an indoor air quality problem, in itself. This was not surprising, although MCS homes aimed for tighter construction. The AAHX's, for the most part, were providing indoor ventilation rates equivalent to those found in current practice homes.

It was decided that only radon and formaldehyde were appropriate pollutants to address specifically within the new residential construction sector. Source control of other pollutants was basically up to occupant behavior; informational materials on the other pollutants were developed and distributed as part of Bonneville's MCS support programs. Program monitoring and mitigation procedures were developed for formaldehyde and radon. In the 1986 Super GOOD CENTS program, (a marketing approach with financial incentives) homebuilders and homebuyers were given the options of building a much tighter (Package B) or slightly tighter (Package A) home with an AAHX or a slightly tighter home (Package A) without an AAHX only if they accepted the following monitoring and mitigation approach for the two pollutants.

Formaldehyde.

If formaldehyde monitoring results exceeded an action level of 0.100 parts per million (ppm) (ASHRAE 62-81 recommended standard), then the builder was required to install an AAHX.

A product requirement that specified low-formaldehyde-emitting products for structural components was also imposed after an extensive regional survey confirmed that builders would not be faced with an undue cost or availability burden.

Radon.

Radon monitoring and mitigation procedures were more complex and were triggered by a Bonneville action level of 5 pCi/l. For new energy-efficient homes that exceeded the action level, the intent, at best, was to achieve a 50 percent reduction in concentration. Mitigation alternatives varied according to a house's characteristics (e.g., crawlspace, slab, full or partial basement) and radon mitigation specifications were developed.

Model Conservation Standards - 3rd Generation (1987-beyond)

New Technical Information.

Bonneville initiated an evaluation of the MCS in the summer of 1986. Were MCS measures providing cost-effective energy savings for the power system? (I.e., do MCS homes free up kilowatt-hours of electricity at a cheaper long-term cost than would be involved in generating an equal number of kilowatt-hours?) Which of these measures were economically feasible to consumers? (I.e., which of these measures would reduce the total cost of owning and heating a home?)

Evaluation of the thermal data indicated that the air infiltration control options were generally not as cost effective as the insulation options. Simultaneously, measurements of natural air infiltration for 124 RSDP control (current practice) homes were made using both fan pressurization (blower door) and perfluorocarbon tracer gas (PFT) measurement techniques. From these results, it appeared that, on the average, current practice natural ventilation rates of 0.35 ACH should be used in MCS analysis. Use of the PFT produced lower measurements of natural infiltration (0.35 ACH) than did the blower door calculation technique (0.5 ACH). Further, calibration of the thermal performance engineering model (SUNDAY) indicated that the PFT results were the more valid for estimating thermal ventilation rates.

New Cultural Information.

Although the media was touting radon as "the risk" of the times, the public, in general, throughout Bonneville's service area was not demonstrating a level of concern which reflected alarm over the issue. This was evidenced by the relatively low percentage of the public who accepted the offer of free radon monitoring.

An initial adverse public response to the mechanical ventilation requirement was anticipated. AAHX's comprised a new industry foreign to the public. Costs, maintenance, uncertainties, fear of "drafts," combined with a general fear of technology in the home, caused some homebuyer and builder reluctance. Because of the program requirement, several hundred homeowners had AAHX's installed and they were very satisfied with them. A minor percentage of this populace was dissatisfied, mostly due to poor

installation rather than the technology itself. However, although in reality the AAHX provided the majority with satisfactory performance, the general public and builders' organizations were still perceiving a risk; asking for alternatives.

New Questions.

Along with the new information came new questions to answer, which brings us to today. Although Bonneville and the Northwest Power Planning Council don't have all the answers, we do have a responsibility to address the new questions in a timely manner.

The new MCS is an expanded MCS with new cost-effective energy saving options for the consumer. However, there are key questions facing us all. How effective is dilution to the solution? Is there a certain point that, when exceeded, dilution is no longer effective? As consumers choose higher levels of insulation, how will this affect natural ventilation in MCS homes? Are houses really tighter, or is measurement technology still unreliable?

New Indoor Air Quality (IAQ) Program Elements.

An evaluation and subsequent public review was conducted of recommendations developed from the cost-effectiveness study of specific measures in MCS. More comments were received regarding ventilation and indoor air quality than any other technical issue. In general, the comments received supported Bonneville's basic position based on the following two principles: Source control is the most effective means of dealing with any pollutant, when feasible; and minimum levels of mechanical ventilation are necessary in any house, MCS or current practice.

In essence, our new programs separate source control from ventilation. Until the lingering uncertainties of ventilation can be clarified, MCS is considered to be equivalent to current practice with natural rates of 0.35 ACH.

Mechanical ventilation is required for builders who choose to build tighter homes (advanced air leakage control), and Bonneville has expanded the options to include non-heat recovery strategies (e.g., exhaust only with makeup air capabilities).

Source control is accomplished by retaining the formaldehyde product standard and requiring gravel subgrade to be installed for slab-on grade or basement structures so that, if radon monitoring indicates the need for sub-slab mitigation techniques, they can be applied inexpensively. (Bonneville was sensitive that this may be a needless expense in some geographic areas, and, thus, proposed an option of required monitoring and mitigation.)

Informational materials on indoor air quality continue to be a mainstay of our strategy for dealing with the issue.

Conclusion

As this paper is being written, new and improved MCS programs are being prepared, and the draft EIS is approaching a regional comment opportunity.

Since the main area of uncertainty and concern is still ventilation, Bonneville has expanded research and development efforts in this area. Of key concern is the effectiveness of various mechanical ventilation strategies as compared to natural ventilation.

Although many issues have been raised and subsequently laid to rest, we continue to struggle with new issues, related to both technical and cultural risk. As additional research will provide us a level of technical clarity never before achieved, Bonneville will assuredly still be faced with the problems of institutional positioning as we continue to address the cultural risks. Thus, our key objective to success in the future will be a continuing awareness and balanced response to both technical and cultural risks.

1. "Preliminary Formaldehyde Testing Results for RSDP", Reiland, McKinstry, Thor; Bonneville Power Administration; August 1985; p. 1.

2. "Preliminary Radon Testing Results for RSDP", Reiland, McKinstry, Thor; Bonneville Power Administration; August 1985; p. 1.

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INDOOR AIR QUALITY: RADON AND FORMALDEHYDE

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Abstract

The WHO Regional Office for Europe organized a Working Group on Indoor Air Quality: Radon and Formaldehyde, held in Dubrovnik, Yugoslavia, 26-30 August 1985. With respect to indoor radon daughter concentrations (which are considerably higher than outdoors, and of the order of 2-5 Bq/m^3 equilibrium equivalent radon (EER) concentration), the Group recommended that, in general, buildings with concentrations of more than 100 Bq m^3 EER, as an annual average, should be considered for remedial action to lower such concentrations, if simple measures are possible. With respect to formaldehyde, it was recommended that an average daily indoor concentration of 0.12 mg/m^3 should not be exceeded.

Introduction

The WHO Regional Office for Europe has organized three meetings on indoor air quality since 1979 (1,2,3), and convened a fourth Working Group on radon and formaldehyde, in Dubrovnik, Yugoslavia, 26-30 August 1985. In the light of the anticipated and observed health problems caused by radon and formaldehyde, the Working Group was asked to review and evaluate the risks involved, and to recommend appropriate guidelines. The Group split into two subgroups, one for each pollutant. The subgroups discussed the current state of knowledge about radon and formaldehyde, respectively, and produced subgroup reports that were reviewed and approved by the Group as a whole, particularly with respect to conclusions and recommendations.

Radon

Much of the natural background radiation to which the general public is exposed comes from the decay of radium-226 which produces radon gas and other products. Because radium is a trace element in most rock and soil, indoor concentrations of radon can come from a wide variety of substances; for example, from building materials such as concrete or brick to the soil under building foundations. Tap water taken from wells or underground springs may be an additional source. Tests indicate that indoor concentrations of radon and its decay products are often higher than those outside. High indoor concentrations of radon are of concern due to the potential carcinogenicity of its decay products. (The United States EPA Office of Radiation Programs has estimated that current exposure to radon gas could account for a much as 10% of all lung cancer deaths in the United States).