Volume III Comment Letters and Responses

BPA

U.S. Department of Energy
Bonneville Power Administration

Final Environmental Impact Statement on New Energy-Efficient Homes Programs

August 1988

DOE/EIS-0127F

Assessing Indoor Air Quality Options

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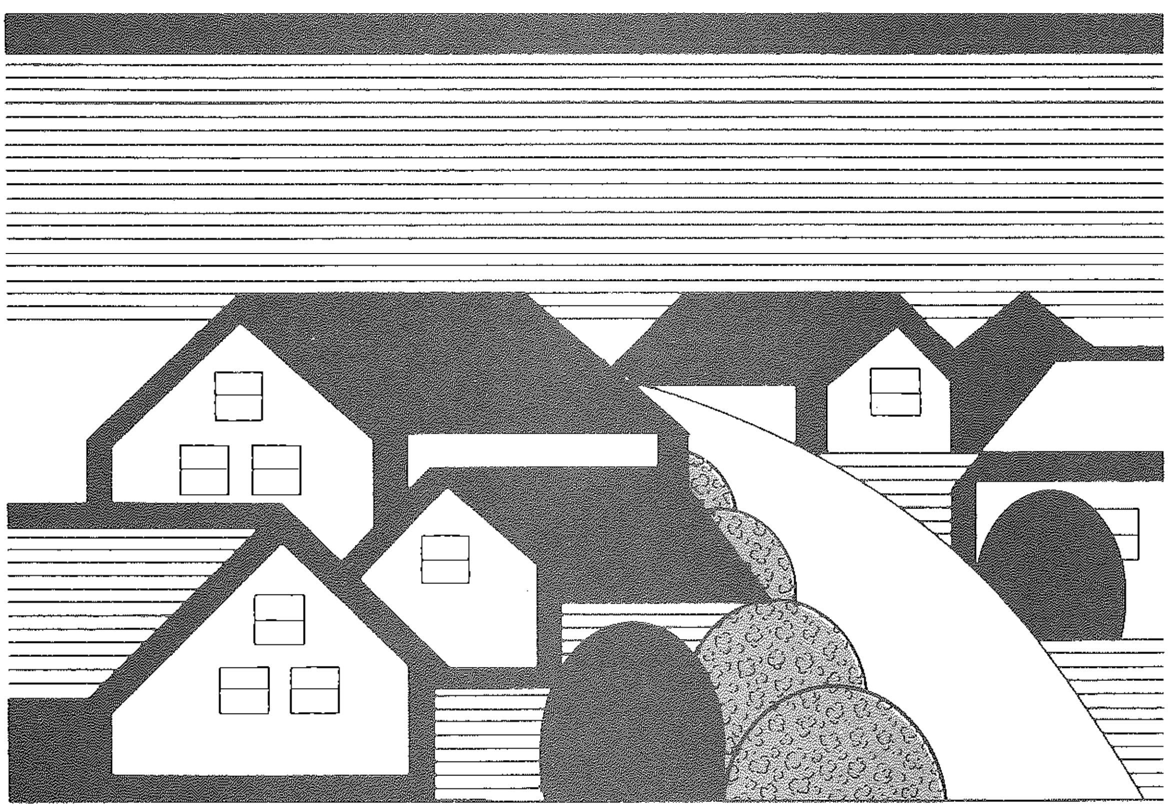

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CONTENTS

COMMENTS AND RESPONSES

The New Energy-Efficient Homes Programs Draft Environmental Impact Statement (DEIS) was distributed for public review in March 1987. Approximately 1000 copies were sent to interested citizens and public agencies. Comments were received from many sources and covered a wide range of subjects. In addition to the 22 parties who submitted written comments, a great many informal comments and questions were given orally at public meetings held in April 1987 for the purpose of discussing the DEIS.

All comments were reviewed and considered. The comments and responses have been arranged by topic. Where several comments are related, they are grouped together and summarized. Numbers in parentheses indicate the letter number and comment number within the letter; e.g., 18-3 refers to the third comment noted on the letter numbered 18 out of 22. The letters are coded and reprinted at the end of this Comments and Responses section. Comments from public meetings are referenced by an "M" (for meeting), followed by the initial letter of the city hosting the meeting, and the comment number, using the following code: MK=Kennewick MSP=Spokane MS=Seattle ME=Eugene MI=Idaho Falls MB=Boise

LISTING OF COMMENT LETTERS RECEIVED

Letter Number
001 Oregon Intergovernmental Relations
002 Larry Palmiter, Ecotope
003 Montana Intergovernmental Review
004 Compliance Systems Publications Incorporated
005 Idaho State Historical Society
006 U.S. Department of Health and Human Services
007 Oregon Intergovernmental Relations, Executive Department
008 Oregon Intergovernmental Relations, Department of Environmental Quality
009 Washington Department of Social and Health Services
010 Cavalier Corporation
011 Airxchange, Inc.
012 Natural Resources Defense Council
013 Northwest Power Planning Council
014 Washington State Energy Office
015 Pacific Power
016 New York State Department of Environmental Conservation
017 U.S. Department of Health and Human Services, Centers for Disease Control
018 Puget Sound Power and Light Company
019 Bader, Max
020 U.S. Department of the Interior
021 U.S. Environmental Protection Agency, Region 10
022 Flathead Electric Cooperative

1.0 DEFINITION OF ALTERNATIVES

Comment--Most of the comments in this category addressed the baselines, and generally favored deleting the Dynamic Baseline. One commentor pointed out that while builders are learning to tighten houses over time, they will also be learning about indoor air quality (IAQ), so it might not be appropriate to use a baseline that assumes only house tightening and not additional ventilation (18-5). Others recommended that the dynamic baseline be dropped because there was no information to support the assumption that ventilation rates might decline over time (14-5, 17-2); and if they were to decline without BPA programs, such programs would be unnecessary (14-5).

Response--We have deleted the dynamic baseline in response to comments.

Comment--The use of more than one baseline was thought to be confusing and counterproductive, and it was recommended that we use the best estimate of current ventilation as the baseline and take into account the uncertainty in this baseline or present the results with a range (17-2, 18-4).

Response--The Final EIS has one baseline that is estimated from two different techniques for measuring ventilation in houses. These two tests capture the uncertainty associated with current building practices, and thus obviate the need for creating an artificial range around the estimate yielded by each technique. BPA believes that estimates of ventilation rates derived from the perfluorocarbon tracer gas (PFT) and fan pressurization (or blower door) tests provide an appropriate range of rates for comparing health effects of the various pathways. Therefore, there is no need to develop additional ranges around these estimated ventilation rates since that would only expand the total range between the highest and lowest value and so obscure the resulting differences in health effects among the pathways.

Comment--It is misleading to show health effects from a Current Action Alternative based on fan pressurization tests. These tests measure only air leakage, and do not account for a building's mechanical ventilation (MV) system; the implication is that BPA's current programs do not require mechanical ventilation, which is not true. That is, a pathway that includes house tightening without ventilation should not be labelled "current action" (13-10).

Response--The Current Action Alternative has been converted to the No Additional Action Alternative in the Final EIS, where it represents a tight home with an air barrier and an AAHX continuously operating. The ventilation rate for the new No Additional Action has been adjusted to take into account both natural infiltration and mechanical ventilation.

Comment--One commentor thought that the various alternatives should be defined in terms of specific design options for specific programs rather than by aggregating program activities (14-4). This would make it possible to evaluate specific program design issues.

Response--Many specific program design elements such as how the program is to be sponsored or how high to set the incentives may have policy impacts but do not in and of themselves lead to environmental effects. An economic effect by itself does not require an EIS. Design issues are covered through the program planning process, which includes a public review and comment period. Relevant documentation on new homes programs such as Super Good Cents (SGC) and Early Adopters (EA) is available from BPA's public information office. The EIS is intended to cover the environmental effects of future programs that BPA may offer for energy-efficient new homes. The design of these future programs, if any, will be conducted through the standard planning and public involvement process.

2.0 COMMENTS ON PATHWAYS

Comments on pathways fell into two large categories--general comments not directed toward specific pathways and comments on specific issues related to the individual pathways. The five original pathways have been redesigned in response to comments. There are 11 new pathways developed for the Final EIS. To avoid confusion between the original five and the new 11, Table 2.1 from the DEIS and Table 2.1 from the Final EIS are reprinted here for the reader's reference. All comments refer only to the original five pathways.

2.1 General Comments

Comment--Four of the letter writers and two individuals commenting informally in public meetings said that BPA needs to construct a pathway that reflects

TABLE 2.1. Possible Mitigation Strategies for the Proposed Action Alternative[a]

Options	Pathway 1		Pathway 2	Pathway 3	Pathway 4	Pathway 5
	Houses With Air Barriers	Houses Without Air Barriers	Houses With Air Barriers	Houses With Air Barriers	Houses Without Air Barriers	Houses With Air Barriers
Infiltration (ACH)						
Fan pressurization	0.1	0.3	0.1	0.1	0.3	0.1
PFT baseline	0.1	0.2	0.1	0.1	0.2	0.1
Dynamic baseline	0.1	0.3	0.1	0.1	0.3	0.1
Additional Balanced Mechanical Ventilation (ACH)[b]						
Fan pressurization baseline	0.4	0.2	0.3	0.2		
PFT baseline	0.2	0.1	0.18	0.1		
Dynamic baseline	0.3	0.1	0.27	0.15	None	None
Operation of mechanical ventilation	Continuous	Continuous	Only when occupied & when determined by outdoor conditions	Only when determined by indoor conditions	NA	NA
Dehumidifier[c]	No	No	No	No	Yes	Yes
Exhaust fans[c] w/controlled openings	No	No	No	No	Yes	Yes
Clean air technologies[c]	No	No	No	No	Yes	Yes
Radon package	No	No	Yes	Yes	Yes	Yes
Total effective ventilation (ACH)						
Fan pressurization baseline	0.5	0.5	0.4	0.3	0.3	0.1
PFT baseline	0.3	0.3	0.28	0.2	0.2	0.1
Dynamic baseline	0.4	0.4	0.37	0.25	0.3	0.1

(a) All pathways assume code required exhaust fans, product standards for formaldehyde, and an information packet for consumers.
(b) Whole-house balanced mechanical ventilation: wall- or window-mounted units may be used, but several may be needed to adequately ventilate the whole house.
(c) Pathways 4 and 5 have the option of using any or all of these mitigation strategies.

TABLE 2.1. Pathways for Single Family Homes

Pathway	Infiltration Control(a)	Estimating Technique(b)	Infiltration Rate, ACH	MV System	MV Operation(e)	MV Rate, ACH	Total Ventilation Rate, ACH Average	Total Ventilation Rate, ACH Effective
1	Standard	BD	.32	None	NA	.00	.35	.32
		PFT	.28				.30	.28
2	Standard	BD	.32	MVHR(d)	Continuous	.18	.63	.50
		PFT	.28			.18	.48	.46
3	Standard	BD	.32	MVHR(d)	Intermittent	.06	.41	.38
		PFT	.28			.06	.38	.34
4	Standard	BD	.32	Exhaust	Continuous	.23	.48	.46(c)
		PFT	.28			.23	.41	.40
5	Standard	BD	.32	Exhaust	Intermittent	.08	.42	.39(c)
		PFT	.28			.08	.35	.34
6	Standard	BD	.32	Exhaust	Intermittent	.05	.39	.36(c)
		PFT	.28			.05	.34	.32
7	Advanced	BD	.17	None	NA	.00	.18	.17
		PFT	.13			.00	.14	.13
8	Advanced	BD	.17	MVHR(d)	Continuous	.25	.43	.42
		PFT	.13			.25	.39	.38
9	Advanced	BD	.17	MVHR(d)	Intermittent	.08	.26	.25
		PFT	.13			.08	.22	.21
10	Advanced	BD	.17	Exhaust	Continuous	.25	.34	.34(c)
		PFT	.13			.25	.31	.30
11	Advanced	BD	.17	Exhaust	Intermittent	.08	.28	.25(c)
		PFT	.13			.08	.24	.20

(a) Standard = Minimum MCS construction for air leakage control; advanced = continuous air barrier.
(b) BD = Blower door or fan pressurization tests; PFT = perfluourocarbon trace gas tests.
(c) Because the building behaves differently with an exhaust ventilation system than with an AAHX, natural and mechanical ventilation do not sum directly for a total effective ventilation rate.
(d) MVHR = Mechanical ventilation system with heat recovery, or air-to-air heat exchanger.
(e) Continuous = 24 hours/day; intermittent = 8 hours/day.

the current (1987) Model Conservation Standards (MCS) (12-9, 13-1, 14-1, 18-3, MK-2. MI-11). However, one commentor thought there were already too many options in the Proposed Action, which could be confusing to builders and consumers (17-9).

Response--When the DEIS was prepared, the 1987 amendment to the MCS had not yet been proposed. In response to public comment, the Final EIS includes Pathway 5, which corresponds to the MCS as amended in 1987. The purpose of assessing a wide array of pathways or options is to permit greater flexibility in dealing with IAQ in new energy-efficient homes. The BPA Administrator will decide which of the pathways are acceptable to the agency. The unacceptable pathways will be deleted from further consideration, thereby reducing options available to builders and consumers. When the acceptable pathways have been selected, BPA will develop program support features that will explain the options to builders and residents. These features are likely to include information booklets, training courses and workshops.

Comment--Some commentors said BPA should allow only those pathways that require mechanical ventilation to control indoor pollutants or that meet ASHRAE's ventilation standard (11-3, 14-7), or that maintain current practice levels of air quality (MF-4).

Response--While BPA may limit the pathways chosen for the Preferred Alternative, we do not need to do so for the EIS. An EIS allows inclusion and consideration of even those alternatives that have adverse effects. The Administrator may choose in the Record of Decision to eliminate those pathways that result in ventilation below what is current practice, but the EIS is the place to assess all the alternatives.

Comment--One commentor said the radon package should be required for all pathways (14-18). Another recommended that BPA select an environmentally safe path without "fancy controls," since people would not know how to use them (MB-5). Two commentors asked what effect change in ownership might have on installed equipment (ME-7, ME-9).

Response--The radon package will be required for all pathways. Change in ownership is always an issue if the dwelling contains a fairly new technology that is not yet widely known and used. The same question could have been raised when homes were first equipped with electric stoves, garbage disposal units or heat pumps. Bonneville is exploring ways of informing new owners of IAQ equipment how to operate and maintain the equipment. One possibility is to place a sticker on some designated spot in the house informing new occupants to contact their utility or BPA for information about the equipment installed to handle IAQ. None of the new pathways rely on what may be perceived as "fancy controls" that are complicated or difficult to use.

Comment--An air barrier should be required in all the alternatives and pathways given its several benefits: it minimizes energy use through minimizing infiltration; it increases the longevity of the insulation by reducing migration of moisture-laden air into the envelope; and it decreases the stack effect and negative pressure, which inhibits the introduction of radon into the house (11-7, 11-14).

Response--A continuous air barrier is included in Pathways 7 through 11 as part of the advanced air leakage control package. The advanced barrier is recognized to have the attributes cited by the commentor; however there are other considerations. First, without mechanical ventilation, the barrier results in unacceptably low air exchange rates. With mechanical ventilation with heat recovery (i.e., an AAHX), the total package cost is very high. Our studies show that homes without air barriers, if built to energy-efficient specifications for insulation, caulking, glazing and other aspects of construction, can save energy at less cost than homes built to current practice. A home without air barriers now serves as an illustrative prescriptive path in the 1987 MCS. Because homes both with and without air barriers offer cost-effective energy savings, the new pathways for the Final EIS allow for construction of both types of homes.

2.2 Comments on Individual Pathways in the DEIS

Comments--Three persons commented on Pathway 1, and two found it acceptable because its method of continuous mechanical ventilation has been demonstrated to effectively control moderate levels of indoor radon and will minimize the health impact of all pollutants (11-8, 18-8). Letter writer 11 said an MV system with greater capacity would allow occupants to match ventilation rates more closely to changing needs (11-8). Letter writer 18 questioned whether continuous operation could be enforced or realistically expected (18-9). The third commentor was concerned about energy loss from a continuous ventilation system (22-1).

Response--An MV system with greater capacity would lead to overventilation, which would cause drafts and related discomfort. Such a system would also consume additional electricity. If more ventilation is needed for special circumstances, spot ventilation such as exhaust or portable fans can be used.

Continuous operation of MV systems cannot be enforced. Households will receive information about the need and advisability of continuous operation, and some will choose to follow that advice. BPA recognizes that continuous operation of MV systems is idealistic rather than realistic. For this reason, only 2 of the 5 pathways in the Preferred Alternative depend on continuous ventilation.

Continuous ventilation without heat recovery does constitute an energy loss. For this reason, as well as the previous one, one of the pathways (4) having continuous ventilation but no heat recovery was not included in the Preferred Alternative. Pathway 10 does have continuous ventilation without heat recovery but its extremely tight construction reduces heat loss.

Comment--The control strategy for Pathway 2 in the DEIS is based on a sensor that would activate ventilation when outdoor conditions are not supplying natural ventilation; commentors pointed out that such a sensor is not commercially available (11-9, 18-10, 13-9, 22-2). One commentor said that the pathway should therefore be dropped (13-9). Another said the pathway is acceptable if the MV controls are manual, but not if based on an automatic sensor, because infiltration could not provide sufficient ventilation to a house with an air barrier (11-9). Another commentor thought the option should remain in the EIS for estimating purposes (18-10).

Response--We have deleted control technologies dependent on outdoor equipment. All pathways now have the same control technologies, which consist of commercially available automatic controls based on humidistats or automatic timers with manual override.

Comment--Pathway 3 is unacceptable because no sensor exists that can monitor for all pollutants, which means that the MV systems would not be activated under some high pollution conditions, leading to greater risks than calculated (8-1, 11-10). One commentor, however, said it was the best pathway and best dealt with indoor air pollutants and humidity (22-3). Another said that our analysis of Pathway 3 (and 2) ignored the benefits of controlled ventilation and that these pathways could result in adequate air quality while saving energy (18-1, 18-10). A similar argument was made for Pathway 4 and the effectiveness of clean air technologies (18-2).

Response--Control technologies designed to sense indoor air pollutants have been deleted. Humidity itself is not considered a pollutant although excess moisture in a home can lead to the growth of molds and mildew. Intermittent ventilation in Pathways 3, 5, 6, 9 and 11 in the Final EIS is to be controlled through automatically operated equipment such as humidistats and timers with manual override. Thus ventilation will be activated when humidity increases.

Comment--One commentor recommended combining Pathways 1, 2 and 3 in the DEIS, all of which rely on whole-house MV systems, since there is no way to ensure continuous operation of the system (14-19).

Response--To integrate all whole-house ventilation options and ignore variations in operation would not be appropriate for the EIS. In the Final EIS BPA has decided to retain the distinction between continuous and intermittent ventilation, even though it is impossible to ensure that occupants will operate the system continuously, to exhibit all reasonable options and evaluate tradeoffs among them. The analysis accounts for the fact that mechanical ventilation is more effective than infiltration in removing pollutants because, unlike infiltration, mechanical ventilation is not dependent on the vagaries of weather; it is controllable and dependable. Clean air technologies have been deleted from the pathways because their effectiveness is variable and difficult to estimate.

Comment--One commentor stated that Pathway 4 was unacceptable because it did not require the air barrier; this would dilute expected energy savings (22-

4). All others commenting on Pathways 4 and 5 said they were unacceptable because they result in increased health risks and a ventilation rate below that recommended by the IAQ Committee of Oregon's Dept. of Energy (i.e., .5 ACH) (8-2, 8-3) and ASHRAE (11-11). These DEIS pathways are based on dehumidifiers and filters, which are incapable of controlling the broad range of pollutants found in the home (11-11). Pathway 5 has unacceptable increases in health effects (17-7, 22-5); one commentor said that the pathway is an irresponsible course of action and should be dropped from the Proposed Action (14-20).

Response--Our studies show that homes without air barriers, if built to energy-efficient specifications for insulation, caulking and glazing, can save energy at less cost than homes built to current practice. A home without air barriers now serves as an illustrative prescriptive path in the 1987 MCS. Because homes both with and without air barriers offer cost-effective energy savings, the new pathways for the Final EIS allow for construction of both types of homes.

Concerns about the higher health risks associated with some of the pathways are reflected in the choices for the Preferred Alternative. This alternative includes only those pathways with ventilation rates close enough to the rates for current practice homes to be within the uncertainty range of estimation. Since humidity in a home increases whenever bathing, cooking or laundry activities occur, it is a reasonable surrogate for other pollutants for switching on ventilation. All pathways have minimum requirements for consumer information, exhaust fans in bathrooms and kitchen, and the control of radon, formaldehyde and some combustion byproducts at their sources.

3.0 VENTILATION ISSUES

3.1 Fan Pressurization/PFT Issues

Comment--It was recommended that the PFT results be updated to .35 ACH to be consistent with BPA's recent MCS cost-effectivenss analysis (13-19).

Response--Text and analysis changed to reflect the comment.

Comment--One commentor questioned the logic of the results of the two tests, i.e., why would estimates from the PFT tests be lower than those from the blower door tests (14-6)? Others expressed uncertainty about how the air infiltration rates were determined (MSP-1, MS-4).

Response--At first glance, it would seem that air exchange rates as predicted by blower door tests should yield a lower estimate than the PFT test; however, in practice, we observe that the PFT more frequently measures an air change rate considerably less than that predicted by the blower door. There are a number of reasons why the PFT measurement may be biased low and the blower door test biased high. These biases may be as much as 30% in either direction, causing the two tests to switch roles as the underpredictor and overpredictor. This is discussed in detail in Appendix A (Related Technical

Information) of Bonneville's MCS Cost-Effectiveness Study. Appendix A of the Final EIS describes how the infiltration rates are used.

3.2 Mechanical Ventilation

Comment--One commentor said that we should consider mechanical exhaust ventilation with heat recovery, which complements zonal heating systems and uses a heat pump (12-4).

Response--Mechanical exhaust ventilation with heat recovery is discussed in the DEIS, Vol. II, Appendix C (Indoor Air Quality Mitigation Technologies), Section 3.3.2. That combination is not included as part of the pathways because too little information exists on North American installations for us to model its performance and effectiveness.

Comment--Another commentor felt that we had not addressed the state-of-the art in heat recovery ventilation, and disputed a number of statements in our specific discussion of regenerative process air-to-air heat exchangers (AAHX). It was pointed out that rotary regenerator AAHXs are available and were used in the Residential Standards Demonstration Program (RSDP). The DEIS statement that regenerators are only suitable for central systems was countered with the fact that three manufacturers market wall inserts (11-17, 11-19).

Response--The information in the DEIS, Vol. II, Appendix C, was gathered mainly in 1985 and includes references available through early 1985. The information was thought to be timely and up-to-date when the document was completed. We stand corrected on the availability of regenerative AAHXs: they are available, but not widely available for the residential marketplace.

Comment--One commentor said that AAHXs were ineffective for reducing indoor radon, expensive to operate, and uncomfortable; furthermore, radon source control is the only sensible approach (10-3).

Response--BPA agrees that radon source control is the best technique for controlling radon. However, we disagree with the absolute statement that AAHXs are not effective for controlling radon; studies indicate the contrary (Sivyer-Rowan, S. 1987). When radon source strengths are not excessive (below 40 pCi/l, according to [EPA 1986]), AAHXs may reduce indoor concentrations through dilution and ventilation. These devices are more likely to be effective in tight homes with low air leakage rates. The EPA further notes that when used in basements AAHXs have reduced radon levels by up to 96% (EPA 1986a). AAHXs are also an effective mitigation device for pollutants other than radon, such as nitrogen oxides, moisture, and household chemicals.

The pathways outlined in the DEIS allowed one to compare the effectiveness of using continuously operating AAHXs only, using intermittently operated AAHXs along with radon source control techniques, and using radon source control techniques by themselves. In the Final EIS we assume that radon source control techniques are used in each of the pathways for homes with radon levels exceeding 5 pCi/L. Costs associated with these techniques are reported in Appendix H of the Final EIS.

Comment--One commentor wanted a clear description of the 1987 SGC ventilation specifications and how the air exchange rates were determined (22-7).

Response--See Super GOOD CENTS Technical Specifications (BPA 1987a) for a detailed description of the ventilation specifications. Appendix A in the Final EIS indicates how the air exchange rates were determined.

3.3 Mechanical Ventilation Controls

Comments--Most of the comments on MV controls were made in response to Pathways 2 and 3. See section 2.2 for a summary of these comments (11-9, 13-9, 18-10, 14-19).

Response--BPA has considered these comments and decided to delete strategies based on these types of controls and sensors as part of any pathway (see Response to Pathways 2 and 3 in section 2.2). However, these control technologies do exist and are likely to be mature in the next 5 years or so; in principle, since an EIS is a planning document, it is appropriate to consider these technologies as possible options for new homes programs.

Comment--Canada's R-2000 Program indicated that ventilation systems operated by dehumidistat do not provide acceptable air quality (11-10).

Response--In the R-2000 program, moisture problems occurred because the houses were very airtight so that the fans had to run longer than would ordinarily be the case and therefore had a tendency to burn out. But the European experience with exhaust fans has been more effective. The Swedes and the French have had exhaust fans run continuously for ventilation for many years, without problems. If problems with moisture, humidistats, or ventilation arise in BPA's New Homes Programs, corrective steps will be taken.

Comment--One commentor argued that controlled (not continuous) ventilation could maintain adequate air quality while saving energy, and that the analysis ignored the benefits of controlled ventilation and was based only on the resulting overall ventilation rate in Pathway 3 (18-1).

Response--It is true that we model only the ventilation rates and not the ebb and flow of pollutants throughout the day because there are no data for modeling this. For this reason, for each set of pathways in the Final EIS, the one with continuous ventilation leads to better health effects than the one with intermittent ventilation. The benefits of controlled ventilation are indicated in the Final EIS by the "effective" ventilation rate. A ventilation system that operates only when pollutant concentrations exceed certain guidelines may indeed lead to acceptable IAQ as well as save more energy than a system that operates continuously; however, studies to demonstrate this have yet to be performed.

3.4 Relation Between Health Effects and Ventilation

Comments--One commentor said that mechanical ventilation with outdoor air is the only strategy recommended for the broad spectrum of indoor contaminants (11-3, 11-12). Indeed, if the EIS examined the pathways' effects on health and not simply on radon-induced cancer, then only those pathways requiring mechanical ventilation would survive analysis (11-13). It is a mistake to rely on average infiltration because natural forces such as wind do not produce a constant rate rate of infiltration and there are windless periods when the effective ventilation rate can approach 0 (troughs). It is thus necessary to recognize that infiltration, which is not controlled, is not equivalent to mechanical ventilation (11-6, 13-3), and that mechanical ventilation produces better IAQ than an equivalent average amount of infiltration (13-4, 18-8).
These commentors argue that MCS houses, therefore, will have lower average pollution concentrations, and thus fewer adverse health effects, than current practice houses because constant mechanical ventilation will eliminate pollution peaks caused by low infiltration periods in a current practice house (12-3,13-2,13-4, 18-8). These commentors said that mechanical ventilation did not receive full credit in the calculation of health effects. This includes exhaust fans, which should be modelled to show their effect on air change rates when measured from the Baseline, e.g., in Pathways 4 and 5 (13-5, 13-18).

Response--We have responded to these comments by incorporating data on wind speed and temperature in the calculation of natural infiltration rates for the new pathways. For pathways specified to have whole-house mechanical ventilation, such infiltration has been incorporated in the analysis according to the latest accepted theory regarding how that type of ventilation increases the total ventilation rate of homes. For pathways not relying on such MV systems, incidental mechanical ventilation is not included because there are no data on the use of such systems or the effectiveness of those systems to move air. In addition, the total effective ventilation rates for each pathway were determined from a wide distribution of actual measurements in homes. Including various levels of incidental mechanical ventilation from these individual dwellings would merely expand the range over which the single "average" value of total ventilation rates was determined and would not significantly affect this average. By assuming no additional ventilation, BPA is analyzing the scenario most likely to result in the greatest adverse impacts.

In the Final EIS the analysis of health effects is based on an effective ventilation rate by which is meant the "effectiveness" of the ventilation to dilute pollutants. This effectiveness includes the capability of an MV system operating continuously to provide a more stable ventilation rate by eliminating troughs in natural infiltration. The "effective" rate is almost always lower than the "average" ventilation rate. (See Appendix C.)

Comment--One commentor noted that health effects estimates may be sensitive to assumptions about air mixing and uniform ventilation throughout the house (14-13).

Response--This is a good scientific point; it is indeed possible that health effects estimates may be sensitive to assumptions about air mixing and uniform ventilation. However, to make any definitive statements regarding that relationship requires a major research and computational effort. The relationship of the interaction of a ventilation system and physical phenomena particular to the indoor environment is complex and includes, for example, gross mixing characteristics resulting from location of vents, mixing due to buoyancy effects of heat gain (loss) through walls, inter-room connections, and structure geometries. Current theoretical models are not yet well established. To develop a model that could simulate these relationships would be costly, and the value of the information to be derived would not sufficiently enhance the Administrator's ability to decide which pathways to pursue.

3.5 Relation Between Radon and Ventilation

Comment--Three commentors questioned our focus on the usefulness of air changes per hour as the primary index of IAQ, specifically for radon (9-2, 21-4, ME-3). One stated that the most important factor in regard to radon is the differential pressure between the house's atmosphere and the soil gas, and that ventilation rates have little effect on this pressure.

Response--BPA recognizes that the pollutant source term is the most important part of the relationship. However, the focus of the EIS is on the difference between energy-efficient houses and homes built to current practice. Thus factors such as radon source strength, soil characteristics, and weather conditions are considered the same across all pathways for purposes of assessing IAQ effects for the two different types of homes. In this way, ventilation becomes the key variable for assessing IAQ. This approach is supported by various studies. For example, in homes where ventilation is alternately increased and decreased for experimental purposes, radon concentrations change in inverse proportion to the air change rate (DOE 1986). Therefore, similar differences in concentrations would occur between houses with different ventilation rates built at the same site with the same characteristics if that were possible. After radon has entered the living space, ventilation plays a key role in the radon decay process by reducing the equilibrium factor (EPA 1986b).

Comment--Closing inlet vents of an exhaust ventilation system could increase negative pressure enough to increase radon entry into the house (14-27).

Response--True. Any ventilation system (natural or mechanical) can be improperly operated or abused by the occupant, which could increase negative pressure inside the house. However, the MCS exhaust ventilation system includes fresh air ports as a mandatory part of the system. These ports prevent negative pressure inside the dwelling when the exhaust fans are operating.

Comment--Controlling radon entry into the house is better than using an AAHX to rid the house of radon (10-3).

Response--All pathways include radon source control features for reducing entry of radon into dwellings.

4.0 MITIGATION STRATEGIES

4.1 Radon Package

Comment--The 50% radon reduction assumed for the mitigation techniques in the radon package was said to be inadequate "as a goal" (10-1). Another commentor asked that we supply the basis for that assumption (17-4).

Response--The assumption of a 50% radon reduction has been revised to 70% as a result of additional findings from demonstration studies conducted for BPA (BPA 1987b). The 70% reduction is not a "goal"; the goal is to reduce concentrations in houses with levels exceeding 5 pCi/l. For purposes of estimating health impacts, we assume a 70% reduction as a realistic and responsible estimate of the effectiveness of available technology because we cannot guarantee anything more. Radon mitigation technology is relatively new, so there is some uncertainty associated with its level of performance and effectiveness. Although in many houses these techniques have reduced concentrations by more than 70%, a greater effectiveness should not be assumed because, in addition to the reasons cited above, these techniques are sufficiently new that neither their life spans nor the amount of maintenance that would be required to assure this continued level of effectiveness is known. In an EIS, it is better to overestimate rather than underestimate the adverse health effects of a proposed action, thereby imparting a "conservative" bias to the information upon which the Administrator will base a decision.

Comment--BPA should provide the rationale for choosing 5 pCi/l as the action level in the radon package and explain why it chose a level different from EPA (12-8, 21-6, MB-1).

Response--BPA chose the 5 pCi/l in October 1984, almost 2 years before EPA's choice of 4 pCi/l. BPA viewed 5 pCi/l as a balance between the lowest of recommended levels at that time: ASHRAE's 2 pCi/l and the higher levels such as 8 pCi/l recommended by the National Council on Radiation Protection and Measurement (NCRP). In choosing an action level of 5 pCi/l, BPA also took into account the distribution of radon in the Pacific Northwest and the uncertainty of measuring radon accurately. At 5 pCi/l the uncertainty factor of measurement is about 30%. Thus the actual concentration, in contrast to the measured concentration, might be as low as 3.5 pCi/l or as high as 6.5. The action level of 5 pCi/l helps ensure that homes with higher concentrations are identified while reducing the likelihood that homes with low concentrations are falsely identified as high. For more information, see the Federal Register (1984). BPA's level is comparable to that recommended by the International Commission on Radiological Protection (ICRP) for new houses.

Comment--BPA should clarify whether radon measurements and estimates of health effects are based on a 3-month or a 12-month exposure of the monitors (13-21).

Response--Both 3-month and 12-month readings were taken in the RSDP. The DEIS relied on the 3-month data because the 12-month readings were not yet available. BPA is using 12-month readings for the Final EIS. However, analysis of the two data sets shows a high degree of correlation and no statistically significant difference between the two sets in aggregate.

Comment--BPA should consider other radon mitigation technologies, including other means of ventilation and other construction techniques that block entry of radon into the home (15-1).

Response--Radon reduction technology is an area of rapid growth and development. BPA is aware that there are available technologies beyond those identified in the EIS; however, to our knowledge, they are untested and unproven and therefore, at this point, less reliable than those identified.

Comment--The radon package will not protect public health from the effects of other indoor pollutants such as combustion products, tobacco smoke, etc. (11-2).

Response--It is true that the radon package addresses radon only. However, all of the pathways include other control techniques for other pollutants: e.g., product standards for formaldehyde emissions from building materials, spot ventilation located near sources of moisture and cooking, and outside air for combustion supplied directly to fire boxes in wood burning appliances. Approaches applicable to most indoor air pollutants include consumer information and whole-house MV systems. All pathways except 1 and 7 have some form of whole-house mechanical ventilation.

Comment--The radon package should be more fully described--e.g., what defines "high radon areas", precisely how are the radon mitigation measures activated, how are these systems maintained and monitored, how do we ensure that mitigation is activated, and who will bear the costs (13-16, 14-16, 14-17). Persons at the public meetings made similar comments, asking for more specific information on the radon package (MK-3, MK-4, MB-2, MSP-3, MS-2, MS-5, MS-6, MI-4, MI-6, MI-9, MI-10, MB-2, MB-3).

Response--We have changed the way the radon package is applied and have expanded our description of it to address these questions. See Appendix H in the Final EIS.

Comment--More specifically, one commentor wanted us to a) address the merits of buried pipe loop in relation to a tiling system and the sensitivity of the weeping tiling field method to installation (14-23), and b) to cover aspects of basement ventilation that are unique to basements (14-28).

Response--Perforated pipe is a possible alternative to tiling systems. However, we are not aware of any research directly comparing the relative effectiveness of these two technologies for their short and long-term reductions in concentrations. It is true that incorrect installation of a weeping tiling field can aggravate existing radon problems. This method is not popular or widely used in the Northwest and so does not have enough of an impact to influence our analysis. BPA is not aware of any aspects unique to basement ventilation and not covered under crawlspace ventilation that would make a significant difference.

Comment--The option of sealing alone should be dropped and unventilated crawlspaces disallowed in all areas, regardless of whether it is a high or low radon area (13-16, 13-17).

Response--"Sealing" was a clerical error in the DEIS and should be replaced with "basement pressurization." Similarly, unventilated crawlspaces are not allowed. Crawlspace ventilation is specified for all new MCS homes consistent with the Uniform Building Code.

Comment--Builders should have the option to mitigate before or after construction (MI-5).

Response--This option is available in the radon package.

4.2 Radon Mapping

Comment--BPA should start mapping those areas where there is a potential radon problem and then develop appropriate building construction standards (16-1).

Response--BPA is in contact with some of the experts on the subject of radon release from soils, but is not aware of any firmly established methodology for identifying high radon areas. BPA continues to engage in research toward that end, e.g., since 1984, monitoring radon concentrations in homes that are being weatherized. These data, aggregated by range and township, are being mapped to show the distribution of radon throughout the Pacific Northwest.

Maps and reports are issued quarterly and are available from BPA. In 1988 BPA will undertake a study with the U.S. Geological Survey to use our monitoring data in conjunction with geological and uranium site information to identify more rigorously the areas of potential radon emissions.

The radon package already allows for appropriate construction techniques in high radon areas, once we have developed the mapping capability and can assesss a building site prior to construction (see Appendix H on the radon package). However, houses even next door to each other can have widely divergent radon concentrations. Whether this reflects differences in radon emissions from soils or differences in house construction is uncertain. Even if this uncertainty is resolved, mapping will provide only an indication of possible radon problems for any one house, not absolute certainty.

4.3 Formaldehyde

Comment--One commentor strongly supported the source control approach of a product standard for all of the pathways (14-15). Another stated that adoption of the formaldehyde standard for wood products is appropriate only as a starting point. Without requirements for ventilation (e.g., as HUD assumes .5 ACH), it is not possible to guarantee that the target will be met and health effects avoided (11-4).

Response--BPA agrees with the first comment and has a formaldehyde product standard in all pathways for the structural portion of the dwelling; furthermore, builders are encouraged to use products that meet this standard for finish work, such as cabinetry. Even though the homes in the RSDP study were not required to have structural components meeting HUD's formaldehyde product standard, the average formaldehyde levels in both the energy-efficient and the current practice homes were well below HUD's indoor ambient air target of 0.4 ppm. Also, both sets of homes were either below or close to the ASHRAE-recommended level of 0.1 ppm. See Section 3.7.2 in the Final EIS for information on formaldehyde measurements taken over two heating seasons for current practice and energy-efficient homes.

Comment--What is the effectiveness of coatings and other barriers to formaldehyde referred to in the DEIS, Vol. II, Appendix C, p.3.4 (14-24)?

Response--Some of the coatings and barriers cited by Fisk et al. (Fisk et al. 1984) were reported to reduce formaldehyde emissions by a factor of 10 (Hawthorne et al. 1985). However, we believe product standards are a more effective means of controlling formaldehyde than coatings and barriers.

Comment--Why did BPA not estimate cancer rates from formaldehyde in manufactured housing since it is known to often have high levels of formaldehyde (17-3)?

Response--It is true that formaldehyde has been more of a problem in manufactured housing. However, when BPA began preparing the DEIS, there were no measured data of formaldehyde in new HUD code or manufactured homes, so cancer rates could not be estimated. We now have such data and are using it to estimate cancer rates for formaldehyde in the Final EIS (see Chapter 4).

4.4 Clean Air Technologies

Comment--Comments ranged from categorically stating that technologies such as dehumidifiers and filtration are incapable of controlling the range of pollutants likely to be found in a home (11-11, MS-6) to asking that the effectiveness of these technologies to control pollutants be more closely examined in the analysis to estimate health effects (18-2, 14-11).

Response--A brief literature review has been conducted to update the discussion of other mitigation technologies and is included in Ch. 3 of the Final EIS.

5.0 HEALTH EFFECTS

Comment--A number of comments on health effects focused on the uncertainty surrounding the estimates. One commentor asked if the changes in lifetime cancers were statistically significant and at what level (17-6).

Response--This question would imply that pollutant risk factors were statistically estimated from data on cancers and pollutant concentrations and that BPA had data on the incidence of additional cancers expected to occur at a given pollutant concentration. In fact, as the model in Section 4.1.2 in the Final EIS shows, we calculate the number of additional cancers; and rather than performing another statistical analysis, we used a consensus risk factor based on other researchers' estimated risks (e.g., .0021 for radon). As a check, our estimates for the region were compared to normal health statistics regarding occurrence of lung cancer from radon and were found to be similar.

Comment--Others recommended that health effects be indexed and shown as changes relative to the baseline (13-8) or in increments from one alternative to the next (14-12) since the relative change is more important than the actual numbers.

Response--We have made changes in the Final EIS as suggested.

Comment--Modeling results were said to be inconsistent with measured data from RSDP, which showed no difference in radon concentrations between current practice and MCS houses; thus, there should be no increase in cancer rates from the Baseline to the Current Action (13-11). A similar argument was made for results shown in the No Additional Action and the Current Action (18-7).

Response--At the time the DEIS was prepared only a small number of radon measurements were available for current practice houses (DEIS, vol.I, Table

A.8). Instead of using this very small data set to characterize the region for current practice, this data set was combined with the data for MCS homes so that more meaningful statistics were available, but which resulted in a questionnable conclusion. In the Final EIS we use concentration data from current practice houses to define the baseline and scale accordingly to estimate health effects.

Comment--Estimates of health effects were said to be problematic because they do not account for the effectiveness of mitigation technologies that do not rely on ventilation, and therefore cannot be compared to those associated with other mitigation steps and pathways (14-11).

Response--In the Final EIS all pathways have the same control technologies, and estimates of health effects associated with these technologies are now comparable. As noted in an earlier response, clean air technologies have been deleted because their effectiveness is variable and difficult to estimate.

Comment--Two commentors said the estimates of health effects in multifamily buildings were probably overestimated because the pollutant concentrations are overestimated. The model used to determine the concentrations in multifamily buildings should be reviewed and modified, especially the volumetric adjustment used in the model. The commentors suggested radon concentrations may be more sensitive to the size of the whole building than to the size of the individual unit and may be sensitive to the location of the unit within the building. Concentrations would probably not increase in multifamily buildings with multiple levels because radon gas would have less opportunity to reach the elevated spaces since the source term varies as a function of soil contact area. (18-12, 21-2).

Response--Our analysis is based on measured data in single-family houses, but scaled by volume and ventilation rates in multifamily homes because of the paucity of measured data for this housing type. The scaling is based on the difference in dwelling unit volume as described in Appendix C in the Final EIS.

BPA recognizes that the resultant radon concentrations are probably greater than what is likely to occur in individual multifamily units. However, an approach that bases the scaling for an individual unit on the volume of the entire building would result in much lower concentrations than would actually occur. We believe ours is a better and more consistent approach given the scarcity of data.

Limited data indicate that there is no relationship between radon concentrations in individual units and the height of the unit above the ground floor (Abu-Jarad 1982). The concentrations tend to correlate with unit air exchange rates rather than building height. Apartment units are constructed with common walls and thus act as natural pathways for radon migrating from the soil to all above-grade units. In some new apartment buildings in the region, the mechanical ventilation for the units is served from a common plenum, which can also be a conduit for radon migrating to upper units. These construction practices could explain why radon concentrations are similar in upper and ground floor units.

Basement units, however, have been found to have higher levels of radon than upper units (Abu-Jarad 1982). The new multifamily buildings have so few basement units that it would be impractical to analyze them separately. BPA believes its assumption of uniform radon concentrations in all levels of a multifamily building is valid for this region.

Comment--Radon health effects in manufactured houses were also disputed. Concentrations could not be predicted to increase in manufactured housing because generally this type of housing lacks the ground coupling that would funnel radon into the living space (4-1). The floors are generally tighter than in site-built homes, leaving less possibility for infiltration of soil gas into the house and thus lower radon concentrations (21-3).

Response--BPA recognizes that the HUD Standard for manufactured homes requires sealing or caulking the interface between the wall and floor and the floor and foundation and placing a moisture membrane to enclose the underside of those homes installed below floor joists. However, this membrane is not an air or vapor barrier. Nor is there scientific evidence or field data to indicate that the floors of HUD code homes are tighter and have less leakage area than site-built homes. The construction practices that reduce floor leakage can be offset by other practices unique to manufactured homes, e.g., leakage can occur in the joint (seam) of multisectional homes and in floors at the openings for heating vents or in the crossover duct in centrally-heated homes. Other sources of infiltration occur at openings for water, sewage, electrical connections, and around the duct passages for free-standing fireplaces and woodstoves, which were ducted through the floor from under the house. There appears to be no significant difference between manufactured homes and site-built homes in regard to infiltration of radon gas from the soil through the floor openings.

Comment--One commentor said the EIS should address the relation between lung cancer, smoking, and concentrations of indoor radon progeny, and the relation between ventilation rates, smoking and other particulates that might affect the working level (WL) (16-3).

Response--This relationship is discussed in the DEIS, Vol. II, "Potential Health Effects of Certain Indoor Air Pollutants," Appendix B, Section 5.2, which is available from BPA. However, there are too many variables and confounding technical factors to be able to quantify the relationships.

6.0 RISK DISCUSSION

Comment--The EIS should reference the EPA's work on risk assessment for radon (9-1).

Response--The risk assessment for the DEIS was based on risk factor information that was available prior to November 1985. Since completion of the DEIS, we have been reviewing more recent information, including EPA's work. Information available from EPA since early 1986 is reviewed and referenced in the Final EIS (Chapter 3).

Comment--Four commentors took issue with the presentation of risk comparisons in the DEIS, Vol. I, Appendix C (10-2, MS-3, ME-6, MI-8). One said that BPA's comparison is different from EPA's, which indicates the average person is breathing between .5 and .8 pCi/l of radon for life rather than our number of .0048; also EPA says 10-15 pCi/l of radon is equivalent to smoking one pack of cigarettes a day, versus BPA's comparision of 1 pCi/l of radon to 1/6 cigarette a day (10-2). Another commentor asked that this presentation include additional examples for different radon concentrations as well as other causes of fatality to compare with typical households' exposure to radon (18-14).

Response--This cited discussion allows readers to compare the risk of developing lung cancer from exposure to radon with risk of experiencing a fatality from engaging in voluntary activities without regard to when that activity may occur (FEIS, Vol. I, Appendix D, Table D.1). Table D.1 is scaled to levels of activity that have a risk of one death per 100,000 persons involved in that activity, regardless of when the activity or fatality occurs. It is in this context that BPA uses the exposure figure of .0048 pCi/l. The table simply shows that travelling 7000 miles by air has the same risk of one fatality out of 100,000 as does exposure to .0048 pCi/l of radon.

Table D.2 is scaled similarly but includes time and allows for slightly different risk comparisons. Thus the risk of motor vehicle fatalities is 25 deaths per year per 100,000 people. In comparison, breathing .3 pCi/l of radon over a lifetime leads to less than one fatality per year per 100,000 people. The risk factor for radon in the tables is based on data from both the ICRP and NCRP. These data are considered the best available information. Information provided by the EPA is based on its assumptions regarding the development of a risk factor for radon.

The value of .3 pCi/l of radon is equivalent to average measured concentrations within the Puget Sound area of Washington. For other parts of the Pacific Northwest the average measured concentrations are higher; therefore the estimated deaths per year per 100,000 people would be greater than 1.

The same Appendix also includes an arithmetic example of how to use the risk comparison information given in Table D.1. The example shows that the risk of lung cancer from exposure to 1 pCi/l of radon over a lifetime is equivalent to the risk of lung cancer from smoking 2083 to 6250 cigarettes over a lifetime. This averages to 1/4 cigarette a day, assuming 50 years of smoking, or 1/6 cigarette a day, assuming 70 years of smoking.

If one is exposed to 15 pCi/l of radon over a lifetime, the risk of lung cancer would be equivalent to the risk from smoking about 2/3 of a pack of cigarettes a day for 50 years. In contrast, EPA equates the exposure from 15 pCi/l of radon to smoking a full pack of cigarettes a day. The reason for the difference is that BPA uses the NCRP/ICRP risk factors, which are somewhat lower than those chosen by EPA. Since risk comparisons are very dependent on the assumptions made about exposure, we do not think much would be gained by expanding the examples in the appendix on risk reprinted as Appendix D in the Final EIS.

Comment--One commentor suggested that any action that establishes risk for radon-induced cancer beyond a specified level may be preempted by future legislation, citing an article which indicated that federal agencies always regulate risk greater than 4 x (10^{-3}) (11-5).

Response--At this time no federal agency has the authority, or is planning, to regulate radon concentration levels for the general population living in residential buildings. EPA has thus far eschewed the regulatory approach for radon in favor of developing and disseminating information and leaving regulation to the states (EPA 1987a). Regulations do exist for residences built on lands contaminated with uranium tailings. If regulatory legislation is passed, BPA will be required to meet any standards established by the legislation.

Comment--Another commented that the EIS should address the issue of risk associated with estimating health impacts by setting current practice to .3 ACH and later determining that current practice is actually .5 ACH (14-9).

Response--This should not be a problem since the analysis covers effects based on both cases; that is, we are not choosing a "true" or absolute value for current practice. To address the issue of uncertainty surrounding ventilation rates in current practice homes, the DEIS relied on two analyses of potential risk. One analysis was based on blower door test results and used .49 ACH as the air leakage rate found in current practice homes. The other analysis was based on PFT test results and assumed that 0.35 ACH was the air leakage rate found in current practice homes. Because we conducted two analyses, independent of one another, it is possible to compare the risk between the two different ventilation rates. The Final EIS also uses two separate analyses, though the starting air leakage rates in current practice homes have been updated to reflect the most current data.

Comment--One letter cited a recent article in the International Journal of Epidemiology (March 1987 16:7-12) which does not confirm EPA's view that high concentrations of indoor radon will cause lung cancer. This commentor says that it is more important to alert people in high radon areas that the risks of smoking are much higher (19-1).

Response--BPA agrees that it is important to inform consumers of the potential risk of smoking cigarettes, but this risk has little to do with living in energy-efficient homes. We disagree with the point that radon is not a carcinogen. Though one article may contradict the point that radon is a carcinogen, many more conclude that it is. More information and specific references can be found in "Potential Health Effects of Certain Indoor Air Pollutants," Appendix B of Vol. II of the DEIS.

7.0 ADDITIONAL ANALYSIS

Commentors suggested additional work in a number of areas, which are summarized here.

Comment--BPA should evaluate tradeoffs between IAQ, fuel switching effects, energy savings, and costs of each alternative (14-4).

Response--The numbers presented in Table 1 in the Summary of the DEIS indicate the tradeoffs among these effects; the evaluation of these tradeoffs was left to the reader in the DEIS. In the Final EIS, BPA's evaluation is indicated in its choice of a Preferred Alternative and an Environmentally Preferred Alternative.

Comment--BPA should reevaluate fuel switching by assuming incentives extend beyond 1988 (13-14).

Response--In the DEIS the level and duration of incentive payments to be made to builders or buyers of SGC homes were based on assumptions in The 1986 Super Good Cents Program (BPA February 1986). While it is possible that the incentives could continue if there is too little adoption of MCS as code, to date no BPA decision has been made to extend the incentives beyond 1988.

Comment--BPA should address environmental merits of both the AAHX and mechanical exhaust ventilation with heat recovery, and compare them with the MCS path of mechanical ventilation without heat recovery (12-6).

Response--In the Final EIS Pathways 2, 3, 8, and 9 include mechanical ventilation with heat recovery (AAHXs); Pathways 4, 5, 6, 10, and 11 include mechanical exhaust ventilation systems, but without heat recovery (Pathway 5 represents the 1987 MCS). From the perspective of IAQ, ventilation is the key variable, and heat recovery has no effect on our analysis of the health effects. It does have an effect on energy savings and program costs. These are all compared summarily in Table 1 and in some more detail in Chapter 4.

Comment--BPA should conduct analysis to distinguish between design specifications and actual performance of various IAQ technologies (including occupant operation of equipment) and account for this difference in the analysis (14-10).

Response--Design specifications are targets established by BPA or the Northwest Power Planning Council (NWPPC) and represent an optimal level of performance. Actual installations and occupant operation often do not meet these targets. However, with training and experience, both builder and resident should continue to come closer to the design specifications. Occupant behavior and installation are incorporated in the analysis in two ways. The PFT technique accounts for operation of mechanical equipment and occupant behavior; if MV systems are improperly sized or if occupants do not operate them, the PFT results reflect that situation. Also, we have established five pathways which allow intermittent operation of the MV system. The operating time of the MV system is estimated to be 8 hours, based on occupant surveys and on end-use monitoring of the equipment.

Comment--BPA should determine the effectiveness and benefits of nonventilating technologies (filtration and adsorption) for reducing pollutant concentrations (18-2).

Response--The effectiveness of these technologies has not yet been determined, so they cannot be treated quantitatively. The Final EIS includes the results of a literature review on the subject in Section 3.8.

Comment--The EIS should better examine impacts of groundwater as a source and pathway for radon, particularly where groundwater is obtained from rocks that are likely sources of radon (20-1).

Response--Studies show groundwater is not a major source of indoor radon in homes in the Pacific Northwest (Nero et al. 1982). Therefore, the analysis assumes that all of the radon found in the homes monitored to establish our base radon levels came from soil gas.

Comment--The analysis relied too heavily on radon and formaldehyde to the neglect of other contaminants. It was suggested that we consider other indoor air pollutants such as combustion gas, particulates and chemical vapors. The health effects data for these pollutants are as good as the data for radon and formaldehyde (17-1), and radon is not even the most significant pollutant (11-1). One commentor said that we should not ignore the qualitative evidence of risk associated with these other contaminants (11-1). One person wanted to know if BPA was considering the effects of asbestos (MI-7).

Response--We decided to quantify the health effects resulting from exposure to radon and formaldehyde for the following reasons:

- These pollutants are commonly found in the air inside of homes and there are measured data for these pollutants.
- Scientists have developed risk factors for radon and formaldehyde making it possible to estimate potential cancers resulting from exposure.

We also selected these pollutants for analysis because consumers have little control over them. In the Northwest, the main source of radon is the soil beneath the structure and the pollutant can only be detected with monitors.

Consumers may control sources of formaldehyde brought into the home after consuruction but often have little control over sources used in building the structure.

Concentration levels for some pollutants are affected primarily by choices occupants make and actions they take. For example, the decision to smoke in a house affects the level of combustion by-products. Using hobby glue when the window is closed affects the level of chemical vapors. Concentrations of radon and formaldehyde are not directly affected by these types of voluntary choices and actions, often clustered under the heading of "lifestyle." In contrast, radon occurs naturally; its presence has to be monitored with special equipment; and special steps need to be taken to keep it out of the house. In the case of formaldehyde, consumers usually have little control over building materials for subflooring and "built-in" furnishings such as kitchen cabinetry.

Pollutants inherent in the structure of the home or that otherwise are out of consumers' control are more likely to be affected by changes in ventilation than by consumer behavior. Pollutants that do result from consumer actions, such as cigarette smoke and household chemicals, are more related to "lifestyle" than to energy-efficient features of houses.

However, lack of consumer control is not a prerequisite for inclusion in the analysis. For example, the Final EIS includes an updated review of the literature on potential health effects from exposure to environmental tobacco smoke (ETS), which indicates that health professionals have not yet reached a consensus about quantifying the risks to health from ETS.

BPA recognizes that homes with reduced ventilation may have increased levels of other pollutants besides radon and formaldehyde, but adequate data are lacking on other pollutants to permit quantification. Asbestos is unlikely to be found in newly built homes. Furthermore, the presence of asbestos is not affected by ventilation.

8.0 METHODOLOGICAL/MODELLING ISSUES

8.1 Uncertainty

Comment--A number of comments focused on the need to convey the uncertainty in the analysis--either through a systematic sensitivity analysis or through a separate section discussing the uncertainty associated with the values in the model and the estimates of various impacts (14-13, 13-6, 17-6, 18-15, 21-5). This would allow BPA to evaluate a range of penetration rates and fuel switching forecasts as well as assumptions about ventilation that would affect health impacts (14-13, 18-13). For example, one commentor said the analysis needs to account for the uncertainty surrounding current practice, and thus the entire baseline, which affects the size and type of ventilation equipment required (14-8).

Response--An additional appendix for the Final EIS has been prepared to address some of these issues. There is no real benefit to estimating health effects based on a range of penetration rates because the range would be applied to all alternatives and pathways, and the absolute change in resulting health effects would remain the same.

Comment--Those factors that could not be incorporated into the analysis but that affect the viability of the pathway should be described (13-7).

Response--Several new sections have been added to cover some of these issues. Two specific factors cited were: 1) estimating pollutant concentrations as 1/ACH does not reflect the time required for pollutants to reach equilibrium concentrations if low air change rates are only experienced for short periods of time; and 2) it is uncertain if the health response to low concentrations scales linearly with health impacts observed from exposures to high concentrations. The Final EIS addresses the first of these points in Appendix A, with related information presented in Appendix B. Linearity of health risks is discussed in the DEIS, Vol. II, "Potential Health Effects of Certain Indoor Air Pollutants," Appendix B, and in Section 3.6 in the Final EIS.

8.2 Fuel Switching

Comment--The analysis of fuel switching was said to be simplistic and misleading, being based on the assumption that MCS are adopted for electrically-heated houses while codes for other fuels remain unchanged, with the result that consumers choose other fuels as a cost saving measure. This approach results in overstating the long-term impact of MCS on fuel switching (12-7, 13-13). It is further argued that MCS will probably only be adopted as code when the costs are reduced, and those lower costs will mean less fuel switching (13-13). And if costs of achieving MCS are not reduced over time, incentives to consumers may continue beyond 1988, which will have the effect of dampening fuel switching (13-14).

Response--In the DEIS, BPA's 1985 housing forecast was used as a baseline, and two MCS cases, with and without incentives, were created. At the time the DEIS analysis was developed, Washington and Oregon had not yet adopted energy efficiency codes for new buildings. These codes are fuel blind and have now been melded into BPA's 1986 housing forecast, which are used in the Final EIS. BPA's 1986 housing forecast predicts 18% of new homes will be heated with fuels other than electricity (fuel switching) in order to avoid building to MCS. This is less than the 24% based on the 1985 forecast and presented in the DEIS.

Comment--Another issue was that fuel switching was treated as conservation in the calculation of energy savings, and thus resulted in overestimated savings. This approach is inconsistent with the definition of conservation in the Northwest Electric Power Planning and Conservation Act (the Act). The calculation of energy savings from the MCS is said to be incorrect because the model counts households that leave electricity for other fuels as savings, when the calculation should be based only on houses that are electrically-heated that adopt the MCS measures (13-14,13-15).

Response--The DEIS did include the reduced electric load from fuel switching in the calculation of energy savings. This has been corrected in the Final EIS.

Comment--The penetration rates assumed for the analysis are overoptimistic (14-14).

Response--Penetration rates for the Final EIS have been scaled down from 85% to 75%.

Comment--One commentor thought there was sufficient uncertainty in the estimate of fuel switching to consider a range estimate (18-13).

Response--The Final EIS is based on BPA's 1986 medium housing forecast rather than the 1985 forecast. This results in a lower estimate of fuel switching. A comparison of the 1986 MCS forecast for fuel choice for space heating to the 1986 baseline forecast indicates that an additional 18% of homes would choose a fuel other than electricity in the MCS forecast. The uncertainty range for this estimate can be obtained by examining the amount of fuel switching associated with BPA's low and high housing forecasts for 1986. Under the low forecast, with MCS, an additional 12% of homes would swich from electricity to another fuel. Under the high forecast, with MCS, there would actually be an increase of electrically heated homes, with 14% of homes switching from another fuel to electricity. Assumptions about population growth, the demand for housing, and prices of heating fuel are the main factors accounting for the different estimates of fuel switching among the low, medium, and high forecasts. For more information, see BPA (1986).

8.3 Other Methodological Issues

Comment--The methodology for estimating pollutant concentrations for the different alternatives should be more fully explained, as well as how the RSDP data were modelled to provide results shown in Tables 4.2,3, and 4 (17-8).

Response--We have expanded the explanation of the methodology in the text. See sec. 4.1.2. The concentration data are actual measurements from the RSDP control houses. These measured data were then used to estimate concentrations in other housing types by scaling the concentration data according to the inverse ratio of the volumes of the housing types. This was explained in the DEIS, vol. I, Appendix A. This appendix has been revised in the Final EIS to discuss how the analysis was changed to account for concentration data now available for multifamily and manufactured houses built to MCS.

Comment--Our use of a model that assumes a constant radon source term was said to be incorrect (21-1).

Response--The intention is to make comparisons between alternatives and pathways rather than to predict absolute pollutant concentrations. The use of a dynamic model may or may not change the absolute pollutant concentrations predicted for each of the pathways, but it will not change the relative position of the pathways. Also, the analysis is based on data collected from homes throughout the Pacific Northwest using the Tracketch method, which gives an average time-integrated measurement. To use these data in anything but a steady-state model would require manipulating the data and increasing the uncertainty of the assessment. We therefore believe the steady state model is best suited for this work. This is further discussed in a new Appendix B to the FEIS.

Comment--One of the studies cited in the DEIS, Vol. II, Appendix C was said to be based on faulty flow measurements (14-22).

Response--It is true that some of the AAHX measurements contained in the reference were obtained through an imperfect technique. It was discovered after the measurements were taken that the flow measuring system reduced the actual flow rates by increasing the AAHX system back pressure. Actual flow rates would be higher than that reported in the reference by some small amount. However, even if a correction is applied to the results, the conclusions of the referenced report are not altered.

Comment--The square footage assigned to single-family houses was questioned. If single-family housing is defined as 1-4 units, then the average size of a single-family dwelling will include the smaller units (950 sq ft) in duplexes and quadplexes. That will bring the average size of single-family housing down from the 1848 sq ft used by BPA to forecast energy savings from the MCS as well as the costs of MCS. If this number is used, the costs and savings are said to be overestimated (13-20).

Response--The 1848 sq ft prototype was used only as a basis for cost assumptions in Vol. I, Appendix E in the DEIS. All other calculations used the three prototypical sizes and weighting factors used by the NWPPC as described in the DEIS, Vol. II, Appendix A, sec.5.1.4.2. This distribution assumes the mean size of single-family housing is 1400 sq ft.

9.0 COST ISSUES

Comment--It was recommended that the EIS include more detailed costs associated with each of the pathways to better evaluate their cost-effectiveness relative to each other (18-11). A meeting participant asked if the high cost of equipment and repairs had been taken into account (MS-1).

Response-- The cost analysis has been expanded in response to the comments. See Appendix E to the Final EIS.

Comment--One commentor stated that regenerative heat exchangers are less competitive than AAHXs, disputing our claim that an RHX probably has lower first-costs than an AAHX. This commentor also thought that our information on heat recovery ventilation was out of date and did not reflect the developments in cost and performance achieved in that technology (11-18, 11-19).

Response--"Indoor Air Quality Mitigation Technologies," Vol. II, Appendix C, sec. 3.3, in the DEIS addresses methods of increased ventilation with heat recovery. The cost of an RHX system was thought to be lower than an AAHX system, not just the AAHX. The system includes both the AAHX and the air distribution system for the dwelling. The information includes references available through 1985 and was thought to be up-to-date when the document was prepared.

Comment--One commentor had a number of questions regarding the radon package. Are our costs for sealing drains and floors high? (14-23). What are the costs associated with each of three subslab depressurization techniques? (14-23).
Does our crawlspace ventilation cost (DEIS, Vol. II, Appendix C) reflect the fact that some crawlspace ventilation may already be required in some codes? (14-26).

Response--The costs cited from Fisk et al. (1984) may be high for the Northwest, but we thought they represented a reasonable estimate for retrofit applications. No data were found on the individual subslab depressurization techniques in our survey of the literature. The crawlspace ventilation cost does not reflect any code requirements; it is only an estimate, based on a survey of builders, of how much it would cost to install crawlspace ventilation, regardless of whether it is already required in codes. Basically, costs are treated incrementally between what is required by current code and what would be required under the radon package.

10.0 EIS DECISIONS AND PLANNING

Comment--One commentor recommended that the environmentally preferred alternative be clearly identified, that it be made clear to decisionmakers that properly built and operated MCS houses are environmentally preferrable to "current practice" houses (12-1).

Response--The environmentally preferred alternative is identified in the Final EIS. It consists of Pathway 8 and is described in Chapter 2, along with those pathways that comprise the Preferred Alternative.

Comment--One commentor suggested BPA adopt two new pathways that would better protect public health, maximize energy savings, and still provide some alternatives to builders. One pathway is similar to Pathway 1 (DEIS) but includes control options such as on-off switches, which permit occupants to operate the system. Radon monitoring is available as an option. The second pathway proposed for testing is an unbalanced MV system, continuously operated and sized to provide the capacity prescribed by the MCS. This pathway also has minimal control options like the preceding pathway, as well as openings for make-up air. Radon monitoring is required in this new pathway (11-15).

Response--Both of these suggestions have been incorporated into the new pathways. See Pathways 3, 5, 9 and 11 in the FEIS.

Comment--BPA should describe how the EIS fits into other BPA planning processes and decisionmaking activities, and especially how EIS comments will affect program decisions (14-2). One meeting participant said BPA should delay its EA and SGC Programs until the EIS is completed (MI-3).

Response--The New Homes EIS does not fit neatly into new homes programs planning processes because the EIS process sometimes moves at a slower rate than the need and process for changing programs. In this case, just as the DEIS was being completed, the results of BPA's study of the cost-effectiveness of the MCS led to some major program changes, particularly approaches to maintaining current practice ventilation rates. These changes were effected through a planning process that included public review and consultation with the Council. The EIS, in effect, will validate decisions that were made during fall and winter 1986-87, when the DEIS was being cleared by U.S DOE for publication, being printed, and going through its 60-day public comment period.

BPA chose not to delay the Early Adopter and SGC programs because: 1) ongoing programs can suffer a serious loss of momentum through stop-restart procedures; 2) during the hiatus more homes would have been built to current practice, thus constituting a "lost opportunity" for obtaining energy savings; 3) there were no environmental reasons to stop the programs since both old and new program specifications required builders to keep air changes up to current practice and to take additional steps for controlling some pollutants at their sources.

Although completion of the EIS is unlikely to change the operation of ongoing new homes programs, its completion, which includes incorporation of the comments, will have the following effects: 1) it will enable BPA to demonstrate that IAQ in homes built to MCS can be equal or even better than IAQ in current practice homes; 2) the decisions that result from the EIS can be incorporated into future programs; 3) it allows BPA to address the fact that builders sometimes build houses that are tighter than current practice because building is not an exact science.

Comment--The EIS should indicate how other BPA research, e.g., further PFT studies, will affect the EIS and decisions (14-3).

Response--Findings from BPA research projects that are available in time for inclusion in the Final EIS are included. However, the fields of residential ventilation and IAQ are extremely dynamic. The literature on these topics has grown exponentially in the past 10 years. BPA is doing its best to base this Final EIS on the most recent literature. But we cannot keep deferring completion of the EIS because there is yet another study underway. Otherwise, the EIS would never be completed. Once completed, BPA will decide which approaches to incorporate into its programs; and the agency will continue to monitor findings from relevant research. If new findings indicate a need to refine or change our approach, we shall do so. At that time the agency shall also consider the type of environmental documentation that may be needed for a proposed change in approach. Our experience has been that changes based on new findings usually fit within the scope of our environmental documents so that a new major environmental document, such as another New Homes EIS, is usually not needed.

11.0 CORRECTIONS, MINOR POINTS, TERMINOLOGY

Comment--The assumption that for every decrease in ventilation, indoor pollutants double was improperly stated and led to an incorrect calculation (2-1, 13-13, 17-5).

Response--The example with the erroneous calculation has been corrected; however, the underlying conclusion is not affected by the correction.

Comment--One commentor writes that BPA research homes were not the first examples of whole-house AAHX in manufactured homes, and suggests that the problems with the AAHX in these homes were due to improper equipment selection and installation, not to anything fundamental to the technology itself (11-16).

Response--Text changed to reflect the comment.

Comment--The DEIS incorrectly asserts that the technology for mechanical exhaust ventilation with heat recovery is not available (12-5).

Response--Change made in text. It is true that the technology is available, but it is not widely available. It has only recently been introduced in the U.S., and at least one of the two examples cited of its use was experimental in nature, that is, a demonstration program.

Comment--It was noted that exhaust fans for kitchens and bathrooms are not required by code (13-2).

Response--Change made in text. Exhaust fans are not required by current code but are often installed in new homes built under current code as an option for supplying spot ventilation (see UBC, sec. 1205, 1985 Edition).

Comment--The 1986 Washington State Energy Code is not reflected in our description of current practice (14-21).

Response--The Washington State Energy Code (and changes made in Oregon's Code) were not reflected in BPA's 1985 housing forecast used for the DEIS nor in the table describing current practice. The Final EIS is based on the 1986 forecast, which does incorporate Washington's and Oregon's new energy requirements as part of the baseline. The table has also been updated to reflect both codes.

Comment--In DEIS, Vol. II, "Indoor Air Quality Mitigation Technologies," Appendix C, Table 2.1 has errors related to the 1987 MCS (15-2).

Response--The Final EIS includes all changes made to the MCS in 1987. The DEIS was prepared before the Council revised the MCS.

Comment--The statement that .0048pCi/l is "very concentrated" is erroneous (21-13).

Response--We agree. The text should read that 0.0048 pCi/L is a very dilute concentration.

Comment--The EIS should use radon "guidelines" instead of "standards" since standards are enforceable and guidelines are not (9-3).

Response--Appropriate changes are made throughout the text.

Comment--Discussion of crawlspace ventilation (Vol. II, "Indoor Air Quality Mitigation Technologies," Appendix C) should indicate that fans should be installed to blow air into the crawlspace to pressurize the space rather than pull air out (14-25).

Response--We are not aware of research to support crawlspace pressurization. The U.S. DOE suggests that ventilation is effective in itself and does not indicate any advantage to pushing radon back into soil by pressurization instead of venting to outdoors (DOE 1986).

Comment--The word "baseline" is overused; it should only be used to refer to current practice homes, not to the three different methods of estimating infiltration (18-6).

Response--The text has been changed to reflect this comment. We have one baseline with two methods of estimating it.

Comment--The DEIS states that radon has two radioactive progeny; it has more than two (21-7). Buildings materials such as brick contain radium, not radon, which may decay to and emanate radon (21-10). Risk of lung cancer is due to the radon progeny, not radon (21-11).

Response--Corrections made in the text.

Comment--Concentrations of radon should be expressed in working levels (WL) rather than pCi/l; radon exposure is not measured in WL (21-8, 21-9).

Response--We have made some minor changes in the text to increase the precision of the language. However, both units are acceptable for expressing concentration levels of radon, although working levels are primarily associated with occupational settings.

Comment--One commentor said there is a body of data on miner exposures that contradicts our statement that epidemiological evidence is based on exposures which are high compared to residential levels. These data overlap the distribution of residential exposures, which means that only a portion of the data requires a wide dose-response extrapolation (21-14).

Response--This comment refers to research findings indicating that approximately 1 million homes in the United States may have radon levels exceeding 8 pCi/l (Nero et al. 1986). Since 16 pCi/l is the exposure limit set by the U.S. Mine Safety and Health Administration for occupational exposure in mines (which assumes a monthly exposure of about 170 hr in comparison to the 504 to 648 hr/month estimated for the general population at home), somewhere between 5 and 10 % of the U.S. population may experience radon exposure that equals or exceeds miners' exposure to radon. For this portion of the population the epidemiological studies on miners have more direct applicability; the uncertainty associated with extrapolating the effects of exposure from higher radon concentrations to lower concentrations is removed. However, the uncertainty of generalizing from an adult male working population to the entire population remains. Furthermore, the problem of generalizing health risks from situations of higher exposure to situations of lower exposure still remains for most homes in the United States and most homes in BPA's service territory. Nationally, the average residential radon concentration is 1.5 pCi/l (Nero et al. 1986). Within BPA's service territory, the average is 1.1 pCi/l, with over 95 % of the homes having concentrations of 5 pCi/l or less (BPA 1987c).

No Response Needed--Letters 001, 013, 005, 006, and 007.

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