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Summary

BPA

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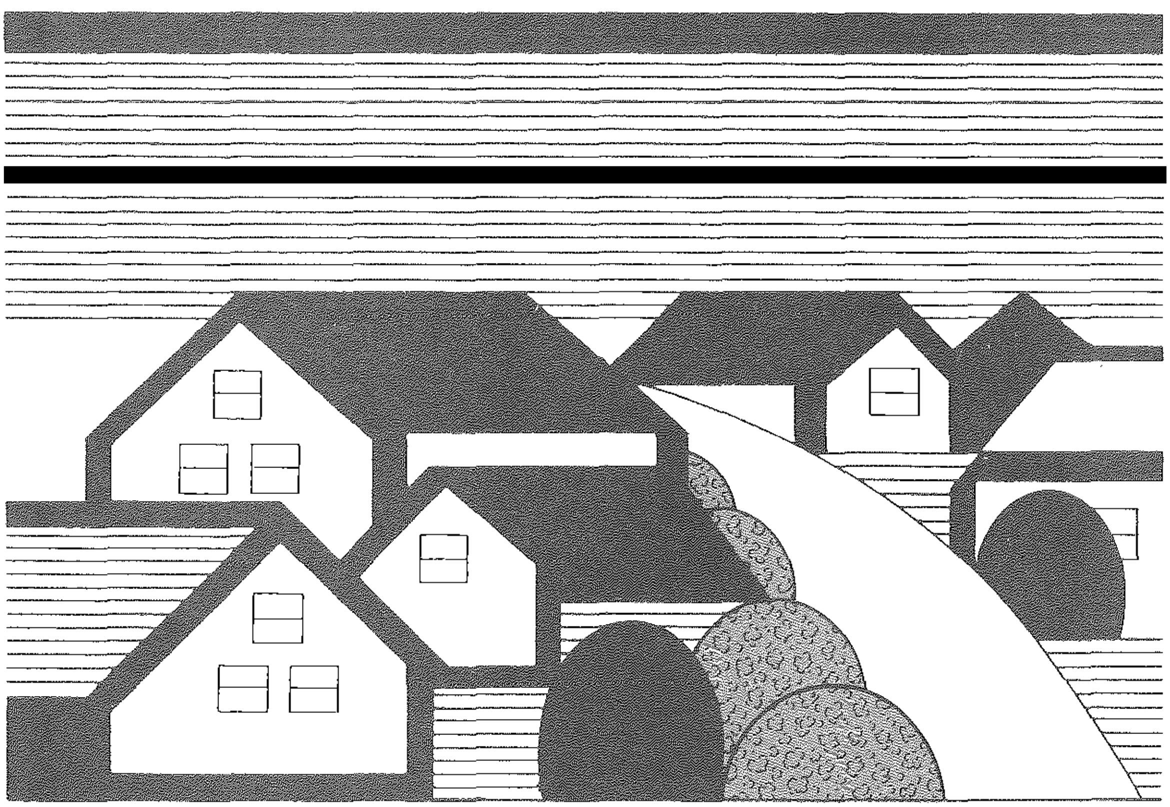
Final Environmental Impact Statement on New Energy-Efficient Homes Programs

Assessing Indoor Air Quality Options



SUMMARY

Bonneville Power Administration (Bonneville) promotes the construction of new energy-efficient homes through a variety of programs. These programs include such features as marketing and incentive payments to encourage the construction of energy-efficient homes, financial assistance to jurisdictions that incorporate Model Conservation Standards (MCS) into building codes, and implementation of a surcharge policy. The MCS are energy-efficient performance standards, which were development by the Northwest Power Planning Council (Council), for electrically heated buildings. The purpose of these programs is to save energy in new homes in compliance with provisions of the Pacific Northwest Electric Power Planning and Conservation Act, (Public Law 96-501). This law mandates Bonneville to:

* acquire all necessary energy resources to serve Northwest utilities choosing to acquire power from the agency (Bonneville serves customers in the states of Idaho, Montana, Oregon, and Washington);

* give cost-effective conservation highest priority in responding to the demand for electricity;

* promote the Council's MCS for the construction of energy-efficient homes as a means of controlling future electrical load growth though conservation;

* levy a rate surcharge on utilities that serve territories where reasonable steps are not being taken to save energy from MCS or other programs acceptable of Bonneville and the Council.

The primary environmental issue for new energy-efficient homes is whether tighter construction increases indoor air pollution, which may in turn adversely affect the health of the occupants. To date, Bonneville has prevented or reduced this possible effect in energy-efficient homes built under its programs by either (1) using mechanical ventilation (MV) systems to maintain ventilation rates at levels generally found in homes built when the MCS were first adopted (1983 building practice), or (2) requiring monitoring and mitigation of formaldehyde and radon levels above 0.1 parts per million (ppm) or 5 picoCuries per liters (pCi/l), respectively.

Bonneville has prepared this Environmental Impact Statement (EIS) to explore whether other approaches will control indoor air quality (IAQ) and still maintain cost-effective energy savings. Its purpose is to provide builders and consumers with more flexibility in how they control IAQ in energy-efficient homes. Different building techniques and mitigation measures are analyzed for their ability to maintain IAQ comparable to that found in 1983 building practices, or to even improve it.

THE PATHWAYS

To give builders and consumers the flexibility mentioned above, a broad menu of practical, commercially available methods are combined to make up 11 pathways.

All of the pathways start with consumer information packets; the offer of radon monitoring; radon preparatory construction measures (e.g., sub slab gravel, crawlspace ventilation) or required monitor and mitigation; exhaust fans in kitchens, bath, and utility rooms; and formaldehyde product standards for particle board and plywood. The proposed program includes two types of energy-efficient homes: homes with advanced air leakage control packages (i.e. air barriers) built with very low infiltration rates, and those with more standard air leakage control measures (i.e., well-sealed with caulking and weather stripping), which result in higher infiltration rates still below those of current practice.

The pathways are structured around three key variables:

1) the infiltration control applied to the house;

2) the mechanical ventilation (MV) system which includes four choices:

* no whole-house MV system,

* central mechanical ventilation with heat recovery (e.g., an air-to-air heat exchanger (AAHX)),

* central mechanical exhaust ventilation system with openings for outside air supply, and,

3) the occupants' operation of the MV system.

The three basic MV systems are sized to provide different capacities.

We analyzed two operating or control options. A continuously operating (24-hr) MV system results in a controlled, constant rate of air exchange. The other option is intermittent operation and assumes the system operates 8 hrs per day. The second option acts as a proxy in the analysis for control technologies that are not widely available and used today but that are likely to be commonplace in new homes by the year 2000. These controls would be triggered by such things as occupancy, humidity, and pollution levels. The pathways are described below.

<u>Pathway 1</u>. Pathway 1 applies to well-sealed energy-efficient houses that do <u>not have</u> air barriers as one of the conservation measures. This pathway has no central MV system, relying only on dehumidifiers and exhaust fans for spot ventilation. Since incidental mechanical ventilation is not included in the calculation of the total ventilation rates, the rates are the same as the design ventilation rates of well-sealed houses without air barriers: (0.35 and 0.28 effective air changes per hour (ACH) for upper and lower bound estimates, respectively).

<u>Pathway 2</u>. Pathway 2 also applies to houses with standard infiltration <u>control</u>, but whole-house, balanced, mechanical ventilation, operating continuously, is sized to give ventilation levels equivalent to, or greater than, current practice (0.53 and 0.47 effective ACH for upper and lower bound

estimates, respectively). Wall- or window-mounted balanced MV devices may be used, but several may be needed to achieve a "whole-house" effect.

Pathway 3. Pathway 3 is the counterpart of Pathway 2. Everything is the same, except that the MV system operates intermittently, for a total of 8 hrs per day instead of 24. This intermittent operation results in a lower effective ventilation rate than Pathway 2 (0.41 and 0.35 effective ACH for upper and lower bound estimates, respectively).

Pathway 4. In Pathway 4, the standard infiltration control is combined with a central exhaust MV system, instead of an AAHX, which intakes to supply makeup air. The system is operated continuously and provides an effective ventilation rate of 0.48 and 0.40 effective ACH for upper and lower bound estimates, respectively.

Pathway 5. Pathway 5 is identical to Pathway 4, except for intermittent operation of the MV system. The intake ports provide the makeup air to give a pressure-balanced system; the also provide better distribution of the makeup air because of their placement. Because of MV system is operated only 8 hrs per day, this pathway results in lower ventilation rates (0.42 and 0.34 effective ACH for upper and lower bound estimates, respectively).

Pathway 6. Pathway 6 is a variant of Pathway 5; its difference is the absence of intake vents for makeup air supply, which results in an unbalanced system and ventilation rates of 0.38 and 0.31 effective ACH for upper and lower bound estimates, respectively.

Pathway 7. Pathway 7 represents one of the extreme options but is included for completeness of analysis. It applies to houses that take the advanced approach to infiltration control by installing a continuous air barrier, but the home includes no MV system. Therefore, no ventilation is added to the natural infiltration rate, resulting in the lowest effective ventilation: 0.18 and 0.156 effective ACH for upper and lower bound estimates, respectively.

Pathway 8. Pathway 8 includes continuously operating, whole-house, balanced, mechanical ventilation in energy-efficient houses built with air barriers. Even with the air barrier, the continuously operating AAHX provides an effective ventilation rate equivalent to current practice: 0.43 and 0.40 effective ACH for upper and lower bound estimates, respectively.

Pathway 9. Pathway 9 is identical to Pathway 8 except the AAHX operates intermittently and this results in significantly lower ventilation rates: 0.27 and 0.23 effective ACH for upper and lower bound estimates, respectively.

Pathway 10. Pathway 10 consists of advanced air leakage control and a whole-house exhaust MV system operating continuously. Although the technology for an automatic continuously operating exhaust system is available and is in use in Europe, it has not yet been widely introduced in the U.S., but will be in the future. This pathway has effective ventilation rates of 0.34 and 0.31 for upper and lower bound estimates, respectively.

Pathway 11. Pathway 11 is identical to Pathway 10 except the exhaust MV system operates only 8 hours per day, resulting in lower ventilation rates: 0.26 and 0.22 effective ACH for the upper and lower bound estimates, respectively.

These 11 pathways encompass the extremes of options available for construction of new energy-efficient homes in the Pacific Northwest. While some pathways appear unreasonably extreme, they all fall within the bounds of reality and completely frame the range of reasonable choices.

BASELINE AND ALTERNATIVES

We chose four alternatives to assess and compare environmental effects. The alternatives were determined by the fundamental issue to be explored through the EIS: maintaining the current action, which relies on a limited approach for protecting IAQ (maintaining ventilation levels that prevailed in 1983 buildings through a combination of infiltration and mechanical ventilation) or broadening that approach by adding other means of protecting IAQ. The decision to be made is whether all or some IAQ pathways in the Proposed Action Alternative should be adopted. An important element of our analysis of the alternatives is BPA's forecast of new home construction. The forecast estimates both the number of new homes which will be built to prevailing building practice and the number built to energy-efficient standards for the planning period 1986 through 2006. These estimates are given in the following description of the Baseline and four alternatives.

Baseline: The Baseline is derived from BPA's 1986 medium housing forecast for the Pacific Northwest and the assumption that no energy-efficient new homes programs are underway. In the Baseline we estimate that, from 1986 through 2006, about 2.9 million people will live in some 603,300 new electrically heated single-family homes, some 356,800 multifamily homes, and 247,300 manufactured homes, all built to prevailing construction practices (hereafter referred to as "current practice homes").

No Additional Action Alternative: The No Additional Action Alternative represents the programs BPA has pursued since 1985 to promote new energy-efficient home construction. In these programs, BPA has supplied technical and sales training, cooperative advertising funds, a regional marketing campaign, financial incentives, and information about IAQ. There were also programs aimed at technology transfer and code adoption. Analysis of this alternative assumes the marketing program continues from 1986 through 2006.

By the year 2006 about 1.3 million people are forecast to be residing in 436,600 new single-family, electrically heated homes, of which 270,800 will be built to MCS standards; some 568,800 living in 354,900 multifamily homes, of which 228,100 are energy-efficient; and 570,400 living in 247,300 manufactured homes, of which 59,700 are energy-efficient.

Proposed Action Alternative: The Proposed Action Alternative is identical to the No Additional Action Alternative in regard to programs, number of participants, and number of current practice and energy-efficient homes built. However, unlike the other alternatives, this one has a broad menu of building techniques and mitigation measures from which builders and consumers may choose to maintain IAQ. These measures are combined into a set of 11 "pathways".

All pathways in the Proposed Action require the radon package, which includes the offer of radon monitoring to all households. It also includes the option of installing measures (a ventilated crawlspace and/or a gravel base under a concrete slab floor) which would allow more effective mitigation of radon if the homeowner chooses. Those homes for which builders have not installed these measures for post-construction source control require monitoring for radon concentrations. If monitoring shows that levels exceed 5 pCi/l, mitigation techniques must be installed and activated. We assume these actions reduce concentrations by 70 percent(%).

Preferred Alternative: Bonneville considered a number of factors in the selection of the Preferred Alternative; of these "decision factors", health effects and flexibility were particularly important. For the first criterion we chose pathways for which health effects were close enough to those in the Baseline to be within the range of uncertainty. For the second criterion, within the tolerances allowed by the uncertainty surrounding the health effects and energy savings, we wished to allow maximum flexibility for builders and utilities. Based on these criteria, BPA has chosen to include Pathways 3, 5, 6, 8, and 10 in its Preferred Alternative.

Environmentally Preferred Alternative: This alternative would result in the greatest overall health benefits to the population through reduced incidence of lung cancer and reduced impacts from alternative generating resources relative to the Baseline. Pathway 8 of the Proposed Action represents this alternative.

VENTILATION

Our analysis of health effects is based on estimated changes in ventilation rates in new energy-efficient homes compared to those in houses built to 1983 building practice. We realize the most important factor in determining the health risk for each individual is the actual pollutant concentration in the home, which is based on the interaction between strength of the pollutant source and the infiltration of fresh air. Because pollutant source strengths and indoor concentrations vary widely, we decided to use average pollutant concentrations with varying ventilation rates to estimate health effects. If one assumes that homes built under BPA's program would have been built without the program in approximately the same geographic locations and in the same basic configurations, then changes in ventilation rates becomes a valid predictor of health effects. As the purpose of this EIS is to compare impacts of various alternatives to those estimated for the Baseline, this assumption is acceptable.

Since 1984 BPA has measured ventilation rates in newly constructed homes as part of its Residential Standards Demonstration Program (RSDP). Two measurement techniques were used. The first technique uses a blower door and relies on the principle of fan pressurization to measure an equivalent leakage area (ELA), which can be thought of as the sum of all the holes and cracks of the building's envelope or exterior shell. The ELA was combined with typical weather conditions and additional assumptions regarding the home's physical characteristics to estimate an average natural ventilation rate for the heating season. The second technique uses a perfluorocarbon tracer (PFT) gas test, which measures a building's "effective" ventilation rate. The result of the PFT test includes the effects of a home's MV system and of occupant behavior in addition to the naturally occurring infiltration rate. Simply stated, the ventilation rate estimated by the PFT test is a tracer "dilution rate" and is called the "effective ventilation rate."

Baseline: These two ventilation measurement techniques have yielded different results within the same house. The fan pressurization test generally yields higher average results than the PFT test and spans a broader range of results. However, we believe these two tests are representative of the uncertainty in residential ventilation rates and our inability to accurately determine the rate in any particular home. If we could accurately measure a home's ventilation rate, we estimate the actual rate would lie between the results of these two tests. Given this uncertainty and guided by the previous testing experience, BPA elected to develop ventilation rates for the various alternatives in this EIS by establishing upper and lower bound estimates. These estimates not only account for the uncertainty but also provide a range of environmental effects which is linked to the actual distribution of ventilation rates found in homes. The values used for the Baseline and the other alternatives are given in Tables 1 through 3.

Note that for all three housing types (Tables 1-3) identical ventilation rates are given for the Baseline and the No Additional Action Alternative. Since the current New Energy-Efficient Homes Programs, which compose the No Additional Action Alternative, are designed to maintain IAQ at least comparable to 1983 practice, we assume the ventilation rates are the same as the Baseline.

Proposed Action Alternative: Ventilation rates for the Proposed Action Alternative depend on the characteristics of each pathway. For example, the alternative includes two types of energy-efficient homes: homes with advanced air leakage control packages (i.e., air barriers) built with very low infiltration rates (Pathways 7-11); and homes with more standard air leakage control measures (i.e., well-sealed with caulking and weatherstripping), which result in higher infiltration rates but still below those of 1983 practice (Pathways 1-6).

Three ventilation options are possible for both types of houses. That is, the five pathways for homes with air barriers, and thus very low infiltration rates, include the same ventilation options as the six pathways for homes with standard infiltration control (with one exception). Those options are: 1) whole-house mechanical ventilation with heat recovery (AAHX); 2) a central mechanical exhaust ventilation system (with controlled openings for outside air supply); or 3) no MV system, but only spot ventilation with exhaust fans. Houses with the standard infiltration control have one other option, a distributed exhaust system with a larger capacity fan but without controlled openings for outside air. This pathway requires houses to be checked and to achieve a minimum leakage area.

The amount of ventilation provided by these ventilation systems depends in part on their frequency of operation. They can operate either continuously or intermittently (up to 8 hr/day); the continuously operated system provides more ventilation than one operated intermittently.

Preferred Alternative: Ventilation rates for this alternative come from the various pathways selected to compose this alternative. In evaluating this alternative, we assume each pathway is represented by a percentage of all new energy-efficient homes. The percentages change over time to reflect increasing acceptance and use of newly available technology in MV systems.

Environmentally Preferred Alternative: The ventilation rate for this alternative is the same as that estimated for pathway 8 of the Proposed Action Alternative.

INDOOR AIR QUALITY

The primary environmental concern for the New Energy-Efficient Homes Programs is the effects that increased levels of indoor pollutants may have on residents' health. Many factors affect the level and mix of pollutants found in a given home, including source strength, house volume, occupant behavior, and ventilation rates. Reducing air flow between indoors and outdoors is an effective way to conserve energy, but may also contribute to the buildup of indoor pollutants.

To determine the health effects of the Baseline and the various alternatives, our quantitative analysis focuses on radon and formaldehyde. We emphasize these two pollutants for a number of reasons. 1) These two pollutants are commonly found indoors and have effects ranging from short-term discomfort to possible incidence of lung cancer. 2) Occupants have less control over the presence of these pollutants in homes than over other pollutants because their presence is affected only indirectly by occupant decisions and behavior and more by the pollutant source term. Pollutants inherent in the site or structure of a home are more likely to be affected by changes in ventilation than by occupant behavior; this is especially true of radon. Exposure to other pollutants results from individuals' choices such as smoking tobacco, using a wood stove, or pursuing particular hobbies. 3) Radon and formaldehyde levels can be affected through builders' construction decisions. 4) Finally, researchers have developed risk factors for these pollutants, making it possible to quantify lifetime cancer rates based on concentration levels over long time periods. Whereas no short-term or acute health symptoms are associated with radon, scientists have found that formaldehyde can cause severe, short-term health effects; however, these effects are not quantifiable and sensitivity among exposed persons differs.

Other indoor pollutants, such as respirable suspended particulates (RSP), combustion gases, household chemicals, moisture, and microorganisms also pose problems. However, our review of the scientific literature indicates insufficient information to accurately quantify or to be definitive about the health effects of these pollutants.

We based our analysis on concentration data taken from 1983 single-family homes monitored as part of BPA's RSDP. Using measured concentrations of radon and formaldehyde and estimated ventilation rates from these homes, along with prototypical sizes of single-family, multifamily, and manufactured homes, we estimated pollutant concentrations to match different ventilation rates and housing types.

Baseline: Radon measurements were divided into two groups, readings below and above 5 pCi/l, for the region's three climate zones. Then median values were obtained for each group by climate zone. For single-family homes, the group below 5 pCi/l had values of 0.41, 1.51, and 2.23 pCi/l for climate zones 1, 2, and 3, respectively. The median values for the group above 5 pCi/l were 10.52, 9.56, and 9.76 for the same climate zones. The number of homes falling into the respective groups was based on the percentage of measurements within the two groups by climate zone. Formaldehyde concentrations in single-family homes were 0.09 ppm for all three climate zones.

No Additional Action Alternative: Since the current New Energy-Efficient Homes Programs, which compose the No Additional Action Alternative, are designed to maintain IAQ at least comparable to 1983 practice, we assumed the concentrations in the various housing types are the same as the Baseline.

Proposed Action Alternative: Radon and formaldehyde concentrations for the different housing types were estimated for each pathway by increasing or decreasing the Baseline's concentrations by the magnitude of change in the ventilation rate. For example, single-family homes in Pathway 1 have ventilation rates 71 and 74% of the upper and lower estimates of the Baseline's ventilation rates. Since concentration is inversely proportional to ventilation rate, the concentrations for Pathway 1 will be 1.41 and 1.35 times those for the upper and lower values in 1983 houses. Using this approach, concentrations were estimated for each pathway for each housing type. If the measured concentrations exceeded 5 pCi/l and mitigation measures were implemented, we assumed concentrations were reduced by 70% to account for implementation of the radon package. However, we assume only a small fraction of the homes with estimated concentrations above 5 pCi/l will implement the radon mitigation measures, that is, only those homes with large measured radon concentrations.

Preferred Alternative: Since this alternative is made up of various pathways from the Proposed Action Alternative, concentrations are the same as those estimated for the selected pathways of that alternative.

Environmentally Preferred Alternative: Since Pathway 8 represents this alternative, the concentrations are the same as estimated for that pathway.

HEALTH EFFECTS

The key health effect in this EIS is lifetime lung cancer from exposure to radon and nasal cancer from formaldehyde. We estimated the number of lifetime cancers that may occur per 100,00 persons exposed to estimated concentrations of radon and formaldehyde that may be found in energy-efficient homes. We based our estimates of lifetime cancers on the assumption of a "linear dose-response": that the likelihood of contracting cancer is directly proportional to pollutant exposure (doubling the exposure doubles the risk). We assumed that cancers occur at all pollutant levels and that there is no threshold below which pollutant levels do not result in a risk of cancer. We also assumed that we can use information about risks from exposure to pollutants at high concentrations to calculate risks at low concentrations; this assumption is known as high-to-low dose extrapolation.

Lifetime cancer rates for each of the alternatives are listed in Tables 1 through 3 for single-family, multifamily, and manufactured homes. The numbers in these tables are an approximation of relative changes in risk and do not predict what will actually occur. We have estimated not the certain incidence of cancer for a given individual, but rather the probability of lung cancer for each individual of a larger population at risk.

Baseline: We estimated 335 lifetime cancers per 100,000 persons result from radon exposure and 10 lifetime cancers per 100,000 result from formaldehyde in single-family homes. In manufactured homes, a rate of 413 lifetime cancers per 100,000 persons is estimated for exposure to radon and 12 for formaldehyde. In multifamily homes the cancer rate from radon is 306 per 100,000 and 12 for formaldehyde.

No Additional Action Alternative: There is no increase in cancer rates from this Alternative because ventilation rates are identical to the Baselines's ventilation rates.

Proposed Action Alternative: We estimated the health effects for each pathway of the Proposed Action by using both the upper and lower estimates of ventilation and by assuming that all new energy-efficient homes would follow that pathway. The estimated lifetime cancer rates given in Tables 1 through 3 all show the same pattern: as ventilation rates decrease, cancer rates increase. For single-family homes, the lowest lifetime cancer rate from radon is 277-293 for Pathway 2, which has the highest ventilation rate. The highest lifetime cancer rate is 601-629 for Pathway 7, which has the lowest ventilation rate. Another pattern is more clearly illustrated in Figure 1: with the exception of Pathways 1, 7, 9, and 11, the health effects of the various pathways are not very different from one another, nor from the Baseline.

To help put the risk estimates of lifetime lung cancers in context, the following risk comparisons can be made. For each comparison we assume exposure occurs over a lifetime. Exposure to 1 pCi/l of radon is equivalent to the risk of contracting lung cancer from smoking 1/4 or less of a cigarette per day. Exposure to 5 pCi/l is equivalent to the risk from smoking about 1 cigarette per day.

Finally, the relative differences between the estimates are much more important than the absolute numbers for comparing the health effects of the alternatives to the Baseline. These numbers may not represent absolute or "true" effects, but they do convey the relative consequences of the various alternatives so BPA is able to select among alternative actions to make a policy decision.

TABLE 1. Environmental Impacts of the Alternative Actions Associated with Single-family Dwellings

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH: Energy-Efficient Homes	Ventilation Rate, ACH: 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons	Energy Savings, Average Megawatts
Baseline								
Upper	0	603,337	1,799,281	--	0.45	335	10	0
Lower	0	603,337	1,799,281	--	0.35	335	10	0
No Additional Action								
Upper	270,808	436,630	1,305,409	0.45	0.45	335	10	104
Lower	270,808	438,630	1,305,409	0.35	0.35	335	10	97
Proposed Action:								
Pathway 1								
Upper	270,808	438,630	1,305,409	0.32	0.45	398	12	113
Lower	270,808	436,630	1,305,409	0.26	0.35	385	12	107
Pathway 2								
Upper	270,608	436,630	1,305,409	0.52	0.45	293	9	107
Lower	270,808	436,630	1,305,409	0.45	0.35	277	8	87
Pathway 3								
Upper	270,808	436,630	1,305,409	0.37	0.45	360	11	115
Lower	270,808	436,630	1,305,409	0.31	0.35	343	11	95
Pathway 4								
Upper	270,808	436,630	1,305,409	0.45	0.45	319	10	78
Lower	270,808	438,630	1,305,409	0.38	0.35	304	9	74
Pathway 5								
Upper	270,808	436,630	1,305,409	0.38	0.45	354	11	97
Lower	270,808	438,630	1,305,409	0.31	0.35	343	11	93
Pathway 6								
Upper	270,808	436,630	1,305,409	0.35	0.45	373	12	105
Lower	270,608	436,630	1,305,409	0.29	0.35	358	11	99

TABLE 1. (Continued)

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH: Energy-Efficient Homes	Ventilation Rate, ACH: 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons[c]	Energy Savings, Average Megawatts
Pathway 7								
Upper	270,808	436,630	1,305,409	0.17	0.45	629	20	148
Lower	270,808	436,630	1,305,409	0.14	0.35	601	19	134
Pathway 8								
Upper	270,808	436,630	1,305,409	0.43	0.45	326	10	134
Lower	270,808	436,630	1,305,409	0.40	0.35	295	9	114
Pathway 9								
Upper	270,808	436,630	1,305,409	0.21	0.45	537	17	140
Lower	270,808	436,630	1,305,409	0.18	0.35	499	16	120
Pathway 10								
Upper	270,808	436,630	1,305,409	0.34	0.45	381	12	113
Lower	270,808	436,630	1,305,409	0.30	0.35	351	11	99
Pathway 11								
Upper	270,808	436,630	1,305,409	0.24	0.45	486	15	131
Lower	270,808	436,630	1,305,409	0.20	0.35	462	14	119
Preferred Alternative								
Upper	270,808	436,630	1,305,409	N/A	N/A	352	11	111
Lower	270,808	436,630	1,305,409	N/A	N/A	352	10	100
Environmentally Preferred Alternative								
Upper	270,808	436,630	1,305,409	0.43	0.45	326	10	134
Lower	270,808	436,630	1,305,409	0.40	0.35	295	9	114

(a) Total number of single-family homes projected through 2006.

(b) Lifetime cancer rates include both energy-efficient and baseline homes. The net effect of BPA's activities can be estimated by subtracting the lifetime cancer rate of the Baseline from those of the alternatives.

(c) HCHO=formaldehyde

TABLE 2. Environmental Impacts of the Alternative Actions Associated with Multifamily Dwellings

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH Energy-Efficient Homes	Ventilation Rate, ACH 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons	Energy Savings, Average Megawatts
Baseline								
Upper	0	356,889	573,395	--	0.30	306	12	0
Lower	0	356,889	573,395	--	0.20	306	12	0
No Additional Action								
Upper	228,159	353,991	568,819	0.30	0.30	306	12	28
Lower	228,159	353,991	568,819	0.20	0.20	306	12	21
Proposed Action:								
Pathway 1								
Upper	228,159	353,991	568,819	0.19	0.30	419	16	36
Lower	228,159	353,991	568,819	0.15	0.20	371	15	27
Pathway 2								
Upper	228,159	353,991	568,819	0.45	0.30	240	9	32
Lower	228,159	353,991	568,819	0.40	0.20	208	8	21
Pathway 3								
Upper	228,159	353,991	568,819	0.24	0.30	355	14	35
Lower	228,159	353,991	568,819	0.20	0.20	306	12	24
Pathway 4								
Upper	228,159	353,991	568,819	0.47	0.30	235	9	16
Lower	228,159	353,991	568,819	0.42	0.20	203	8	11
Pathway 5								
Upper	228,159	353,991	568,819	0.29	0.30	312	12	28
Lower	228,159	353,991	568,819	0.24	0.20	273	11	21
Pathway 6								
Upper	228,159	353,991	568,819	0.24	0.30	355	14	29
Lower	228,159	353,991	568,819	0.19	0.20	316	12	24

TABLE 2. (Continued)

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH: Energy-Efficient Homes	Ventilation Rate, ACH: 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons	Energy Savings, Average Megawatts
Pathway 7								
Upper	228,159	353,991	568,819	0.12	0.30	599	24	39
Lower	228,159	353,991	568,819	0.11	0.20	468	18	29
Pathway 8								
Upper	228,159	353,991	568,819	0.37	0.30	268	11	36
Lower	228,159	353,991	568,819	0.36	0.20	218	9	25
Pathway 9								
Upper	228,159	353,991	568,819	0.15	0.30	502	20	39
Lower	228,159	353,991	568,819	0.14	0.20	390	15	28
Pathway 10								
Upper	228,159	353,991	568,819	0.41	0.30	253	10	22
Lower	228,159	353,991	568,819	0.40	0.20	208	8	13
Pathway 11								
Upper	228,159	353,991	568,819	0.21	0.30	390	15	33
Lower	228,159	353,991	568,819	0.19	0.20	316	12	23
Preferred Alternative								
Upper	228,159	353,991	568,819	N/A	N/A	304	12	30
Lower	228,159	353,991	568,819	N/A	N/A	260	10	24
Environmentally Preferred Alternative								
Upper	228,159	353,991	568,819	0.37	0.30	268	11	36
Lower	228,159	353,991	568,819	0.36	0.20	218	9	25

(a) Total number of multifamily homes projected through 2006.

(b) Lifetime cancer rates include both energy-efficient and baseline homes. The net effect of BPA's activities can be estimated by subtracting the lifetime cancer rate of the Baseline from those of the alternatives.

TABLE 3. Environmental Impacts of the Alternative Actions Associated with Manufactured Homes

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH Energy-Efficient Homes	Ventilation Rate, ACH 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons	Energy Savings, Average Megawatts
Baseline								
Upper	0	247,293	570,410	--	0.41	413	12	0
Lower	0	247,293	570,410	--	0.41	413	12	0
No Additional Action								
Upper	59,687	247,293	570,410	0.41	0.41	413	12	39
Lower	59,687	247,293	570,410	0.41	0.41	413	12	37
Proposed Action:								
Pathway 1								
Upper	59,687	247,293	570,410	0.31	0.41	432	13	37
Lower	59,687	247,293	570,410	0.29	0.41	440	13	36
Pathway 2								
Upper	59,687	247,293	570,410	0.53	0.41	384	11	35
Lower	59,687	247,293	570,410	0.50	0.41	388	11	34
Pathway 3								
Upper	59,687	247,293	570,410	0.36	0.41	416	12	35
Lower	59,687	247,293	570,410	0.34	0.41	422	12	33
Pathway 4								
Upper	59,687	247,293	570,410	0.46	0.41	394	11	37
Lower	59,687	247,293	570,410	0.43	0.41	399	12	35
Pathway 5								
Upper	59,687	247,293	570,410	0.38	0.41	411	12	29
Lower	59,687	247,293	570,410	0.35	0.41	419	12	28
Pathway 6								
Upper	59,687	247,293	570,410	0.35	0.41	419	12	32
Lower	59,687	247,293	570,410	0.32	0.41	428	13	31

TABLE 3. (Continued)

Alternative	New Energy-Efficient Homes(a)	Total Electric Additions(a)	Affected Population	Ventilation Rate, ACH Energy-Efficient Homes	Ventilation Rate, ACH 1983 Practice Homes	Rn-Induced Lifetime Cancers/ 100,000 Persons[b]	HCHO-Induced Lifetime Cancers/ 100,000 Persons	Energy Savings, Average Megawatts
Pathway 7								
Upper	59,687	247,293	570,410	0.16	0.41	539	16	33
Lower	59,687	247,293	570,410	0.13	0.41	578	18	32
Pathway 8								
Upper	59,687	247,293	570,410	0.42	0.41	401	12	41
Lower	59,687	247,293	570,410	0.39	0.41	408	12	40
Pathway 9								
Upper	59,687	247,293	570,410	0.20	0.41	495	15	40
Lower	59,687	247,293	570,410	0.17	0.41	526	16	38
Pathway 10								
Upper	59,687	247,293	570,410	0.34	0.41	422	12	40
Lower	59,687	247,293	570,410	0.30	0.41	436	13	39
Pathway 11								
Upper	59,687	247,293	570,410	0.23	0.41	473	14	35
Lower	59,687	247,293	570,410	0.19	0.41	504	15	34
Preferred Alternative								
Upper	59,687	247,293	570,410	N/A	N/A	419	12	34
Lower	59,687	247,293	570,410	N/A	N/A	410	12	35
Environmentally Preferred Alternative								
Upper	59,687	247,293	570,410	0.42	0.41	401	12	41
Lower	59,687	247,293	570,410	0.39	0.41	400	12	40

(a) Total number of manufactured homes projected through 2006.

(b) Lifetime cancer rates include both energy-efficient and baseline homes. The net effect of BPA's activities can be estimated by subtracting the lifetime cancer rate of the Baseline from those of the alternatives.

Preferred Alternative: The estimated number of lifetime cancers due to exposure to radon is similar to the values estimated for the Baseline. Estimates for single-family homes is slightly higher, while estimates for multifamily and manufactured homes are slightly lower.

Environmentally Preferred Alternative: The estimated number of lifetime cancers is lower than estimates for the Baseline. This is consistent with the Pathway's (8) higher ventilation rates.

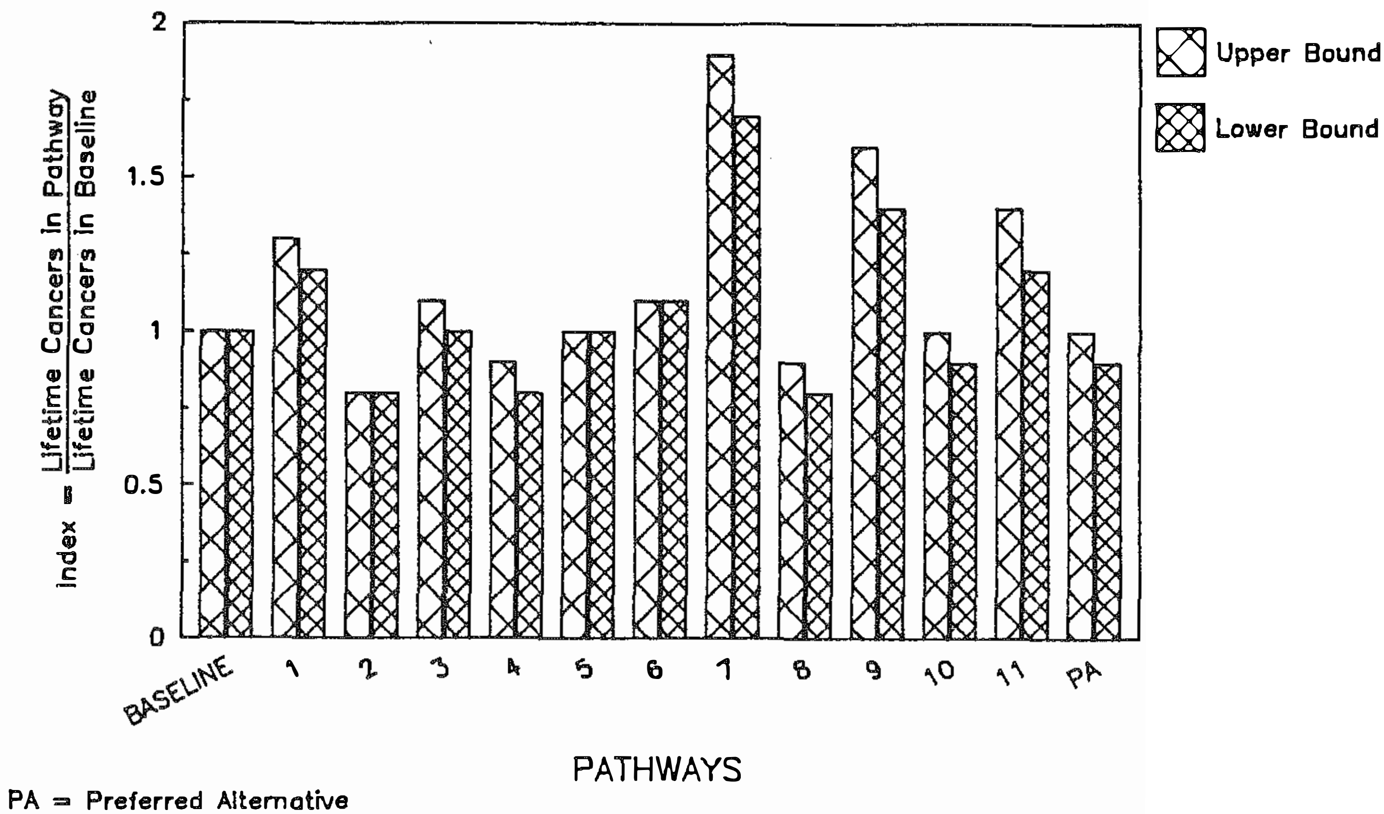


Figure 1. Health Effects Associated with Pathways

SOCIAL AND ECONOMIC IMPACTS

The primary social and economic impacts are in the areas of fuel choice and energy savings. Fuel choice refers to the decision made by consumers regarding which fuel (electricity or other fuels) they will use to heat their home. If new electrically heated homes are required to be built to energy-efficient standards while homes with other fuel types are not so required, then homes using other fuels could have a lower purchase price than electrically heated homes. However, energy-efficient homes will have lower energy costs over the life of the structure, leading to lower life-cycle costs. Still, the greater first-time costs may induce some consumers to choose natural gas or oil, instead of electricity, to heat new homes.

Baseline: We assumed no energy savings for the Baseline. This is consistent with the assumption that, without New Energy-Efficient Homes Programs, homes in the future are constructed to prevailing building practices.

No Additional Action Alternative: Programs forming this alternative are estimated to result in energy savings of 155 to 171 average megawatts at a cost of $233 million.

The number of households choosing a fuel other than electricity because of an energy-efficiency standard for electrically-heated new homes is given in BPA's 1986 medium growth forecast of new homes. The number of new single-family and multifamily homes built from 1986 through 2006 that choose an alternative fuel instead of using electric space heat is 169,605, or 18% of the Baseline. Paying incentives dampens the effect of what would otherwise occur with only an energy efficiency standard and no incentive.

Proposed Action Alternative: For this alternative, estimated energy savings range from a low of 113 average megawatts to a high of 228 average megawatts. Costs range from approximately $229 million to about $522 million. These figures vary with each of the pathways. See Figures 2 and 3 and Tables 1 through 4.

Preferred Alternative: For this alternative, estimated energy savings range from 158 to 165 average megawatts depending on whether the upper or lower bound of the ventilation estimate is used. Expenditures for this alternative are approximately $379 million.

Environmentally Preferred Alternative: For this alternative, estimated energy savings range from 179 to 211 average megawatts, depending on whether the upper or lower bound of the ventilation estimate is used, at a cost of $522 million.

AVOIDED IMPACTS

Avoided impacts refer to environmental consequences that are avoided because electric generating resources are not required to supply the energy that is being supplied through implementation of the New Energy-Efficient Homes programs. Both the Council's resource portfolio and BPA's 1986 resource strategy indicate that small hydropower would be the next resource to be developed if the conservation resource were not acquired. Other potential resources include cogeneration, combustion turbine generators, and coal-fired generators. Some of the avoided impacts of not developing these other resources are summarized in Table 5.

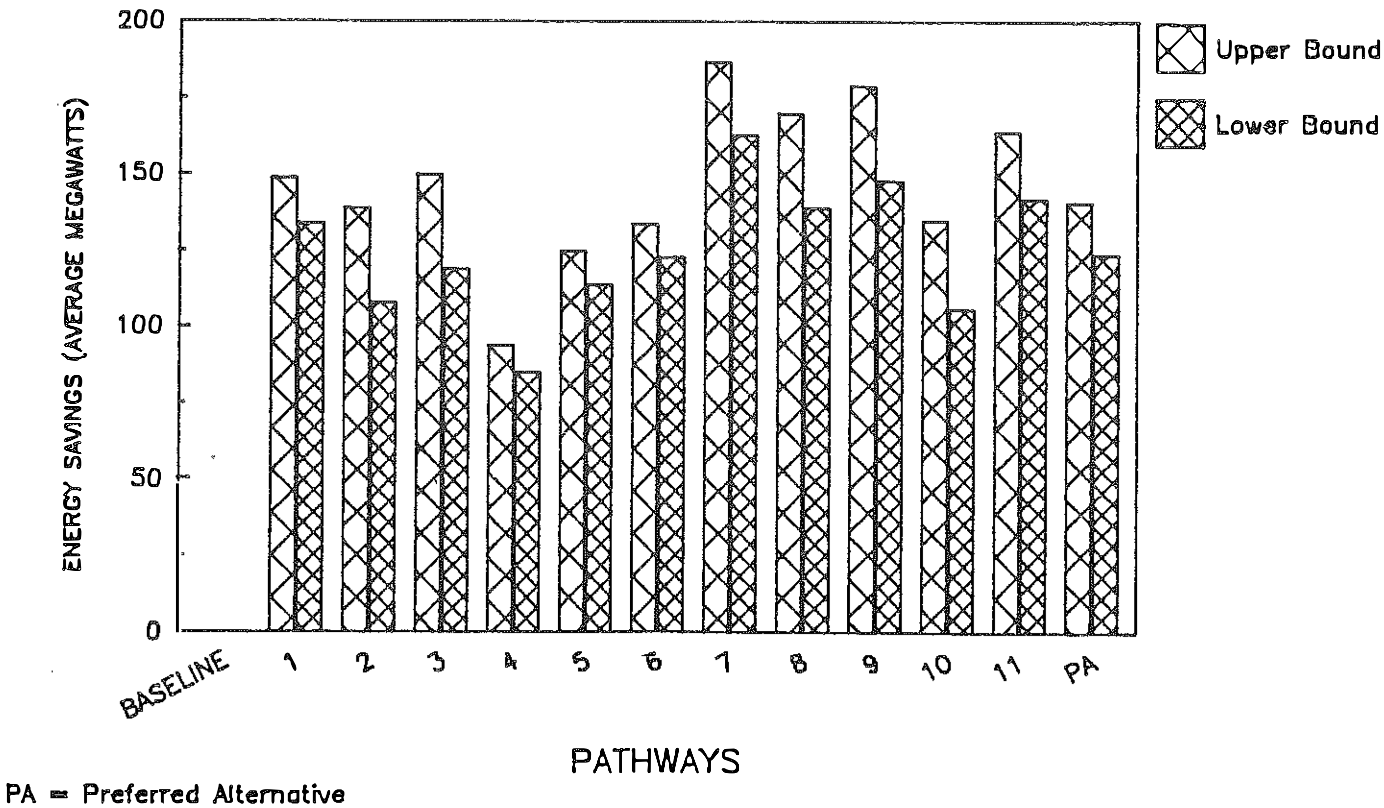


Figure 2. Energy Savings Associated with Pathways

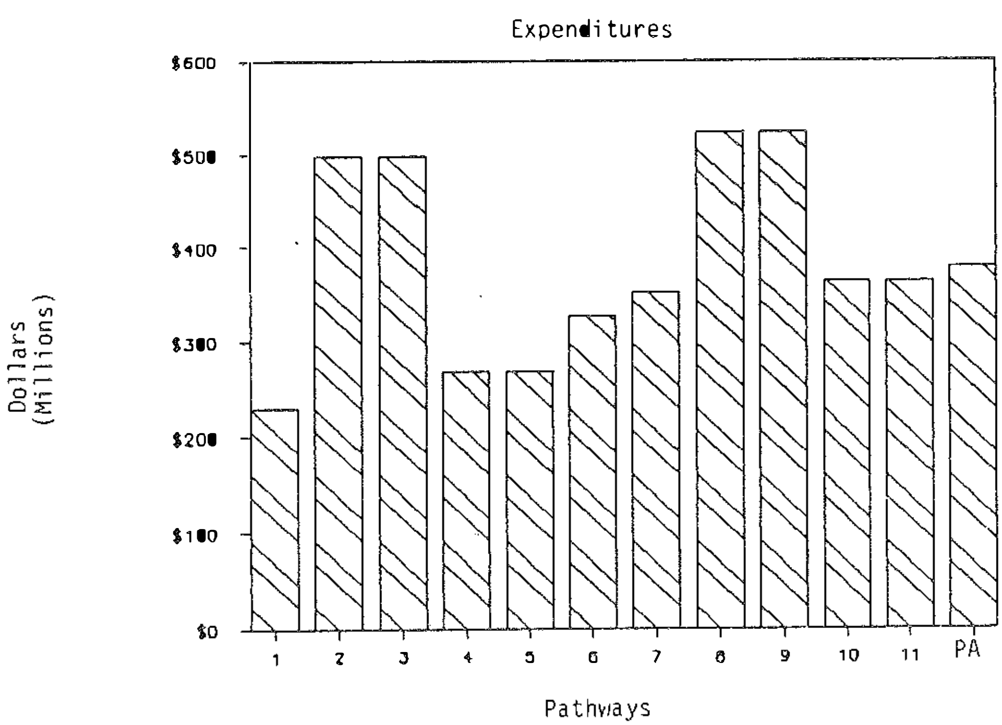


Figure 3. Expenditures Associated with Pathways

TABLE 4. Regional Expenditures of the Alternatives

Alternative	Expenditures (1986 Million $)
No Additional Action	233
Proposed Action Pathways	
1	229
2	497
3	497
4	268
5	268
6	326
7	351
8	522
9	522
10	390
11	390
Preferred Alternative	379
Environmentally Preferred Alternative	522

TABLE 5. Total Avoided Impacts of Alternative Actions[a]

	Small Hydropower	Municipal Solid-Waste Cogeneration	Combustion Turbine	Coal-Fired Plant
No Additional Action				
Public mortality	--	77[b]	0	.40
Public injury and morbidity	--	--	.40	3.4
Solid waste (tons)	0	(c)	Negligible	470,000
Air emissions (tons)	Negligible	7,330	2,176	4,810
Water use/consumption	2.6 M acre-ft	280 M gal	504 acre-ft	1,168 M gal
Land use (acres)	9,050	137	25	229
Proposed Action Pathway 4				
Public mortality	--	54[b]	0	.30
Public injury and morbidity	--	--	.30	2.5
Solid waste (tons)	0	(c)	Negligible	345,000
Air emissions (tons)	Negligible	5,292	1,477	3,446
Water use/consumption	2.0 M acre-ft	209 M gal	357 acre-ft	825 M gal
Land use (acres)	6,523	98	17	160
Proposed Action Pathway 7				
Public mortality	--	104[b]	0	.55
Public injury and morbidity	--	--	.55	4.7
Solid waste (tons)	0	(c)	Negligible	620,000
Air emissions (tons)	Negligible	9,939	2,930	6,487
Water use/consumption	3.7 M acre-ft	390 M gal	670 acre-ft	1,570 M gal
Land use (acres)	12,555	188	35	314

(a) Baseline not included because no energy savings are assumed. Estimates based on energy savings of site-built homes only.

(b) Mortality and morbidity are combined, based on linear dose response.

(c) Burning solid waste as fuel results in net reduction of solid waste requiring disposal.