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SUMMARY OF COMMERCIAL CONSERVATION
PROGRAMS ENVIRONMENTAL ISSUES AND
PROGRAM CONSISTENCY

M. C. Beachler

June 1989

Prepared for
the Office of Energy Resources
Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

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SUMMARY

Pacific Northwest Laboratory (PNL) conducted this study for the Office of Energy Resources at the Bonneville Power Administration. This report summarizes environmental issues that the Bonneville Power Administration's conservation programs for commercial conservation programs may encounter. This document is intended as an introduction to help environmental and program staff decide what types of additional study and environmental documentation may be needed for further program support.

One of the key questions facing commercial programs is whether they are pushing or possibly exceeding the limits of activities defined by current environmental documents.

It appears that programs may now exceed the environmental scope in three areas:

- serving building types that have not yet been assessed in an environmental document
- incorporating conservation measures that have not yet been assessed
- gradually modifying the procedures established in environmental documents.

New environmental documentation may be needed if the programs are to continue unabated or be expanded.

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SUMMARY OF COMMERCIAL CONSERVATION PROGRAMS ENVIRONMENTAL ISSUES AND PROGRAM CONSISTENCY

1.0 INTRODUCTION

The Northwest Power Planning Act authorizes the Bonneville Power Administration to acquire all necessary energy resources to serve Northwest utilities choosing to acquire power from the agency and, further, to give conservation the highest priority in responding to the demand for electricity. To help meet this mandate, the agency has established conservation programs, including activities for the commercial sector.

This report summarizes the environmental issues that Bonneville's commercial building conservation programs may encounter. Rather than exhaustively describing these issues, this document provides an introduction to help environmental and program staff decide what types of additional study and environmental documentation may be needed for further program support. The report concentrates on issues that Bonneville may face in future environmental documents. Issues such as the proper use and installation of high-pressure sodium lamps are important, but, because Bonneville has a documented policy in place, are discussed only briefly here.

One of the key questions confronting commercial programs is whether they have pushed the limits of the scope of activities defined by the current environmental documents. Another important question is whether new information warrants a change in the scope to address new or unforeseen issues. With these questions as a backdrop, the purposes of this analysis are as follows:

- to determine the scope of activities defined in current environmental documents
- to compare the environmental scope of activities with past and present program activities
- to review new information that may warrant changing the scope of activities
- to provide information to aid program planning in light of potential environmental issues and new information.

2.0 CHARACTERIZATION OF THE COMMERCIAL SECTOR AND BONNEVILLE PROGRAMS

Bonneville's main motive for pursuing conservation programs in the late 1980s has been to prepare the agency to acquire cost-effective conservation when the present power surplus ends and additional electrical resources are needed. Thus, programs have been targeted where the most could be learned, the savings are not likely to occur without Bonneville's intervention, and a near-term effort is likely to help make larger acquisition efforts possible in the future. Bonneville's past efforts have been a series of selective experiments to better understand the commercial sector. The current emphasis is to apply past lessons where they can have the most impact with the least cost.

The material presented in the section is taken from Bonneville's Commercial Sector Activities Notebook, which was prepared by the Commercial Programs Branch, Division of Resource Management (Bonneville 1988). Refer to this document for more complete descriptions and explanations of program activities and projected acquisitions.

2.1 COMMERCIAL SECTOR CHARACTERIZATION

The commercial sector, including street lighting, made up about 23% of Bonneville's firm regional sales in 1986, accounting for the total 15,140 average megawatts sold. Bonneville's Base Case Energy Forecast indicates that commercial loads will increase by approximately 50% over the next 20 years. The actual rate of growth may be substantially greater or less, depending on the condition of the region's economy.

Though there is a great deal of uncertainty in projecting potential energy savings, Bonneville estimates that about 900 average megawatts could be saved if all conservation measures are achieved that cost less than 50 mills per kilowatt-hour saved. About half of these savings could come from consumers with Bonneville taking no action. The remaining potential is unlikely to occur unless Bonneville provides some form of assistance. Offices, retail stores, and restaurants are critical components of the commercial conservation potential. These three building types account for more than half of the potential savings in both new and existing buildings.

In general, conservation measures in three categories--lighting; structure; and heating, ventilation, and air conditioning (HVAC) and other--will provide the bulk of potential savings. Projections of conservation from improvements in these three areas show that 446 average megawatts will be available in existing buildings for the year 2005. For new buildings, this projection is 176 average megawatts. Although the figure is smaller for new buildings, these potential load reductions are given a high priority because they are considered "lost opportunity resources." The lost opportunity refers to conservation measures that are most easily installed, and in some cases may be installed only during new construction or major renovation. Thus, conservation that is not captured during construction may be lost.

The HVAC and other savings category includes all improvements to heating systems, cooling systems, and fans. This category includes better scheduling controls for equipment; advanced equipment, such as variable air-volume systems; radiant heaters; waste-heat recovery systems; and economizer cycles. Measures to make grocery-store refrigeration equipment more efficient are also included in this category. Bonneville's planners project that, for the year 2005, HVAC and other measures will amount to 301 average megawatts of savings in existing buildings, 83 average megawatts in new buildings.

Lighting measures include efficiency improvements to interior and exterior lighting systems. Typical measures include the removal of excessive lighting, installation of efficient ballasts and bulbs, and improved lamp reflectors and controls. Some of the savings from lighting measures comes from decreased air-conditioning loads because inefficient lighting systems produce waste heat that must be removed from buildings. Lighting measures in existing and new buildings will account for 129 and 77 average megawatts projected savings, respectively, in the year 2005.

Structure measures are improvements to building shells, such as wall and roof insulation, double glazing, tinted glazing, caulking and weatherstripping. In many individual buildings, especially small ones, shell measures can be quite important. However, regionally these measures do not amount to large savings. Bonneville's planners project 16 average megawatts for each of existing and new buildings available in the year 2005.

2.2 DESCRIPTION OF COMMERCIAL SECTOR PROGRAMS

Bonneville administers five different types of commercial programs. The following describes the purposes of each program type.

- acquisitions - programs with the primary purpose of purchasing energy to serve the Bonneville Administrator's obligation, for example, Street & Area Lighting, Institutional Buildings, and Commercial/Industrial Lighting Conservation
- capability development - programs that are designed to develop and test administrative systems, incentives, quality- and cost-control procedures, and delivery approaches - These programs are generally limited in scope and duration. Examples include Purchase of Energy Savings and the Commercial Incentive Pilot Program.
- technical assistance - programs and projects designed to support energy conservation through education and information, including the Commercial Audit Program, Smart Design, Early Adopter, and the Lighting Laboratory
- research, development and demonstration - projects designed to answer specific questions or to examine specific subjects through highly structured investigation or experimentation - These investigations focus on the discovery and interpretation of facts, revisions of accepted theories, or the practical applications of new or revised technologies and theories. Examples of these types of studies are the Carbon Dioxide-Based Ventilation Control System, Indoor Air Quality Measurements in 38 Pacific Northwest Commercial Buildings, the End-Use Load and Consumer Assessment Program, Screw Compressor Super Market Refrigeration System, and the Energy Edge Program.
- special investigations/studies - these entail an exploratory analysis, or an examination and analysis, of phenomena, developments, or questions, followed by the preparation of a written report describing the findings. These investigations include the Indoor Air Quality Audits for Commercial Buildings and Measure Life of Energy Conservation Measures.

Several of these programs are of particular interest for this review of environmental consistency because they offer specific examples of how environmental obligations have been implemented or of future trends that programs may follow. Specific cases are discussed more fully in Chapter 4 of this report.

3.0 ENVIRONMENTAL DOCUMENTATION AND OBLIGATIONS

The environmental obligations now tied to the various commercial conservation programs have as a common root the 1982 Environmental Assessment of Energy Conservation Opportunities in Commercial-Sector Facilities in the Pacific Northwest (EA) and its accompanying Finding Of No Significant Impact (FONSI) (Bonneville 1982a, b). These documents defined a scope of activities that the programs were to cover and identified procedures based on then-current information, to ensure there were no significant environmental impacts.

Taking the EA as a starting point, environmental procedures and obligations have continued to evolve through a series of Brief Memorandums. Bonneville writes each of these as an environmental document with a narrow focus for a specific pilot program or study, or for a specific type of program, e.g., design assistance. The current obligations and procedures are contained in a document called Environmental Requirements for Existing Commercial and Institutional Buildings (Bonneville 1986). These environmental requirements are mandatory for existing buildings and are recommended for programs affecting new buildings.

This chapter summarizes the EA's scope and examines its fit with current information as well as present program and environmental activities. Chapters 5 and 6 give greater detail on new environmental issues that may suggest that the EA's scope should be modified.

3.1 ENVIRONMENTAL ASSESSMENT SCOPE SUMMARY

Three specific programs are covered by the EA:

- the Institutional Buildings Program, which was to run for 5 years and included nonprofit existing buildings
- the Commercial Audit Program, which was to run for 15 years and included all types of existing buildings
- the Financial Incentives Component, which was to run for 15 years and would offer financial incentives to commercial building owners for installing cost-effective conservation measures identified through energy audits.

The key environmental concern identified in the EA and FONSI was the potential adverse effect on indoor air quality (IAQ) that may result from Bonneville's conservation actions in commercial buildings. In addition to indoor air quality, the documents also covered issues such as

- low- and high-pressure sodium vapor lights
- toxic transfer fluids in solar heating systems
- the disturbance or removal of asbestos
- processes for assessing geothermal projects for commercial buildings
- historical preservation
- training requirements for auditors.

3.1.1 IAQ Analysis and Procedures

The EA and FONSI analyzed radon, formaldehyde, and combustion products for 12 existing building types and an "Other" category. Each building type was further disaggregated into small, medium, and large square footage areas. Pollutant concentrations were calculated for each building type using a mass balance model and estimates of baseline pollutant concentrations and ventilation rates. A mass balance model is based on the inverse relationship between pollutant concentration and ventilation rate, given a steady source term for the pollutant. The mechanics of this relationship are such that, for every halving of ventilation, there is a doubling of pollutant concentration.

Baseline pollutant concentrations were estimated for each building type using worst-case and typical-case assumptions for emissions from various sources. Examples of radon sources included soil, concrete, and well water. Ventilation rates in the existing building stock were assumed to be seven times the rates specified by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in Standard 62-1981 for nonsmoking areas, and two times the rates set for smoking areas (ASHRAE 1981).

The EA lists the following key programmatic requirements for maintaining indoor air quality. The main thrust of these requirements is that ventilation rates are to be calculated and maintained to ensure that radon, particulates, and formaldehyde concentrations did not exceed criteria levels.

- Building air exchange rates were to be established at the time of energy audits. Auditors were to calculate the lowest limits to which air exchange rates could be reduced for each area of a building and still provide enough ventilation to keep radon and particulate levels less than the criteria values described below.
- Building air exchange rates were to be set sufficiently high to ensure that radon did not exceed the criterion value of 3 picocuries per liter (pCi/l) and that particulate concentrations did not exceed 75 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$).
- In clothing stores and funeral homes, air exchange rates were to be set to ensure that formaldehyde concentrations did not exceed $120 \mu\text{g}/\text{m}^3$, or conservation measures that reduced air flow were to be disallowed.

3.1.2 Other Environmental Requirements

Other environmental requirements in the EA and FONSI, covering lighting, solar installations, asbestos, geothermal projects, historical requirements, and training, were as follows:

- Low-pressure sodium vapor lights were not to be installed indoors because of the unpleasant monochromatic light produced.
- High-pressure sodium vapor lamps were to be used indoors only for general lighting in warehouses and industrial buildings.
- Toxic transfer fluids were not permitted in solar heating systems.
- Asbestos already in place was not to be disturbed or removed.
- Geothermal projects for commercial buildings were to receive individual site-specific assessments prior to funding.
- Historical properties were to be protected through compliance with applicable federal laws and consultation with State Historic Preservation officers.
- In the Institutional Buildings Program, technical assistance analyses were to be conducted by licensed architects or engineers. The analyses were also to be reviewed by licensed engineers hired by the states, and licensed mechanical engineers were to perform onsite inspections of all retrofit projects.
- For the Commercial Audit Program and Financial Incentives Component, Bonneville was to develop workbooks that referred to applicable building codes and standards for public health and safety. Energy auditors were also to receive specific training regarding applicable building codes and standards for public health and safety in buildings.

3.1.3 Conservation Measures

The EA included program conservation measures such as efficiency improvements for lighting systems, motors, building heat gains and losses, water heating, boilers, refrigeration, and heating and ventilating systems. About 130 specific retrofit conservation measures and 155 operation and maintenance measures are listed in the EA. A listing of all specific conservation measures is included as Appendix A of this document.

3.2 EVOLUTION OF ENVIRONMENTAL REQUIREMENTS

Since the EA and FONSI were published in 1982, several Brief Memorandums and other actions have modified the environmental requirements. This section briefly discusses the evolution of the changes and summarizes the requirements as they now stand.

3.2.1 Indoor Air Quality Procedures

The indoor air quality requirements outlined in the EA and FONSI were based on the assumption that a methodology could be developed for calculating ventilation rates for each building participating in Bonneville's programs. After the FONSI was issued, Bonneville adopted a set of interim guidelines stating that conservation measures that reduced the supply of outside air were excluded from the commercial and institutional programs. In 1984, about a year and a half after issuing the FONSI, Bonneville concluded that a practical methodology could not be devised and prepared a new strategy (Love 1984).

The new strategy listed three requirements. First, fresh air ventilation rates could be reduced to conform to the smoking limit defined in ASHRAE Standard 62-81. However, buildings were to be screened for potential pollution sources, and any potential problems were to be corrected prior to retrofit. Second, for buildings with ventilation rates below the ASHRAE 62-81 smoking level but greater than or equal to state or local code, retrofit measures could be applied only to the extent that fresh air supplied to occupants remained unchanged. Third, buildings with ventilation rates below applicable state or local code requirements were required to meet state or local code before

ventilation retrofit measures were applied. The procedure also ensured that buildings were checked for properly operating HVAC systems.

The 1984 strategy was also found to be too restrictive and not practical to implement (Love 1985). In 1985, Bonneville proposed to defer to local fresh-air codes for naturally ventilated buildings and to the greater of either ASHRAE 62-81 or local codes for mechanically ventilated buildings. Bonneville noted in its environmental documentation supporting these changes that some energy conservation measures may improve IAQ. Improved ventilation control techniques were given as an example. The document also noted that Bonneville would require that ventilation systems be tested and corrected, if necessary, prior to HVAC system retrofits that affect ventilation rates in occupied spaces. Bonneville further noted that, because of the requirement that buildings supply ventilation at a rate equal to the greater of either ASHRAE Standard 62-81 or local code, many buildings were likely to increase their minimum ventilation rates. The document also provides the rationale that pollutant levels in commercial buildings are typically low, health effects resulting from increases in pollutant levels are viewed as insignificant, and program provisions may result in improved indoor air quality.

The 1985 Brief Memorandum forms the basis for the current environmental requirements related to IAQ and ventilation as listed in Environmental Requirements for Existing Commercial and Institutional Buildings (Bonneville 1986). These requirements are summarized below.

- In mechanically ventilated buildings, a qualified analyst shall visually inspect the HVAC system and identify deficiencies that could affect ventilation air rates. All deficiencies must be corrected prior to Energy Conservation Measure (ECM) installation.
- In mechanically ventilated buildings, ventilation systems shall be tested if ECMs will decrease the amount of ventilation air during occupied periods. Minimum ventilation rates must meet or exceed current local code or ASHRAE 62-81, whichever is greater.
- Naturally ventilated buildings must, at a minimum, meet the Uniform Building Code (UBC) ventilation requirements.
- Apartments are to be monitored for radon prior to ECM installation. If any single apartment in the building has radon levels above 5 pCi/l, the

building would not qualify for ECMs affecting natural ventilation or ventilation air.

- All apartments receiving ECMs affecting natural ventilation or ventilation air shall have IAQ stickers placed in an easily visible location.
- All occupants of these apartments are to receive an IAQ booklet.

As the rationale for these requirements, Bonneville noted the following points in its environmental documentation: the requirement that buildings supply ventilation at a rate equal to the greater of either ASHRAE Standard 62-81 or local code is likely to result in many buildings having increased minimum ventilation rates; pollutant levels in commercial buildings are typically low; and health effects resulting from increases in pollutant levels are viewed as insignificant.

3.2.2 Environmental Procedures for Issues Other Than IAQ

The current requirements for a variety of environmental issues not related to indoor air quality are summarized below.

- Indoor applications of high-pressure sodium (HPS) lamps shall be limited to buildings such as warehouses, and parking garages that have warning signs and danger signals illuminated by light sources with good color rendition, low-visual demand activities, and short-duration occupancy patterns. HPS lamps may be used in high-bay areas that have warning signs as above and are also equipped with one incandescent, fluorescent, or metal halide fixture for each HPS fixture. Special wiring is needed to reduce the stroboscopic effect in areas with rotating machinery. These procedures are in basic agreement with those outlined in the 1982 EA and FONSI, but have been refined based on new information (W. S. Fleming 1987).
- Low-pressure sodium lamps shall not be used indoors. This was also specified in the EA and FONSI.
- Asbestos must be left alone or removed in accordance with procedures established by the State of Oregon. The EA and FONSI did not allow for the removal of asbestos.
- Toxic transfer fluids are not allowed in solar water-heating systems. The EA and FONSI contained the same requirements.
- All energy conservation measures shall comply with applicable building codes. The 1982 FONSI includes provisions requiring the Institutional Buildings Program to have mechanical engineers or licensed architects involved in building inspections and evaluation to help ensure that the

conservation actions comply with building codes and health regulations. The Commercial Audit and Financial Assistance Programs were required to have energy auditors trained regarding applicable building codes and standards for public safety and health.

- In addition to meeting the requirements pertaining to occupied buildings, contractors must screen proposals for unoccupied buildings, such as outdoor swimming pools, waste-water treatment plants, and stadiums. The EA did not address this issue.
- Urea formaldehyde foam insulation is not a permissible retrofit material. The EA did not address this issue.
- Projects involving subsurface resources, such as geothermal or well water, shall be handled on an individual basis and will require site-specific information. In some cases a preliminary report will be adequate. However, information must be transmitted to Bonneville to determine the required scope. This requirement further refines that specified in the EA and FONSI.
- Historic preservation requirements were established by a 1983 Memorandum of Agreement between Bonneville and the Advisory Council on Historic Preservation. The memorandum lists a group of exempt conservation measures that may be installed in all buildings. If nonexempt measures are to be installed in a building 45 or more years old, the contractor must confer with the State Historic Preservation Officer. These requirements further refine those outlined in the EA and FONSI.

3.3 CHAPTER SUMMARY

The 1982 Environmental Assessment of Energy Conservation Opportunities in Commercial-Sector Facilities in the Pacific Northwest and its accompanying FONSI (Bonneville 1982a, b) serve as a starting point for the commercial conservation program's environmental requirements. Environmental procedures and obligations have continued to evolve through a series of Brief Memorandums, each written as an environmental document with a narrow focus for a specific pilot program, study, or a specific type of program, e.g., design assistance. The current obligations and procedures are contained in Environmental Requirements for Existing Commercial and Institutional Buildings (Bonneville 1986). These environmental requirements are mandatory for existing buildings and are recommended for programs affecting new buildings, though the 1982 National Environmental Policy Act (NEPA) documents did not include an analysis of new buildings. The current environmental requirements cover areas such as

indoor air quality, high- and low-pressure sodium lamps, asbestos, toxic transfer fluids, applicable building codes, unoccupied buildings, urea formaldehyde foam insulation, subsurface resources, and historic preservation.

4.0 PROGRAM RESPONSE TO ENVIRONMENTAL DOCUMENTATION AND OBLIGATIONS

Seven commercial programs were reviewed to evaluate the Bonneville programs' response to environmental requirements. Specific questions asked in reviewing each program were:

- Do the program's activities fall within the scope of the EA and FONSI?
- How is the program implementing modifications to the procedures specified in the EA and newer environmental requirements?
- Has the program uncovered any new environmental issues?

Four of the programs reviewed are for existing commercial buildings. These are the Institutional Building Program, the Purchase of Energy Savings Pilot Program, the Commercial Incentives Pilot Program, and the Commercial Industrial Lighting Program. Three of the programs cover new commercial buildings. These programs include the Energy Edge Program, the Smart Design Program, and the Northwest Energy Code Program.

The information leading to the points outlined below was gathered from program descriptions of various sorts, Bonneville's Commercial Sector Activities Notebook (Bonneville 1988), contractual documents with program sponsors, and interviews with program staff.

4.1 INDOOR AIR QUALITY AND VENTILATION

Listed below are instances related to indoor air quality and ventilation in which programs may push the scope of activities covered by environmental documents, environmental documents may not be in place, or new environmental issues have been uncovered.

- Most program contracts contain provisions for installing ECMs in multifamily buildings with more than three stories. This building type was not addressed in the 1982 EA or FONSI. Although the environmental requirements now contain provisions for protecting IAQ in multifamily buildings, it appears that multifamily units are outside the scope of the 1982 environmental documents. The 1985 Brief Memorandum documenting the latest ventilation and IAQ policy states that it does not apply to large multifamily buildings (Love 1985). Thus, the contract provisions allowing multifamily actions in both existing and new buildings do not appear to have been specifically addressed in a NEPA document.

- The Purchase of the Energy Savings Pilot Program (PES) contract does not contain the 1986 Environmental Requirements' provisions for monitoring radon in multifamily buildings. The PES staff reports that the provisions were added after the contract was issued and that this is the only program in which radon monitoring in multifamily buildings was actually performed.
- A subtle change occurred between the ventilation policy stated in the 1985 Brief Memorandum and that contained in the 1986 Environmental Requirements and program contract documents. The 1985 policy states that "BPA would require ventilation systems to be tested and corrected prior to HVAC system retrofits affecting ventilation rates in occupied space" (Love 1985, emphasis added). The new policy states that analysts shall "conduct a ventilation test if ECMs will decrease the amount of ventilation air during occupied periods" (Bonneville 1986, emphasis added). Occupied space may be interpreted as an area intended for occupancy with no regard for fluctuations in occupancy levels over time. Occupied periods may be interpreted as times when any given space has a high occupancy, such as during the work day. However, the space may have a low occupancy at other times, such as during the night. The new policy allows for the installation of conservation measures without testing that may not have been permitted under the 1985 Brief Memorandum. For example, the 1985 Brief Memorandum may be interpreted as requiring ventilation tests if ventilation levels are reduced at night in an office space. The new policy may not require tests in this situation. This new policy has not been reviewed in a NEPA document.

4.2 ENVIRONMENTAL ISSUES OTHER THAN IAQ AND VENTILATION

This section discusses specific instances related to a variety of environmental issues in which programs may exceed the EA scope, environmental documentation may not be in place, or new environmental issues have been uncovered.

- new buildings - Because of the "lost opportunity" nature of the resource, new commercial buildings are the focus of much of Bonneville's attention. Several pilot programs have been tried or are being initiated, and a full-scale program is being planned. However, new buildings were not included in the 1982 EA, and none of the later Brief Memorandums has analyzed new buildings. Discussion with the Office of Energy Resources Environmental Coordinator indicates that the environmental requirements for existing buildings are to be recommended for new buildings, although this policy is not included in an environmental document. No such recommendations were included in at least one contract under the Energy Edge Program. Thus, any new-buildings programs appear to be outside the scope of the 1982 EA and FONSI. New-buildings programs offering only technical assistance may be covered by categorical exclusion from further NEPA review. Therefore, commercial-buildings programs offering financial incentives are most likely to be outside the scope of existing NEPA documents.

- multifamily buildings - As discussed in Section 4.1, several program contractual documents allow for conservation measures to be installed in multifamily buildings. These buildings have not been included in any NEPA review.
- geothermal - Several buildings have been constructed under the Energy Edge Program that include either ground-source or groundwater source heat pumps. These devices may be interpreted as geothermal resources. At present such resources require a site-specific assessment of environmental impacts. Apparently no such report was prepared for the Energy Edge buildings. Additional information on ground-source heat pumps is presented in Chapter 6 of this document.
- polychlorinated biphenyls (PCBs) - A discovery coming from the Commercial and Industrial Lighting Program is that fluorescent lighting fixtures manufactured before 1977 may be contaminated with PCBs. As part of the lighting program, a procedure was developed to test a method of collecting, transporting, storing, and incinerating contaminated fixtures. Additional PCB information is contained in Chapter 6 and Appendix 8.
- new conservation measures - In addition to geothermal heat pumps, examples of other potential, new conservation measures include carbon-dioxide sensors for controlling ventilation systems in occupied spaces, carbon-monoxide sensors for controlling parking-area ventilation systems, and techniques for tempering incoming air. These and other new techniques are not now included in NEPA documents.

4.3 CHAPTER SUMMARY

The environmental issues and procedures outlined in the 1982 EA and FONSI, together with later Brief Memorandums, define a scope of activities that no longer completely fit Bonneville's commercial-buildings conservation programs. The programs and the environmental requirements have evolved to include features not covered by the 1982 documents. Examples of issues that were unforeseen in 1982, new information that has been developed, or program changes that have been made include new indoor air quality procedures, the addition of multifamily buildings to program contracts, the implementation of new-building programs, the development of new conservation measures, and the discovery of PCBs as an environmental issue in lighting programs. Because these issues fall outside the scope of the EA and FONSI, and because many of the issues have not been

addressed by any other environmental document, the preparation of new NEPA documents may be in order.

5.0 VENTILATION STANDARDS AND GUIDELINES

Bonneville's environmental requirements for commercial programs currently state that minimum ventilation rates must meet or exceed current local code or ASHRAE Standard 62-81, whichever is greater. To help assess this approach and compare it with other approaches, this chapter briefly describes the requirements specified by ASHRAE 62-81, potential revisions to the ASHRAE standard, and the U.S. Department of Energy (DOE) Environmental Assessment in Support of Proposed Interim Energy Conservation Standards for New Commercial and Multifamily Highrise Residential Buildings (DOE 1986).

5.1 ASHRAE STANDARD 62-81

The first ventilation standard was published by the American Standards Association (ASA) in 1946 (Harrje and Janssen 1984). ASHRAE updated this standard in 1973 with its Standard 62-73. Both the 1946 ASA A53.1 and the 1973 ASHRAE 62-73 recommended basic ventilation rates of 10 cubic feet per minute (cfm) per person. The ASHRAE standard specified an absolute minimum of 5 cfm per person to control carbon dioxide levels at a steady state of about 2500 parts per million (ppm) or 0.25% (Harrje and Janssen 1984).

In 1981 ASHRAE updated 62-73, making the new standard 62-81. ASHRE 62-81 addresses indoor air quality much more directly than did the earlier standards. The basic outdoor air ventilating rate was reduced to 5 cfm, and only minimum rates were published for various applications.

Tobacco smoke was recognized as a special problem that required more outside air than the basic rate of 5 cfm. The standard established a prescriptive procedure that specifies substantially higher ventilation rates when smoking is permitted. The recommended rates are based on diluting particulates generated from one-third of the population smoking two cigarettes per hour. The recommended minimum outdoor air flow rate under these conditions is 20 cfm, 4 times the nonsmoking rate. The recommended rate increases to 35 cfm for locations such as bars, where the incidence of smoking is generally greater. Standard 62-81 also established acceptable contaminant levels for incoming outdoor air used for dilution.

A distinguishing feature of Standard 62-81 is the alternative "Air Quality Procedure," which placed responsibility for achieving acceptable indoor air quality on the designer. The procedure recommends limits for most common indoor pollutants and allows the designer to use whatever level of outdoor air he or she finds necessary to dilute the contaminants to the acceptable level. The procedure makes it possible to use innovative methods, such as air cleaners or filters, to meet the standard. In addition to meeting specified pollutant concentrations, the alternative procedure calls for a panel of at least 20 persons to judge odor acceptability (ASHRAE 1981).

Standard 62-81 can be criticized on at least three levels:

- the lack of a consistent basis for choosing indoor pollutant concentration limits
- the potential that the alternative procedure may lead to poorer air quality than the prescribed procedure
- the practical difficulty of using the alternative procedure, especially if large numbers of pollutant measurements must be taken to ensure compliance and a panel must judge the potential for any odor problems (Nero and Grimsrud 1984).

ASHRAE accelerated development of the next version of its ventilation standard. This came after researchers acknowledged that Standard 62-81 relied on the inadequate database that was available at the time for indoor pollutant exposure, toxicity, and source controls (CARB 1989). Further subsequent research suggested that the ventilation rates of the 1981 standard did not adequately address odor complaints and building-related illness in nonsmoking areas (CARB 1989). Two years after its adoption, the standard was strongly opposed by the tobacco and formaldehyde industries. In addition, some groups such as the American National Standards Institute and the Building Officials and Code Administrators International chose not to sanction or adopt all or part of Standard 62-81 (CARB 1989).

5.2 ASHRAE STANDARD 62-1981R

Five major revisions to Standard 62-1981 are being proposed. Like the 1981 standard, the revised version is intended to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and

minimize adverse health effects (Janssen and Grimsrud 1986). Janssen and Grimsrud (1986) list the following modifications to Standard 62 in an article published in the ASHRAE Journal.

- The minimum ventilation rate has been raised from 5 cfm of outdoor air per person to 15 cfm per person and the distinction between smoking permitted and nonsmoking areas has been abandoned. The recommended rate proposed for office space is 20 cfm. For bars and cocktail lounges, 35 cfm is recommended.
- The 1981 standard was tied to achieving a carbon dioxide level of 0.25 percent using 5 cfm outside air per person. The revised standard is aimed at reducing carbon dioxide levels to 0.10%. This concentration is consistent with current recommendations of the World Health Organization, most European countries, and Japan.
- Outdoor air requirements for a number of locations have been reduced from the smoking-allowed rates in the 1981 standard.
- The explanation of the use of filters has been expanded to include the consideration of both constant-flow and variable air volume systems, the effects of constant or variable supply air temperature, and the effect of a constant or proportional outdoor air supply.
- The alternative air quality procedure has been retained, allowing the designer to use any outdoor air flow rate, if it can be shown that pollutant levels will be kept within acceptable levels. Certain contaminant levels have been adjusted based on new data. Recommended radon levels have been adjusted upward from 0.01 working level (WL) to 0.027 WL. Recommended formaldehyde levels have been raised from 0.1 ppm to 0.4 ppm.

5.3 DOE'S ENERGY CONSERVATION STANDARDS

DOE has established voluntary performance standards for new commercial and multifamily high-rise residential buildings. The standards are mandatory for federal agencies constructing new buildings. But the standards are voluntary guidelines for the construction of non-federal buildings (54 FR 4538-4720). ASHRAE Standard 62-1981 is the ventilation standard specified by DOE.

DOE issued a Finding of No Significant Impact (FONSI) for the performance standards on November 3, 1986. DOE concludes that the standards will result in minimal changes in indoor air quality. This conclusion is based on the assumption that the standards did not result in any change in ventilation

rates. The minimal effect that is reported results from the increased use of different types of insulation (DOE 1986). Emission rates measured in milligrams per square meter per hour ($\text{mg}/\text{m}^2/\text{h}$) for new building insulation materials are presented in Table 5.1. A mass balance model was used to assess the effects of the standards. This model is similar to the one Bonneville used in its 1982 EA and the two residential program environmental impact statements. Table 5.2 lists many of the assumptions used in DOE's model.

TABLE 5.1. Organic Emissions from New Building Insulation Materials^(a)

<u>Material</u>	<u>Description</u>	<u>Organic^(b) Emission, $\text{mg}/\text{m}^2/\text{h}$</u>	<u>Formaldehyde^(c) Emission, $\text{mg}/\text{m}^2/\text{h}$</u>
Fiberglass	Fiberboard, 0.5 in	0.017	--
Fiberglass	Batt, 3.0 in	--	0.02 to 0.17
Mineral wool	Insulation batch	0.012	--
Organic	Woodfiber board	0.120	--
Foam	Polystyrene	1.4	--
Foam	Polyurethane	0.12	--

(a) Source: U.S. Department of Energy (1986).

(b) Taken from Molhave (1982).

(c) Comparable form of emission computed from 0.3 to 2.3 $\mu\text{g}/\text{g}/\text{day}$ emission rate given by Gupta, Ulsamer and Preuss (1982). Organic emissions from fiberglass materials were based on fiberboard emissions.

TABLE 5.2. Assumed Building Characteristics Used in the DOE Environmental Assessment(a)(b)

Building Category	Number of Floors	Average Floor Height, ft	Single Floor Area, (c) ft ²	Total Carpet Floor Area, (c) ft ²	Number of Occupants	Standard ASHRAE 90A-1980 Design Air Recirculation, cfm	Proposed Standard Design Air Recirculation, cfm	Fresh Air Ventilation Rate, (d) ACH
Small Office	1	16.0	2,500	1,488	19	2,547	2,230	0.570
Medium Office	3	12.0	16,500	34,155	330	47,130	46,390	0.667
Large Office	40	13.5	21,612	24,845	3,972	745,050	387,230	0.408
Retail Store	2	19.0	106,730	106,730	2,008	116,020	113,050	0.965
Strip Store	1	18.0	11,760	5,875	286	11,830	10,430	2.027
Apartment	9	8.8	46,308	116,710	1,310	301,000	272,000	1.066
Hotel	10	9.6	31,550	152,490	2,900	183,000	154,840	1.522
Warehouse, Storage	1	24.0	38,640	0	20	243,080	243,080	0.237(e)
Warehouse, Offices	1	12.0	2,112	1,478	16	2,350	2,090	0.758
Assembly	1	18.8	14,150	9,198	614	12,463	11,810	2.922
School	2	13.0	42,230	35,473	2,161	43,660	34,630	0.770

(a) Source: U.S. Department of Energy (1986, p. 3.6).

(b) In locations other than Seattle, the air recirculation figures may vary slightly, causing the use of minor HVAC System modifications. The remaining building parameters do not change for the other locations.

(c) Average area of a single floor. Total floor area can be derived by multiplying this number by the number of floors.

(d) Air changes per hour (ACH), derived from ASHRAE Standard 62-1981, are the same for both the ASHRAE 90A-1980 design and proposed standard design.

(e) Assumed minimum ACH for structure.

6.0 NEW INFORMATION ABOUT INDOOR AIR QUALITY

Increased levels of indoor air pollutants and resulting health effects are the environmental concerns most often associated with energy conservation programs. Bonneville was among the first federal agencies to recognize this problem and has been in the forefront of efforts to develop programs and policies to mitigate negative impacts on indoor air quality. The environmental policies for the commercial-sector programs were developed in the 1982 EA and were updated in Brief Memorandums in 1984 and 1985. Since Bonneville prepared these documents, scientists have developed new information that may be useful in developing new environmental policy. The information summarized in this section emphasizes areas that add to Bonneville's knowledge base. Thus, little is included about radon, formaldehyde and combustion byproducts, which Bonneville has already studied extensively. However, more extensive information is provided on volatile organic compounds and biological contaminants, which have received little past attention.

6.1 VENTILATION

One point raised in the 1985 Brief Memorandum, which forms the basis of Bonneville's current ventilation requirements, is that the requirements may lead to improved ventilation rates in many buildings. In 1985 Bonneville decided to defer to local fresh air codes for naturally ventilated buildings and to the greater of either ASHRAE 62-81 or local codes for mechanically ventilated buildings. The requirements call for visual inspections of HVAC systems and correction of deficiencies. Testing of HVAC systems is required if ECMs that reduce ventilation are to be installed. Naturally-ventilated buildings must meet the minimum requirements of the Uniform Building Code.

The 1985 Brief-Memorandum noted that, by following the required procedures, the commercial conservation programs may result in increased ventilation in buildings. Little data is available to support this contention. The 1982 EA contends that designers of most buildings typically design ventilation rates to be 7 times greater than the rates required in ASHRAE 62-81 for nonsmoking areas and 2 times the rate for smoking areas (Bonneville 1982a,

pp. B.7-B.9). Although these assumptions seem excessive, they suggest that few buildings have ventilation rates lower than those required by code.

6.1.1 Field Studies

Field measurements also suggest that ventilation rates typically exceed ASHRAE Standard 62-81. A study conducted for Bonneville by Seton, Johnson, and Odell (1984) concludes that nominal ventilation rates based on actual occupancy will be significantly higher than the design rates listed in ASHRAE 62-81. The difference arises because the standard is based on a worst-case condition. Designers achieve, often exceed, the ASHRAE recommended rate, but because occupancy levels are less than those assumed by ASHRAE, the nominal ventilation rate is much higher than that specified in the standard. The study also concludes that actual ventilation rates are not equal to design rates in many buildings because of confounding factors such as fan cycling, economizer operation, infiltration, poor design, misuse, and improper operation of HVAC equipment.

A study conducted for Bonneville by Lawrence Berkeley Laboratory (Turk et al. 1987) found that ventilation rates in a sample of 40 buildings ranged on average from about 2 to 8 times the rates recommended by ASHRAE 62-81 for smoking areas (Turk et al. 1987, p. iv-3). Five of the buildings were at or below the ASHRAE recommendation for smoking areas; all had rates greater than those recommended for nonsmoking areas. This sample emphasized large, mechanically ventilated, nonresidential buildings, and is not representative of typical regional commercial stock. But the study does help demonstrate a possible trend that, on average, buildings provide ventilation rates greater than those recommended in ASHRAE 62-81.

Although average whole-building measurements of ventilation rates appear elevated, outdoor air supplied to local areas may be less than recommended levels (Turk et al. 1987, p. iv-6). This situation may be due to local areas having disproportionately high occupant densities or to differences in equipment installation and operation between zones.

Persily (1989), a researcher at the National Institute of Standards and Technology (NIST), also notes that a building's actual ventilation rate may be

very different than its design rate. The NIST has taken 3,000 ventilation rate measurements in 14 U.S. office buildings. This small number of buildings is not representative of the entire stock of existing office buildings, but NIST's work does provide insight into the effects on ventilation of building age, construction style, and ventilation system design. Persily notes that the actual air-exchange rate in a mechanically ventilated building can be quite different from design values. The actual rate includes both uncontrolled air infiltration through the building envelope and intentional outdoor air intake through the ventilation system. The air-exchange rate is determined by the ventilation system design, including outdoor air intake controls, systems operation schedules, building envelope airtightness, and the interior configuration of the building.

Persily found the average air-exchange rate for all of the NIST buildings to be about 0.9 ACH. About one-half of the measured air exchange rates are below the buildings' minimum outdoor air intake specifications. About 40% of the air-exchange rates are below the proposed ASHRAE standard of 20 cfm per person. Persily reports that the only reliable way to determine actual air-exchange rates is to use tracer gas measurements.

6.1.2 Potential Program Implications

The following implications may be drawn for Bonneville's commercial conservation programs:

- Bonneville's requirements for visual inspections, system tests, and meeting either local code or ASHRAE Standard 62-81 may result in increased minimum ventilation rates in many buildings, especially within specific zones. However, this improvement cannot now be quantified, and the regional effect may be small.
- If conservation measures reduce ventilation rates from levels greater than ASHRAE 62-81 recommendations down to the recommended levels, this change may result in a negative impact on indoor air quality.
- Establishing baseline ventilation rates for both existing and new buildings will be difficult. A representative sample of ventilation rates in Northwest building stock is not now available. Potential sources of data include the research reports cited above (Seton, Johnson and Odell 1984; Turk et al. 1987; Persily 1989); a literature review to determine other applicable studies (e.g., Persily and Grot 1985; Silberstein and Grot 1985); and interviews with energy auditors working under Bonneville's commercial programs. A more costly and time-consuming approach, but also

the most accurate, is to develop a representative sample and conduct ventilation measurements.

- Naturally ventilated buildings may raise their own set of issues. Air distribution, ventilation effectiveness, air cleaning techniques, and other pollution mitigation methods will differ from those for mechanically ventilated buildings. Bonneville's residential programs now require that all new homes be equipped with minimum amounts of mechanical ventilation. This action may set a precedent for naturally ventilated commercial buildings.
- Bonneville's current ventilation testing requirements may not be adequate if tracer gas measurements are the only reliable way to determine actual air-exchange rates.

6.2 SICK BUILDING SYNDROME

One national survey reports that 25% of American workers feel that the quality of their workplace air affects their work adversely (Sheldon et al. 1988a). "Sick building syndrome" refers to health and comfort problems associated with working or being in a particular building (EPA 1988). The term generally applies to problems related to indoor air pollution, rather than describing complaints stemming solely from humidity control or inadequate temperature. If the problems result in clinically defined illness, disease, or infirmity in occupants, the building is said to manifest building-related illness (EPA 1988). These conditions may be caused by a number of interacting factors. The EPA lists the following key contributing factors:

- inadequate ventilation
- pollutants emitted inside of buildings
- contamination from outside sources
- biological contamination.

These factors interact with other environmental considerations such as inadequate temperature, uncomfortable humidity, or poor lighting. The causes of sick building syndrome and building-related illness are complex. Once a building has been implicated, the causes often remain undetermined. Perhaps the best explanation for occupant responses in the absence of standardized testing and pollutant concentration requirements was offered by Carey et al.

(1985): Virtually all cases of sick building syndrome are discovered by nature's imperfect pollution detector, the human body."

Although it is not the source of the pollutants causing distress, inadequate ventilation is an often-cited cause of sick buildings. As of December 1985, the National Institute for Occupational Safety and Health (NIOSH) had conducted 365 health-hazard evaluations of building-related problems. The NIOSH has concluded in most cases that the problem could be eliminated by improved ventilation (Melias et al. 1984). Other causes identified in these evaluations include immunological sensitizing agents, infectious agents, chemical contaminants, and environmental conditions such as temperature and humidity (Kreiss 1984). Specific classes of pollutants and their associated potential health effects are discussed below.

Lighting can also affect occupants' perceptions of buildings. Sterling and Sterling (1984) report that there is a significant relationship between poor lighting and building illness. Office workers with poor lighting were found to be more likely to think of their buildings as contributing to poor health.

6.3 VOLATILE ORGANIC COMPOUNDS

Because of their irritant properties, volatile organic compounds (VOCs) are considered a possible cause of building-related illness. As was noted in the 1985 Brief Memorandum (Love 1985), the levels of individual VOCs found in buildings are often several times below threshold limit values, levels considered to be harmful for any one chemical. However, many indoor VOC concentrations have been found to be much higher than levels found outdoors. Sheldon et al. (1988a) found indoor-outdoor ratios of total organics of 2 or 3 to 1 in three older buildings. In a new office building, this ratio was 50 to 1, dropping to 10 to 1 after two months, and 5 to 1 after three additional months. A total of about 500 compounds were found at least once in all of the buildings sampled. In a companion study, Sheldon et al. (1988b) found indoor levels of total organics in two new buildings up to 400 times greater than outdoor concentrations. After several months these concentrations dropped to from 3 to 30 times outdoor levels.

6.3.1 VOC Sources

The proliferation of new building materials, consumer goods, and office equipment after World War II has made VOC sources ubiquitous. Wallace (1987) has concluded that nearly every home and place of business contain common materials that may cause elevated levels of toxic chemical exposure. In chamber study and head space purge experiments assessing 15 materials grouped in four categories--cleaners and polishes, floor and wall coverings, glues, and pesticides--Wallace identified from 10 to 82 offgassed compounds (stainless steel polish had the most).

In other chamber studies, the National Aeronautics and Space Administration (NASA) has tested over 5000 materials that may find their way into spacecraft. Ozkaynak (1987) has divided these materials into groupings such as adhesives, coatings, fabric, foam, labels, lubricant, papers, plastic, rubber, tape, thread, velcro, wire, clothing, computer equipment, cosmetics, deodorants, electrical equipment, and so on. Ozkaynak reported findings for 19 VOCs. Of these, benzene was found in 387 materials, styrene in 284, trichlorethylene in 381, and ethylbenzene in 19. At the 95th percentile, the highest concentrations were found in health and beauty aids. Mass balance calculations have also shown paint to be a substantial source of VOCs (Baechler et al. 1989).

Sheldon (1988b) found that building materials collected from new buildings emitted high rates of the air pollutants found in the buildings. Furthermore, these compounds were similar in two new buildings suggesting the findings may be generally true for many buildings. Materials emitting these compounds at the highest rates were surface coatings, such as adhesives, caulking, and paints; wall and floor coverings, such as molding, linoleum tile, and carpet; and other materials such as telephone cable. Emission rates from 31 materials collected from new office buildings are shown in Table 6.1. The results show that while some solvent-based materials were the highest emitters, other solvent-based building materials emitted none of the target compounds. Table 5.1 in Section 5 lists emission rates for various types of insulation.

TABLE 6.1. Summary of Emission Results from Building Materials(a)

Sample	Emission Rate, $\mu\text{g}/\text{m}^2/\text{h}$			
	Aliphatic and Oxygenated Aliphatic Hydrocarbons	Aromatic Hydrocarbons	Halogenated Hydrocarbons	All Target Compounds
Cove adhesive	(b)	(b)	(b)	>5000
Latex caulk	252	380	5.2	637
Latex paint (Glidden)	111	52	86	249
Carpet adhesive	136	98	-(c)	234
Black rubber molding	24	78	0.88	103
Small-diameter telephone cable	33	26	1.4	60
Vinyl cove molding	31	14	0.62	46
Linoleum tile	6.0	35	4.0	45
Large-diameter telephone cable	14	20	4.3	38
Carpet	27	9.4	-	36
Vinyl edge molding	18	12	0.41	30
Particle board	27	1.1	0.14	28
Polystyrene foam insulation	0.19	20	1.4	22
Tar paper	3.2	3.1	-	6.3
Primer/adhesive	3.6	2.5	-	6.1
Latex paint (Bruning)	-	3.2	-	3.2
Water repellent mineral board	1.1	0.43	-	1.5
Cement block	-	0.39	0.15	0.54
PVC pipe	-	0.53	-	0.53
Duct insulation	0.13	0.15	-	0.28
Treated metal roofing	-	0.19	0.06	0.25
Urethane sealant	-	0.13	-	0.13
Fiberglass insulation	-	0.08	-	0.80
Exterior mineral board	-	0.03	-	0.03

(a) Source: Adapted from Sheldon et al. (1988).

(b) Emission rate for cove adhesive is a minimum value; sample was overloaded. It is estimated that cove adhesive is one of the highest emitters of volatile organics.

(c) No detectable emissions.

6.3.2 Health Effects

Both chronic and acute health effects may result from VOC exposure. Chronic health effects, including cancer, may be caused by long-term exposure. Benzene is a recognized human carcinogen. Chloroform, trichloroethylene, carbon tetrachloride, and p-dichlorobenzene have been found to cause cancer in animals, and may do so in humans. Risk assessments carried out for VOCs in residential environments suggest that risks are considerably greater in indoor air than in outdoor air, except for chloroform (Sheldon et al. 1988a; Wallace 1986). Wallace (1986) points out that in the thousands of volatile organics that are likely to be found indoors, only a few have been tested for carcinogenic activity. Thus, the upper bounds of risk from exposure to VOCs is not well defined.

A study of the lifetime risk of contracting cancer from exposure to organic chemicals in four Dutch houses found the upper-bound estimates of risk for each of 45 chemicals to be greater than the action levels used by the U.S. Food and Drug Administration (FDA) and the EPA for accidental food additives or pollutants in water and air (Tancrede et al. 1986).

Acute health effects caused by VOCs include eye, nose and throat irritation; headaches, depression, irritability, and forgetfulness; and general malaise. These are the very symptoms often referred to as sick building syndrome. Molhave's work (Molhave et al. 1985; Molhave 1984) suggests that sick building syndrome may result from the additive or synergistic effect of the complex mixture of VOCs found in buildings, rather than from any one single pollutant. His work may be among the first objective proofs that a major component of the sick building syndrome may be caused by common indoor organic vapors at levels far below occupational health standards (Wallace 1984).

6.3.3 Mitigation

Other than avoiding the use of materials that emit VOCs, ventilation seems the best method of dissipating the pollutants. Sheldon et al. (1988a) state that the half-lives of the compounds found in two new office buildings ranged from 2 to 8 weeks. Thus, the time for the building to approach outdoor VOC concentrations would range from 3 to 12 months. Sheldon points out that this

finding compares well with the Scandinavian decision to require 100% makeup air for the first 6 months of a new building's life.

Girman et al. (1987) report a process called "bake out" as a potential mitigation technique for high VOC levels in new commercial buildings. The bake-out procedure involves subjecting the indoor environment to high temperatures and high ventilation rates to encourage the emission and removal of VOCs. A building in San Francisco was heated to a maximum of 39° Celsius for 24 hours, at a ventilation rate of 1.59 air changes per hour. Fourteen VOCs were quantified. The total VOC concentration increased by 400% during the bake out and was reduced to 71% afterward. Girman concludes that longer bake-out periods may be more effective. In addition to demonstrating the effectiveness of this mitigation technique, Girman underscores the important role of temperature, aging, and ventilation in influencing VOC concentrations.

The best means of mitigating VOC pollutant concentrations is source control. Product standards provide one means of limiting the use of high polluting sources. An example of this type of measure is the formaldehyde product standard now enforced in the residential new-homes programs. The standard requires that structural building materials used in Bonneville's new-homes programs must meet the U.S. Department of Housing and Urban Development (HUD) requirements for manufactured housing, or be rated for exterior use.

This product standard helps to reduce formaldehyde emissions from products using ureaformaldehyde-based glues. If adequate information is available, Bonneville could impose similar limits on other products, such as caulking compounds, paints, glues, and furnishings. Reports suggest that catalogs will soon be published as a compendium of EPA and DOE research in this area to guide in the selection of materials with low pollution potential (McNall 1988). Rather than imposing its own product standards, Bonneville could work with other agencies and code-adopting entities to develop new building practices. In the absence of standards, consumer and designer information and training may be an approach to avoiding VOC sources in new construction.

6.3.4 Potential Program Implications

The following summarizes the implications of VOCs for Bonneville's commercial programs.

- VOC concentrations inside buildings are often much higher than those found outside and should be viewed as a potential threat to public health.
- Health effects from exposure to organic compounds include both chronic and acute responses and should not be dismissed as insignificant.
- VOC concentrations are greatest in new buildings. Any assessment of Bonneville's new commercial building programs should pay particular attention to conservation measures or building practices that may adversely affect VOC concentrations.
- Potential sources of VOC from conservation measures include latex caulk and insulation.
- Reductions in ventilation rates and modifications to the ventilation system may affect VOC concentrations.
- Potential mitigation techniques include higher ventilation rates (100% outside air during initial occupancy), building bake-out, and product standards.

6.4 BIOLOGICAL AGENTS

Many biological contaminants have their origin outdoors and enter indoor spaces through cracks, windows, and doors, or through ventilation, air conditioning, and humidifying systems. Pollens are contaminants that enter from the outside. Pollen concentrations vary seasonally. Their building entry is further determined by indoor/outdoor pressure differentials, quantity and type of ventilation, wind conditions, temperature and humidity (Burge 1984). Animal dander and excreta, especially from birds such as pigeons roosting near air inlets, can also enter indoors. Other interlopers from outside include algae, amoeba, and fungi, all of which can colonize, given suitable indoor environments. Ideal growing conditions for these microorganisms include moisture, humid air, and warm temperatures (Burge 1984). Any organic material can serve as a medium for fungal growth. Spores that have settled in the indoor environment are easily spread through the air by activities such as vacuuming, sweeping, and scrubbing of contaminated surfaces (Burge 1984). Humans also release biological agents through sneezing, coughing, speaking, and the sloughing off of skin dander.

Bacteria, fungal spores, amoeba, and viruses may be distributed throughout buildings by ventilation systems, and by the stack effect in stairway and elevator shafts. Growth indoors is promoted by moisture and organic food

sources. Thus, upholstery, bedding, carpets, plumbing, and food-preparation areas tend to be sources of continuing contamination. Ventilation systems may also serve as growth areas if moisture is present.

6.4.1 Microbial Contamination in HVAC Systems

In a sampling of 21 buildings suspected of harboring reservoirs of microbial growth, 18 were found to be contaminated (Morey 1988). The most common reason for the contamination was inadequate maintenance of mechanical systems. Morey (1988) notes that even where mechanical systems were accessible, operators gave maintenance low importance. Typical maintenance problems included drain pans containing stagnant water and microbiological slimes, dust and debris accumulating on wet mechanical surfaces, and dirty fan coil induction units. Other significant causes of contamination included the presence of porous manmade insulation on the inside surface of air-handling and fan coil units; floods in the HVAC system and the occupied space; excessive relative humidity in the occupied space; and the location of air intakes near cooling towers and other external sources of bioaerosols. In five of the buildings Morey (1988) investigated, replacement or renovation of the HVAC system or replacement or modification of the HVAC internal insulation had occurred or was planned.

Earlier investigations also found microbial contamination associated with building mechanical systems. Table 6.2 includes a sample of contaminated mechanical equipment and the mitigation measures employed. Not included in Table 6.2 is the case of Pontiac Fever, a disease that led to an epidemic in Pontiac, Michigan, in 1968 (Feeley 1984). Investigators on this case noted that their team members became sick when the building's air conditioning system was operating. Investigators found two potential contamination points: 1) defects allowed water from the evaporative condenser to enter the general air circulation ducts; and 2) ducts were positioned so that the exhaust vent of one air-handling system was less than 2 meters from the intake of a second system, allowing cross-contamination. The agent causing the epidemic was later identified as Legionella pneumophila, or Legionnaire's Disease. It was this same disease that caused 182 illnesses and 29 deaths at a 1976 American Legion Convention at Philadelphia's Bellevue Stratford Hotel.

TABLE 6.2. Building-Related Microorganism Outbreaks

<u>Source</u>	<u>Etiology</u>	<u>Remedial Measures and Comments</u>
Ceiling dust	Amoebae, other organisms	Modified humidifier; water run to waste; replaced ceiling; discarded carpet; moved office workers to new building; no recurrence in 24 months.
Water in ventilation ductwork	Thermophilic actinomyces	Cleaned ductwork.
Contaminated air filters	Amoebae	Closed school and dispersed staff to other schools; in 1 month 1/3 were well, 2/3 improved.
Tap water	Undetermined	Removed humidifier.
Furnace humidifier	Micropolyspora faeni	Removed furnace and humidifier.
Heating or air conditioning systems	Thermophilic actinomyces	Moved from contaminated environment or removed contaminated appliance.
Humidifier, air conditioner, or tap water source	Cephalosporium in one case; undocumented in five cases	Removed humidifier or air conditioner.

Source: Adapted from Kreiss and Hodgson (1984).

Morey (1985) states that scientific documentation of the effectiveness of control techniques of microbial agents is limited. Preventative maintenance or housekeeping together with protection from floods and moisture incursion will reduce the chances of contamination. Morey (1985) points out that consumers as well as designers must be aware that practices resulting in warm, moist indoor environments may increase human health risks. Restricting moisture is the most direct method of limiting microorganism growth. Thus, reducing relative

humidity and eliminating stagnant water can be effective control methods (Morey 1988). Relative humidity levels greater than 70% appear optimal for fungal growth; humidity levels less than 50% are needed to keep mold levels below average (Burge 1984). Removal of nutrients needed for microbiological growth may also control contamination. Prevention requires fastidious maintenance of each of the following: reservoirs, such as cooling towers and filters where microorganisms accumulate; amplifiers, such as cooling towers and humidifiers where microorganisms proliferate; and disseminators, such as HVAC systems and their outdoor air intakes through which microorganisms may be transmitted (Morey 1985).

6.4.2 Health Effects

Among the 18 buildings in which Morey (1988) found microbiological contamination, the most common health problems were widespread irritation of the eyes and upper respiratory system, headache, and odor annoyance. A more serious problem, which was rarely found by Morey (1988), is hypersensitivity pneumonitis. In this disease, lung inflammation results from an allergic reaction to inhaled organisms (Turiet 1985, p. 116). Asthmatic reactions and other respiratory ailments may also result from exposure to molds (Kozak and Gallup 1984).

In a study conducted on modern and old army barracks, a team of doctors found that rates of acute respiratory disease were at least 50% higher in modern barracks than in old (Brundage et al. 1988). Explaining this difference, Brundage states "In tight buildings with closed ventilation systems, airborne-transmitted pathogens are not only recirculated and concentrated but are efficiently dispersed through indoor living spaces, while in 'leaky' buildings, airborne-transmitted agents are diluted by fresh, outdoor air" (Brundage et al.; p. 2112). These results may apply to commercial buildings, such as multifamily living units, health-care facilities, and motels and hotels.

6.4.3 Implications

Implications of biological agents for Bonneville's commercial-buildings programs include the following:

- Inspections and tests of existing HVAC systems may uncover reservoirs of microbiological contamination. The current environmental requirements suggest that discovered problems must be cleaned up before ventilation conservation measures are installed. Thus, Bonneville's energy audits and other conservation activities in existing buildings may lead to improvements in the indoor environment.
- Training of auditors and building operators in spotting and remedying microbiological outgrowths would further enhance environmental effects.
- Training new-building mechanical system designers could help avoid sources of biological contamination, as well as make all system components accessible for easy maintenance.
- On balance, improvements in energy efficiency and limiting microbiological growth in ventilation systems go hand-in-hand. However, Bonneville does not have an explicit policy covering situations in which auditors or installers discover contaminated HVAC equipment or other problems.
- Interviews with energy auditors and mechanical engineers participating in Bonneville's programs may provide information about the extent of microbial growth in buildings on which they have worked.
- Some research suggests that low ventilation rates may affect respiratory disease rates in commercial buildings where people reside. The causes of such an effect may include conservation measures.

6.5 RADON

Radon is an inert, radioactive gas that occurs naturally in the environment. Radon is a decay product of uranium and it, in turn, decays to form radioactive progeny that may attach to dust particles or remain unattached. If these progeny are inhaled, they can be drawn into the lungs, where they emit alpha energy and may cause lung cancer.

Radon's behavior in commercial and multifamily buildings is poorly understood. Turk et al. (1987) point out that in residential radon studies, higher radon entry rates are known to be due to pressure-driven convective flow. Convective flow is induced by structure depressurization caused by the stack effect because of the pressure gradient between indoor and outdoor temperatures, wind-created pressure differences, and, in some cases, exhaust ventilation devices (Turk et al. 1987) or combustion appliances (Mowris and Fisk 1987). In the mechanically ventilated commercial buildings studied by Turk for Bonneville (Turk et al. 1987), the average ventilation rate is higher than in residences. The forced-air system alters the indoor-outdoor

interaction and pressure distribution seen in residential structures. However, Turk points out that an obvious source of radon, and the location of its entry into the commercial building envelope, is the soil's contact with the basement or open soil/rock in unfinished basements.

Turk's study results suggest that radon is not equally distributed throughout a multistory structure (Turk et al. 1987, p. iii-55). Turk found that radon concentrations tend to be elevated in basement and ground floors. Abu-Jarad and Fremlin (1982) found no systematic reduction of radon activity with height in two high-rise buildings studied in Great Britain. Abu-Jarad and Fremlin attribute differences in radon levels to variations in room ventilation rates.

6.5.1 Radon Analysis in the 1985 Brief Memorandum

The 1985 Brief Memorandum (Love 1985) assumed that ECMs would reduce ventilation rates an average of 15%. This reduction was calculated to result in an increase in lifetime cancers due to radon exposure of 1 in 10,000 affected individuals. This level of increased risk was viewed as insignificant in the 1985 document. For comparison, the FDA and the EPA each accept a lifetime risk of 1 in 1,000,000 as the minimal acceptable risk (Hallenbeck and Cunningham 1986). New information may be helpful in reevaluating potential risk. Two considerations should be taken into account. First, pollutants other than radon may pose risks to health. These should be included in a risk assessment or be addressed by an environmental document.

Second, the 1985 document assumed a radon exposure time of 1000 hours per year for 30 years. The National Academy of Sciences reports that employed men and women spend 23 to 32% of their time in nonresidential indoor locations, including businesses, restaurants, and places of employment (NAS 1981, pp. 20, 286-291; reported in Turk et al., 1987) Samet et al. (1987) report that employed men spend 28% and employed women 22% of their day at work. Using a conservative estimate of 25% of an individual's time spent in nonresidential indoor settings, and reducing that time an additional 25% to account for time away from place of employment, a person spends about 1,500 to 1,600 hours in their place of employment. This suggests that the 1985 analysis may have underestimated exposure time. However, the 1985 calculation may have reduced

exposure time to account for other factors, such as part-time employment and outdoor workers, but these assumptions are not made explicit.

6.5.2 Potential Program Implications

The implications for Bonneville's commercial-buildings programs include the following:

- The 1985 Brief Memorandum (Love 1985) and the 1982 EA each implicitly assume an equal distribution of radon throughout commercial building interiors. Turk's results suggest that equal distribution is a worst-case assumption (Turk et al. 1987). However, uncertainty about how radon is distributed in commercial buildings above the basement and ground floors may make these assumptions the most prudent for modeling occupant exposure.
- Turk's results are not based on a representative sample. Thus, the reported concentrations should not be used to gauge the baseline of existing radon concentrations found in commercial buildings.
- Comparisons with other federal agencies' thresholds of significance suggest that the risks posed by radon calculated in the 1985 Brief Memorandum may be interpreted as significant.
- The 1985 Brief Memorandum may underestimate risk because of low estimates of exposure time.

6.6 MINERAL AND GLASS FIBER INSULATION

No conclusive evidence has yet linked fiberglass fibers to respiratory effects similar to those caused by asbestos exposure. However, this issue is controversial and was the subject of World Health Organization (WHO) symposia held in 1982 and 1986. A summary prepared by WHO (WHO 1987) of the latest symposium lists the following key conclusions:

- Researchers have found an increased lung cancer risk in production and maintenance workers employed in the early days of the rock/slag wool and glass wool industry.
- The risk has been greater in the rock/slag wool sector of the industry than in the glass wool sector. No increased risk has been found after full introduction of dust suppressing agents.
- The increased risk may not have been caused by fibers alone.
- It is not now possible to calculate the lung cancer risks associated with varying degrees of exposure because of the absence of a detailed dose-response relationship.

- It is unlikely that work place exposure over the last 30 years has resulted in any clinical respiratory damage other than the risk of cancer.

Although this research seems preliminary, the fourth conclusion about the absence of a detailed dose-response relationship means that cancer risks cannot now be calculated, but it does not rule out the possibility that low-level exposure to non-suppressed fibers may increase the risk of cancer.

One possible source of glass fibers is insulation used in ventilation ducting. However, Gamboa et al. (1988) have concluded that fiberglass fibers released from Type 475 duct board and fiberglass duct liner are well below the 3.0 fibers per cubic centimeter permissible exposure limit proposed in 1977 by the NIOSH. At the maximum air velocity recommended by the manufacturer, the researchers found that duct board and fiberglass liner released four orders of magnitude fewer fibers than the proposed NIOSH standard. But even at these low levels, the quantities released resulted in fiber levels approximately twice background concentrations.

In Section 6.4, it was noted that man-made porous duct liners may contribute to microbiological growth (Morey 1988). If relative humidity in the duct is greater than 70 or 80% there is adequate moisture for fungal amplification. Any duct liner that is porous may accumulate dirt and debris that act as microbial nutrients. Porous liners are usually found in air-handling units in high-pressure ductwork just downstream of cooling coils, not generally in low-pressure ductwork near diffusers.

6.6.1 Potential Program Implications

Potential program implications for Bonneville's commercial buildings programs are as follows:

- If commercial conservation programs result in increased occupant, installer, energy auditor or inspector exposure to these fibers, the program may result in an increased risk of lung cancer. However, it is not now possible to calculate the impact.
- An environmental document reviewing glass-fiber contamination may consider structural and duct insulation as potential sources.
- Glass-fiber contamination may be related to microbial growth.

6.7 MITIGATION TECHNIQUES

This section briefly summarizes indoor air quality control methods. The primary sources for the discussion are papers presented in 1988 at an ASHRAE conference on indoor air (ASHRAE 1988).

6.7.1 Material Elimination or Substitution

When materials or processes are identified as important sources of pollution, they should be eliminated if possible. McNall (1988) states that catalogs are planned that will help designers select low polluting materials. HUD's product standard for formaldehyde emissions from particle board and plywood used in manufactured homes is an example of a policy designed to eliminate a pollutant source. Many potential sources of volatile organic compounds are cleaning agents. Substitute cleaners may be available if the sources of VOC are identified.

6.7.2 Source Mitigation Methods

Permeation barriers have proved successful at reducing emissions from solid sources of formaldehyde (Mathews et al. 1983). Vinyl sheet flooring, paints, shellac, and lacquer have been shown to be effective. The coating must be continuous and stay intact to work. However, it is possible that these coatings may, in turn, be sources of organic compounds other than formaldehyde.

6.7.3 Ventilation

Ventilation is often viewed as the key technique for combating indoor pollutants. This may be a valid method for pollutants from unavoidable sources, such as some building materials or required furnishings. To dispel concentrations of organic compounds in new commercial buildings, Sheldon et al. (1988a) reports that Scandinavian countries now require that 100% outside air be circulated for the first six months of occupancy. Sheldon concurs with this approach, based on calculations of pollutant removal using the half life of total organics found in several buildings. Girman et al. (1987) suggest another approach called "bake out," that uses ventilation in conjunction with intense heat. Several aspects of ventilation that may affect indoor air quality are described below.

- Dilution reduces indoor pollutant levels by mixing contaminated air with cleaner air. This implies near perfect mixing of ventilation air to avoid

short circuiting of clean air entering the space, or pockets of contaminated air where the clean air does not reach. Ventilation standards are based on the dilution principle.

- **Ventilation effectiveness** is a measure of how well or imperfectly ventilation air mixes in the occupied zone, or, more importantly, the breathing zone (McNall 1988). If mixing is imperfect, there is a bypass of ventilation air, and occupants receive less clean air than had been planned.
- **The displacement control or differential pressure control principle** uses the strategic placement of supply and return outlets to create pressure differences within or between zones to direct general air flow and prevent contamination in a local area from entering other areas. This approach may be useful for containing smoking areas. An elaborate system using air curtains and filtration techniques for recirculated air is being promulgated in Beverley Hills, California, for restaurants with smoking areas (Smola 1988).
- **Local exhaust** is a traditional means of removing localized pollutants.

6.7.4 Air Cleaning

Air cleaning is a technique that may be used in conjunction with HVAC systems. Particulate-filter test methods are available in ASHRAE Standard 62-1981, which is under revision. Particles are the easiest contaminants to remove from the air (Meckler and Janssen 1988). General types of air cleaners are: media filters, electrostatic air cleaners, adsorbers/absorbers, centrifugal separators, and air washers. The following summary is taken from Meckler and Janssen (1988).

Media filters and electrostatic air cleaners are used in building HVAC systems. Media filters consist of a porous material, frequently fibrous glass, which strains out particles. Applications of these filters range from lint and large dust particle removal in most warm air furnaces to high-efficiency particulate air (HEPA) filters that can remove submicron particles. The collected particulate matter on media filters tends to increase their effectiveness, but the increased pressure loss across the filter reduces air flow. Media filters require regular maintenance with cleaning or replacement.

Activated carbon and activated alumina are adsorbers or absorbers. Activated carbon has a very large surface area due to the fine voids in its structure. Gas molecules adhere to the surface of the carbon structure, removing gases and vapors from the air stream. Effectiveness is related to the

size of the molecules being trapped. Activated carbon is quite effective in removing large odor-causing molecules, but is ineffective in removing small molecules such as carbon monoxide. Activated carbon filters require regular replacement. These filters can be regenerated with steam. This process is not considered viable for building HVAC systems, though these filters have been used in some applications.

Activated alumina is a porous material similar to activated carbon, but more expensive. Because of the expense, alumina is rarely used in pure form. Activated alumina treated with potassium permanganate is an effective chemically active air cleaner. Potassium is a strong oxidizing agent that is very effective in oxidizing odor molecules. Activated alumina treated with potassium permanganate is effective at removing formaldehyde, which is converted to carbon dioxide and water. These filters require regular replacement. The potassium permanganate is a consumable reagent and the filter must be replaced when the reagent is exhausted.

Particles passing through the charging section of an electrostatic air cleaner receive an electric charge that causes them to be attracted to the oppositely charged plates in the collector section. Electrostatic air cleaners can have a very high efficiency for collecting particles in the range of 0.01 to 5 microns, with little pressure loss. Regular cleaning is required to remove collected material from collector plates. Although these devices are mostly effective in removing particulate matter, evidence suggests they are somewhat effective against certain gases and vapors. Radon decay products tend to attach to particles. Therefore, when particles are removed, some radon progeny are also removed. However, the proportion of unattached radon progeny is likely to increase, so the effect on health risk is unclear. The air cleaners may ionize some gases, such as carbon dioxide, but the removal efficiency is low.

Centrifugal separators are dependent on the difference between density of the air and density of the particles and on the particle size. These systems do not work well for very small particles that have a relatively large surface area for their mass. Centrifugal separators are used mostly for dust removal in industrial applications.

Air washers are also used in industrial applications and in dessicant cooling systems. Chemical reagents can be used as the washing fluid to remove gases such as sulfur dioxide from power plant boiler emissions. Atomic submarines use air washer systems to remove carbon dioxide. These systems are costly and, thus, not practical for use in commercial buildings.

6.7.5 HVAC Control Techniques

The following summary is taken from Dorgan (1988). Currently one of the best approaches to indoor air quality control is to use carbon dioxide sensors. Carbon dioxide control will provide more make-up air than the ASHRAE minimum during peak occupancy, and constant or slightly more air during partial occupancy. An on-off control strategy supplies a fixed amount of make-up air regardless of occupancy levels. A fixed level of outside air of 5 cubic feet per minute (cfm) should be a constant minimum level of ventilation to guard against control failure.

Carbon monoxide sensors controlling exhaust systems in parking garages are now being used in Energy Edge buildings.

With the computer power available in some new buildings the concept of adaptive-learned control is possible. The essential concept is to gather feedback from individuals or zones, or use statistical feedback from all occupants, to optimize functional needs. This information is used to adapt future control sequences based on similar occupancy, weather conditions, task, or time. Indoor air quality evaluation could be based on indirect data, such as absenteeism, or on direct data collected by using sensors or through phone surveys. Varying the ventilation air and lighting levels could be used to develop control strategies for optimizing indoor air quality. In some buildings, air quality may vary by individual, but, for most buildings, room or zone sensors and controls can be used.

Occupancy detectors that determine total occupants in each space and/or activity level can benefit indoor air quality. Although 20 cfm per person may be adequate for a typical office, some spaces require more ventilation to remove pollutants in addition to respiratory contaminants. A copy room is a good example.

Knowledge-based expert systems may eventually be used for control of building systems. These systems may be used to evaluate and design indoor air quality building needs. A system of this sort is now under development for radon mitigation in residential applications (Brambly and Parker 1989).

Voice-communication systems may provide for direct communication with computers operating buildings. The computer could use the information to notify building operators or to make adjustments directly.

6.7.6 Potential Program Implications

The implications for Bonneville's commercial programs are listed below.

- Design assistance that includes technical information about the selection and installation of pollutant mitigation techniques may help reduce pollutant concentrations.
- If incentive payments are offered for the installation of conservation measures that affect ventilation rates, similar payments may be in order for indoor pollution mitigation measures.
- Ventilation practices similar to those adopted by Scandinavian countries--requiring that 100% outside air be circulated for the first 6 months of building occupancy--may reduce VOC exposure.
- Bonneville's residential programs now require that all new homes be equipped with minimum amounts of mechanical ventilation. This action may set a precedent for naturally ventilated commercial buildings.

7.0 OTHER ENVIRONMENTAL ISSUES RELATED TO COMMERCIAL CONSERVATION

This section summarizes environmental issues other than those related to indoor air quality and ventilation. The information presented below emphasizes areas that add to Bonneville's knowledge base. Thus, nothing is included about high- and low-pressure sodium lights, for which Bonneville has a long-standing policy. Sections are included on fluorescent fixtures containing polychlorinated biphenyls (PCBs), and ground- and water- source heat pumps. Bonneville has not yet addressed these issues in an environmental document.

7.1 POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) belong to a broad family of organic chemicals called chlorinated hydrocarbons. PCBs range in consistency from heavy oily liquids to waxy solids. Prior to 1979, PCBs were widely used as coolants in electrical equipment, such as transformers, capacitors, and switches, because the compounds do not easily burn, conduct electricity, or react with other chemicals.

When released into the environment, PCBs do not easily decompose. The compounds are relatively insoluble in water and have a high solubility in lipids, such as fats. As a result, PCBs accumulate in the food chain. Laboratory data show that PCBs cause cancer in animals. Although there is no direct proof that they cause cancer in humans, the Environmental Protection Agency's policy is to consider any animal carcinogen as a potential human carcinogen (EPA 1985). Animal studies show adverse reproductive and developmental effects from repeated exposure to PCBs. PCBs are toxic to fish at low levels of exposure, and adversely affects their survival rate and reproductive success. EPA believes there may be similar cause for concern when humans are exposed to large doses of PCBs (EPA 1985). Exposure can cause chloracne (a painful disfiguring skin illness) nausea, dizziness, eye irritation, and bronchitis. Ingestion can cause liver damage and digestive problems. The National Institute for Occupational Safety and Health recommends that PCBs be regarded as potential human carcinogens in the workplace (NIOSH 1986, p. 1).

In 1976, Congress passed the Toxic Substances Control Act, requiring EPA to regulate all chemicals that present an unreasonable risk. PCBs were the only chemicals Congress singled out for regulation (Oatman et al. 1985). Standards or guidelines exist for occupational exposure to PCBs, PCB levels in drinking water, and for contamination of certain food products. However, there are no generally accepted guidelines for PCB surface levels or air concentrations in buildings (Oatman et al. 1985).

The EPA does not regulate the disposal of light fixtures containing PCBs. Conversations with the EPA's Region 10 office in Seattle, Washington, suggest that the intent of not regulating disposal is to allow individual consumers to dispose of small quantities of fixtures that may be found around the home.^(a) The EPA office, together with an informal survey of regional hazardous-waste transport and disposal companies suggest that many landfills will not accept contaminated fixtures for disposal. The EPA office urged that, at a minimum, contaminated ballasts be disposed of at an approved chemical landfill. The EPA office preferred that the PCBs be disposed of at an approved incinerator.

7.1.1 PCB Contamination in Commercial Buildings

A potential source of PCBs in buildings are fluorescent light fixtures containing ballasts manufactured before 1978. Ballasts manufactured since 1978 should be marked "NO PCBs". If the ballast does contain PCBs, about 1 to 1½ ounces of PCB fluid will be located inside the small capacitor. If the ballast fails, the capacitor may break open, allowing the PCB oil to leak. The EPA reports that a condition that may lead to ballast failure is the operation of energy-saving lamps with a standard ballast, or standard lamps with an energy efficient ballast (EPA 1985). However, this position is controversial. Some researchers believe that energy-efficient lamps only accelerate the failure of old ballasts that would soon fail anyway, and do not contribute to PCB leaks.

In an effort to characterize background and contaminated PCB concentrations, Oatman et al. (1985) found that the average level of airborne PCBs in buildings with PCB-contaminated fluorescent light fixtures was nearly

(a) Personal communication with Bill Hedgebets, Environmental Protection Agency, Region 10, Seattle, WA, March 1, 1989.

twice the level in buildings without such fixtures: 0.457 and 0.227 $\mu\text{g}/\text{m}^3$, respectively.

In measurements taken in Seattle classrooms 34 days after ballast burnout, NIOSH (1987) found airborne PCB concentrations ranging from 0.74 to 1.2 $\mu\text{g}/\text{m}^3$. The PCB levels were much greater immediately after the ballast failure. NIOSH did not detect PCBs in classrooms that had not experienced burned out ballasts. Two classrooms had levels greater than noncontaminated rooms 140 days after burnout. NIOSH reports that these findings are similar to results found by MacLeod (as reported in NIOSH 1987, p. 8) in a study of a single ballast burnout. MacLeod found PCB concentrations of 11.6 $\mu\text{g}/\text{m}^3$ initially, 1.3 $\mu\text{g}/\text{m}^3$ at 31 days, and 0.50 $\mu\text{g}/\text{m}^3$ at 61 days after burnout.

These data show that incidents of fluorescent light ballast burnout can release PCBs into indoor air and result in concentrations above comparable background levels. Furthermore, the contamination may exceed NIOSH recommended occupational levels. The NIOSH recommended standard for occupational exposure is a time-weighted average of 1 $\mu\text{g}/\text{m}^3$ total PCBs in air for up to a 10-hour work day, 40-hour work week (NIOSH 1987, p. 6). NIOSH reports typical background concentrations in commercial office buildings ranging from below detection to 0.33 $\mu\text{g}/\text{m}^3$.

Ballast failure may also lead to surface contamination. NIOSH (1987) found that PCB concentration in classrooms with burnout ranged from below detection to 2.4 $\mu\text{g}/100\text{ cm}^2$. The classrooms without burnout ranged from below detection to 1.2 $\mu\text{g}/100\text{ cm}^2$. The mean concentration of the contaminated rooms was about twice that of the noncontaminated rooms: 0.57 and 0.23 $\mu\text{g}/100\text{ cm}^2$, respectively. Oatman et al. (1985) also found that PCB surface levels may be elevated in buildings with contaminated transformers, as compared to other buildings.

NIOSH investigators use 50 to 100 $\mu\text{g}/\text{m}^2$ as a guideline to assess PCB exposure from contaminated surfaces in commercial office buildings (NIOSH 1987, p. 7). The EPA has recommended a cleanup criteria of 10 $\mu\text{g}/100\text{ cm}^2$ for surface areas likely to have high skin contact (52 FR 10688). NIOSH (1987, p. 7) reports typical background surface concentrations in commercial office buildings ranging from below detection to 21 $\mu\text{g}/\text{m}^2$.

In addition to ballast failure, fire may also cause PCB contamination in buildings. Fire-related incidents are defined as incidents in which heat from any source causes the release of PCBs from electrical equipment casing. In soot-producing incidents an actual fire exposes PCBs to extremely high temperatures, forming a black carbonaceous material. PCBs have been identified in soot following numerous electrical equipment fires (NIOSH 1986).

7.1.2 Ballast Removal

Oatman attempted to characterize PCB levels in public buildings because of public concern in Minnesota about PCB contamination in public buildings. In Milwaukee, Wisconsin, the largest retrofit to solid-state ballasts in this country may also be the largest PCB-contaminated ballast disposal project (Energy User News 1989). In this project for the Milwaukee Public School District, about 175,000 fluorescent fixtures are being replaced. The capacitors are being removed, transported, and incinerated at a total cost of about \$2 per ballast.

In addition to the public building example above, there is also interest in disposing of PCB-laden ballasts from commercial buildings. One disposal contractor reported that his firm had worked on 5 projects in the last several months involving the removal, transport and disposal of fluorescent ballasts containing PCBs.^(a) The firm typically disposes of the ballasts in an EPA approved hazardous chemical landfill. This level of activity suggests that during building remodeling or removal, private companies are disposing of PCBs in EPA-approved landfills--to limit future liability and because solid-waste landfills will not accept large quantities of ballasts.

7.1.3 Potential Program Implications

The following may have implications for Bonneville's commercial building conservation programs. Additional information is presented in Appendix B.

- Bonneville has developed a general strategy for disposing of PCB-contaminated fluorescent light fixtures as part of a small-scale lighting change-out project conducted in Clark County, Washington. A region-wide process has not been developed. The small-scale strategy is not yet covered by a NEPA document.

(a) Personal communication with Mr. Gary Hahn, principal of Hahn and Associates, April 6, 1989.

- Bonneville's current strategy for disposing of ballasts when entire fixtures are replaced may not cover the potential danger of installing energy-efficient lamps in old standard ballasts. The EPA reports that this practice may lead to ballast failure, which in turn may lead to PCB leaks. The EPA recommends that replacement lamps should only be used with ballasts marked "No PCBs". EPA's position on this issue is controversial and is based on unpublished consultants' reports. Some researchers believe that energy-efficient lamps only accelerate the failure of old ballasts that would soon fail anyway. Some researchers also believe that installing energy-efficient lamps in PCB-laden fixtures does not contribute to PCB leaks.

7.2 GROUND- AND WATER-SOURCE HEAT PUMPS

A water-source heat pump uses a water-to-refrigerant heat exchanger to extract heat from a heat source. The source can be ground water, river or lake water, city water, or stored solar energy. Ground-coupled heat pumps use the earth itself as a heat source and a heat sink. An earth-coupled system transfers heat through a closed loop of water in polybutylene, polyethylene, or copper piping that is buried underground. The environmental requirements currently ask that site-specific environmental reports be prepared for each project involving subsurface resources. In some cases, Bonneville may determine that preliminary information submitted by contractors is adequate. At least one building participating in the Energy Edge Program utilizes a groundwater-source heat pump, but an environmental report was not prepared for it.

7.2.1 Environmental Effects

Several types of fluids are commonly used in heat exchangers: plain water; water mixed with an antifreeze, such as ethylene glycol, propylene glycol, or calcium chloride; or refrigerant. The water and antifreeze mixtures protect pipes from freezing and bursting. Ethylene glycol is a permanent antifreeze similar to that used in automobiles. It is highly toxic and may not be permitted by building codes. However, installers have listed it as a common antifreeze additive. Propylene glycol is less toxic than ethylene glycol. The 1986 Environmental Requirements (Bonneville 1986) note that food-grade propylene glycol is "relatively nontoxic." Calcium chloride is nontoxic. The refrigerants used in heat pumps are nontoxic. However, see Section 7.3 for other environmental effects.

Thermal withdrawals and discharges into water and the ground are not likely to have substantial effects. Ground-source heat pumps should be designed so that pipe runs are below the frost line and no additional ground freezing should occur around the pipes. Only in extremely cold climates has ground freezing been a problem.

In water-source heat pumps discharge water often causes temperature changes around the recharge well. Thermal changes caused by water-source heat pumps are generally considered insignificant. But temperature changes may cause the following: dissolution or precipitation of mineral constituents that may eventually plug the aquifer; swelling and movement of clays; increased bacterial growth; additional sinkholes in areas with carbonate rocks; and alteration of species distribution due to consistent temperature gradient around the discharge.

Federal, state, and local regulations impose restrictions and mandate various requirements for well construction, groundwater use, and effluent disposal. The Safe Drinking Water Act was enacted to ensure that states adequately protect public water systems. Heat pumps that use a reinjection system, or discharge water in a way that could affect drinking water, may be subject to regulations as a Class V well discharge system, depending on the particular state's interpretation of the Act.

Ground-water heat pumps may affect water quality if a polluted aquifer is tapped by supply or injection wells. Heat pumps using a dual-aquifer system may spread pollution from one aquifer to another. Heat pumps may also spread pollutants within a single aquifer to contaminate previously clean areas.

7.2.2 Potential Program Implications

The following considerations may affect Bonneville's commercial building programs:

- A survey of how the Northwest states are implementing the Safe Drinking Water Act may be needed.
- Bonneville now requires that heat exchanger fluids used in active solar systems be nontoxic. Similar restrictions may be appropriate for ground- and water-source heat pumps.

- The distinction between ground-source and water-source heat pumps is not clear in the 1986 Environmental Requirements. Further review may show that different requirements are needed for each.
- Bonneville's environmental requirements for ground-source and water-source heat pumps have not been included in a NEPA document.

7.3 OZONE REDUCTION AND GLOBAL WARMING

7.3.1 Ozone Depletion

Chlorofluorocarbons (CFCs) are compounds containing fluorine, chlorine, carbon, and sometimes hydrogen that scientists have recognized as depleting stratospheric ozone. The EPA has predicted that every 1% decrease in ozone will result in a 1% to 2% increase in melanoma skin cancer incidence. In addition, other environmental effects of ozone depletion include global warming, the increased production of atmospheric ozone, crop damage, and increased degradation of manmade materials.

In response to the global nature of CFC production and potential impacts, representatives of over 60 nations met in Montreal, Canada, and established the Montreal Protocol. The Protocol requires ratifying nations to limit to 1986 levels the short-term production of CFC-11, -12, -113, -114, and -115, based on their relative ozone depletion rates. These acts are to be followed by a phased reduction to 80% and 50% of 1986 levels beginning in mid-1993 and mid-1998, respectively (UN 1987; 53 FR 30566). Nations are continuing to meet to discuss even more stringent CFC restrictions. Meanwhile, the EPA is now implementing rules in accordance with the Montreal Protocol to limit production and consumption of these compounds through an allocated quota system (53 FR 30574; 53 FR 30566).

Although the CFC issue is global in scope, local governments are also taking steps to control production. The banning of polystyrene foam food containers from Portland, Oregon, restaurants demonstrates the regional interest in controlling CFCs.

Two of the compounds that EPA is regulating are CFCs-11 and -12. These compounds are used as blowing agents in the production of plastic foam insulation and as a heat transfer compound in refrigerators and heat pumps. These compounds are used because of their excellent thermodynamic properties,

low cost, and nontoxicity. The drawbacks of substitutes include reduced performance in the areas where CFC-11 and -12 excel, but also corrosiveness, explosiveness, combustibility, and processing difficulties (Ember et al. 1986). Methylene chloride, pentane, and carbon dioxide are alternative blowing agents that have been available for years. However, each has its drawbacks. Methylene chloride is a carcinogen and is difficult to dispose of. Pentane is flammable and contributes to photochemical smog. And carbon dioxide results in denser flexible foams with poorer insulating properties (Brown et al. 1989).

However, new blends of compounds similar to CFCs may hold promise. Recently the world's largest producer of CFCs, E.I. du Pont de Nemours & Company, announced a new blend of chemicals that may replace widely used CFCs such as CFC-12 (Science News 1989). The new mixture, HCFC-124, along with two compounds already available, HCFC-22 and HFC-152a, may work in existing refrigeration and air conditioning equipment with little change in design. Du Pont claims that the new blends can perform as well as CFC-12, but are 97% less damaging to stratospheric ozone. These compounds have not yet been fully tested and will require approval from the EPA, a process that may take as long as 4 years.

Alternative refrigerants that are now being used include helium and ammonia. A New Jersey company is producing helium cooled energy-efficient refrigerators. Ammonia refrigerants are now used in Japanese commercial buildings (Brown et al. 1989).

The scientific, industrial, and regulatory communities have come close to consensus on the need to limit production. Dow Chemical, a leading manufacturer of rigid foam insulation, has announced it will stop using regulated CFCs by 1989 (Brown et al. 1989).

An example of the type of tradeoffs that are occurring from the need to limit CFC consumption is found in the current debate over the U.S. Department of Energy's setting of energy-efficient standards for refrigerators (The New York Times 1989). Industry argues that new standards requiring reliance on highly efficient insulation are unfair because of the uncertainty surrounding possible substitutes, such as vacuum-sealed insulators. Public interest groups argue that the standards are necessary to conserve energy and reduce load

growth. A recent editorial in the Portland Oregonian (January 16, 1989) argued that new standards should not come at the expense of ozone depletion that may result from the use of foam insulation.

7.3.2 Global Warming

Carbon dioxide contributes to global warming because of the greenhouse effect. A substantial source of carbon dioxide is the burning of fossil fuels. Thus, generating resources that rely on fossil fuels, especially coal and oil, must be evaluated in terms of their potential impact on the greenhouse effect. These impacts should result in increased social costs of using these resources.

7.3.3 Potential Program Implications

The following may affect Bonneville's commercial conservation programs.

- There is a high degree of environmental awareness surrounding CFCs. This may put pressure on Bonneville to limit the programmatic use of CFCs for plastic foam insulation, refrigerants, and thermal-transfer compounds.
- As the CFC products become more scarce they are likely to become more expensive. This added expense and scarcity may disrupt the assumptions underlying cost-benefit analyses, the structural framing modifications needed to meet specific thermal requirements, and the construction industry's and appliance manufacturers' acceptance of energy-efficient codes.
- Conservation's ability to forestall load growth and reduce future demand for new generating resources, suggests that conservation also forestalls the greenhouse effect. Thus, the social utility for conservation should include credit for reducing greenhouse gasses. To date, economic analyses in the Northwest have not recognized conservation's utility for reducing the greenhouse effect. But such recognition would make conservation more competitive with generating resources that burn fossil fuel. Such an improved competitive position may lead to increased demand for conservation programs in the future or allow for more expensive conservation to be purchased.

8.0 CONCLUSION

One of the key questions confronting commercial programs is whether they are pushing or possibly exceeding the limits of the scope of activities defined by the current environmental documents. It appears that programs may now exceed the currently defined scope in three ways: 1) by serving buildings types that have not yet been assessed in an environmental document, 2) by incorporating conservation measures that have not yet been assessed, and 3) by gradually modifying the procedures established in environmental documents.

8.1 PROGRAMS ACTIONS POSSIBLY OUTSIDE THE SCOPE

Areas in which the commercial buildings programs appear to be outside the scope of existing environmental requirements are as follows:

- including multifamily buildings in program contracts
- conducting programs to serve new buildings
- allowing the installation of conservation measures not covered by environmental documents, such as water- or ground-source heat pumps, economizers, air-to-air heat exchangers, and new types of sensors
- changing environmental requirements without NEPA documentation. Examples include updating asbestos removal procedures, applying requirements for existing buildings as recommendations for new building programs, or establishing PCB procedures in existing buildings.

8.2 NEW INFORMATION

New information suggests that the scope of existing requirements may no longer be broad enough to address many pertinent issues. The 1982 EA and FONSI address the indoor pollutants radon, particulates, and formaldehyde, but covers few other issues. The following are examples of issues that have emerged since 1982 that should be addressed by NEPA documents.

- Baseline ventilation rates in new and existing regional building stock
- Bonneville's residential conservation programs require mechanical ventilation in all new structures. This requirement may serve as an example for commercial buildings with natural ventilation

- Adverse affects on VOC concentration from changes in ventilation rates
- Design methods to avoid biological contamination in HVAC and other building systems
- Potential mitigation techniques for VOC concentrations in new buildings, such as supplying 100% outside air during the first six months of building occupancy or building 'bake out'
- Potential mitigation strategies for ground- and water-source heat pumps, such as requiring nontoxic transfer fluids
- Procedures for PCB-contaminated light fixture removal and disposal
- The effects of installing energy-efficient lamps in standard ballasts, which may cause ballast failure and PCB leaking
- Possible alternatives for refrigerants using CFCs.

A new environmental document enlarging the scope of enviromental requirements may be needed if the programs are to continue unabated, or be expanded.

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APPENDIX A

LIST OF ENERGY CONSERVATION MEASURES AND
ACTIONS FROM THE 1982 ENVIRONMENTAL ASSESSMENT

APPENDIX A

LIST OF ENERGY CONSERVATION MEASURES AND ACTIONS FROM THE 1982 ENVIRONMENTAL ASSESSMENT

Appendix A is excerpted from the Environmental Assessment of Energy Conservation Opportunities in Commercial-Sector Facilities in the Pacific Northwest, DOE/EA-0187, which was prepared by the Bonneville Power Administration in August 1982. The material presented here as Appendix A was included in the 1982 Environmental Assessment as Appendix I. The material is printed directly from the original text, except that the page numbers have been changed to indicate the organization of the present document.

APPENDIX I

LIST OF ENERGY CONSERVATION MEASURES AND ACTIONS

I.1 POTENTIAL ENERGY CONSERVATION MEASURES (RETROFITS)

I.1.1 LIGHTING SYSTEM

- Remove lamps and fixtures
- Use only necessary illumination (microprocessor control)
- Use natural light
- Improve efficiency of existing fixtures
- Use more efficient lenses
- Install more efficient lamps
- Install more efficient fixtures
- Install more efficient ballasts
- Reduce the height of luminaires
- Install additional switching
- Use automatic dimming control systems
- Use photocells or timeclocks to turn off exterior lighting
- Replace inefficient incandescent systems
- Replace inefficient mercury vapor systems
- Install self-powered exit lights
- Use task lighting to reduce overall general lighting
- Install high frequency electronic ballasts

I.1.2 POWER SYSTEMS

- Reduce peak loads
- Use high efficiency motors and transformers
- Replace oversized motors
- Correct the power factor
- Use energy monitoring and control system
- Use variable speed pumps
- Use variable speed fans
- Install solid-state motor drives on elevators
- Install demand-type elevator controls
- Convert primary distribution system to high voltages
- Disconnect lightly loaded transformers

I.1.3 BUILDING ENVELOPE SYSTEMS

- Reduce transmission of heat through walls
- Reduce transmission of heat through windows and skylights
- Reduce transmission of heat through roof
- Reduce transmission of heat through floors
- Reduce space load due to outside air infiltration
- Insulate foundation (crawl space)
- Insulate slab perimeter
- Insulate/install skirting
- Install moveable insulation
- Reduce window areas to reduce heat loss/gain
- Install storm windows
- Use multiple glazed windows
- Reduce door size
- Install storm doors
- Install screen doors
- Replace existing doors with insulated doors
- Enclose loading docks
- Install loading dock door seals
- Reduce solar heat gain with solar film, overhangs, louvers or other screening/shading devices
- Install vestibules to reduce infiltration
- Seal vertical shafts to reduce infiltration (elevators, stairwells)
- Change surface colors to reflect/absorb heat or light

I.1.4 MECHANICAL SYSTEMS

Boilers/Heating Systems

- Install boiler flue gas heat recovery
- Install return condensate system to boiler
- Add flue dampers to gas systems
- Preheat boiler feed water
- Adjust fuel/air ratios of firing systems
- Install flue gas analyzer to boiler
- Replace existing boilers with modular boilers
- Preheat combustion air and heavy fuel oil to increase boiler efficiency
- Replace steam atomizing burners with air atomizing burners
- Blowdown - heat recovery and optimizer
- Replace steam traps
- Install automatic control valves for radiators
- Rezone heating system
- Replace gas pilots with spark ignition
- Install variable speed chiller motor
- Reset chilled water temperature

1.1.4 MECHANICAL SYSTEMS

Refrigeration/Cooling Systems contd

- Install automatic condenser cleaning
- Install chiller economizer
- Install spot cooling
- Increase evaporator and/or decrease condenser water temperatures and modify controls
- Isolate off-line chillers and cooling towers
- Replace air-cooled condenser with cooling towers
- Use a piggyback absorption system
- Install strainer cycle to chillers
- Install earth cooling tubes
- Install roof spray system
- Set cooling set-point up during summer
- Set heating set-point down during winter
- Prevent simultaneous use of heating/cooling
- Reduce heating requirements during night or unoccupied times
- Install energy monitoring control systems
- Install radio relay control systems
- Install enthalpy control/dry bulb economizer
- Reset of hot deck temperature
- Reset of cold deck temperature
- Zone optimize reheat systems
- Use duty cycling for fan control
- Install dead band thermostats
- Install warm-up cycle controls
- Reduce pump energy by reducing resistance and flow rates
- Insulate ducts
- Insulate piping
- Install heat pump systems
- Install high efficiency furnace
- Install high efficiency air handler
- Install high efficiency air-conditioning unit
- Convert existing air distribution system to a variable air volume system
- Install heat recovery systems

1.1.5 VENTILATION SYSTEMS

- Reduce energy consumption for fans by reducing air flow rates and resistance to air flow
- Employ heat recovery from exhaust air
- Minimize outside air intake
- Utilize dual speed fans
- Install outside air reset controls
- Install attic ventilation
- Install air stratification systems
- Eliminate unnecessary roof vents

I.1.5 VENTILATION SYSTEMS contd

- Recirculate exhaust air using activated carbon filters
- Use separate make-up air for exhaust hoods
- Employ evaporative cooling of outdoor air
- Employ desiccant dehumidification
- Use low leakage dampers

I.1.6 DOMESTIC HOT WATER SYSTEMS

- Insulate hot water storage tank and piping
- Use heat recovery systems to heat water
- Replace central system with local heating units and/or separate summer dehumidification
- Use low leakage dampers
- Use heat recovery systems to heat water
- Replace central system with local heating units and/or separate summer generation of hot water
- Use solar heating systems
- Use a heat pump system
- Install electronic spark ignitors on gas systems
- Install flue gas dampers on gas systems
- Install tankless heater systems to eliminate storage
- Install a timer on electric systems
- Install flow restrictors to limit water use
- Turn off domestic hot water pumps during off hours

I.2 POTENTIAL OPERATIONS AND MAINTENANCE OPPORTUNITIES

I.2.1 LIGHTING SYSTEMS

Remove lamps

Clean lighting fixtures and replace lamps on a regular maintenance schedule

Install timers to cut off lights and equipment automatically

Reduce outdoor security lighting

Turn off flood lighting that is strictly decorative

Light building for occupied periods only

Turn off lights that are not needed

Illuminate specific task areas to that level, for each area, which provides adequate lighting to perform the required task satisfactorily and reduce illumination levels in adjacent areas

Clean windows and skylights

Where practical, schedule cleaning and meetings during periods of building occupancy to make maximum use of daylight

Locate tasks that need the best illumination closest to the windows, with the task-viewing angle parallel to the windows.

Switch off electric lights in areas when natural light is available

Increase the inter-reflectances of interior surfaces

Consider replacing present lamps with those of lower wattage, which still provide adequate illumination

Remove fluorescent tubes, often one of every two, and remove ballasts to save ballast no load loss

I.2.2 POWER SYSTEMS

Load shedding

Disconnect all unnecessary devices. For example, ventilation fans can be turned off in elevators where smoking is not permitted.

Turn off devices that are not being used

Provide shading for exterior switch gear

Remove obstructions which diminish natural ventilation of switch gear

Shade exterior transformer banks from solar radiation to prevent heat build-up and resultant losses

Ventilate transformer banks to keep them as cool as possible

De-energize transformers wherever possible

If building has automatic load-shedding or demand-limiting equipment, connect elevators to the system to enable automatic shut-down of one or more to limit peak demand

If elevators are taken out of service, waiting period (floor dwell time) automatically will increase. If none are taken out of service, however, floor dwell time can be lengthened thus increasing the passenger load factor

If elevators have demand controls, adjust controls so that the fewest number of elevators travel the shortest distance that demand on the system allows

Do not permit elevators to time out and shut down too rapidly. They should idle long enough so that power consumption is equal to or just less than power consumed in motor generator starting

I.2.2 POWER SYSTEMS contd

Reduce the number of elevators in service during hours when the majority of persons are not leaving or entering the building
Turn off the motor-generator set located in the elevator machine room when not in use
Encourage occupants to walk up and down stairs instead of using the elevator

I.2.3 BUILDING ENVELOPE SYSTEMS

Inspect building exterior and interior surfaces and caulk all cracks that allow outdoor air to penetrate
Caulk around all pipes, louvers, and other openings that penetrate the building skin
Repair broken or cracked window panes
Weatherstrip and caulk exterior doors and windows
All operable windows should have sealing gaskets and cam latches that work properly
Cover window air-conditioners with plastic covers in the winter unless air-conditioners are used for heating
Inspect condition of indoor shading devices such as drapes and blinds which can reduce heat gain as much as 50 percent
During the heating season, close all interior shading devices before leaving space to reduce night-time heat losses
Use opaque or translucent insulating materials to block off and thermally seal all unused windows
Inspect all automatic door closers to ensure they are functioning properly
Inspect gasketing on garage and other overhead doors
Consider placing a small sign next to each door leading to the exterior or unconditioned spaces advising occupants to keep door closed at all times when not in use
Consider installing signs on exterior walls near delivery doors providing instructions to delivery personnel on operation of doors
Establish rules for all building personnel regarding opening and closing of doors, directing them to keep them closed whenever possible
Close off unused areas and rooms. Where possible, be certain that blinds or other shading devices are drawn, registers closed, etc.
If possible, have persons working after hours work in proximity to one another to lessen lighting and HVAC (heating, ventilating and air-conditioning) requirements
When repainting, consider use of light wall surfaces to reflect both heat and light
If possible, place in proximity to one another those persons whose tasks require similar lighting levels

I.2.4 MECHANICAL SYSTEMS

Shut down central heating, ventilating, and air-conditioning equipment during unoccupied periods to achieve substantial savings

1.2.4 MECHANICAL SYSTEMS contd

Isolate off-line boilers: when heating demand can be met by just one boiler of a multiple-boiler installation, energy can be saved by isolating boilers not in use

Fireside of the furnace and tubes must be inspected for deposits of soot, fly ash, and slag

Inspect boilers for scale deposits, accumulation of sediment, or boiler compounds on water-side surfaces

Keep a daily log of pressure, temperature, and other data obtained from instrumentation

Inspect linkages periodically for tightness

Inspect door gaskets

Observe the burner when firing units shut down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve

Inspect and clean nozzles or cups on oil-fired burners on a regular basis

Check burner fan blades for accumulation of dirt

Check burner firing period. If it is improper, it could be a sign of faulty controls

Clean mineral or corrosion build-up on gas burners

Inspect all boiler insulation, refractory, brick-work, and boiler casing for hot spots and air leaks

Inspect stacks. They should be free of haze. If not, it probably indicates that a burner adjustment is necessary

Replace all obsolete or little-used pressure vessels

Clean mineral or corrosion build-up on gas burners

Check flue gas analysis on periodic basis: the efficient combustion of fuel in a boiler requires burner adjustment to achieve proper stack temperature, CO₂, and excess air settings

Use an oil additive to provide better combustion. Introduce water vapor into the oil before combustion. (Water particles explode when heated, breaking up oil molecules to cause more complete combustion)

Operate boilers at lower pressure and temperatures in accordance with space heating demand

Consider elimination of hot standby boilers since, in many cases, a boiler failure will not cause serious hardship

Operate only the heating water pumps necessary

Inspect electrical contacts and working parts of relays and maintain in good working order for electric boilers

Check heater elements for cleanliness

Check controls for proper operation

Check and repair oil leaks at pump glands valves or relief valves

Inspect oil line strainers

Inspect oil heaters to ensure that oil temperatures are being maintained according to manufacturer's or oil suppliers recommendations

Inspect coal-fired stokers, grates and controls for efficient operation

Operate one of multiple compressors and chillers at full load, rather than two or more at partial loads

Improve operating efficiency by raising evaporator temperatures

Improve efficiency of chillers and compressors by lowering condensing temperatures

1.2.4 MECHANICAL SYSTEMS contd

Operate only the chilled water pumps and cooling tower fans necessary
Elevate chilled water temperatures when humidity conditions permit
Chillers must be kept clean. Inspect on a regular basis
Inspect for evidence of clogging
Keep water-side condenser tubing clean, and keep the refrigerant side free of noncondensables
Perform chemical testing of cooling tower water to determine if solid concentrations are being maintained at an acceptable level
Maintain cooling tower draft eliminators in good condition to keep water loss at a minimum
Regulate cooling tower water blowdown to the minimum
Check overflow pipe clearance for proper operating level in cooling towers
Check cooling tower fan by listening for any unusual noise or vibration.
inspect condition of v-belt. Align fan and motor as necessary
Keep the tower clean to minimize both air and water pressure drop
Clean intake strainer, of cooling tower
Determine if there is air by-pass from tower outlet back to inlet. If so, by-pass may be reduced through addition of baffles or higher discharge stacks
Inspect cooling towers for proper nozzle performance
Inspect gravity distributed tower for even water depth in distribution basins
Reduce use of heating and cooling systems in spaces which are used infrequently or for short periods of time.
When there is no danger of freezing, turn off radiators or supply registers in areas that do not have a separate thermostat
Turn off portable electric heaters and portable fans when not needed and during unoccupied periods
Shut off radiators or registers in lobbies
Adjust automatic timers or add time clocks for night and weekend operations for all areas occupied infrequently
Shut down cooling equipment at night and during days when the building is unoccupied
Develop an after-hours equipment operation checklist for use by custodial and other building personnel as well as occupants who may use various spaces after normal periods of occupancy
Schedule operating and maintenance work during the daytime, if possible
Inspect tension and alignment of all belts and adjust as necessary
Inspect insulation on suction and liquid lines. Repair as necessary
Look for unusual compressor operation such as continuous running or frequent stopping and starting
Inspect air compressor intake filter pads and clean or replace as necessary
Keep condenser coil face clean to permit proper air flow
Determine if hot air is being by-passed from the fan outlet to the coil inlet
Inspect refrigeration piping connections to the condenser coil for tightness
Keep fan blades clean
Inspect and lubricate bearings regularly
Inspect drive belts. Adjust or replace to insure proper operation. Proper tensioning of belts is critical
Inspect inlet and discharge screens of fans. They should be kept free of dirt and debris at all times

I.2.4 MECHANICAL SYSTEMS contd

Inspect fans for normal operation

Inspect ductwork for air leakage. Seal all leaks by taping or caulking

Inspect damper blades and linkages. Clean, oil, and adjust them on a regular basis

Inspect air valves in dual duct mixing boxes to insure full sealing and minimum air leakage

Inspect mixing dampers for proper operation

Clean or replace air filters on a regular basis. Maintain pressure drop across filters within preselected limits

Inspect ductwork insulation. Repair or replace as necessary

Inspect for leakage around coils or out of the casing. Seal all leaks

Inspect all room air outlets and inlets (diffusers, registers, and grilles).

They should be kept clean and free of all dirt and obstructions

Check alignment between motors and equipment

Keep motors clean

Inspect insulation of hot and chilled water pipes. Repair or replace as necessary. Be certain to replace any insulation damaged by water.

Determine source of water leakage and correct

I.2.5 VENTILATION SYSTEMS

Inspect filters carefully. If necessary, create a filter replacement schedule

Add a warm-up cycle to air handling units with outdoor air intake

When outdoor air dampers are not operating on economizer cycle, close them for the first and last hours of occupancy if outdoor air has to be heated or cooled

Shut off exhaust fan hoods in laboratories, kitchens, bakeries, and cafeterias when operations are completed

Establish a ventilation operation schedule so exhaust systems operate only when they are needed most

Consider cutting off direct outdoor air supply to toilet rooms and other potentially "odorous" areas

Reduce volume of toilet exhausts in buildings which have multiple toilet exhaust fans having a total fan capacity in excess of outside air requirements

If a food preparation area exhaust hood is oversized, adjust it so no more air than necessary is exhausted

Minimize the amount of fresh air intake during heating season in units equipped with mixed air controllers

Concentrate smoking areas together so that one ventilation system can serve them all. Adjust outdoor air to serve those areas and reduce outdoor air to all other systems

Reduce outdoor air to the minimum required

Inspect all outdoor air dampers. They should be as airtight as possible when closed. Check operation of position indicators for accuracy

In buildings with high ceilings, such as auditoriums, which are used for short periods or intermittent operation, outdoor air is frequently unnecessary

1.2.5 VENTILATION SYSTEMS

Provide general ventilation in accordance with occupancy, not on a continuous basis
Install baffles to prevent wind from blowing directly into an outdoor air intake

1.2.6 DOMESTIC HOT WATER SYSTEMS

Encourage off-peak hot water use to reduce system energy demand
Flush water heater during seasonal maintenance of heating systems. Clean very thoroughly
Repair leaky faucets
Repack pump packing glands of recirculation hot water heaters to reduce leaking of hot water
For boilers with immersion, tankless, domestic hot water coils, make sure boiler water covers coils
Inspect water supply system and repair all leaks, including those at the faucets
Inspect and test hot water controls to determine if they are working properly
Inspect insulation on storage tanks and piping
Reduce generating and storage temperature levels to the minimum required for washing hands, usually about 105°F
If hot water is distributed through forced circulation, turn off the pump when the building is unoccupied
Disconnect all refrigeration from water fountains if acceptable to building occupants
Discontinue sterilization of drinking water where possible and practical
Consider relocating water heater as close to point of use as possible
Consider replacing existing hot water faucets with spray type faucets having flow restrictors

APPENDIX B

PCB CONTAMINATION IN COMMERCIAL BUILDINGS: CHARACTERIZATION AND DISPOSAL OPTIONS

APPENDIX B

PCB CONTAMINATION IN COMMERCIAL BUILDINGS: CHARACTERIZATION AND DISPOSAL OPTIONS

1.0 LIGHT FIXTURES CONTAINING PCBs

1.1 INTRODUCTION

The proper disposal of light ballasts contaminated with polychlorinated biphenyls (PCBs) is an environmental issue that emerged at Bonneville from the Industrial Lighting Incentive Program. Portland Energy Conservation, Inc. (PECI), the contractor administering the lighting program, discovered that there was no Bonneville-sanctioned method for disposing of fluorescent and mercury vapor ballasts containing PCBs. Bonneville and PECO then established procedures to suit the relatively small-scale lighting program, which served only one utility and generated a total of four (4) barrels and one undefined box of PCB-contaminated ballasts. In October 1986, Bonneville issued interim guidance for PCB handling and disposal to be followed until the method of disposal used in the lighting program could be evaluated for future use. An evaluation of the PCB disposal process used in the Industrial Lighting Conversion Program is contained in the Program's environmental appraisal (BPA 1989).

The purpose of this report is to answer two broad questions regarding PCB contaminated ballasts: 1) Is this an issue that warrants further Bonneville attention? 2) If this issue does warrant Bonneville's attention, what are the costs of various options for disposing of PCB-contaminated ballasts?

1.2 DO PCB CONTAMINATED BALLASTS WARRANT FURTHER BONNEVILLE ATTENTION?

Polychlorinated biphenyls (PCBs) belong to a broad family of organic chemicals called chlorinated hydrocarbons. PCBs range in consistency from

heavy oily liquids to waxy solids. Prior to 1978 PCBs were widely used in electrical equipment such as transformers, capacitors, and switches as coolants because the compounds do not easily burn, conduct electricity, or react with other chemicals.

1.2.1 BACKGROUND INFORMATION

When released into the environment, PCBs do not easily decompose. The compounds are relatively insoluble in water and have a high solubility in lipids, such as fats; as a result PCBs accumulate in the food chain. Laboratory data show that PCBs cause cancer in animals. Though there is no direct proof that they cause cancer in humans, the Environmental Protection Agency (EPA) policy is to consider any animal carcinogen as a potential human carcinogen (EPA 1985). Animal studies show adverse reproductive and developmental effects from repeated exposure to PCBs. PCBs are toxic to fish at low levels of exposure, and adversely affects their survival rate and reproductive success. EPA believes there may be similar cause for concern when humans are exposed to large doses of PCBs (EPA 1985). Exposure can cause chloracne, a painful disfiguring skin illness, nausea, dizziness, eye irritation, and bronchitis. A study of personnel exposed to PCBs released from fluorescent light fixtures in an office complex, found the following acute symptoms: headache, eye irritation, sore throat, nasal congestion, nausea, dizziness, and itchy skin (Tavris et al. 1984). Ingestion can cause liver damage and digestive problems. The National Institute for Occupational Safety and Health (NIOSH) recommends that PCBs be regarded as potential human carcinogens in the workplace (NIOSH 1986, p. 1).

In 1976 Congress passed the Toxic Substances Control Act requiring EPA to regulate all chemicals that present an unreasonable risk. PCBs were the only chemicals Congress singled out for regulation (Oatman et al. 1985). Standards or guidelines exist for occupational exposure to PCBs, PCB levels in drinking water, and for contamination of certain food products, but there are no generally accepted guidelines for PCB surface levels or air concentrations in buildings (Oatman et al. 1985).

The EPA does not regulate the disposal of light fixtures containing PCBs. Conversations with the EPA, Region 10 office in Seattle, Washington, suggest that the intent of not regulating disposal is to allow individual consumers to dispose in landfills of small quantities of fixtures that may be found around the home.(a) The EPA office, along with an informal survey of regional hazardous waste transport and disposal companies, suggests that many landfills will not accept contaminated fixtures for disposal. The EPA office urged that, at a minimum, contaminated ballasts be disposed of at an approved chemical landfill. The EPA office preferred that the PCBs be disposed of at an approved incinerator.

1.3 PCB CHARACTERIZATION AND REMOVAL FROM COMMERCIAL BUILDINGS

A potential source of PCBs in buildings are fluorescent light fixtures containing ballasts manufactured before 1978. Ballasts manufactured since 1978 should be marked "NO PCBs". If the ballast does contain PCBs, about 1 to 1½ ounces of PCB fluid will be located inside the small capacitor. If the ballast fails, the capacitor may break open, allowing the PCB oil to leak. A condition that may lead to ballast failure is the operation of energy-saving lamps with a standard ballast, or standard lamps with an energy efficient ballast (EPA 1985).

1.3.1 Airborne Contamination From Ballast Failure

In an effort to characterize background and contaminated PCB concentrations, Oatman et al. (1985) found that the average level of airborne PCBs in buildings with PCB contaminated fluorescent light fixtures was nearly twice the level in buildings without such fixtures, 0.457 and 0.227 $\mu\text{g}/\text{m}^3$, respectively.

In measurements taken in Seattle classrooms 34 days after ballast burn out, NIOSH (1987) found airborne PCB concentrations ranging from 0.74 to 1.2 $\mu\text{g}/\text{m}^3$. The PCB levels were much greater immediately after the ballast failure.

(a) Personal communication with Bill Hedgebets, Environmental Protection Agency, Region 10, Seattle WA, March 1, 1989.

NIOSH did not detect PCBs in classrooms that had not experienced burned out ballasts. Two classrooms had levels greater than noncontaminated rooms 140 days after burnout. NIOSH reports that these findings are similar to results found by MacLeod in a study of a single ballast burnout. MacLeod found PCB concentrations of $11.6 \mu\text{g}/\text{m}^3$ initially, $1.3 \mu\text{g}/\text{m}^3$ at 31 days, and $0.50 \mu\text{g}/\text{m}^3$ at 61 days after burnout (as reported in NIOSH 1987, p. 8).

These data show that incidents of fluorescent light ballast burnout can release PCBs into indoor air and result in concentrations above comparable background levels. Further, the contamination may exceed NIOSH recommended occupational levels. The NIOSH recommended standard for occupational exposure is a time weighted average of $1 \mu\text{g}/\text{m}^3$ total PCBs in air for up to a 10 hour work day, 40 hour work week (NIOSH 1987, p.6). NIOSH (1987 p.6) reports typical background concentrations in commercial office buildings ranging from below detection to $0.33 \mu\text{g}/\text{m}^3$.

1.3.2 Surface Contamination From Ballast Failure

Ballast failure may also lead to surface contamination. NIOSH (1987) found that PCB concentration in classrooms with burnout ranged from below detection to $2.4 \mu\text{g}/100 \text{ cm}^2$. The classrooms without burnout ranged from below detection to $1.2 \mu\text{g}/100 \text{ cm}^2$. The mean concentration of the contaminated rooms was about twice that of the noncontaminated rooms, 0.57 and $0.23 \mu\text{g}/100 \text{ cm}^2$ respectively. Oatman (1985) also found that PCB surface levels may be elevated in buildings with contaminated transformers, as compared to other buildings.

NIOSH investigators use 50 to $100 \mu\text{g}/\text{m}^2$ as a guideline to assess PCB exposure from contaminated surfaces in commercial office buildings (NIOSH 1987, p.7). The EPA has recommended a cleanup criteria of $0.001 \mu\text{g}/\text{m}^2$ for surface areas likely to have high skin contact (52 FR 10688). NIOSH (1987, p. 7) reports typical background surface concentrations in commercial office buildings ranging from below detection to $21 \mu\text{g}/\text{m}^2$.

1.3.3 Contamination from Fire

In addition to ballast failure, fire may also cause PCB contamination in buildings. Fire related incidents are defined as incidents in which heat from any source causes the release of PCBs from electrical equipment casing. In

soot producing incidents an actual fire exposes PCBs to extremely high temperature and forms black carbonaceous material. PCBs have been identified in soot following numerous electrical equipment fires.(NIOSH 1986)

1.3.4 Ballast Removal

Oatman attempted to characterize PCB levels in public buildings because of public concern in Minnesota about PCB contamination in public buildings. In Milwaukee, Wisconsin the largest retrofit to solid-state ballasts in this country may also be the largest PCB contaminated ballast disposal project (Energy User News, February, 1989). In this project for the Milwaukee Public School District, about 175,000 fluorescent fixtures are being replaced. The capacitors are being removed, transported and incinerated at a total cost of about \$2 per ballast.

In addition to the public building example above, there is also interest in disposing of PCB laden ballasts from commercial buildings. One disposal contractor reported that his firm had worked on 5 projects in the last several months involving the removal, transport and disposal of fluorescent ballasts containing PCBs.^(a) The firm typically disposes of the ballasts in an EPA approved hazardous chemical landfill. This level of activity suggests that during building remodeling or removal, private companies are disposing of PCBs in EPA approved landfills to limit future liability, and because solid waste landfills will not accept large quantities of ballasts.

1.4 SUGGESTIONS FOR QUESTION 1

Telephone interviews with the EPA Region 10 office and regional hazardous waste disposal contractors, and the literature suggest that PCB light ballast contamination is an important issue. Public Health Agencies, such as the EPA and NIOSH, consider PCBs as potential human carcinogens, and recognize many other human and animal impacts. Private and public entities are taking safeguards to properly dispose of PCBs removed during conservation retrofits and when buildings are remodelled or demolished. As a means of limiting

(a) Personal communication with Mr. Gary Hahn, principal of Hahn and Associates, April 6, 1989.

potential liability, as well as protecting the human environment, Bonneville should consider establishing a procedure to ensure the proper removal, transport, and disposal of PCBs from light ballasts manufactured before 1979.

The EPA information (EPA 1985) reports that ballast failure, possibly leading to PCB leaks, may result from installing energy-efficient lamps in ballasts built before 1979. The private reports that EPA uses to substantiate this claim should be reviewed. If this claim is true, Bonneville should consider restricting the installation of energy-efficient lamps in older fluorescent ballasts.

The EPA does not give recommendations for mercury-vapor lamps. And no literature citations were found of case studies or environmental assessments of mercury-vapor fixtures containing PCBs. But if PCB contamination is present as reported by PECI, then Bonneville should implement safeguards similar to those for fluorescent fixtures.

2.0 QUESTION #2: WHAT ARE THE COSTS OF THE VARIOUS OPTIONS FOR DISPOSING OF PCB CONTAMINATED BALLASTS

Disposing of PCB contaminated light ballasts can be broken down into a four step process, as follows: 1) Removal of the fixtures and ballasts from the building, 2) Transport (to either a storage area or for disposal), 3) Storage of the ballasts to allow for accumulation to achieve economies of scale, and 4) Disposal of the ballasts at either an EPA approved landfill or EPA approved incinerator. For each step of this process Bonneville may either turn to a contractor, or complete the job in house. This section reviews potential market costs of using a contractor. Bonneville staff are preparing estimates of costs of using internal resources.

The information for this report was gathered from an informal survey of four hazardous waste disposal contractors. Of the four, three agreed to provide information. These three firms are listed at the end of the report. The informal survey data are compared with actual contract costs that General Electric charged Bonneville for transport and disposal of PCB laden ballasts from the Industrial Lighting Conversion Program. Comparisons are also made with cost data prepared by PECI., a contractor that administered the Industrial Lighting Conversion Program, and with data that Bonneville compiled, which is reported in a memorandum from Michael Berg, dated February 10, 1989, entitled "Cost Study--Hazardous Waste Management Options."

2.1 BALLAST AND FIXTURE REMOVAL

Ballast and fixture removal involve removing the fixture from the building and detaching the ballast. The ballast must then be packed in an approved drum. This work could be conducted by an independent contractor or by the firms retrofitting new lights in the building. The costs presented below do not include decontaminating any part of the building structure or furnishings because of PCB leaks.

2.1.1 Informal Survey Data

- Labor costs: \$45 per hour. To remove 2000 fixtures, and separate and pack the ballasts in approved drums is estimated to require 80 hours

- Cost of drums for packing range from \$45 to \$55

2.1.2 Comparison With Other Data Sets

Table 2.1 shows a comparison of applicable data sets.

TABLE 2.1. Comparison of Removal Costs

	Informal Survey	PECI	1986 GE Contract	Bonneville	Other
Labor per hour	\$45-55	\$40-65	--	--	
2000 ballasts	\$3600	NA	--	--	
Drum	\$45-55	\$30-50	*	--	
Packing Material	--	\$10-15	--	--	

* Drum costs included in pickup, storage, disposal charge of \$467.27 per drum.

2.2 TRANSPORT

Transport refers to the pick-up and moving of ballasts. Transport will be needed to move ballasts from the commercial building site to a storage area, and from a storage area to disposal.

2.2.1 Informal Survey Data

One hauler reported they charged whatever rate was prescribed by the state tariff. Other haulers reported wide ranges of possible costs because of the varying sizes of loads and the uncertainty in distances. All of the haulers agreed that Bonneville, or the commercial building owner, would be required to provide equipment for picking up the drums. If large PCB sources are to be included, such as large transformers, equipment such as a forklift may be needed.

- Cost of full truck load from Ashland to Vancouver: \$21.00 per drum
(A full truck load is 88 drums)
- Cost of full truck load from Seattle to Vancouver: \$14.50 per drum

- Note: Portland was included in our list of cities but we did not receive any reliable data for costs from Portland to Vancouver. One hauler did report that the cost per drum in a full load from Portland to Arlington was \$20. Arlington is the site of an approved chemical waste landfill. We requested data for cities on the east side of the Cascade Mountains, but haulers did not provide any reliable information.

Assuming a full truck load, the above responses for specific cities may be used to calculate the average cost per drum per mile. The following formula was used:

Step 1: $(\text{cost per drum from the above list}) / (\text{mileage from City X to Destination}) = \text{cost of transport per mile per drum for that particular city:}$

Ashland to Vancouver: $\$21 \div 300 \text{ miles} = \$.07/\text{drum}/\text{mile}$

Seattle to Vancouver: $\$14.50 \div 164 \text{ miles} = \$.09/\text{drum}/\text{mile}$

Portland to Arlington: $\$20 \div 136 \text{ miles} = \$.15/\text{drum}/\text{mile}$

Step 2: Add costs for all three cities:

$$.07 + .09 + .15 = .31$$

Step 3: Divide by the number of cities:

$$0.31 \div 3 =$$

Step 4: = The average cost of transport per mile per drum for the western part of the region.

$\$0.10/\text{drum}/\text{mile}$ in a fully loaded truck (88 drums)

= \$8.80 per fully loaded truck per mile

Step 5: Assuming 200 ballasts fit in one drum the cost per ballast per mile is as follows:

$$0.10 \div 200 = \$.0005/\text{ballast}/\text{mile}$$

In addition to travel costs there are also labor costs to label, load, and unload the drums. One hauler estimated it required 4 hours labor for 10 drums.

- Labor: $4 \text{ hrs} \times \$45/\text{hour} = \180 for ten drums. Assuming a linear relationship the following labor costs are associated with a full truck: $(88 \text{ drums} \div 10) \times \$180 = \$1600$

2.2.2 Comparison With Other Data Sets

Table 2.2 shows a comparison of applicable data sets.

Table 2.2 Comparison of Transport Costs

	Informal Survey	PECI	1986 Contract	Bonneville	Other
Transport per loaded truck per mile	\$8.80	--	--	\$3.75*	\$2.18+
per drum	\$0.10**	--	\$221.24++	--	--
Labor per hour	\$45	--	--	--	--
total to load 10 drums	\$180	--	--	--	--

*Bonneville's transportation cost for shipments from the Ross Complex to a generic TSD facility (Berg 1988, p. 2).

+Cost per mile of using Bonneville's "candy wagon". Programs may not be required to pay all of these costs because the candy wagon runs between substations regardless of the need for picking up PCBs. Apparently this cost would include all labor charges (Berg 1988, p. 2). These costs are useful if the substations are used as storage areas.

**Per drum per mile, based on the calculations and assumptions listed in Section 2.1.1.

++Cost per drum includes both storage and transportation. Local mileage was charged at \$0.57 to 0.60 per mile. \$221.24 was the storage, handling, and transport charge from Portland to an incinerator.

2.3 STORAGE

Only one hauler reported storage costs, which were \$5 per day per drum. The hauler noted that this cost was high. The reason for the high cost is to discourage the use of their limited storage area. Several options for storing hazardous chemical at the Ross Complex are presented in a memorandum by Michael Berg, dated February 10, 1988, and entitled "Cost Study--Hazardous Waste Management Options." The 1986 contract with General Electric lists combined transportation and storage costs per drum of \$221.24.

2.4 DISPOSAL

PCB contaminated transformers may be disposed of at either EPA approved chemical waste landfills, or at an EPA hazardous waste incinerator.

2.4.1 Informal Survey Data

The cost of disposal at an EPA approved landfill was reported by one hauler as \$190 per drum including transportation. Another hauler reported a cost of \$120 per drum if there were 10 drums.

The cost of incineration was reported by only one hauler. He gave a price of \$665 per drum plus transportation. Transportation to Chicago would be \$110 per drum if the drum was part of a full load of 88 drums. Assuming a full load this amounts to \$775 per drum. Assuming 200 ballasts per drum, this amounts to \$3.88 per ballast for transport and incineration.

For comparison a Bonneville analysis of GE's cost in the 1986 contract showed a total cost of \$12.10 per ballast for transport and incineration. The analysis is as follows:

- $963 \text{ pounds per drum} / 200 \text{ ballasts per drum} = 4.8 \text{ pounds per ballast}$
- $4.8 \times \$2.27 \text{ per pound incineration cost} = \$110.00 \text{ per ballast for incineration}$
- $\$221 \text{ per drum} / 200 \text{ ballasts} = \$1.10 \text{ per ballast for transport}$
- $\$11.00 + \$1.10 = \$12.10 \text{ total cost per ballast.}$

2.4.2 Comparison With Other Data Sets

The table below shows a comparison of applicable data sets.

Table 2.3 Comparison of Disposal Costs

	Informal Survey	PECI	1986 Contract	Bonneville	Other
Landfill per drum	\$120-190	--	--	--	--
Incineration per drum	\$775*	\$750-900+	\$965-2186**	--	\$400++

*Assumes a fully loaded truck with 88 drums traveling to Chicago.

+One hauler included transportation in this cost, others did not.

**Cost based on \$2.27 per pound x 963 pounds, the average weight of the drums picked up by General Electric during the Industrial Lighting Conversion Program. One hauler in PECO's data gave an average drum weight of 425 pounds. Using this figure the General Electric price per drum is \$965.

++Ballast disposal from the Milwaukee, Wisconsin School District. \$2 is the reported cost per ballast for removal, transport and disposal (Energy User News, February 1989, p. 28). Assuming 200 ballasts per drum, this translates into \$400 per drum. The costs at the Milwaukee project are influenced by two considerations. First PCB laden capacitors are removed from the ballasts. Using this technique, about 1500 capacitors fit into an approved drum, rather than the 200 complete ballasts that will fit. Second, the PCB waste was shipped approximately 120 miles to an incinerator near Chicago. The wastes from the Northwest must be shipped much further.

3.0 REFERENCES

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Bonneville Power Administration (BPA). 1989. Environmental Appraisal Report for the Industrial Lighting Conversion Program (Energy Efficient Lighting Systems). Portland, Oregon.

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Tavris D.R., C.L. Brumback. 1984. "Outbreak of Illness due to Volatilized Asphalt Coming from a Malfunctioning Fluorescent Lighting Fixture." AJPH 74(6):614-615.

U.S. Environmental Protection Agency (EPA). 1985. PCBs in Fluorescent Light Fixtures: A Fact Sheet. EPA Region 10 Office, Seattle, Washington.

4.0 ADDITIONAL SOURCES OF INFORMATION

PNL conducted Informal telephone interviews with the following companies:

- Chempro, 2203 Airport Way, Seattle Washington, contact: Kay Eberle, date: 3/10/89.
- Hahn and Associates, 434 NW 6th, Portland Oregon, contact: Gary Hahn, date: 3/10/89.
- Pegasus Waste Management, Inc., 30250 SW Parkway, Wilsonville Oregon, contact: Paul Hopkins, date: 3/9/89.

Information on the 1986 contract with General Electric was provided by Phyllis Dowty, Environmental Specialist; and Andy Eckman, Public Utilities Specialist, Office of Energy Resources, Bonneville Power Administration.

Information on costs gathered by Portland Energy Conservation, Inc., came from an unpublished, nondated report entitled "PC8 Preliminary Report." PECEI presented the report to Bonneville staff in about December, 1985.