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DOE / EIS-0050-FS

Final Environmental Impact Statement Supplement
Commercial and Apartment Conservation Service Program

August 1983

U.S. Department of Energy
Assistant Secretary,
Conservation and Renewable Energy
Office of Buildings Energy R&D

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COVER SHEET

FINAL ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT
COMMERCIAL AND APARTMENT CONSERVATION SERVICE

DOE/EIS-0050-FS

(a) Lead Agency: The Department of Energy.

(b) Proposed Action: Commercial and Apartment Conservation Service Program (CACS).

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For Copies of the Final EIS Supplement Contact: Program Manager at the above address.

(d) Designation: Final Environmental Impact Statement Supplement.

(e) Abstract: The Commercial and Apartment Conservation Service (CACS) is mandated by Congress in Subtitle D of Title V of the Energy Security Act of 1980. This subtitle adds Title VII of the National Energy Conservation Policy Act which established the Residential Conservation Service (RCS) in Title II. Environmental impacts of implementing the RCS program were analyzed in the Environmental Impact Statement, DOE/EIS-0050, issued November, 1979. The present final supplement analyzes health and safety, socioeconomic and physical environmental impacts of the CACS Program and several alternative actions. Impacts at the site of installation, and on the national and region levels have been analyzed, as well as the benefits of the program in terms of energy savings.

(f) The CACS Program will go into effect no earlier than 30 days after the availability of this Final EIS Supplement is announced in the Federal Register.

PREFACE

This Final Environmental Impact Statement Supplement (EIS-FS) analyzes the potential environmental impacts resulting from national implementation of the Commercial and Apartment Conservation Service (CACS) Program. The CACS Program was mandated by Congress in the Energy Security Act (P.L. 96-294) enacted June 30, 1980.

A Draft EIS Supplement (DOE/EIS-0050-DS) for the CACS Program was published in December 1980 as a supplement to the EIS for the Residential Conservation Service (RCS) Program (DOE/EIS-0050). At that time, DOE was in the process of issuing two proposed rules: one for the expansion of the RCS Program to include multifamily buildings without central heating or cooling systems; and one for the CACS Program which addressed small commercial buildings and multifamily buildings with either central heating or central cooling systems. DOE had designed these programs to allow some flexibility on the part of program participants to select whether a multifamily building would be a part of the RCS Program or a part of the CACS Program. Therefore, at the time, it was decided to issue one EIS supplement addressing both proposals.

The RCS and CACS programs' proposed and final rules were among those reviewed by the Agency subsequent to publication as part of the Administration's policy to minimize regulatory burden on affected parties. New proposed rules for the RCS and CACS programs were subsequently published on separate occasions. The new RCS rules include single-family dwellings and those multifamily buildings without central heating or cooling systems; the new CACS rules include small commercial buildings and only those multifamily apartment buildings containing either central heating or central cooling systems.

The RCS rules were amended on June 25, 1982. It was determined that the final EIS for the RCS Program and the draft supplement to the RCS EIS sufficiently addressed the environmental impacts associated with RCS.

The CACS rules are being issued much later. In order to properly address the environmental impacts associated with the proposed CACS Program, and to incorporate the results of new research, DOE is publishing this EIS-FS for the CACS Program.

This EIS-FS for the CACS Program addresses the program scope and the environmental impacts likely to result from these regulations. They reflect the Administration's policy of reducing regulatory burden to the maximum extent possible. Three changes that took place subsequent to the original proposed rule are:

1. through closer adherence to legislative language, reduction in the number of buildings eligible for an energy audit,
2. through closer adherence to legislative language, simplification of audit procedures, which is expected to result in less detailed information provided to customers, and less conservation retrofit activity by customers, and
3. adoption of a 7-year payback period for measures to be addressed in the audits and elimination of some energy conservation and renewable resource measures from the audit, including wind energy systems, active solar systems, and cogeneration systems.

These three changes from the initial proposal are expected to result in decreased program and environmental impacts as compared with those projected in the CACS draft supplement.

In addition, three other considerations are relevant:

1. all apartment and many commercial buildings already have air handling or ventilation systems to assure acceptable air quality,
2. insulation, previously identified as posing a potential fire risk, is no longer expected to be a common retrofit measure, based on new information on current building practices,
3. the Consumer Product Safety Commission has banned the installation of urea-formaldehyde foam insulation (although the status of the ban at this writing is uncertain), considered to pose a health hazard, in residential buildings, and
4. large multifamily buildings, unlike single-family residences, are system-dominant, rather than envelope-dominant. This means that modifications to the mechanical systems of the buildings are the measures most likely to change energy consumption patterns. System modifications are much less likely to impact air change rates and resulting indoor air quality.

These four considerations are also expected to result in a decrease in environmental impacts from those discussed in the previous EIS draft supplement.

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SUMMARY

This document is the Final Environmental Impact Statement Supplement (EIS-FS) to the Residential Conservation Service Program and assesses the implementation of the Commercial and Apartment Conservation Service (CACS) Program. The CACS Program fulfills the requirements of Title VII of the National Energy Conservation Policy Act (NECPA) which was added by Title V of the Energy Security Act (ESA) of 1980.

The Residential Conservation Service (RCS) Program

The precursor to the CACS Program is the present RCS Program. The RCS Program is designed to encourage the installation of residential energy conservation and renewable resource measures through utility-provided energy audits and other services in accordance with state plans or a federal standby plan administered by DOE. The RCS Program allows states and the TVA to submit plans to conduct a program within their jurisdictions. These state plans require that covered public utilities (electric and natural gas) offer a complex of services to owners and tenants of single-family homes and multifamily residences with less than five units; Section 541 of ESA requires that, after January 1, 1982, larger multifamily residences without central heating or central cooling also be included in the RCS Program.

The RCS Program offers eligible customers energy audits; arrangements for the purchase, installation, and financing of covered measures; and lists of contractors, suppliers, and lenders complying with the program. In addition, participating customers are protected by warranty provisions.

In the EIS on the RCS Program, DOE identified the national environmental impact of the RCS Program, including a reduction in air and water pollutant emissions resulting from decreased energy production. The EIS also covered site-specific impacts, including concerns related to urea-formaldehyde insulation, vent dampers, automatic ignition systems, small wind energy systems, and indoor air pollution.

The Commercial and Apartment Conservation Service (CACS) Program

The subject of this EIS-FS is the CACS Program. The CACS Program is similar to the RCS Program in that:

- the same utilities are covered,
- the state plan and federal standby plan concepts are the same,
- many of the energy conservation and renewable energy resource measures are similar,
- the programs involve the provision of energy audits to encourage energy conservation.

The programs are complementary in that they address mutually exclusive sectors of the residential and commercial building inventory, with RCS covering single-family residences and apartments with individual heating and cooling systems and CACS covering larger, centrally heated or cooled apartment buildings and small commercial buildings.

The programs are different in that the RCS Program provides for a number of services not included in the CACS Program (e.g., financing arrangements, warranties, and lists of contractors, suppliers, and lenders). While the RCS Program was designed as a comprehensive program providing consumer assistance in the purchase and installation of energy conservation measures, the CACS Program is more limited in scope and focuses on disseminating information about energy conservation.

Measures in the CACS Program

The program measures included in the CACS Program are listed below.

- caulking and weatherstripping
- insulation of the building or dwelling structure and systems within the building (e.g., ceiling, wall, floor, duct, pipe and water heater insulation)
- storm windows and doors, multiglazed windows and doors, glazing heat gain/loss retardants, reductions in glass area, and other window and door system modifications
- automatic energy control systems and equipment associated with automatic energy control systems which are required to operate various heating, cooling, or ventilating systems
- replacement air conditioners
- furnace or utility plant and distribution system modifications, including:
  - replacement burners, furnaces, and boilers
  - devices for modifying flue openings, and
  - intermittent ignition devices
- replacement of the lighting systems
- energy recovery systems

- solar energy systems, either active or passive, including thermosyphon air systems, solaria/sunspace systems, solar domestic hot water systems, and solar replacement swimming pool heaters

Where possible, DOE has used the RCS Program measures and definitions for the Title VII equivalents in developing the regulations for the CACS Program.

Energy Efficient Improvements Under the CACS Program

Title VII of NECPA requires that the audits consider energy efficient improvements which represent changes in the operation and maintenance of the building or dwelling. DOE defines these energy conserving operation and maintenance procedures to include those listed below.

- furnace efficiency maintenance and adjustment
- water temperature reduction
- raising/lowering thermostats in summer/winter
- water flow reduction in showers and faucets
- conditioned space reduction
- plugging infiltration leaks
- sealing leaks in pipes and ducts
- efficient use of shading
- air conditioner efficiency maintenance
- steam distribution maintenance procedures

Anticipated Program Participation

For the purpose of estimating the impacts of the CACS Program, DOE has estimated the number of eligible covered buildings and apartments and a range of potential program participation rates among those eligible.

There are about 2 million commercial buildings and 328,000 apartment buildings eligible for the CACS Program. Estimates for program participation are based on the analysis conducted in the Regulatory Impact Analysis (RIA) for the CACS Program. The RIA presents three scenarios of potential response to the CACS energy audit, termed high, mid, and low.

Under the mid-case scenario, an estimated 3% of eligible customers will request and receive audits each year; or 18% over the six year life of the program. Of those requesting an audit, 20% will install one or more program measures at an average cost of $500 for commercial buildings and $1000 for apartment buildings, and 60% will adopt energy conserving operation and maintenance procedures which are presumed to have negligible cost. DOE "discounts" the results by attributing only 45% of the actions following an audit directly to the program.

Impacts of the CACS Program

Potential impacts include changes in health and safety due to the installation of program measures, especially impacts on indoor air quality, and reduced energy demand as a result of the program. Human health and environmental impacts in general, can be minimized to negligible levels by appropriate mitigating actions such as enforcing state specific standards, when necessary, concerning utilization of safe materials and proper installation. Health impacts may be mitigated by proper ventilation and airing out of buildings or installation of filtering devices for known pollutants, proper venting of gas stoves, and the elimination of problematic building materials or the isolation of pollutant sources from the indoor air. Consumer information on pollution sources and the relationship between air exchange rates and indoor air quality can do much to prevent potential problems.

The impacts under CACS of those measures analyzed in the RCS EIS are expected to be the same or less than the impacts of the RCS Program. Most are of a lesser magnitude. As with the RCS Program, CACS will have net environmental benefits because of a decrease in emissions from energy producing facilities compared to emission increases involved in materials producing facilities. Most net changes in air and water emissions are beneficial and none of the changes is major on a national scale. In cases where the RCS Program EIS identified no significant impacts associated with a particular measure, reference is made to the RCS Program EIS and the discussion in this EIS-FS is limited. The measures introduced in the CACS Program are not expected to have significant impacts. These impacts are summarized in Table S-1.

Impacts are analyzed through an examination of the known and potential effects of various measures and materials. Particular emphasis is placed upon indoor air quality, where quantitative modeling is used to support a review of the limited but growing literature on this issue. Where possible, reference is made to the RCS Program EIS and other relevant published documents.

Table S-1. Comparison of adoption rates and impacts of measures in the CACS Program

Measure	Included in RCS Program	Adoption rate: Multifamily	Adoption rate: Commercial	Impacts: Environmental	Impacts: Total Energy Savings
Caulking and weatherstripping	yes	moderately low	low	reduced air infiltration: lower indoor air quality	low
Insulation	yes	moderately low	moderately low	reduced air infiltration: lower indoor air quality: formaldhyde emissions if UF foam	low
Window and door modifications	yes	moderate	moderate	reduced air infiltration: lower indoor air quality	moderate
Automatic energy control systems & equipment	yes[a]	moderate	moderate	negligible	low
Furnace modifications	yes[a]	moderate	moderate	negligible	moderate
Replacement furnaces,	yes[a]	moderate	moderate	negligible	moderate
Lighting modifications	no	low	high	negligible	moderate
Energy recovery systems	no	moderate	moderate	negligible	moderate
Solar systems	yes	low	low	negligible	low
Other measures (replacement air conditioner)	yes[a]	moderate	low	negligible	low

[a]Not all measures in this category were in the RCS Program.

Indoor Air Quality

The impact on indoor air quality resulting from implementation of energy conservation measures is receiving wider recognition as a potential environmental problem. The installation of certain energy conservation measures in apartments and small commercial buildings could reduce the total air exchange rate and, in the absence of mitigating measures, lead to increased concentrations of pollutants arising from indoor sources.

The Department of Energy estimates that indoor air quality effects due to potentially reduced air exchange rates will be relatively minor for the CACS Program for several reasons. The principal measures which reduce unintentional infiltration - caulking and weatherstripping - will be installed relatively infrequently. For many apartment buildings such measures are expensive, labor intensive measures, with long pay-back periods. For many small businesses, sufficient customer traffic will pass through the building envelope so that caulking and weatherstripping will not appreciably affect the rate of air exchange.

The vast majority of available data on air exchange rates in the American building stock was obtained from single-family dwellings. The Department of Energy estimates that total air exchange rates in CACS-covered buildings are higher than in single-family detached dwellings and that this will be reflected in lessened indoor air quality impacts. The principal reasons for this conclusion are that model building codes generally require two or more air changes per hour and that the American

Society of Heating, Refrigerating, and Air-Conditioning Engineers recommends ventilation rates in excess of two air changes per hour for most small commercial establishments. (For example, the suggested air exchange rate exceeds two air changes per hour in 33 out of 55 commercial scenarios for which air exchange rates were calculated.) The staff at Oak Ridge National Laboratory has identified only two published studies of measured air exchange rates in apartments and office buildings. Total air exchange rates measured in six apartments in Pittsburgh under normal real-life conditions ranged from 0.3 to 1.7 air changes per hour. In two offices in Boston, total air exchange rates were 1.2 and 1.5 air changes per hour. DOE believes, however, that these data are not statistically representative of CACS-eligible buildings.

The major negative potential impact of the CACS Program may be the increased radiation population dose resulting from exposure to radon progeny. Exposure to radon progeny is known to cause lung cancer in uranium miners. Compared to a 1977 incidence of 95,182 reported deaths due to lung cancer from all causes, quantitative estimates of additional lung cancer deaths due to the CACS Program range from 0 to 7 deaths per year. The upper value is based on the assumption that the background radon progeny level in apartments and small commercial buildings is equal to the average level measured in 403 first floor single-family American dwellings in areas with typical concentrations of radium in the soil. Measurements of radon progeny levels in basements were about twice as high as first floor levels. Other assumptions used in the calculations were conservative which tends to maximize the impacts. If, as is assumed by DOE, air exchange rates are higher (and air exchange rate-reductions less) in the CACS-eligible buildings than in single-family detached dwellings, then the maximum impact would be reduced. If weatherstripping and caulking are infrequently implemented, then the maximum impact will be less. Air exchange reduction is frequently not as effective as assumed in this calculation, and that will also reduce the impact.

For other pollutants from strong indoor sources, air exchange reduction will result in increased exposure but there are insufficient data on which to base quantitative estimates of impacts. Examples of such indoor pollution sources include cigarette smokers, unvented space heaters, certain photocopiers, and products containing urea-formaldehyde resins.

There are three general classes of mitigating measures which will improve indoor air quality. Indoor air quality will be improved by measures which prevent pollutants from entering indoor air. It will also be improved by measures that either remove pollutants from indoor air or dilute them with clean outdoor air. DOE encourages the introduction of these measures into CACS-covered buildings.

Health and Safety

If materials used by the program are properly manufactured, and installed, and measures properly implemented there will be no significant health and safety hazards from utilization of conservation related materials. What hazards there are, are very similar to those of the RCS Program.

There may be some health and safety impacts from solar hot water heaters if heat transfer fluids leak and contaminate potable water or the environment. There are no serious health and safety concerns associated with passive solar systems.

Energy Savings

Total energy savings from the CACS Program are projected to be about 963 billion Btu the first year and about 0.115 quadrillion Btu (20 million barrels of oil equivalent) over the effective life of the program.

Socioeconomic Impacts

The CACS Program will have little impact on national employment levels. Employment gains will be from direct employment created by the program and from manufacturing of materials used in the program and from secondary employment resulting from increased disposable income available to households as a result of energy savings. Losses in employment are expected in the energy producing industries. DOE expects a net national employment increase to range between about 290 in the low-case scenario to about 1130 in the high-case scenario. This compares to an expected employment increase of approximately 30,000 workers directly involved in the RCS Program.

Analysis of Alternatives

In Title VII legislation creating the CACS Program there are a number of options and alternatives for DOE to consider in issuing regulations to implement the program.

Program Options

The Title VII legislation creating the CACS Program allows options for program implementation. Major options include:

- © change the type of audit to either a simplified one or an enhanced audit,
- © change the measures and procedures in the program by adopting a minimum mandatory list that must be covered in an audit or eliminating the state-added option,
- © enhance assistance to customers by making arrangments for purchase, installation, and financing,
- © state-set ceilings on commercial audit costs.

Options that would increase levels of impacts include establishing state-regulatory ceilings on commercial building audit charges, changing to an enhanced audit type, and increasing customer assistance. Impacts would be larger because these options would either increase participation adoption rates. The level of change in impacts would be determined by the magnitude of the increase in participation and adoption.

Options that would decrease impacts by decreasing participation and/or adoption rates are providing no assistance to customers and using a simplified audit. Impacts would decrease commensurate with participation and adoption changes. Changing the audit to a simplified type of audit or eliminating state-added measures and procedures, and having a mandatory national list would result in little or no change in impact levels.

Alternatives to the Program

In addition to the program options within the scope of the CACS Program, this EIS-FS evaluates a number of alternatives to the program. The alternatives fall into three broad classes (no-action, economic incentives, and legislative changes) which are summarized below. These alternatives will result in differing magnitudes of beneficial and adverse environmental impacts.

The No-Action Alternative

Based on trends in the installation of retrofit measures, the availability of information, other programs, and other incentives and disincentives to retrofit, the DOE estimates that, in the absence of the CACS Program, each year one-half of one percent of all eligible buildings will be retrofitted. This would result in a ten percent lower net demand for energy in 1990 compared to 1980.

Economic Incentives

Many of the measures covered in the CACS Program would require relatively large capital investments to cover material and labor costs. Economic incentives which increase the attractiveness of these investments, therefore, would be an alternative to the information dissemination activities of the program. Using such incentives to either reduce the initial costs of conservation investments or improve the rate of return on investments would likely increase retrofit rates and energy savings similar to levels expected for the program.

These economic incentives can take the form of either an indirect or direct subsidy. Direct subsidies could include provision of no-cost audits, grants to install energy conservation measures, or no- or low-interest loans either (1) for conservation investments by individual consumers, (2) to encourage start-ups of energy conservation-related businesses, or (3) on the shared-savings approach of energy service companies.

The primary indirect subsidy presently available is a residential energy tax credit for certain solar and conservation investments. The tax credit is applicable only to residential buildings where the owner resides on the premises.

Legislative Changes

An alternative to the energy audit approach of the CACS Program would be a requirement that all buildings or units meet minimum energy performance standards at the time of transfer (sale, or for commercial buildings, re-let). This would assure that all new owners and tenants receive energy efficient premises. This approach hinges on the turnover rate in the applicable building inventory. This turnover rate, however, may be so low as to make this alternative ineffective in achieving program goals regarding energy savings; both beneficial and adverse environmental impacts would also be reduced. For this approach to be considered, legislative changes are necessary.

1. PURPOSE AND NEED FOR THE CACS PROGRAM

This document is the Final Environmental Impact Statement Supplement (EIS-FS) to the Residential Conservation Service Program and addresses the Commercial and Apartment Conservation Service (CACS) Program. It analyzes the potential environmental impacts resulting from the implementation of the CACS Program mandated by Congress in the Energy Security Act of 1980 (P.L. 96-294). The program described in this chapter is that proposed for implementation by DOE.

The extension of an energy audit program to large apartment buildings (five or more units with central heating and/or cooling systems) and small commercial buildings is a part of a national effort to increase the efficiency of energy use in buildings and to shift from depletable energy sources to inexhaustible and renewable resources. In particular, the CACS Program is part of a broad effort designed to reduce the consumption of petroleum-derived energy in buildings of all types. The energy savings from the adoption of energy conserving measures, coupled with the use of solar and other renewable energy sources, can lead to a reduction in net energy consumption in the residential and commercial sectors, thereby contributing to a reduction in dependence on high-cost imported fuels and the more efficient use of domestic oil and natural gas supplies.

1.1 The Residential Conservation Service Program

The subject of this EIS-FS is the creation of the CACS Program for small commercial buildings and centrally heated or cooled apartment buildings. Since the program is closely related to the existing RCS

Program for single-family and small multifamily residences, a description of the RCS Program will provide the foundation for examining the CACS Program.

1.1.1 RCS Program Description

The RCS Program was created by Title II of the National Energy Conservation Policy Act (NECPA) (P.L. 95-619). The RCS Program is designed to encourage the installation of residential energy conservation and renewable resource measures in the homes of customers of large gas and electric utilities and home heating suppliers. State governments may prepare a State RCS Plan to regulate the development and administration of programs by the utilities in accord with the requirements of the federal rules; if a state fails to prepare a plan, then a federal standby plan applies to the utilities. Covered utilities* are required to initiate a coordinated program to include the following services for owners and tenants of single-family residences and small, individually heated and cooled multifamily residential buildings:

- information about estimated energy and cost savings for selected energy conservation and renewable resource measures,
- energy audits upon request,
- arrangements, upon request, for the purchase, installation, and financing of the selected energy conservation and renewable resource measures, and

*For both the RCS and CACS programs, covered utilities are, by the requirement of Section 211 of NECPA, those whose sales (other than for resale) annually exceed ten billion cubic feet of natural gas or 750 million kilowatt-hours of electricity.

- lists, upon request, of qualified suppliers, contractors, and lenders.

Certain aspects of the RCS Program were amended by the Congress as a part of the Energy Security Act of 1980. It added provisions that allow utilities to contract for and finance the purchase and installation of measures. Other amendments also clarified warranty provisions and the tax and utility rate treatment of parts of the program. Eligibility for the program was expanded to include tenants of multifamily residential buildings which have neither a central heating system nor a central air conditioning system.

The basic concept of the program is that utilities inform eligible customers of the availability of the services including low-cost or no-cost audits. Following the energy audit, the customer is offered the other services indicated above. With information about potential energy savings, and readily available purchase, installation, and financing, most customers are expected to choose to implement some or all of the conservation actions recommended by the audit.

Certain benefits also accrue to customers using the services offered by the utility:

- measures installed under the program must be covered by a manufacturer's warranty,
- billing and repayment services are available from the utility,
- a complaint resolution process is available to the customer should problems arise.

1.1.2 RCS Program Impacts

The environmental impacts of the RCS Program have been assessed by DOE in an Environmental Impact Statement (DOE/EIS-0050) issued in November 1979. In that EIS, DOE determined that the RCS Program will have net environmental benefits due to the decrease in energy production emissions compared to emission increases involved in materials production. DOE also examined the site-specific impacts resulting from utilization of measures covered by the RCS Program. For most measures, DOE determined that the risk to human health and safety, and to the environment in general, can be minimized to a negligible level by appropriate mitigative actions such as state specific standards when necessary for materials and installation and consumer information. Five specific concerns remained: urea-formaldehyde (UF) foam insulation, vent dampers, electrical ignition systems, small wind energy systems, and indoor air pollution due to decreased air infiltration into the living unit. DOE has addressed the concerns related to vent dampers, ignition systems, and small wind energy systems in the Final Rule (44 FR 64602). Concern over formaldeyhyde has been reduced but not eliminated since UF-foam use in residential buildings was banned by the Consumer Products Safety Commission in 1982. (Recently the ban has been vacated in the courts, but the issue has not been legally resolved.) The use of UF-foam in commercial buildings is still allowed. Decreased air infiltration in buildings where UF-foam is in place may lead to a decrease in indoor air quality. With respect to indoor air pollution, one possible mitigating measure identified by DOE is to distribute information to consumers on indoor air quality and sources of indoor air pollution.

1.2 The Commercial and Apartment Conservation Service Program

As a part of the Energy Security Act of 1980, Congress added a new Title VII to the National Energy Conservation Policy Act (NECPA). Title VII created the Commercial and Apartment Conservation Service (CACS) Program of energy audits for small commercial buildings and for multifamily dwellings with five or more units and a central heating system or a central cooling system.* The CACS Program is, in many ways, an extension of the RCS Program which was described in the preceding section. There are, however, significant differences. Similarities and differences are discussed below.

1.2.1 The CACS Program Description

Each state (and the TVA) may submit a state plan to cover regulated utilities in the state. The state plan must also identify which nonregulated utilities and building heating suppliers, if any, are covered under the state plan. If a state does not submit a plan, then a standby plan, issued by DOE, will apply to utilities in that state; nonregulated utilities not covered by a state plan which do not submit their own plan also fall under the jurisdiction of a federal standby plan.

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*"Central" refers to either a heating or cooling system which serves more than one apartment or a heating or cooling system which serves one apartment if the apartment building is centrally metered. For the CACS Program, a commercial building is one which was completed before June 30, 1980; is used primarily for business (profit or nonprofit), or state or local government activities; is not used for manufacturing or the production of products, raw materials, or agricultural commodities; and for which the average monthly use of energy during calendar year 1980 is less than 4000 kWh of electricity, and 1000 therms (100 million Btu) of natural gas, or 100 million Btu of another fuel if supplied by a covered building heating supplier.

Under the CACS Program, covered utilities are required to notify customers of the availability of energy audit services, and to perform commercial energy audits for customers who request them and agree to certain conditions. The energy audits are to be onsite inspections which inform the customer of the energy consumption of the building, the energy efficient improvements appropriate for the building, and the need, if any, for the installation of certain energy conservation and renewable resource measures. The concept of the CACS Program is that, equipped with appropriate information on potential energy savings, the eligible customers will implement the recommended improvements.

Title VII limits the charge for CACS audits in multifamily dwellings to $15 per unit or the actual cost, whichever is less. The state regulatory authority determines the amount a regulated utility may charge for an audit of a commercial building, but Title VII directs it to consider the customer's ability to pay and the effect of the charges on participation in the program.

1.2.2 Covered Measures

Two types of energy conservation improvements are included in Title VII: energy conserving operation and maintenance (O and M) procedures, and energy conserving program measures. Energy conserving O and M procedures have been defined by DOE as changes in the operation and maintenance of a building designed to reduce energy consumption. O and M procedures are generally considered to be no- or low-cost. O and M procedures included under CACS are listed in Table 1-1.

Table 1-1. CACS program measures and operation and maintenance procedures

CACS program measures[a]	O and M procedures
1. Air conditioning replacement	1. Air conditioner efficiency maintenance
2. Automated energy control system	2. Conditioned space reduction
3. Weatherstripping and caulking	3. Efficient use of shading
4. Energy recovery systems	4. Furnace efficiency maintenance and adjustments
5. Furnace/utility plant and distribution system modification	5. Plugging infiltration leaks
a. Intermittent ignition device	6. Steam distribution system maintenance
b. Vent damper	7. Sealing leaks in pipes and ducts
c. Replacement burner	8. Temperature raising in summer
d. Replacement furnace/boiler or heat pump	9. Temperature reduction in winter
e. Distribution system modifications	10. Water flow reduction in showers and faucets
6. Insulation	11. Water temperature reduction
a. Ceiling	
b. Duct	
c. Floor	
d. Pipe	
e. Wall	
f. Water heater	
7. Lighting system replacement	
a. Reducing light levels	
b. Controlling lamp operating time	
c. Replacement of lamps	
d. Daylighting	
8. Passive solar	
a. Thermosyphon air system	
b. Solaria sunspace system	
9. Solar domestic hot water	
10. Solar replacement swimming pool heater	
11. Window and door system modification	
a. Storm windows	
b. Thermal windows	
c. Storm or thermal door	
d. Glazing heat gain/loss retardant	

[a]See 47 FR 53236-58 (November 24, 1982) for description of program measures.

Program measures are defined as installations or modifications of installations designed to reduce the consumption of conventional fuels. Program measures included under CACS are listed in Table 1-1.

Program audits must address all O and M procedures and all program measures listed in Table 1-1 unless the audited building fails to meet specified applicability criteria. States may add O and M procedures and program measures as appropriate without DOE approval.

1.2.3 Comparison of the RCS and CACS Programs

The descriptions of the RCS and CACS programs presented above have noted a number of similarities and differences between the programs. The CACS Program is different in that it requires only that utilities provide energy audits and information about their availability; other RCS services including arrangements for the purchase, installation, and financing of measures and warranty provisions are not included in the CACS Program. Table 1-2 presents a comparison of the two programs. All procedures and measures listed in Table 1-1 are included under RCS with the exception of energy recovery systems, heating/cooling distribution system modifications, lighting system replacement, and steam distribution system maintenance.

1.3 Overview of CACS EIS-FS

The remaining chapters of this EIS-FS present an assessment of the likely environmental impact of the CACS Program.

Chapter 2 presents an analysis of alternatives. It examines options within the program and alternatives to the program.

Table 1-2. Comparison of CACS and RCS programs

Program feature	CACS	RCS
Building eligibility	Apartment buildings that are centrally heated or cooled with more than 4 units	Single-family residences and multifamily apartment buildings that (a) have less than five units, or (b) have neither a central heating nor cooling system
	Commercial buildings with less than 4000 kWh of electricity and 1000 therms of natural gas use (or equivalent) per month	
Utility involvement	Regulated utilities must participate through state plan; non-regulated utilities must submit plan to DOE if not covered by state	Same as CACS
Standby authority	DOE must implement standby plan if state or non-regulated utility does not submit or adequately implement plan	Same as CACS
Role of state goverment	May submit plan describing responsibilities of participating utilities	Same as CACS
Type of audit	Walk-through audit with energy and cost saving estimates for each procedure or measure; measure costs, payback period estimates, and information on purchase and installation	Audit is more detailed
Audit costs	$15 per unit or actual cost of multifamily audit whichever is less; no limit for commercial audits	$15 per unit or actual cost, whichever is less
Exemptions from program participation	State regulatory authority can set criteria for utility exemption	None, however NECPA has established provisions for grandfathering and temporary programs
Measures to be covered in audit	Measures specified by DOE; states can set criteria for determining which measures are covered in an audit; state may add measures	Same as CACS
Standard for measures	None set by DOE	None
Assistance to customers from utility	None	Arrangements for purchase installation and financing of measures; lists of qualified suppliers, contractors and lenders
Announcement schedule	Utilities must inform eligible customers within 12 months of plan approval and every 2 years thereafter	Same as CACS
Accounting	Utilities must maintain separate records of costs	Same as CACS

Chapter 3 is a characterization of the existing environment likely to be affected by the program. It first identifies and characterizes the population of buildings and energy users eligible for the program. This discussion is followed by an examination of the indoor air quality in eligible buildings, particularly in terms of ventilation rates and pollutant sources and concentrations. Finally, a brief survey of the conditions of the industries which produce the materials needed for the program measures is presented.

Chapter 4 examines the impact the program is likely to have on this environment. The analysis first discusses likely participation and retrofit rates. These rates become the basis for estimating the likely changes in indoor air quality, health and safety, potential energy savings and other socioeconomic impacts due to the program.

Chapter 5 is a list of preparers. Appendix A is a list of acronyms and abbreviations used in this document. Appendix B contains an in-depth discussion of the state of knowledge and methodology for assessing indoor air quality. Appendix C contains the comments received on the EIS draft supplement and the response to the comments. Appendix D gives the distribution list for the report.

REFERENCES FOR CHAPTER 1

P.L. 96-294. Energy Security Act.

P.L. 95-619. National Energy Conservation Policy Act.

DOE/EIS-0050. Final Environmental Impact Statement: Residential Conservation Service Program, U. S. Department of Energy, 1979.

44 FR 64602. Residential Conservation Service Program, U. S. Department of Energy, November 7, 1979 (10 CFR 456).

2. AN ANALYSIS OF ALTERNATIVES AND THEIR ENVIRONMENTAL IMPACTS

The purpose of this chapter is to analyze alternatives, both alternatives to the CACS Program and alternatives available within the Title VII legislation which created the program. The alternatives are analyzed in terms of the accomplishment of the goals of the program, as well as the relative environmental impacts each might reasonably be expected to cause. This chapter presents three classes of alternatives: alternatives within the program, the no action alternative, and programmatic alternatives. These are followed by a brief summary analysis of the relative impacts of each alternative.

2.1 Options Within the CACS Program

The enabling legislation allows a limited degree of regulatory flexibility for DOE in implementing the CACS Program. It is the purpose of this section to analyze some feasible program options in terms of both the likely effects on participation rates in the program and subsequent retrofit rates, and the likely energy and environmental impacts. Using relevant program features described in Table 1-2, a listing of program options is given in Table 2-1, together with the expected impacts of the options as compared with the CACS Program feature.

The legislation which created the CACS Program clearly indicates the need for two sets of rules:

- rules for the content, approval, and implementation of state plans (NECPA sections 712, 721 and 722), and rules for non-regulated utilities not included in a state plan (NECPA section 723), and

Table 2-1. Impacts of options within the CACS Program

Program feature	Options	Impacts: Participation rates	Impacts: Adoption rates	Impacts: Environmental impacts[a]
Type of audit	1. Simplified	Decrease	Decrease	Decrease
	2. Enhanced	Increase	Increase	Increase
Measures and procedures to be covered	1. Mandatory minimum national list	No effect	No effect	No effect
	2. Eliminate state additions	No effect	No effect	No effect
Assistance to customers	1. No assistance	Decrease	Decrease	Decrease
	2. Arrangements for purchase installation and financing of measures	Increase	Increase	Increase
Audit costs	1. State-set ceilings on commercial audit costs	Increase	No effect	Increase

[a] Includes energy savings, beneficial and adverse environment impacts. Beneficial environmental impacts are primarily national impacts due to the difference in pollution emissions saved by energy production versus those caused by materials production. These impacts are directly associated with energy saved and inversely associated with materials needed in the program. Adverse environmental impacts are primarily site-specific impacts including indoor air quality and other human health and safety impacts. These are directly related to the installation of specified types of measures which create the effects.

- © a federal standby authority to implement a program, should any state fail to submit and/or adequately carry out an approved plan (NECPA section 741).

The analysis of options within the proposed action alternative will focus on the first of these rules.

2.1.1 Type of Audit

DOE could replace the existing audit with a more simplified version (e.g. walkthrough with no analysis) or an enhanced version (detailed analysis). A simplified audit which takes less time to conduct may decrease the participation rate because audit results are less comprehensive and would likely result in decreased adoption rates. An enhanced audit would increase the participation rate due to greater information provided participants and would result in higher adoption rates. Overall the simplified audit would result in reduced energy savings and environmental impacts. The enhanced audit would result in greater energy savings as participation and adoption rates increase.

2.1.2 Measures and Procedures to be Covered

DOE has options concerning the list of O and M procedures and program measures. These include:

1. specifying a minimum mandatory national list which states do not have the flexibility to change,
2. eliminating the current option for state-added measures.

Option-1 would not have an effect on the participation or adoption rates. Option-2 is also judged to have no effect on participation and adoption rates.

2.1.3 Assistance to Customers

The CACS Program does not include a number of the services contained in the RCS Program, such as arrangements for purchase, installation and financing. DOE may be able to encourage some services through the approval of state plans and similar actions. The provision of such services would increase adoption rates by making actions less complicated for the customer. This would increase energy savings as well as the environmental impacts associated with higher adoption rates and energy savings.

2.1.4 State-set Ceilings on Commercial Audit Costs

The state regulatory authority has the option to set a ceiling on the cost of commercial audits to replace the practice of charging the actual cost. Reduced audit costs should increase the participation rate. This would result in increased energy savings and associated impacts.

2.2 Alternatives to the CACS Program

In addition to options within the CACS Program, there are a number of alternatives outside the proposed CACS Program which could aid in the achievement of program goals, either in lieu of or in addition to the CACS Program. These alternatives can be grouped into two broad classes: economic incentives and regulatory programs. Section 2.2.1 reviews the no-action alternative. Section 2.2.2 reviews alternative economic approaches requiring legislative changes and compares their participation rates, response rates, and environmental impacts to the proposed program. Section 2.2.3 reviews regulatory approaches requiring legislative changes to obtain the program goals. A summary of these alternatives is presented in Table 2-2.

2.2.1 The No-Action Alternative

The no-action alternative is an alternative mandated for consideration and assessment by NEPA. Also, in order to evaluate the net energy effectiveness and the net environmental impact of the CACS Program, a baseline case is necessary for comparison purposes. Thus, the no-action alternative is included in the evaluation of the CACS Program, even though this approach is contrary to current legislation. This baseline case postulates a scenario (same building inventory, same time period) in which the only difference from the program alternatives is the absence of the CACS Program.

The first part of the no-action alternative analysis involves estimating the percentage of eligible buildings in which conservation and renewable resource measures would be installed in the absence of the CACS Program. The factors used by DOE in determining these baseline adoption rates were:

- trends in the installation of such measures in multifamily residential and small commercial buildings,
- other programs (other than CACS) that encourage installation of conservation measures,
- other incentives and disincentives to investments in energy conservation such as the availability of financing, and
- the availability of information, materials, equipment, installation and maintenance services, etc., needed to install a measure.

Table 2-2. Comparison of alternatives to the CACS Program[a]

Alternative approaches	Retrofit rate	Environmental impacts[b]
1. Economic Incentives		
a. Increased direct subsidies	Substantial increase	Substantial increase
b. Increased indirect subsidies	Slight decrease	Slight increase
2. Regulatory standards	Substantial increase	Substantial increase

[a]Alternatives are compared to the expected impacts of the proposed CACS Program.

[b]Impacts include energy savings, beneficial and adverse environmental impacts. Beneficial environmental impacts are primarily national impacts due to the net reduction in pollutant emissions (energy savings caused decreases less materials production caused increases). These are directly related to the amount of energy saved and inversely related to the amount of materials used in the program. Adverse impacts are primarily site-specific impacts, such as indoor air pollution and health and safety risks, associated with the installation of particular measures, such as those which reduce air infiltration.

From this analysis, the DOE determined that each year, one-half of one percent of all buildings eligible for the CACS Program would be retrofitted with one or more conservation or renewable resource measures, in the absence of the program. This would occur due to individual initiative or participation in a limited number of utility sponsored audit programs. Currently, about 18 utilities have audit programs that cover either apartment or commercial buildings or both. While they have been successful, the programs cover only a small fraction of the buildings eligible under CACS.

The second part of the no-action alternative analysis is the determination of the net energy savings in the baseline case. For this purpose, the retrofit rate was input into the Oak Ridge National Laboratory's (ORNL) residential and commercial energy demand models (ORNL, 1981a; ORNL, 1981b; ORNL, 1983). Based on the ORNL models, the baseline retrofit rate, together with other changes in the pool of buildings (the normal rate of building demolition, loss due to fire, etc.), would result in a five to ten percent lower net demand for energy in the eligible building pool (both multifamily residential and small commercial) in 1990.

2.2.2 Economic Incentives

Many of the program measures covered under the CACS Program will require relatively large capital investments. A variety of economic incentives could serve to encourage building owners and tenants to make retrofit investments. These incentives function in one of two ways; either by reducing the initial cost of the capital investment or improving the rate of return on the investment.

Incentives may be classified as either a direct or an indirect subsidy. Direct subsidies are typically loans or grants. Indirect subsidies are usually tax benefits such as credits or deductions.

Grants could be made directly to consumers to pay for the installation of solar and conservation measures or to rebate the cost of an audit which leads to the installation of covered measures. Alternatively, loans could be made available at low- or no-interest to help consumers finance a solar or conservation investment. In either case, such subsidies would likely increase the retrofit rate in proportion to the size of the subsidies and the ease with which they might be obtained.

A different approach might be to provide subsidies to firms which supply solar and energy conservation services such as audits or the installation of measures to assist them with the large, initial capital outlay in starting a business. Subsidies such as low-interest loans from the Small Business Administration could lead to increased availability of needed firms and lower costs of providing solar, conservation, and audit services. This would, in turn, make solar and conservation investments more attractive to consumers.

Such assistance could be particularly effective if a performance contracting approach were used. Under this approach a contractor would offer to install energy conservation or renewable resource measures at no cost to the customer and receive payment from the utility for each unit of energy saved as a result. A similar approach could be used in which the contractor installs measures at no- or low-cost to the owner or tenant, and receives from the building owner or tenant all or a portion of the utility bills saved as a payment for the measures installed, for some specified period of time. In either case, the payment received by the contractor for installation of the measures and their maintenance depends directly on the energy saved. Thus the contractor's interest is to install the lowest cost but most effective measures in order to maximize his receipts. Such an approach would likely lead to higher retrofit rates for the most cost-effective measures.

The Energy Tax Act of 1978 (P.L. 95-618) added special tax credits for certain energy conservation and renewable resource measures for residential building owners. Homeowners (including multifamily building owners if they reside in the building) and renters are eligible for a 15% (up to $300) tax credit for insulation, caulking, weatherstripping, storm doors/windows, automatic furnance ignition systems and clock thermostats. Solar, wind, or geothermal energy systems receive a tax credit of up to $2200 (30% of the first $2000 and 20% of the next $8000).

The rate of response to such incentives is, of course, dependent upon the size of the credit and the ease with which an individual or business can obtain the credit or coordinate the tax benefit with other tax and fiscal matters. In the absence of an energy audit, such incentives encourage the installation of those measures for which there is a tax incentive. These may not be the most energy efficient measures, however. An alternative to the CACS Program would be to increase the tax incentives for renewable resources and energy conservation and to simplify the requirements for obtaining such incentives. This alternative, if coordinated with the proposed CACS Program, would increase retrofit rates, and environmental impacts.

2.2.3 Regulatory Standards

An alternative which has been suggested to the energy audit and retrofit approach of the CACS Program, is to require all buildings to meet certain energy efficiency standards at the time of transfer (sale and, for commercial buildings, re-let). This approach would ensure that new owners or occupants receive an energy efficient building, with potentially less disruption than a retrofit program which takes place during normal occupancy. The effectiveness of a time-of-transfer approach would depend on the rate of turnover in the eligible building stock.

REFERENCES FOR CHAPTER 2

ORNL, 1981a. "A Commercial Energy Use Model for the Ten U.S. Federal Regions," ORNL/CON-41, March 1981 by S. Cohn et. al.

ORNL, 1981b. "Energy Use from 1973 to 1980: The Role of Improved Energy Efficiency," ORNL/CON-79, December 1981 by E. Hirst et. al.

ORNL, 1983. "Modeling Buildings Sector Conservation Impacts of ASHRAE 90A-1980," ORNL/CON-82, by D. M. Hamblin and T. A. Vineyard, to be published.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

This chapter presents a description of the existing conditions of buildings covered under the CACS Program. The information in this chapter provides the background material necessary to understand the impacts of the CACS Program, which are presented in Chapter 4.

The first section identifies and characterizes the population of buildings and energy users eligible under the CACS Program. The following section presents a discussion of ventilation rates and sources and concentrations of pollutants in apartments and small commercial buildings. Finally, a summary is presented of the existing conditions of industries which produce the materials associated with each program measure.

3.1 Inventory of CACS-covered Buildings

3.1.1 Apartment Buildings

The CACS Program covers centrally heated or cooled multifamily dwellings with five or more units that were completed before June 30, 1980. The number of eligible apartment buildings can be estimated by using data from the 1980 Annual Housing Survey conducted by the Bureau of the Census (DOC, 1982). The census data provides a breakdown of the number of units which are in centrally heated or cooled buildings containing 2-4, 5-9, 10-19, 20-49, and 50 or more units per building. The midpoint for each of these categories was divided into the total number of units falling into that category to obtain the number of buildings for each category. Adding the number of buildings for each category above 5 (only buildings with 5 or more units are eligible for the CACS Program), and dividing this number into the number of units in the categories above 5 yields an estimate for the average number of units per building.

Based on an estimate of 7.1 million eligible apartments, this procedure provided an estimate of about 328,000 eligible apartment buildings. These eligible apartments are estimated to consume approximately 0.64 quadrillion Btu of energy (natural gas and electricity) each year. This amount represents about 77% of the 0.83 quadrillion Btu consumed in all multifamily structures each year.

3.1.2 Small Commercial Buildings

Under the CACS Program, an eligible commercial building is one which was completed before June 30, 1980; is used primarily for business (profit or nonprofit), or state or local government activities; is not used for manufacturing or the production of products, raw materials, or agricultural commodities; and for which the average monthly use of energy during calendar year 1980 was less than 4000 kWh of electricity, and 1000 therms of natural gas, or the Btu equivalent of any other fuel. The intent of the law is to cover only small commercial buildings, and it specifies the monthly energy use limit to restrict the number of eligible buildings.

Special tabulations (DOE, 1979b) from the EIA Nonresidential Buildings Energy Consumption Survey were used to estimate the number of potentially eligible commercial buildings. Using the EIA data, the characteristics of buildings using less than 4,000 kWh of electricity and 1,000 therms of natural gas were identified.

The tabulations from the EIA survey data indicate that there are approximately four million commercial buildings in the U.S., 50 percent of which may be covered by the CACS Program, and that the amount of the natural gas and electricity used by potentially eligible buildings compared to that used by all commercial buildings is about 7.5 percent (see Table 3-1). Based on this information, it is assumed that the CACS Program will affect about 7.5 percent of the energy used in the commercial sector or about 0.409 quadrillion Btu per year (taking into account all primary energy including the energy used to produce electricity). Table 3-1 also includes information on the total square footage of potentially eligible small commercial buildings. The 9.7 billion square feet of space that might be affected by the program represents about 20 percent of the total space in the commercial building sector.

Table 3-1. Commercial energy use summary statistics

Numbers	
All commercial buildings	3,995,000
CACS buildings	2,010,000
Energy consumption (quads)	
All commercial buildings	5.457
CACS buildings	0.409
Square footage (million ft^2)	
All commercial buildings	47,685
CACS buildings	9,679

Source: Table 2.3 in CACS Regulatory Impact Analysis.

3.2 Infiltration Rates

A primary concern with regard to the CACS Program is its effect on air exchange rates in apartments and small commercial buildings because air exchange affects indoor air quality. For this discussion, air exchange is defined as the sum of natural and mechanically induced air flows into a room or building. Appendix B reviews what is known about air exchange rates.

Most small commercial establishments, unlike single-family detached dwellings, are required by local building codes to maintain a certain ventilation rate (i.e. mechanically induced air exchange), usually expressed as volume exchange rates per person rather than total air changes per hour. Although local codes may vary somewhat, various organizations such as the Southern Building Council and the Council of American Building Officials recommend guidelines or model codes which serve as the basis for most state and local codes. Two such model codes are discussed.

The Building Officials and Code Administrators International, Inc. (1978) has developed a model building code for the protection of health and safety. Their standard for natural infiltration is based on a volume change of 11 m^3 (400 ft^3) of air per hour per occupant. When natural infiltration as provided by ventilating skylights, louvers, transoms, doors, or other openings in exterior walls or on the roof does not meet the code or when use of the building involves dust, gases, or fumes that present a health or safety hazard, a mechanical ventilating system is required to provide two air changes per hour.

Recirculation of air is permitted, except in kitchens, provided 25 percent of the incoming air is outside air. One hundred percent recirculation is permitted if the system services only a single family unit. Special ventilation requirements are recommended when potentially hazardous materials are present. For example, all rooms and spaces in a high- hazard dry cleaning establishment are required to have a mechanical ventilation rate of 20 air changes per hour. A moderate-hazard dry cleaning establishment must be provided with 10 air changes per hour. Public garages must have sufficient natural or mechanical ventilation to prevent the accumulation of carbon monoxide above 115 mg/m^3 (100 ppm) and gasoline vapors above their lower explosion limit. The owner could be required to provide laboratory testing to determine the adequacy of the ventilation system.

The Uniform Building Code (International Council of Building Officials, 1979) is another example of a model building code. For apartment and hotel rooms, it stipulates a mechanically induced ventilation rate of two air changes per hour. As an alternative, apartment rooms could be provided with windows that have an opening area equal to one-tenth of the floor area. For commercial buildings, the code requires exterior openings of not less than 1/20 of the floor area or mechanical ventilation equal to 5 cfm of outside air with the total circulated volume of air not less than 15 cfm per occupant. Areas that handle hazardous materials must be provided with four air changes per hour. Areas that handle operating cars and trucks indoors must be provided with 400 m^3 (14,000 ft^3) of air per minute per operating vehicle or other assurances that carbon monoxide levels stay below 58 mg/m^3 (50 ppm) over eight hour averaging intervals.

Another organization which has a recommended ventilation standard for acceptable indoor air quality is the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE, 1981). In Appendix B, some air exchange rates have been calculated from these suggested ventilation parameters for a variety of small commercial buildings. With the exception of corridors in large buildings, warehouses, greenhouses, pet shops, meat processing rooms, bank vaults, and libraries all derived air exchange rates exceed 0.6 air changes per hour and range up to 30 air changes per hour.

The author is aware of only one study where measurements of air exchange in apartments and offices have been published (Appendix B). For three high-rise and three low-rise apartments in Pittsburgh, Pennsylvania, air exchange rates ranged between 0.3 and 1.7 air changes per hour. In two office buildings in Boston, Massachusetts, air exchange rates ranged from 1.2 to 1.5 air changes per hour (Moschandreas et al., 1980). Very preliminary results from three low-rise apartment buildings in Chicago suggest that natural infiltration rates range from 0.1 to 0.75 air changes per hour (Malik, 1983). High-rise apartment buildings were found to have considerably higher air exchange rates due to corridor ventilation. If mechanical ventilation systems or fans from heating or cooling systems are operating, air change rates can increase considerably.

3.3 Indoor Air Quality

Several sources of indoor air pollutants currently exist in apartments and small commercial buildings. Pollutants include ozone, carbon monoxide, formaldehyde, nitrogen dioxide, and radon. The following sections describe some of the sources of pollution and the concentrations which have been found in existing residences and buildings.

3.3.1 Pollutant Sources

There are numerous sources of indoor air pollutants in the residential and small commercial establishment environment. Some indoor pollutants and their potential sources are listed below.

Indoor pollutants	Potential sources
Formaldehyde	Particleboard, insulation, plywood, carpet, human occupants, tobacco smoke
Radon	Concrete, stone, surrounding soil, groundwater, wallboard
Carbon monoxide	Heating and cooking combustion sources, tobacco smoke, automotive emissions
Nitrogen dioxide	Heating and cooking combustion sources, tobacco smoke
Respirable particulates	Heating and cooking combustion sources, tobacco smoke, automotive emissions
Organics	Particleboard, insulation, adhesives, paint, furnishings, automotive emissions
Workroom pollutants	Workers' clothing
Biohazards	Human occupants, moist surfaces, tobacco smoke
Ozone	Photocopiers

Sources of many of these pollutants are discussed in Appendix B. Most of these sources have been described in detail in the RCS EIS (DOE, 1979a). In addition, workers' clothing, cigarette smoke, and copying machines are discussed in this section.

Copying machines are a source of ozone (Allen et al., 1978; Selway et al., 1980) and perhaps other pollutants (Lofroth et al., 1980). Ozone is known to decay rapidly indoors (Mueller et al., 1973; Sabersky et al., 1973) which in some cases may mitigate potential ozone buildup. Moschandreas et al., (1980) failed to find ozone levels exceeding outdoor National Ambient Air Quality Standards in offices used for reproduction facilities in a modern, well-ventilated building.

Another source of indoor emissions (which may have an increased impact due to this program) is the clothing of occupationally exposed individuals. I. J. Selikoff and his coworkers are investigating health effects among nonoccupationally exposed individuals who reside with lead or asbestos workers. Preliminary results suggest that these work related toxicants may be carried away from the site of contamination. Such a phenomenon has been demonstrated for radioactive clothing contamination (Bailey et al., 1957). Furthermore, there is evidence that asbestos-related disease may occur among family contacts of asbestos workers (Anderson et al., 1979).

Cigarette smoking is a source of indoor air pollution (Harke, 1973). Sebben et al. (1977) found elevated levels of carbon monoxide in public locations where smoking was permitted and infiltration was relatively poor. Binder et al. (1976) found that children's total exposure to respirable particulate matter was 40 percent higher if a smoker resided in the child's home. Tager et al. (1979) presented data suggesting that the lung function of nonsmoking children was adversely affected by living with smoking parents. Hirayama (1981) and Trichopoulos et al. (1981) have found a correlation between passive smoking and lung cancer. Repace and Lowrey (1980) studied the relationship among ventilation, density of smokers, and levels of respirable particulate matter. They concluded that under typical building ventilation and occupancy conditions, particulate levels generated by smokers may overwhelm the effects of ventilation. In situations where both infiltration is reduced and smoker density is sufficiently high, it may be necessary to remove particulate matter from air.

3.3.2 Pollutant Concentrations

Typical indoor concentrations of pollutants vary widely. Such concentrations depend on strength and proximity of sources and on ventilation factors. Observed concentrations of several pollutants are summarized below. A more detailed discussion can be found in Appendix B.

Radon. Radon is a naturally occurring, radioactive, noble gas. It arises from the radioactive decay of radium and it in turn gives rise to a series of short-lived radioactive daughters. Evans (1969) provides excellent information on radon, its short-lived daughter products, and the rather unusual unit, the working level (WL) which is used as a measure of airborne levels of the short-lived daughters. One WL is any combination of concentrations of radon daughters yielding, in the complete decay to Pb-210, a total alpha particle emission energy of 21 nJ (equivalent to 1.3 x 10^5 MeV) in one liter of air. Radon concentrations are measured in units of Bq/m^3 (1 Bq/m^3 = 1/37 pCi/L).

Ryan (1981) has summarized a comprehensive review of reported radon and radon daughter measurements in houses and other buildings in areas with typical levels of radium in the soil. For main floors, geometric mean levels were 88.8 Bq/m^3 and arithmetic mean levels were 252 Bq/m^3. The variation in these numbers was such that of 296 measurements, approximately 30% exceeded 200 Bq/m^3, a proposed Swedish standard for new buildings. Forty-four percent of the measurements exceeded 111 Bq/m^3, the Nuclear Regulatory Commission standard for offsite releases from nuclear facilities. The EPA standard for remedial action at inactive uranium processing sites, namely 0.02 working levels, is equivalent to 74 Bq/m^3 under conditions of minimal air exchange and 55% of the measurements by Ryan exceeded that number. The ASHRAE standard 0.01 WL (or 37 Bq/m^3) was exceeded by 73% of the measurements.

Ryan (1981) also summarized 403 radon progeny measurements on main floors. The arithmetic and geometric averages were 0.014 and 0.007 WL, respectively. He found that 9.5% of the measurements exceeded the Nuclear Regulatory Commission standard for offsite releases, 18% exceeded the EPA cleanup standard for sites contaminated from inactive uranium processing facilities, and 37% exceeded the ASHRAE standard.

The summary of 296 basement measurements of radon and 298 measurements of radon progeny, showed arithmetic means of 560 Bq/m^3

and 0.027 WL, and geometric means of 239 Bq/m^3 and 0.0127 WL. The Swedish radon standard was exceeded 55% of the time while the Nuclear Regulatory Commission standard was exceeded 72% of the time. For radon progeny, the Nuclear Regulatory Commission standard was exceeded 21% of the time, the EPA standard, 36% of the time, and the ASHRAE standard was exceeded 58% of the time.

Other measurements have been made in American and Canadian homes. The National Academy of Science (1981) reported indoor levels ranging from 0.2 to 1220 Bq/m^3 and 0.0008 to 0.030 WL. McGregor et al. (1980) reported arithmetic average basement levels in 14 Canadian cities ranging from 0.0011 to 0.0067 WL. Other reviews of background levels include Hamrick and Walsh (1974) and Walsh and Lowder (1983). Where the radium concentration in soil is high (>0.19 Bq/g), there is need for adequate ventilation or other mitigation to prevent excessive levels of radon progeny.

Formaldehyde. Formaldehyde is frequently found in indoor air and can evolve from several sources such as subflooring, furniture, and carpets found in apartments and small commercial buildings. A review of recent measurements in residences found a range of 0 to 4.2 ppm (NAS, 1981). This publication suggested that the average levels in homes are likely to range between 0.01 and 0.1 ppm. Gupta et al. (1981) summarized Consumer Product Safety Commission measurements. They report a range from <0.01 to 4.0 ppm in homes that include mobile homes and conventional homes with and without urea-formaldehyde foam insulation. There is much current controversy about formaldehyde levels but ACGIH (1981) has recommended that 8-h, time-weighted average occupational exposures be limited to 2 ppm. ASHRAE (1981) recommends that indoor levels be limited to 0.1 ppm. It is believed that excessive levels of formaldehyde normally do not occur in apartments and small commercial buildings. High levels usually result from the presence of UF-resins inside the building. Where there are excessive amounts of UF-resins, ventilation rates should be increased.

Ozone. Ozone is only found in high concentrations around sources such as photocopiers. It rapidly decays indoor in a process catalyzed by surfaces. In an office with photocopy facilities, the average hourly concentration was 9.8 ppb while in another office without such facilities, it was 2.6 ppb (Moschandreas et al., 1980). In a study of 14 residences, 95% of hourly measurements showed that outdoor levels exceeded indoor levels (Moschandreas et al., 1978). It seems reasonable to assume that ozone is not a problem in residential apartments. For small commercial buildings with photocopiers, ultraviolet lights, electrostatic precipitators, or other sources, there is need for adequate ventilation.

Combustion Products. Near points of indoor combustion, respirable particles are of concern. In residential environments, measured numbers of respirable particles have ranged up to 72×10^3 particles per m^3 and masses up to 82 $\mu g/m^3$. In offices, total (i.e., more than just respirable) particulate levels have ranged as high as 120 $\mu g/m^3$. EPA has established a National Ambient Air Quality Standard for outdoor air of 75 $\mu g/m^3$ and in residences with more than one smoker this level is routinely exceeded (Spengler et al., 1981).

Combustion may also produce hazardous gases, including carbon monoxide and nitrogen dioxide. Typically, residential environments without combustion sources will experience levels of carbon monoxide less than 1 ppm and levels of nitrogen dioxide less than 25 ppb. In the proximity of heating, cooking, or tobacco combustion, residential levels of carbon monoxide can range up to 62 ppm and nitrogen dioxide up to 560 ppb. Carbon monoxide levels have ranged up to 33 ppm in commercial buildings with sections for smokers. The National Ambient Air Quality Standards for outdoor air for these gases are 9 ppm for carbon monoxide and 50 ppb for nitrogen dioxide. Excessive amounts of cigar and cigarette smoke and other combustion products can be greatly reduced by adequate ventilation.

Organic Chemicals. There are many organic chemicals potentially present in CACS-covered buildings. Some of these chemicals may be present at levels ranging up to 1 mg/m^3. Measured levels of total non-methane hydrocarbons have ranged up to 19 mg/m^3 in a commercial art studio. In the vicinity of solvents and other volatile organic chemicals, adequate ventilation can prevent excessive exposures.

Summary. The above material provides a brief overview of the higher levels of key pollutants that have been found in residential or commercial indoor environments. In summary, measured levels of some pollutants in residences frequently exceed government standards prior to implementation of this program. Perhaps as many as 44% of residences have main floor levels of radon that are greater than 111 Bq/m^3 which is the maximum concentration that Nuclear Regulatory Commission licensees are allowed to release offsite. The principal source of radon is the soil, and rooms above the main floor are less exposed (Abu-Jarad and Fremlin, 1981) so these results may not apply to high-rise apartments. Cigarette smoke is likely to be ubiquitous in CACS-covered buildings. Perhaps as many as 60-70% of American residences include at least one smoker which suggests there are many with two or more. Such multiple-smoker residences are likely to have particulate levels approaching the National Ambient Air Quality Standard for particulate matter in outdoor air. Finally, sources of indoor pollution are widespread in covered buildings. These sources include particleboard, plywood, stoves (wood, gas, and kerosene), photocopiers, concrete and stone, and many others.

Most of the studies in the literature report pollutant levels and air exchange rates that were measured in single-family residences. A principal concern in applying these data to CACS-covered buildings is that this be done properly. The actual relationship between single-family detached dwellings and apartment and small commercial buildings is unclear. For some pollutants, the differences in the buildings have no effect except through differences in air exchange rates. It should be noted that the range of published air exchange rates for two offices and six apartments is 0.3 to 1.7 air changes per hour while for 76 homes (see Table B-4) the range is 0.1 to 2.7 air changes per hour.

DOE has studied a sample of 63 apartment buildings eligible under the CACS Program (Patel, 1982). The typical high-rise apartment building has 12 or 13 floors and the typical low-rise apartment building has 2 or 3 floors. The structures are typically free standing brick or concrete block construction. Gas typically is used for space heating and 86% of the buildings have electrical air conditioning. The typical building is 10 to 20 years old with 96% of the gross floor area rented for occupancy. Air exchange rates were not measured.

A similar study has been made of small commercial buildings (Patel et al., 1982). The most common eligible building is single-story, long, and narrow. The side and back walls are usually concrete block. The front wall is mostly glass and includes a self-closing door. The building is generally heated and cooled by a system mounted on the roof. Measurements of air exchange rates were not included in the study.

The sources of indoor air pollutants should, in principle, be similar for apartments and detached single-family residences since similar activities occur in both. However, there are important differences. For example, an upper-story apartment is further removed from the surrounding soil which is a major source of radon, an indoor pollutant of prime concern. Also such apartments are generally far removed from garages where cars are stored. In the case of air exchange rates, there are substantial differences between apartments and detached residences, due to more frequent use of mechanical ventilation in the former. It would appear that if model building codes were met or ASHRAE recommendations followed, that air exchange rates in apartments and small commercial buildings would exceed those in single-family homes and that resultant pollutant levels would be lower in CACS-covered buildings.

3.4 Summary of Existing Industry Conditions

Implementation of the CACS Program will lead to increased production of materials associated with energy conservation and renewable resource measures. A description of each measure is provided in the Revised Notice of Proposed Rulemaking (DOE, 1982).

Table 3-2 provides a general overview of the current industry situations with respect to:

- the number of manufacturers,
- geographic (regional) distribution,
- production capabilities (i.e., capacities), and
- long term limiting factors to production, if any.

As can be seen in the Table 3-2, there is a great deal of variation between the various industries with regard to the first two categories: degree of concentration and geographic dispersion. Some industries are characterized by easy entry into the market and therefore encourage a multitude of firms (small and large) to enter. Other industries are more difficult to enter, as they require a higher capital investment and/or advanced technology; only a few can gain entry into these types of markets. Geographic dispersion also varies from industry to industry, with plant location dependent upon proximity to raw material supply and/or access to the largest market areas.

Table 3-2. Profile of measures-producing industries

Measure	Number of manufacturers (approximately)	Geographic distribution[a]	Present production capabilities	Limiting factors in future production
1. Caulking and	200		High	--
Weatherstripping	100		High	--
2. Insulation:				
Mineral fiber	15	Eastern U.S.	Low "excess" capacity for glass fiber	Raw material supply (glass fiber)
Cellulose	200		Low "excess" capacity	Boric acid and borax
Plastic foams	50	Eastern U.S. and Southern California	Sufficient	--
3. Window/door modifications:				
Storm/thermal	250		Sufficient	--
Heat reflecting/absorbing	8		Sufficient	--
4. Automatic energy control systems	>50		Low	--
5. Replace heating systems	>100	Eastern U.S., Texas, California	Sufficient	--
6. Lighting modifications	>100	Calif., N.Y., Ill., Penn., and Ga.	Sufficient	--
7. Energy recovery systems	>100	Eastern US	Unknown	--
8. Solar energy systems	280		Sufficient	--
9. Air-conditioning replacement	50		Sufficient	--

[a]Distributed throughout the U.S. unless otherwise indicated.

Source: Final Environmental Impact Statement Residential Conservation Service Program (DOE/EIS-0050) November 1979.

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4. ENVIRONMENTAL CONSEQUENCES AND MITIGATING MEASURES

This chapter assesses the potential environmental consequences resulting from implementation of the CACS Program. To do so, assumptions about participation and adoption rates are presented and used to calculate the expected size of the program. The assessment describes those impacts that result from installation of approved energy conservation and renewable resource measures in eligible buildings. In general, the approach adopted is to present all identifiable environmental impacts so that any potentially significant impact will be identified. As with the RCS Program EIS (DOE, 1979), the major site-specific environmental issue is the effect of program measures on indoor air quality. Indoor air quality is explored in depth, and mitigation measures that may be used to reduce any adverse impacts on indoor air quality are identified.

4.1 Estimated Program Size

Based on the apartment building and small commercial building inventories established in Section 3.1 and assumptions about participation and adoption rates for the overall program, estimates of the number of measures and procedures adopted are made on a yearly basis and for the six year program life.

4.1.1 Participation Rates

Based on information made available from 28 utilities and state energy offices, DOE has developed three participation rate scenarios:

1. a low participation rate analysis of 0.5 percent per year; that is, each year 0.5 percent of the eligible stock of buildings would seek a CACS audit,
2. a middle participation rate analysis of 3.0 percent per year, and
3. a high participation rate analysis of 5.0 percent per year.

These rates are assumed to be averages over the six year program life and are the same for commercial and apartment buildings. DOE believes that these scenarios cover the range of possible response rates to the program and permit the assessment of the likely energy savings as well as the magnitude of environmental impacts due to the program. The various analyses which follow, in this report, focus on the impacts associated with a participation rate of 3.0 percent per year, the mid-case participation rate. The reasonable participation rate analysis assumes that, each year, 3.0 percent of the eligible customers will request and receive an audit.

4.1.2 Adoption Rates and Program Fractions

Following the audits, a portion of the buildings will be retrofitted with one or more measures, and/or employ one or more O and M procedures. Based on the same information from utilities and state energy offices, DOE has developed the following adoption scenarios:

1. a "low" adoption rate for measures of 10%,
2. a "high" adoption rate for measures of 30%,
3. a "middle" adoption rate for measures of 20%,
4. a "low" adoption rates for O and M procedures of 40%,

5. a "high" adoption rates for O and M procedures of 80%, and

6. a "middle" adoption rate for O and M procedures of 60%.

Furthermore, the analysis assumes that not all adoptions are attributed to CACS, but rather, some would have occurred without the program. The following program fractions, that is, numbers attributable to the program, have been developed for each scenario:

1. a "high" fraction of 75%,

2. a "middle" fraction of 45%, and

3. a "low" fraction of 15%.

4.1.3 Number of Buildings in the CACS Program Adopting Measures and Procedures

Based on eligible building estimates and using the high, middle and low assumptions about program participation and adoption rates, it is possible to arrive at some estimates of the size of the program. Table 4-1 summarizes the estimates of the number of buildings adopting program measures and O and M procedures under the assumption of each scenario. These were calculated in the following manner:

$$\text{Yearly adoptions} = \text{Number of eligible buildings} \times \text{Audit rate} \times \text{Adoption rate} \times \text{Program fraction}$$

Program totals assume an average yearly adoption rate over the 6 year program life. Inadequate data prevent the estimation of which measures or procedures will be adopted in any given volume, or, for any specific time frame. The numbers do provide the means for qualitatively estimating the degree of program impacts discussed in the remainder of this chapter.

Table 4-1. Projected numbers[a] of audits and measures adopted for the CACS Program

	Apartment Buildings			Commercial Buildings		
	High estimate	Medium estimate	Low estimate	High estimate	Medium estimate	Low estimate
Yearly number buildings audited	16,500	9,900	1,650	100,000	60,000	10,000
Number adopting measures (yearly)	4,950	1,980	165	30,000	12,000	1,000
Number attributed to CACS	3,700	900	25	22,500	5,400	150
Number adopting procedures (yearly)	13,200	5,940	660	80,000	36,000	4,000
Number attributed to CACS	9,900	2,700	100	60,000	16,200	600
Total adopting measures (program life)	29,500	11,900	990	180,000	72,000	6,000
Number attributed to CACS	22,200	5,400	150	135,000	32,400	900
Total adopting procedures (program life)	79,200	35,600	3,960	480,000	216,000	24,000
Number attributed to CACS	54,400	16,200	600	360,000	97,000	3,600

[a]Based on the assumed low, medium, and high audit and adoption rate scenarios and estimates of number of eligible buildings in CACS Regulatory Impact Analysis.

4.2 On-Site Environmental Impacts

This section addresses those on-site impacts which could occur from use of the energy conservation and renewable resource measures under the CACS Program. Of particular concern is the potential health impact on occupants of buildings in which conservation measures have resulted in decreased air change rates or increased indoor pollutant emissions. Other impacts discussed include land use and aesthetics.

4.2.1 Indoor Air Quality

A potential impact of energy conservation measures in apartments and small commercial buildings is the degradation of indoor air quality due to reduced air exchange and increased indoor pollutant emissions. The Environmental Protection Agency and other federal agencies have expressed serious concern over this issue (GAO, 1980). Briefly, the concentration of any substance within small commercial or multifamily residential buildings will depend on the rate at which the substance is generated, the rate at which it decays, and the rate at which air moves into or out of the building. In general, for those pollutants generated within a building, lowering the air exchange rate will increase the pollutant concentration. Similarly, modification of the building structure or systems within the building (e.g., installing insulation or a solar heating system) may increase certain indoor pollutant emissions. Since Americans spend 90 percent of their time indoors and more than 50 percent of their time in their residences (Binder et al., 1976; Robinson, 1977), a substantial increase in the concentration of toxic substances within buildings may imply elevated risks to the health of the American public, although the effects in some cases may be small and difficult to detect (Keller et al., 1979).

Changes in Indoor Emissions Due to the Program. One of the two major categories of impacts on indoor air quality deriving from the CACS Program is the increase in the aggregate strength of indoor emission sources. Many of the additional sources of indoor pollutants will be building materials. Such materials have been shown to emit a wide variety of chemical species (Molhave, 1979). Principal examples of emitting building materials are those which contain urea-formaldehyde (UF) resin. Materials that contain UF tend to emit formaldehyde (Meyer, 1979). Such materials include particleboard, chipboard, and plywood. Another example is UF-foam insulation, but in the future reduced usage can be expected because of the publicity surrounding the ban of its use in residences by the Consumer Product Safety Commission (1982). This ban has recently been vacated by the courts but the issue has not been legally resolved. A detailed discussion of UF-foam insulation can be found in Section 3.2.2.1.8 of the RCS EIS (DOE, 1979). Radium is contained in glass (Goldman and Yaniv, 1978) and perhaps other mineral fibers from which insulation is made. Hence, insulation may be a source of indoor radon. Some building materials may harbor micro-organisms. A cellulose-based fire-retardant material used in a hospital was shown to support the growth of a fungal species and emission of fungi led to infection of several cancer patients (Aisner et al., 1976). Dudney et al. (1982) found evidence of several kinds of fungi in attic insulation from homes although it is not clear from those results whether or not presence of the insulation affected indoor levels of fungi. Any technological development in the future that entails an indoor emission will have a potential health impact that may be exacerbated by virtue of the program's reduction in the average infiltration rate in eligible buildings.

In contrast, some potential situations which cause indoor air pollution may be discovered and prevented by energy auditors and others. For example, it is clear that when furnace flues are blocked, death can result from carbon monoxide poisoning indoors (Kelley and Sophocleus, 1978). Many of the workers who will install conservation measures or who will provide audits may be more aware of proper furnace operation than are some owners or occupants of CACS-covered buildings. There may be some fortunate instances where furnace mulfunctions are noticed and repaired before a serious incident occurs.

Changes in Air Exchange. The second major category of impact on indoor air quality derived from the CACS Program is decreased infiltration, as indicated by several theoretical and experimental studies (Shair and Heitner, 1974; Silberstein, 1977; Moschandreas et al., 1978; Hollowell et al., 1979; Sterling and Kobayashi, 1977). Infiltration is a part of the total air exchange in a building. Air exchange is defined to be the influx of outdoor air by any means and includes both natural infiltration and mechanical or natural ventilation. Theoretical and experimental studies show that, in general, there is some kind of inverse relationship between air exchange rates and concentrations of indoor pollutants. That is, if the infiltration rate is decreased then the concentration of indoor pollutants is increased.

Certain retrofit measures may reduce air exchange. Grot and Clark (1979) found in 24 low-income homes that retrofit measures decreased average fan-induced infiltration by 30-35 percent. Collins (1979) also found a 30 percent reduction in induced air infiltration after retrofit measures were installed in 29 homes in Denver. Others have found lesser effects or even increased infiltration (see Appendix B for details). These studies were all done on single-family dwellings. The author is not aware of any comparable studies for apartments or small commercial buildings. Therefore at this time, it is not possible to quantify the magnitude of the reduction in infiltration in CACS-covered buildings resulting from energy conservation measures. However, DOE believes that the effective decrease in infiltration in CACS-covered buildings generally will be less than the values reported above for single-family dwellings for the following reasons. CACS-covered apartments and small commercial buildings have air handling or ventilation systems that are intended to assure acceptable indoor air quality. Weatherization efforts in CACS-covered buildings therefore are not likely to influence the total air exchange rate as much as similar weatherization efforts in single-family dwellings. Also, caulking and weatherstripping, the principal measures that reduce unintentional infiltration, may be installed infrequently. For many large apartment buildings such measures are expensive and labor intensive, with long pay-back periods. For many small businesses, customer traffic is such that caulking and weatherstripping will not appreciably change the rate of air exchange.

The staff at Oak Ridge National Laboratory has identified only two published studies of measured air exchange rates in apartments and office buildings (see Appendix B). Total air exchange rates measured in six apartments in Pittsburgh under normal real-life conditions ranged from 0.3 to 1.7 air changes per hour. In two offices in Boston, total air exchange rates were 1.2 and 1.5 air changes per hour. These data may not be statistically representative of CACS-eligible buildings. Various model building codes generally require more than two air changes per hour and the American Society of Heating, Refrigerating, and Air-conditioning Engineers recommends ventilation rates in excess of two air changes per hour for most small commercial establishments. For example, the suggested air exchange rate exceeds two air changes per hour in 33 out of 55 commercial scenarios for which air exchange rates were calculated (see Table B-3). It should also be pointed out that there are no recorded before-and-after air exchange rate measurements associated with caulking and weatherstripping in apartments and small commercial buildings.

In conclusion, it is believed that the total air exchange rates in CACS-covered buildings will be higher than in single-family detached dwellings and that this will be reflected in lessened indoor air quality impacts. Such indoor air quality impacts were acceptable in the RCS Program (DOE, 1979) and therefore impacts of lesser magnitude in the CACS Program are deemed acceptable also.

Indoor Air Quality and Human Health. Attempts to estimate the impacts of residential energy conservation on indoor air quality and hence on human health are "fraught with difficulty" (NAS, 1981). The task is no easier with respect to apartments and small commercial buildings. The reasons are:

- American buildings are poorly characterized as regards many parameters which strongly affect air exchange and indoor air quality,
- behavior of building occupants is a major determinant of indoor air quality, and
- the quantitative relationship between human exposure to pollutants and resulting incidence of diseases is very difficult to define.

Many of the pollutants discussed in this report are thought to affect human health. For radon progeny and polycyclic organic compounds, exposures to high levels in occupational settings can lead to increased lung cancer in humans (NAS, 1981). Among non-smoking spouses of cigarette smokers, there is an increased incidence of lung cancer (NAS, 1981). Exposure to formaldehyde causes eye, skin, and lung irritation in human beings as well as nasal cancer in rodents (NAS, 1981). Carbon monoxide can be fatal at high levels of exposure while having much milder, short-lived effects at lower levels (NAS, 1981). Biological effects and exposure levels which have been demonstrated in occupational, clinical, and laboratory settings are shown in Table 4-2. Additional information on governmental standards for some pollutants and some conservative projections of indoor air concentrations can be found in Table 4-3.

The sections that follow will provide analyses of potential indoor air quality impacts and consequences. Radon, ozone,

Table 4-2. Pollutant levels at which health effects have been demonstrated

Pollutant	Demonstrated health effect	Lowest reported exposure level[a]
Radon progeny	Lung cancer in man	1 WL
Formaldehyde	Eye irritation in man; Lung irritation in man; Nasal cancer in rodents; Asthma and skin irritation in man	$0.01\ mg/m^3$ $62\ mg/m^3$ $7.4\ mg/m^3$ (not reported)
Involuntary smoking	Lung cancer in man	Living with a smoker
Carbon monoxide	Acutely toxic in man; Mild effects on endurance, nerves and blood in man	$1700\ mg/m^3$ $120\text{-}230\ mg/m^3$
Nitrogen dioxide	Lung constriction in man	$2\text{-}76\ mg/m^3$
Polycyclic organic compounds	Lung cancer in man	$0.88\ mg/m^3$[b]
Biohazards	Indoor airborne infection in man	(not reported)

[a]Source: NAS (1981).
[b]Source: Mazumdar et al. (1975).

Table 4-3. Projected indoor air quality impacts from conservation in single-family dwellings with high levels of pollutants

Pollutant	Impact		Comparison standards[a]	
	Before	After[b]	NAAQS[c]	OSHA[d]
Radon, Bq/m^3	377[e]	445	See Table 4-4	
Radon progeny, WL	0.023[e]	0.027	See Table 4-4	
Formaldehyde, $\mu g/m^3$	610[f]	620[f]	--	3,710 (8 h)
Respirable particles, $\mu g/m^3$:				
0 smokers	24[g]	28	75 (1 y)	5,000 (8 h)
1 smoker	43[g]	51		
>1 smokers	75[g]	88		
Ozone, $\mu g/m^3$	--	<0.24[h]	0.24	0.2 (8 h)
Carbon monoxide, $\mu g/m^3$	6,000[i]	7,080	10,400 (8 h)	58,000 (8 h)
Nitrogen dioxide, $\mu g/m^3$	1,060[j]	1,230[k]	100 (1 y)	9,500 (instantaneous)
Hydrocarbons, mg/m^3	19[l]	22	--	200[m]

[a]Source: Dudney and Walsh (1981).

[b]Assuming infiltration is reduced 15% and concentration is inversely proportional to infiltration unless noted otherwise.

[c]National Ambient Air Quality Standard (number in parentheses is averaging interval).

[d]Standards issued by Occupational Safety and Health Administration (number in parentheses is averaging interval).

[e]One standard deviation above the geometric mean (Ryan, 1981).

[f]From model of Andersen et al. (1975).

[g]Data from Spengler et al. (1981).

[h]Assuming ASHRAE standard 62-1981 is met.

[i]Data from Moschandreas et al. (1978).

[j]Maximum value reported by Young et al. (1981).

[k]Infiltration dependence of Traynor et al. (1981).

[l]Data from Ahrenholz and Handke (1982).

[m]NIOSH standard for varnish maker's and painter's naphtha (Ahrenholz and Handke, 1982).

formaldehyde, combustion products (tobacco smoke, nitrogen dioxide, carbon monoxide), airborne biohazards, and building-associated epidemics will be discussed. Greater details can be found in Appendix B.

Radon. In any building used for small commercial or apartment applications, there are numerous sources of radon and radon progeny. Radon derives from the radioactive decay of radium which may be found naturally in trace amounts, in soil, concrete, wallboard, glass, and other materials. The levels of indoor radon and its daughters deriving from such sources will be elevated if audit recommendations which reduce air infiltration are adopted. Radon and its progeny are known to cause lung cancer in man (NAS, 1981).

Model calculations presented in Appendix B show that if outdoor levels of radon and its daughters are as George (1972) measured, equivalent to 0.0007 WL, then reducing the total air exchange rate from 1.0 to 0.7 air changes per hour will raise the indoor radon daughter level from 0.0033 to 0.0050 WL. Table 4-4 summarizes radon standards proposed for various purposes by the United States and other countries.

Certain areas in the United States have elevated levels of radium in the soil and radon in the air (DOE, 1979). Such areas include parts of Colorado, Florida, and Montana. While many such areas have ongoing radon exposure abatement programs, building owners in any such areas should implement with great caution any measures which may decrease air infiltration.

The health effect associated with exposure to radon and its progeny is lung cancer. It has been well established that exposure to

Table 4-4. Standards for radon and radon progeny

Country	Average annual working level (unless otherwise specified)	Action	Status	Reference
		Indoor-nonoccupational		
UNITED STATES:				
Sites contaminated by uranium processing	0.02	A cost-benefit analysis is required when level is only slightly above maximum	Final cleanup standard for buildings contaminated by uranium processing sites	1
Phosphate land, Florida: Existing housing	<0.02	Reduce to as low as reasonably achievable	Recommendation to Governor of Florida	2
	>0.02	Action indicated		
New housing	Normal indoor background			
All indoor environments	0.01		Published	3
CANADA:				
	>0.01	Investigate	Policy Statement by AECB	4
	>0.02	Primary action criterion		
	>0.15	Prompt action		
SWEDEN:				
Maximum, existing buildings	200 Bq/m^3 [a]		Proposed Standard	5
Maximum, new buildings	70 Bq/m^3 [a]			
		Occupational		
UNITED STATES (miners)				
Instantaneous maximum	1 WL		MSHA Standard	6
Maximum cumulative dose	5 WLM/y [b]			

NOTES:

(a) Assuming an equilibrium factor of 0.5, these values are 0.027 WL and 0.009 WL, respectively.

(b) Working level-month (WLM) is a unit of cumulative exposure to radon progeny. 1 WLM is any combination of exposure level and exposure time such that the product of level and time equals 173 hours x 1 WL.

SOURCE:

Dudney and Walsh (1981) and Refs. 1 and 3.

REFERENCES:

1. U.S. Environmental Protection Agency, "Standards for Remedial Actions at Inactive Uranium Processing Sites," Fed. Regist. 48:590-604 (January 5, 1983).

2. U.S. Environmental Protection Agency, "Indoor Radiation Exposure due to Radium-226 in Florida Phosphate Lands: Radiation Protection Recommendations and Request for Comment," Fed. Regist. 44: 38664-70 (July 2, 1979).

3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, "ASHRAE Standard 62-1981: Ventilation for Acceptable Indoor Air Quality," 1981.

4. Atomic Energy Control Board (of Canada) (AECB), "Criteria for Radioactive Clean-up in Canada," AECB Information Bulletin 77-2 (April 7, 1977).

5. Department of Agriculture (of Sweden), Preliminary Proposal for Measures to Minimize Radiation Risk in Buildings, Sections 3.2.2 and 3.2.4 (1979).

6. U.S. Mine Safety and Health Administration (MSHA), "Regulations and Standards Applicable to Metal and Nonmetal Mining and Milling Operations," 30 CFR 57: 5-38 and 5-39 (July 1, 1979).

high levels of radon and radon daughters is a major factor in the development of lung cancer in uranium miners. The extent of risk from exposure to low levels is unknown. Laboratory animal studies have not contributed greatly to quantifying a dose-response relationship for radon exposure and lung cancer. Extrapolation of data on miners (see Appendix B) has led to the recommendation of guidelines for radon exposure. EPA has suggested to the State of Florida, for houses on phosphate reclaimed land, that action should be taken to reduce levels that are above 0.02 WL to as low as reasonably achievable, preferably below 0.01 WL (Budnitz et al., 1979). Canada has promulgated similar criteria for houses in four communities associated with uranium mining and processing.

The excess number of lung cancers resulting from increased radon progeny exposure due to this program can be estimated. The three elements of information that are needed are a lung cancer risk estimator factor for radon progeny, an estimate of the number of people likely to be exposed, and the estimated increase in exposure levels. The Environmental Protection Agency (1982) has evaluated several health risk models as applied to available data on lung cancer in populations exposed to radon. They conclude that "based on the risk models and assumptions (described on pgs. 52-55 op. cit.) for lifetime exposure (EPA) estimates an average of 1.0 to 2.4 lung cancer deaths per year for each 100 person-working-levels of such exposures." Person-working-level is a unit of the population's collective exposure; that is, it is the number of people times the average exposure (in working levels) of radon progeny. For employees in small commercial establishments these risk estimators have been divided by three since, conservatively, employees are assumed to be present 56 hours per week.

The total number of people likely to be exposed can be estimated from information in the CACS Regulatory Impact Analysis and in the Statistical Abstract of the United States (DOC, 1981). It has been estimated that there are 7.1 x 10^6 apartment units and 2 x 10^6 small commercial buildings eligible for the CACS Program. The Regulatory Impact Analysis estimates that the overall adoption rate (the product of participation (audit) rate, adoption rate, and program fraction) for conservation measures for both apartments and small commercial buildings will be 1.1%, 0.3%, and 0.01% for high, medium, and low scenarios, respectively. DOE (Patel, 1982) estimated that 54% of those apartments adopting some measures of the CACS Program could implement caulking and/or weatherstripping, which are thought to reduce infiltration. For small commercial buildings, DOE (Patel et al., 1982) found that 40% of eligible buildings adopting CACS-measures could implement caulking and/or weatherstripping. There are 2.75 persons per household in the United States (DOC, 1982) and it is assumed there is one household per apartment unit. The average number of employees in businesses with less than 5 employees is 2.03 (Bureau of the Census, 1982). It is conservatively assumed there are ten persons present in a small commercial establishment during working hours.

Increased exposure levels of radon progeny can be estimated from measures of preexisting radon levels and estimated decreases in the air exchange rate. A summary of 403 measurements on the main floor of American dwellings found an arithmetic average of 0.014 WL and the average of 298 basement measurements was 0.027 WL (Ryan, 1981). This is believed to be worse than the average CACS building. The arithmetic averages found in fourteen Canadian cities ranged from 0.0011 to 0.0067 WL (McGregor et al., 1980). Many studies find an approximate inverse relationship between radon progeny levels and infiltration (Walsh and Lowder, 1983). For example, a 15% decrease in the air exchange rate results in an 18% (100 (1/0.85-1)) increase in exposure.

Calculations for estimating radon-induced lung cancer deaths due to the CACS Program are summarized in Table 4-5. Estimated effects range from 0 to 7 lung cancer deaths per year. The upper end of this range is based on the conservative assumption that the average radon progeny level in apartments and small commercial buildings is equal to the average of 403 first-floor measurements in single-family detached dwellings located in areas with typical radium concentrations in the soil. The average of 296 basement measurements was about twice as large as first floor measurements, and if basement levels are representative, the maximum impact would be increased two fold.

If as DOE assumes, air exchange rates are much higher in CACS-eligible buildings than in single-family detached dwellings, then the maximum radon progeny impacts would be lower than that calculated. If weatherstripping and caulking are less frequently implemented than assumed then the maximum impact will be less. Air exchange reduction may not be as effective as assumed in this calculation, and that will also reduce the impact. For comparison, in 1977 there were recorded 95,182 lung cancer deaths (from all causes) in the United States. The impact from increased radon progeny levels resulting from

Table 4-5. Estimated lung cancer deaths due to increased radon progeny exposure

	Units		Apartments	Small Commercial Buildings
Health risk estimator	$\frac{\text{lung cancer deaths}}{\text{WL x person-year}}$		0.010-0.024	0.003-0.008
Number eligible units	apartment units or commercial buildings		7.1×10^6	2×10^6
People per unit	max	persons		10
	avg	persons	2.75[a]	2.03[b]
	min	persons		1
Overall adoption rate[c] for conservation measures	high	%	1.1	1.1
	medium	%	0.3	0.3
	low	%	0.01	0.01
Rate for application of infiltration reducing measures		%	54[d]	40[e]
Fractional change in concentration due to reduced infiltration	max	%	18[f]	18[f]
	min	%	0	0
Preexisting levels of radon progeny	max[g]	WL	0.027	0.027
	typical range[h]	WL	0.0033-0.014	0.0033-0.014
	min[i]	WL	0.0011	0.0011
Estimated impact[j]		deaths/yr	7	0.4
1977 national lung cancer rate[k]		deaths/yr	95,182	

[a]DOC, 1982.

[b]Bureau of the Census, 1982.

[c]The product of participation (audit) rate, adoption rate, and program fraction (see Sects. 4.1.1 and 4.1.2).

[d]Patel, 1982.

[e]Patel et al., 1982.

[f]Measured reductions in fan-induced infiltration from certain retrofit measures in 53 single-family dwellings averaged 30% (Grot and Clark, 1979; Collins, 1979). There are no similar measurements for apartments and small commercial buildings. However, corridor ventilation in high-rise apartment buildings increases air exchange rates. Mechanical ventilation from heating and cooling systems also increase air exchange rates considerably. Therefore conservation measures in apartment buildings probably have smaller effects on air exchange than in single-family dwellings. For purposes of this analysis, it was conservatively assumed that retrofit measures in CACS-covered buildings result in a 15% decrease in the air exchange rate (half the single-family rate). A 15% decrease in air exchange will result in an 18% increase in radon progeny levels if an inverse relationship exists between air exchange rates and indoor concentrations. The actual concentration change is probably between 0-18%.

[g]Average of 296 measurements in single-family basements (Ryan, 1981).

[h]Probable range for ground-floor levels (Abu-Jarad and Fremlin, 1981; Ryan, 1981).

[i]Average level measured in second floor and higher apartments (Abu-Jarad and Fremlin, 1981).

[j]Estimated maximum impact utilizing health risk estimator factors of 0.024 and 0.008 for apartments and small commercial buildings respectively, 1.1% overall adoption rate, 15% reduction in air changes per hour due to implementation of conservation measures, 0.014 WL for radon progeny, and an average occupancy of 2.03 for small commercial buildings.

[k]Vital Statistics of the United States, 1977. U.S. Department of Health and Human Services (1980) PHS 80-1102.

implementation of the CACS Program could result in about a 0.007% increase in lung cancer mortality.

<u>Ozone</u>. Normally, in the absence of known sources of ozone, the indoor ozone level is a function of the air exchange rate and outdoor ozone concentration. Results have been calculated from a model developed by Shair and Heitner (1974) for an office containing a copying machine producing a typical number of copies during an eight-hour workday and are presented in Appendix B. These authors measured all pertinent aspects of a two-room university office in Pasadena, California. A likely action of a building owner seeking to reduce energy consumption may be reducing the flow of intentionally added outdoor air (i.e., make-up air). From Figure B-2, it is clear that, for a peak outdoor ozone concentration of 50 $\mu g/m^3$, the indoor level is independent of infiltration. For lower levels of outdoor ozone, the indoor level is inversely related to infiltration. For higher levels of outdoor ozone, lower rates of infiltration tend to reduce indoor levels of ozone.

If the CACS Program results in reducing the air exchange rate by 15% from 2.0 to 1.7 air changes per hour, then for a peak outdoor ozone level of 200 $\mu g/m^3$ (typical of some locations in the U.S.), the time-weighted average indoor concentration will be lowered from 110 to 107 $\mu g/m^3$. For higher outdoor ozone levels, which may be typical of southern California, the beneficial effect of reduced infiltration in offices is expected to be even greater.

The primary effect due to ozone exposure at concentrations which might be expected in an office environment is irritation of eyes, mucous membranes, and the upper respiratory system. Such effects have been demonstrated in human beings at concentrations of about 2 mg/m^3. Susceptibility to upper respiratory tract infection and tissue damage has been reported at higher concentrations in animal studies. Ozone also acts as a depressant on the central nervous system. The American Conference of Governmental Industrial Hygienists (ACGIH, 1979) has recommended a standard for workroom exposure of 20 $\mu g/m^3$ (0.01 ppm). The EPA standard for ambient exposure is 235 $\mu g/m^3$ for a one-hour average exposure. The CACS Program will have insignificant effects on ozone levels in apartments and nearly all small commercial buildings. The only exception to this statement is where photocopiers or other ozone producers are present. If ozone is produced within the building, additional ventilation should be provided to mitigate the presence of the ozone which is produced.

Formaldehyde. Cigarette smoke, other indoor combustion products, and materials containing urea-formaldehyde (UF) resins are sources of formaldehyde to which occupants of small commercial and multifamily buildings are likely to be exposed. UF resinous products in such environments include chipboard, particleboard, and plywood which are used in cabinetry, subflooring, and shelving. Exposure to formaldehyde from these is unlikely to be controlled by removal of the sources in the near future. Andersen et al. (1975) studied the relationship between indoor formaldehyde levels in various buildings and meteorological factors. One of the building factors was the amount of particleboard in a room per unit volume of the room.

Formaldehyde levels have been calculated using the model developed by Andersen et al. (1975) and are presented in Appendix B. The values of the model parameters used were the average value in 22 typical Danish residences. In the case where the amount of particleboard is assumed equal to the average value, reducing the air exchange rate from 2.0 to 1.7 air changes per hour is expected to raise the indoor level of formaldehyde from 492 to 521 $\mu g/m^3$. While perhaps such results best apply to Danish residences from which the model was developed, they do suggest that exposure to formaldehyde will not change markedly. This also underscores the fact that some pollutant concentrations do not change as much as an inverse dependence on the air exchange rate would suggest. Both levels cited above are expected to elicit similar biological responses (Borzelleca et al., 1980).

Urea-formaldehyde resins release formaldehyde which can cause adverse health effects. Formaldehyde irritates the eyes, nose, and upper respiratory tract. It may also produce nausea, headaches, and drowsiness. In addition, it can produce an allergic dermatitis or sensitivity in some people which will cause them to respond to much smaller concentrations than the non-sensitive individual. Inhalation studies with mice provide evidence suggesting that formaldehyde may be an animal carcinogen (Swenberg et al., 1980). On the other hand, it has been reported that preliminary results from an epidemiological study of workers exposed to formaldehyde fail to detect any excess cases of cancer (Anonymous, 1982). The significance of these preliminary findings cannot be assessed until enough data are collected to perform statistically valid analysis. Table 4-6 presents

Table 4-6. Representative data on health effects from inhalation of formaldehyde

Concentration (mg/m^3)	Type of exposure	Reported effects	Reference
17.1	Experiment chamber	Eye and nose irritation	Sim and Prattle, 1957
0.6-12.4	Indoor residential	Eye irritation, headaches, stomach and respiratory complaints and skin problems	Sardinas et al., 1979
0.8-6.0	Indoor residential	Vomiting, diarrhea, tearing (infants only)	Wisconsin Division of Health, 1978; fide NRC, 1980
0.4-3.3	Occupational	Annoying odor, tearing, irritation of respiratory tract	Shipkowitz, 1968
0.4-3.1	Indoor residential	Drowsiness, nausea headache, nose and respiratory tract irritation	Breysee, 1977
0.3-1.7	Occupational	Upper respiratory tract irritation, coughing, headaches	Kerfoot and Mooney, 1975
0.2-0.6	Occupational	Burning and stinging of eyes, nose, and throat, headaches	Bourne and Seferian, 1959

representative data on effects in the exposure range pertinent to the proposed program. Appendix B discusses these studies in more detail.

The health effects of UF-resins have been reviewed by Hsiao and Villaume (1978). Eye irritation has been reported among workers exposed to resin-treated fabrics. Skin irritation and dermatoses are reported among workers who came into direct contact with the resin. No reports on carcinogenicity, mutagenicity, or teratogenicity were found in the literature by Hsiao and Villaume (1978). Morin and Kubinski (1978) do report that component materials used in UF-foam insulation chemically react with DNA and other biological macromolecules.

There is much current controversy over the appropriate value for standards pertaining to levels at which people might be exposed to formaldehyde. Currently, OSHA limits occupational exposures to 3.7 mg/m^3 averaged over eight hours. ASHRAE (1981) and American Industrial Hygiene Association (1968) suggest that indoor levels be limited to 0.12 mg/m^3. There are other groups with still other recommendations. However NAS, when contracted by CPSC, was unable to make a recommendation for an acceptable exposure level. It is not clear what is an acceptable level of formaldehyde exposure.

It is believed that levels of formaldehyde will not be a problem in apartments and small commercial buildings except in those cases where excessive amounts of UF-resins have been used in the building. Some measures of the CACS Program may raise ambient levels of formaldehyde slightly in some apartments and small commercial buildings, but with the exception just noted, levels are not expected to be at significant health hazard levels.

Combustion Products. Respirable particles, carbon monoxide, some polycyclic organic compounds, and nitrogen dioxide are generated around indoor combustion sources. In residential settings, such sources are primarily combustion of tobacco, natural gas, wood, and kerosene. All of these are activities of personal choice and, without good data on human activity patterns, it is exceedingly difficult to estimate increases in exposure due to weatherization. For commercial settings, the recent ASHRAE standard (1981) has recommended ventilation conditions which are thought to maintain acceptable indoor air quality. Without data on how well occupants of small commercial buildings will comply with the ASHRAE standard, it is again hard to estimate increased exposure.

The health effects associated with respirable particles range from lung cancer to lung and eye irritation depending on the pollutant. Cigarette smoke includes particles and non-smoking wives of cigarette smokers have been shown to have excess rates of lung cancer (Hirayama, 1981; Trichopoulas et al., 1981). Particles also attach to radon decay products and facilitate subsequent irradiation of lung tissues which may contribute to radon-induced lung cancer. Cigarette smoke and particles from other sources are known to irritate eyes and lungs (NAS, 1981).

Depending on occupant behavior there may be numerous apartments or offices where particulate levels may exceed the National Ambient Air Quality Standard for outdoor air. That standard is 75 $\mu g/m^3$ for respirable particles averaged over a year. Spengler et al. (1981) have shown that in nine homes with two or more smokers, monthly respirable particulate levels ranged from 40 to 120 $\mu g/m^3$ with an overall average of 70 $\mu g/m^3$. In 22 homes with one smoker, the overall average was 43 $\mu g/m^3$ (range:30-60 $\mu g/m^3$). In 38 non-smoking homes the average level was essentially equivalent to outdoor levels, 22 to 24 $\mu g/m^3$. Air exchange rates were not directly measured, but in a companion paper it was shown that fully air conditioned homes had significantly higher particulate levels (Dockery and Spengler, 1981). Such homes are thought to experience less air exchange.

In some cases, energy audit recommendations that result in decreased air exchange may lead to cases where indoor particulate levels are higher, perhaps even exceeding the National Ambient Air Quality Standard for outdoor air. Such impacts will be mitigated by the fact that many local building codes are derived from the Uniform Building Code of the International Council of Building Officials (1979) which stipulates that apartments must maintain an air exchange rate of two air changes per hour or windows that can be opened to an area equal to one-tenth of the floor area. For select classes of commercial occupancy there are other ventilation requirements. Such standards may alleviate impacts on particulate levels. The problem may still be substantial though. About 33% of adult Americans smoke and in one study 70% of the homes sampled reported one or more smokers in residence (NAS, 1981). Assuming these numbers are typical of occupant behavior in CACS-covered buildings, then for those buildings where both, (1) smokers reside or work, and (2) ameliorative standards are not enforced, there is a reasonable likelihood that indoor particulate levels may be increased to unhealthy levels.

The effects of nitrogen dioxide at levels in the range of those reported for indoor exposures are irritation of the eyes, nose, and throat, as well as mechanical and pathological changes in the lungs that lead to increased susceptibility to acute respiratory disease and possibly chronic respiratory disease. The EPA formerly recommended (but did not issue) standards for outdoor short-term exposure, 470 $\mu g/m^3$, and for annual average exposure, 100 $\mu g/m^3$ (Clayton and Clayton, 1978). Representative human dose-response data (Table 4-7) can be compared to these values.

There may be cases where problems with nitrogen dioxide exposure may develop. Experimental studies show that unvented natural gas combustion can lead to levels in excess of the National Ambient Air Quality Standard if air exchange rates are less than 2.5 air changes per hour (Hollowell et al., 1978). Levels in kitchens as much as ten fold above the National Ambient Air Quality Standard were reported in a review by Young et al. (1981). Similar to the situation with respirable particles, for those cases where unvented natural gas combustion occurs and where ameliorative building code standards are not enforced, there is a reasonable chance that nitrogen dioxide levels may reach unhealthy levels.

Carbon monoxide adversely affects body tissue by competing with oxygen for binding of hemoglobin in blood cells. Hence, it interferes with the transport of oxygen to body tissue. Manifest effects of carbon monoxide are increased risk of various cardiovascular diseases

Table 4-7. Representative epidemiological data on health effects due to inhalation of nitrogen dioxide

Population studied	Average NO_2 concentration ($\mu g/m^3$)	Reported effect	Reference
Japanese railroad workers	300-1130	Decrease in several measures of pulmonary function as compared to controls	Yamazaki et al., 1969; fide NRC, 1977b
Chattanooga school children, aged 7-8	150-280	Borderline decrease in lung function test	Shy et al., 1970a
Central city vs suburban policemen in Boston	100 vs 80	No differences in various measures of pulmonary function	Speizer and Ferris, 1973a,b
Seventh-day Adventists in Los Angeles vs San Diego	96 vs 43	No differences in various measures of pulmonary function	Cohen et al., 1972
Czechoslovakian children, ages 7-12	20-70	Two-fold excess in acute respiratory disease compared to unexposed group	Petr and Schmidt, 1966
USSR adolescents in chemical and fertilizer plants	<10	Excess in acute respiratory disease ranging from 11-27%	Giguz, 1968
Individuals living within 1 km of USSR chemical plant	580-1120	44% increase in physician visits for respiratory, visual, nervous system, and skin problems	Polyak, 1970
Families in Chattanooga, Tennessee	150-280	Excess in acute respiratory disease -- 1-17% in children, 9-33% in adults	Shy et al., 1970a,b
Infants and children 6-9 in Chattanooga, Tennessee	150-280	Infants exhibited 10-58% excess of acute bronchitis, children 6-9, 39-71% excess	Pearlman et al., 1971

and behavior changes such as time perception and the ability to detect small changes in one's environment. EPA has established thresholds for ambient exposure of 10 mg/m^3 (9 ppm) maximum for an eight-hour exposure or 29 mg/m^3 (25 ppm) maximum for a one-hour exposure. These were designed to protect those individuals with existing cardiovascular disease that may be susceptible to the effects of carbon monoxide (National Research Council, 1977a).

Combustion products — primarily tobacco smoke and other particulates, CO, and NO_2 — are materials that result mainly from the particular life style of building occupants. In some cases, air concentration levels may be high enough to affect the health of the occupants. The CACS Program may increase these concentration levels if air exchange rates are decreased by the adoption of certain CACS measures. However, it is believed that air exchange rate changes will be small and affected less in CACS-covered buildings than in single-family detached dwellings. As a result, any exacerbation of health effects will be less for the CACS Program than for the RCS Program. The effects were considered to be acceptable for the RCS Program and, because they will be less, they are acceptable for the CACS Program also.

Other Organic Chemicals. There are numerous sources of volatile organic compounds in both the residential and commercial settings. DOE feels that these chemicals do not cause a health problem but acknowledges that typical indoor levels have not been well characterized and increased exposures are difficult to estimate. Section B.2.3.2 provides examples of organic chemical pollutants.

Biohazards. Dimmick and Wolschow (1980) have recently completed a study of conservation measures and air hygiene in public buildings. They failed to find any retrofit situation which caused an increase in airborne bacteria above that present in other usual and common situations. In one case they did find that reducing ventilation five-fold in a public building increased airborne bacteria two-fold in a large waiting room, but not at all in a small office. In those locations where infectious individuals are more likely to be found, there may be an increased risk of infection if infiltration is greatly reduced.

Building-Associated Epidemics. Studies of buildings with reduced air exchange rates indicate that this can have harmful effects on the office environment (Rand, 1979), although the detailed knowledge of the mechanisms leading to that harm, including the role of energy conservation measures, is not currently available. Taylor et al. (1980) reported a study of employees who worked in an energy-efficient one-story office building on Long Island. Observed symptoms included headaches, blurred vision, dizziness, irritation of eyes, nose, and throat, nausea, and increased urinary frequency. Significantly higher incidence rates were found among female employees who more often used copying machines, particularly dry process copying machines. The researchers discovered that indoor carbon monoxide levels increased during the day and that there was less fresh air intake than is recommended by the American Society of Heating, Refrigerating, and Air-conditioning Engineers. When air exchange increased, symptoms and carbon monoxide buildup abated. The chemical or physical agent or combination of agents causing these symptoms is unknown.

In the three and one half years that a new, energy-efficient building in Maine had been occupied by approximately 600 employees, about three quarters of them had been affected by various symptoms (Zineski and Hinckley, 1980). The symptoms, which included headaches, drowsiness, upper respiratory and eye irritation, dizziness, and excessive thirst, occurred at high rates among men, administrators, and engineers, and significantly higher rates among women and clerical workers. The study also found a significantly higher incidence among employees who worked on floors above ground level. Extensive air testing by state and federal industrial hygienists failed to reveal a pollutant present at elevated levels. Consultant ventilation engineers found fresh air ventilation equivalent to about two air exchanges per hour. The complex nature of the indoor environment sometimes hinders identification and correction of the cause of some building-related problems. Kreiss (1983) has recently reviewed the field of building-associated disease.

Indoor Air Quality Summary. Many elements go into establishing the standards presented in Tables 4-3 and 4-4. The NAAQS are standards for outdoor air developed by EPA and, in general, they represent levels to which the general population can be exposed continuously without undue health effects. The OSHA standards are limits for workplace exposure, and they represent levels to which healthy workers can be exposed eight hours per day, five days per week, without adverse health effects.

A typical effort at weatherization may reduce the infiltration rate by as much as 15%. This could result in up to an 18% increase in the indoor level of any pollutant whose concentration is inversely related to the air exchange rate. While formally this is not an upper bound of the impacts, it does approach that limit statistically. Many weatherization efforts are not this effective and in at least one case, weatherization increased air exchange (Burch and Hunt, 1978). There is a wide range of air exchange rates in the American buiding stock. DOE believes that no more than 40-60% of CACS-eligible buildings can implement infiltration-reducing measures. Also concentrations of some pollutants change less than inversely proportionally to infiltration rates and this will reduce the impacts. Table 4-3 summarizes possible concentrations of pollutants in environments having typical levels of pollution.

Mitigation Measures. Indoor air quality in a building depends strongly on the behavior of the occupants. Personal activities (including cigarette smoking, cooking, use of unvented space heaters, and opening windows) have major effects on indoor air quality. To the extent that building occupants understand the relationship between indoor air quality and such activities, indoor air quality impacts are likely to be reduced.

The General Accounting Office (1980) has identified several mitigation measures:

1. installation of filtering devices for known pollutants,
2. proper use of ventilation systems,
3. periodic airing out of small commercial buildings,

4. use of vents above gas stoves,
5. application of a vapor barrier to pollutant sources, and
6. elimination of problematic building materials such as urea-formaldehyde foam insulation.

These mitigating measures work in one of three general ways: (1) removal of pollutants from indoor air, (2) introduction of relatively clean outdoor air, or (3) prevention of indoor emission. The first method is exemplified by air filters, electrostatic precipitators, vents above gas stoves, and ultraviolet irradiation of air in forced air heating systems. Air to air heat exchangers and mandated air exchange rates (e.g. see the Bonneville Power Administration program discussed in the following paragraph) are examples of the second method. Finally, indoor emissions are suppressed by measures such as applying sealants or impermeable paints to surfaces known to emit radon or formaldehyde. Another example is the prevention of installation of known sources such as asbestos or urea-formaldehyde foam insulation.

The Bonneville Power Administration has identified several measures which might mitigate indoor air quality impacts under a commercial building conservation program (Pacific Northwest Laboratory, 1982). The principal measure is that energy auditors ensure that air exchange rates in audited buidings remain high enough for acceptable indoor air quality. At the time of energy audits in participating buildings, building air exchange rates are set such that: (1) levels of radon do not exceed 333 Bq/m^3; (2) levels of formaldehyde do not exceed 120 $\mu g/m^3$, and (3) particulate levels do not exceed 75 $\mu g/m^3$.

Under the CACS Program auditors and utilities will be encouraged to promote the use of all of the above mitigating measures where or if they seem appropriate on an individual case basis.

4.2.2 Health and Safety Impacts

Impacts included here are impacts other than those related to indoor air quality impacts which were discussed in Section 4.2.1.

Potential health and safety impacts for each of the program measures may result from defective material, defective installation and/or improper utilization. In the case of many of the measures, their improper manufacture and/or installation should not create adverse health or safety impacts. Certain conservation measures, however, could result in some probability of adverse health and safety impacts. These include ceiling, wall, floor, water heater, duct and pipe insulation; storm and thermal doors and windows; replacement furnaces or boilers; and oil furnace replacement burners. In addition, there are potential problems associated with flue opening modifications and electrical or mechanical ignition systems. All of the foregoing measures have been sufficiently described with respect to their health and safety impacts in Section 3.2.2.1 of the RCS EIS (DOE, 1979).

4.2.3 Solar Water Heating Systems

Potential health impacts associated with the utilization of solar water heating systems include those health effects resulting from contamination of the water supply (by leakage or backflow of the liquid heat transfer fluids and/or system flushing). Possible safety risks associated with solar heating systems include structural failure, collector glass breakage, and glare.

Water contamination can result from leakage or backflow of liquid heat transfer fluids. Certain liquid or solid storage media could result in the contamination of potable water supplies. This problem is particularly serious when domestic hot water systems use nonpotable heat transfer and/or storage media. Contamination could result from either the fluids themselves (i.e., ethylene glycol/water) or from various additives used such as corrosion inhibitors, pH controllers, and biocides.

Both chromate and dichromate salts may be used in heating-cooling operations to prevent corrosion of aluminum piping and/or absorber plates. A rupture in the piping or storage systems would release the dissolved salts to the environment. Chromate contaminated water could pose a health problem if the water were ingested. The probability of water supply contamination is highest for systems with direct exchange of heat between the transfer fluid and the hot water supply. Even a small leak in the heating coil in the hot water heater could result in contamination of the hot water supply beyond EPA's standard of 0.05 mg/L, e.g. about 0.008 gallon (0.03 L) of working fluid would have to leak into a nominal 50 gallon (190 L) hot water heater. The amount required to produce acute symptoms over a short-term ingestion period is likely to be higher.

Nitrates may also be used in some heat transfer systems. Toxic effects from topical exposures to nitrates, both acute and chronic, are unknown. Systemic toxicity due to ingestion or inhalation is described as moderate. Large amounts taken by mouth may have serious or even fatal effects; symptoms include dizziness, abdominal cramps, vomiting, bloody diarrhea, weakness, convulsions, and collapse. Small repeated doses may lead to weakness, general depression, headache and mental impairment.

Ethylene glycol/water is a common heat transfer fluid in solar applications. If ingested, its effects on human beings are similar to grain alcohol and its toxicity is slightly greater. Ethylene glycol causes initial central nervous sytem stimulation, followed by depression. Later it causes kidney damage which can be fatal. The lethal dose for humans is reported to be 100 mL (Sax, 1968).

A number of steps can be taken to guard against potable water contamination. Several of these are outlined in the HUD Minimum Property Standards (NBS, 1976). These include: separation of circulation loops between nonpotable working fluids and the domestic potable water system; identification of nonpotable fluid and potable water systems by color-coded piping or metal tags; and nonpotable fluid leak indicators, such as harmless vegetable dyes. In addition, proper double wall heat exchanger systems can provide a high degree of protection against potable water contamination.

Many of the working fluids and/or liquid storage media used in solar heating and cooling systems will degrade over time thus requiring periodic flushing and replacement. Releases of these fluids may also occur as a result of system failure. Release of these fluids into local water bodies could have significant impacts on aquatic life and be harmful to man if such impacted water bodies were used as sources of drinking water. In addition, disposal of such fluids into a sewer system could potentially reduce the effectiveness of sewage treatment in areas where large numbers of such solar systems are used.

4.2.4 Passive Solar Space Heating

There are no serious health and safety concerns associated with passive solar systems. The only two potential areas of impact which can be identified are indoor air quality and problems related to accidents or pollution resulting from the use of water in heat storage systems. Buildings modified to capture and store solar heat tend to be better sealed and can therefore potentially suffer from degradation of interior air quality. The potential health effects resulting from such degradation have been discussed previously.

Using water as the heat storage medium in a water wall creates a risk of leakage from the container. The danger can be minimized by adding anticorrosion inhibitors to the water, or by lining the containers with polyethylene; antifreeze additives might also be added to prevent freezing. Handling and disposal of these materials present the same potential environmental impact problems as do heat transfer and storage fluids used for active solar systems. The mitigating measures for environmental protection presented for the active solar systems are also appropriate for passive applications.

4.2.5 Land Use and Aesthetic Impacts

Energy conservation measures included within the CACS Program are installed either on or within the existing multifamily or small commercial structure. It is assumed that all installations will be accomplished in accordance with any applicable state and local building codes. Given the list of approved measures (e.g., insulation, caulking and weatherstripping, clock thermostats, storm windows and doors, replacement heating systems, etc.), only a few of the measures will even be visible from outside the building. Visible measures include storm doors and windows, and heat reflective and heat absorbing window and door materials. It is unlikely that any of these measures will result in adverse land use or aesthetics impacts. Most have been in common use for years and it is not anticipated that any major changes in design or use will occur.

Land use and aesthetic considerations have not yet been a significant barrier to the acceptance of solar utilization. Visual impacts of individual buildings adopting solar measures will depend on the size, type, and location of the collector and on overall building design. For individual buildings, visual impacts will be greatest for retrofit systems which are not integrated into the existing building and which contrast with the building style. There have been some instances of dissatisfaction with the aesthetics of given solar installations, but in general, most solar systems have been compatible with traditional designs for new and retrofit installation. A possible exception here is the effect of solar installations on historical sites. The installations may be visually out of character with the traditional landscape and architectural styles associated with historic properties or within historic districts. Where roof top collectors are forbidden by a restrictive ordinance, collectors may be placed on the ground and screened from view by a fence. Flat plate collectors mounted on a roof produce almost no aesthetic problems, and it is believed that there will be few cases where solar systems will conflict with state and local land use restrictions on appearance.

Buildings using detached solar collectors rather than a roof-top system could require a larger land area than conventionally heated and cooled buildings. Thus, widespread use of solar systems could alter traditional land use patterns and require alterations of local planning, zoning and control procedures.

Solar access has become an issue related to the continued development of solar energy. Many states have now passed solar access laws which specify the vertical and horizontal angles at which the solar easement extends over the real property subject to an easement. A variation of the law authorizes local zoning commissions to use traditional land use controls to assure access to direct sunlight. In California, solar collectors are entitled to shading of no more than 10 percent of the absorption surface area between 10 a.m. and 2 p.m. Shade trees that lead to a violation of these rights to receive sunlight are declared a public nuisance under the California law. The incidence of such cases, however, is likely to be very low, with or without the CACS Program.

In urban areas, the issue of solar access may be more prevalent, particularly where multifamily apartment complexes are densely located. There could be buildings where sunlight would be blocked by higher buildings, ruling out solar as an alternative energy source.

4.3 National Impacts

National and regional impacts of the CACS Program will occur through two major mechanisms. First, the program will result in the saving of energy which would otherwise be consumed. Associated with the reduction in energy use will be reductions in certain pollutants and in employment in energy production. The second major mechanism is the increase in the production of materials used in the measures covered by the program. These increases in production will result in increases in pollutant emissions and in employment.

There are also a number of related issues which are less significant than energy savings and increased production of materials. First, additional changes in employment will be brought about by the labor to install measures due to the program and by the spending of money saved by customers who rent or own more energy efficient premises. Second, certain risks to the health and safety of workers may be created by the increase in materials production. These issues are also addressed in this section.

4.3.1 Energy Savings

The net reduction in energy use resulting from the adoption of measures and procedures, under the CACS Program are estimated in Table 4-8. These were calculated by assuming that the adoption of one

Table 4-8. Estimated energy savings (in 10^9 Btu) by scenario

Scenario	High	Middle	Low
Estimated first year savings	4,915	963	23
Estimated sixth year savings	29,490	5,778	138
Estimated maximum total energy savings (26 year period)	589,800	115,560	2,760

Source: CACS Regulatory Impact Analysis.

or more measures would result in an average energy savings of 15 (high), 10 (middle) or 5 (low) percent over present average use depending on the scenario. Energy savings from procedures adoptions are estimated to be 10 (high), 8 (middle) and 6 (low) percent. Given the adoption levels in Table 4-1, the Btu savings by scenario that are in addition to the no-action scenario can be calculated. (Totals have been adjusted to account for adoptions that would have taken place in the absence of the program.) Under the "middle" scenario about 963 x 10^9 Btu are saved in the first year of the program and 5,778 x 10^9 Btu per-year by the end of the program. This translates into an equivalent savings of about 1 million barrels of oil in the sixth year.

The life of a measure installed in the program is estimated to be about 20 years, thus the energy savings impacts of the program will be realized over a 26 year period. If we total the energy savings for each year of a 26 year effective program life, an upper bound of total potential energy savings can be estimated. For the "middle" scenario, this amounts to about 115,560 x 10^9 Btu or about 20 million barrels of oil. These are savings that are attributable to the CACS Program. The actual savings may be less due to decreasing efficiencies or a laxness in procedure implementation.

The decrease in energy use will result in a reduction in pollutant emissions associated with energy production. These reductions will be small when compared to total emissions from energy production. Savings from the program in an average year amounts to about .005 Quads; currently about 72 Quads of energy are consumed annually in the U.S. Small emission reductions will occur for air-borne particulates, SO_x, NO_x, HC, CO, and aldehydes, and, water-borne COD, TSS, metals and sulfates. These pollutants are commonly associated with energy production.

4.3.2 Health and Safety in Producing Facilities

Occupational exposures to chemical and physical agents will increase as the demand increases for materials used in each energy conservation measure. However, this does not necessarily imply that a health hazard exists. In some instances, industrial processes involved in the production and manufacture of energy conservation alternatives are adequately controlled to preclude excess exposures even under increased production. In other industries, adequate control of occupational exposures to chemical and physical agents may be lacking. Increased demand for products from these industries may result in increased worker exposure as well as an increased number of workers exposed. While specific increases in exposures cannot be estimated, data in Table 4-1 suggests that the increase in demand for conservation measures will not be large enough to lead to significant changes in occupational exposure during production.

4.3.3 Socioeconomic Impacts

The CACS Program will have small, but measurable impacts on employment. The types of employment changes likely to occur may be categorized as follows:

(1) direct employment - includes professional and administrative workers associated with implementation of the program; clerical workers; auditors; installers; manufacturing workers; and transportation workers whose employment is directly related to the program, and

(2) indirect employment - the secondary employment, usually in the retail and service industries, that results from the goods and services demanded by direct employment. An additional factor that affects indirect employment is the increased disposable income that will be available to households as a result of energy savings. This is an important factor affecting the long-term beneficial socioeconomic impacts of the program. It is somewhat offset by a loss of employment in the energy producing industries (e.g., fuel oil supplies, utilities, and mining), but the net result is an increase in overall employment.

Assuming the 3 percent participation rate and 20 percent adoption rate under the CACS Program, the anticipated changes in employment are shown in Table 4-9. At the beginning of the program, substantial initial employment is generated by the program with comparatively few jobs lost in the energy producing industries, and no new jobs through increased personal expenditures. Over a period of time the direct employment will remain constant, and jobs lost in the energy producing industries will increase slightly. The net result, however, is a long-term net increase in employment through implementation of the CACS Program.

Table 4-9. Total employment levels from the CACS Program

Sector	Low estimate	Medium estimate	High estimate
Utilities:			
Auditing	83	498	831
Overhead	88	138	178
State government	92	92	92
Federal government	5	5	5
Federal contractors	25	25	25
Total employment	293	758	1,130

Source: CACS Regulatory Impact Analysis.

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APPENDIX A

ACRONYMS/ABBREVIATIONS

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ACRONYMS/ABBREVIATIONS

ACGIH - American Conference of Governmental Industrial Hygienists

AECB - Atomic Energy Control Board (Canada)

ANSI - American National Standards Institute

ASHRAE - American Society of Heating, Refrigerating, and Air-conditioning Engineers

BOCA - Building Officials and Code Administrators

BOD - biological oxygen demand

Bq/m^3 - becquerels per cubic meter

Btu - British thermal units

°C - degree Celsius

CACS - Commercial and Apartment Conservation Service

CEQ - Council on Environmental Quality

cfm - cubic feet per minute

CO - carbon monoxide

COD - chemical oxygen demand

CPSC - Consumer Products Safety Commission

CWLM - cumulative working level month

DNA - deoxyribonucleic acid

DOE - Department of Energy

EIA - Energy Information Administration

EIS - Environmental Impact Statement

EIS-FS - Environmental Impact Statement - Final Supplement

EJ - exajoule = 10^{18} joules

EPA - Environmental Protection Agency

ESA - Energy Security Act

°F - degree Fahrenheit

ft - feet

g - gram

h - hour

HC - hydrocarbons

HVAC - heating, ventilation, and air-conditioning

HUD - Department of Housing and Urban Development

ICBO - International Council of Business Officials

IID - intermittent ignition device

kg - kilogram

kWh - kilowatt hour

L - liter

m^3 - cubic meter

MeV - million electron volt

$\mu g/m^3$ - microgram per cubic meter

mg/m^3 - milligram per cubic meter

mL - milliliter

min - minute

mph - miles per hour

m/s - meter per second

MSHA - Mine Safety and Health Administration

NAAQS - National Ambient Air Quality Standard

NAS - National Academy of Science

NECPA - National Energy Conservation Policy Act

NEPA - National Environmental Policy Act

NIOSH - National Institute of Occupational Safety and Health

nJ	-	nanojoule = 10^{-9} joules
NO_x	-	oxides of nitrogen (e.g. NO_2)
NRC	-	National Research Council
NTIS	-	National Technical Information Service
ORNL	-	Oak Ridge National Laboratory
O and M	-	operation and maintenance
OSHA	-	Occupational Safety and Health Administration
Pa	-	pascal
pCi/L	-	picocurie per liter = 10^{-12}Ci per liter
ppb	-	parts per billion = 1 part per 10^9 parts
ppm	-	parts per million = 1 part per 10^6 parts
RCS	-	Residential Conservation Service
RIA	-	Regulatory Impact Analysis
s	-	second
SD	-	standard deviation
SO_x	-	oxides of sulfur (e.g. SO_2)
TLV	-	threshold limit value
TSS	-	total suspended solids
TVA	-	Tennessee Valley Authority
UF	-	urea-formaldehyde
WL	-	working level
WLM	-	working level month
y	-	year

APPENDIX B

AIR EXCHANGE AND INDOOR AIR QUALITY: DATA, METHODOLOGY, AND ANALYSES

APPENDIX B. AIR EXCHANGE AND INDOOR AIR QUALITY: DATA, METHODOLOGY, AND ANALYSES

This appendix contains detailed data, analyses, and a description of the methodology used with respect to impacts of the CACS Program on indoor air quality. The discussion in this appendix is a technical presentation in more detail than that contained in Chapters 3 and 4 of this document.

B.1 Introduction

B.1.1 Overview of building energy conservation and indoor air quality

In general, a problem can develop when a building is so well built or retrofitted that insufficient air can move between the inside and the outside to maintain good indoor air quality. There are usually numerous cracks and crevices through which air can flow. Unintentional outflowing air can represent substantial energy losses since this air has been modified so that its temperature, moisture content, and pollutant load are acceptable to the building's occupants. The inflowing air has not been so modified; thus if the rate at which unconditioned air enters the building increases, then the building heating, ventilating, and air conditioning (HVAC) system must operate more. Thus, reductions in unintentional air flows will save energy.

But, unintentional air flows have benefits also, namely, they provide a way in which indoor air pollutants can be diluted. Everyone is familiar with how stuffy a room can get if it is kept tightly closed. Such stuffiness is due to the buildup of certain pollutants and moisture. The following table lists some indoor pollutants and their potential sources:

Indoor pollutants	Potential indoor sources
Formaldehyde	Particleboard, insulation, plywood, carpet, human occupants, tobacco smoke
Radon	Concrete, stone, soil, groundwater, wallboard
Carbon monoxide	Heating and cooking combustion sources, tobacco smoke, automotive emissions
Nitrogen dioxide	Heating and cooking combustion sources, tobacco smoke
Respirable particles	Heating and cooking combustion sources, tobacco smoke, automotive emissions
Organics	Particleboard, insulation, adhesives, paint, furnishings, automotive emissions
Workroom pollutants	Workers' clothing
Ozone	Photocopiers
Biohazards	Human occupants, moist surfaces, tobacco smoke

Many of the chemical and biological substances represented in the above list are known to cause one or more health effects. Some cause cancer in man or animals. Some cause or exacerbate respiratory diseases. Some evoke allergic reactions, are infectious agents, or are severe poisons. The potential health effects due to building energy conservation effects on indoor air quality will be discussed in this appendix.

The frequency of health complaints related to the office environment seems to be increasing. In a recent one year period, 13% of requests for investigation received by the National Institute for Occupational Safety and Health were for complaints from workers in nonindustrial settings who thought their symptoms were building-related. Three years before only 5% of health hazard evaluation requests were thought to be building related. The majority of 115 investigations between 1978 and 1981 failed to identify a causative factor other than inadequate ventilation and temperature and humidity control (Kreiss, 1983). Clearly, there may be a potential problem in this area, and our knowledge of the factors affecting building-related disease is increasing (see list of relevant reports below).

B.1.2 Relevant reports

The subject of indoor air quality has been studied with increasing effort over the last decade. This appendix summarizes current knowledge of indoor air quality and its impacts. More detailed discussions are found in recent reviews such as:

Author(s)	Year
Yocum	1982
Young et al.	1981
National Academy of Sciences	1981
Dudney and Walsh	1981
General Accounting Office	1980
Office of Technology Assessment	1979
Geomet, Inc.	1979
Hollowell et al.	1978
Sterling and Kobayashi	1977

B.2 Existing Condition of Building Stock

The thrust of the CACS Program will be to provide information to energy consumers on how to modify certain buildings so as to improve their energy efficiency. In order to assess the effect of such modifications on indoor air quality, it will be necessary to review what is known about the present American building stock. Specifically, information on infiltration rates and indoor air quality will be reviewed.

B.2.1 General comments on eligible buildings

There are two major categories of structures covered under CACS. One category is centrally heated or cooled apartment buildings with five or more units which were completed before June 30, 1980. The other category consists of small commercial buildings which:

(1) were completed before 30 June 1980,

(2) are used primarily for business (including for-profit, non-profit, and state or local government),

(3) are not used for manufacturing, and

(4) in calendar year 1980 used less than 4,000 kWh of electricity and 1000 therms of natural gas or the energy equivalent of any other fuel.

The first category will be referred to as apartments and the second as small commercial buildings.

DOE has studied a sample of 63 apartment buildings eligible under the CACS Program (Patel, 1982). The typical high-rise apartment building has 12 or 13 floors and the typical low-rise apartment building has 2 or 3 floors. The structure is typically free-standing brick or concrete-block construction. Gas typically is used for space heating and 86% of the buildings have electrical air conditioning. The typical building is 10 to 20 years old with 96% of the gross floor area rented for occupancy.

A similar study has been made of small commercial buildings (Patel et al., 1982). The most common eligible building is single-story, long, and narrow. The side and back walls are usually concrete block. The front wall is mostly glass and includes a self-closing door. The building is generally heated and cooled by a system mounted on the roof.

The sources of indoor air pollutants should, in principle, be similar for apartments and detached single-family residences since similar activities occur in both. There are much more data on indoor air quality for single-family residences, and they will be heavily cited in this analysis. However, it should also be noted that there are important differences. For example, an upper-story apartment is further removed from the surrounding soil which is a major source of radon, an indoor pollutant of prime concern. Also such apartments are generally far removed from garages where cars are stored. In the case of infiltration rates, there are substantial differences between apartments and detached residences, due to more frequent use of mechanical ventilation in the former.

The universe of small commercial buildings covered by CACS is enormously varied with respect to potential pollutant sources. One measure of this wide variety may come from examining the most recent Census of Retail Trade (DOC, 1979). Table B-1 was constructed, assuming that non-governmental small commercial buildings are largely represented by retail establishments without payrolls, so called "mom and pop" operations (DOC. 1979).

It is clear from Table B-1 that occupants of small commercial buildings are involved with all sorts of materials. In addition, there are other small commercial buildings where services are offered, such as dry cleaning, governmental functions, merchandise repair, etc. Clearly, many of these small commercial buildings will contain sources of pollutants which are infrequently encountered in the typical indoor environment. These infrequent and unusual pollutants will not be considered in detail here. No data have been found which characterize

Table B-1. Small commercial establishments without payroll

Standard industrial classification	Type of business	Number of establishments	Percent of total
52	Building materials	24,569	4.6
53	General merchandise	10,588	2.0
54	Grocery	80,379	14.9
55 (-554)	Car dealers	44,206	8.2
554	Gas stations	29,942	5.6
56	Apparel	25,313	4.7
57	Home furnishings	46,837	8.7
58	Eating and drinking places	59,452	11.0
591	Drugs	2,401	0.4
592	Liquor	9,201	1.7
593	Used merchandise	35,352	6.6
5941	Sporting goods	14,371	2.7
5942	Books	5,129	1.0
5943	Stationery	1,603	0.3
5944	Jewelry	14,434	2.7
5945	Hobbies, toys and games	11,973	2.2
5946	Cameras	2,122	0.4
5947	Gifts and novelties	16,940	3.1
5948	Luggage and leather	933	0.2
5949	Sewing and needlework	8,993	1.7
598	Fuel and ice	5,591	1.0
5992	Flowers	9,283	1.7
5993	Cigars	1,336	0.2
5994	Newsstands	5,670	1.1
5999	Miscellaneous	72,846	13.5
	Totals	539,464	100.2

Source: Census of Retail Trade (DOC, 1979).

indoor air quality in any small commercial building except for offices. Furthermore, it seems reasonable to assume that standard practices in the majority of small commercial buildings will have identified those pollutants with most potential for harm although this may not be true for all small commercial buildings.

The structures which are covered under CACS will vary widely. Some small commercial buildings may be part of a residence while other small businesses operate in modified mobile homes and some are in large strip shopping centers. Clearly, such a wide range of structures will have a variety of infiltration rates. To the extent that the recommendations of ASHRAE standard 62-1981 (ASHRAE, 1981) are followed, ventilation in this highly varied group of buildings will be sufficient to maintain reasonable indoor air quality.

B.2.2 Air exchange rates

The rate at which air moves into or out of a building depends on many factors, including wind speed and direction, quality of construction, indoor-outdoor temperature difference, height of the building, relative humidity, occupants' behavior, and indoor combustion. The author is aware of only one study in which air exchange rates were measured in apartment buildings. Moschandreas et al. (1978) measured air exchange rates in three low-rise and three high-rise apartment buildings in Pittsburgh, Pennsylvania. Those results are summarized in Table B-2. The overall range of observed air exchange rates in the six apartments is 0.3 to 1.7 air changes per hour. The three story low-rise building had brick exteriors and was in a residential neighborhood. The measured apartments were on the second and third floors with individually controlled forced air heating systems. The 11-story high-rise brick building was surrounded by residential and commercial buildings. Each apartment had individually controlled forced air heating and cooling systems. The results show that air exchange measurements within an apartment varied by a factor of 2 1/2 and measurements between apartments varied by a factor of 3. Because of the limited number of measurements, it is impossible to arrive at an air exchange rate that would be appropriate for all apartment buidings in the United States or for the CACS Program. These apartments therefore may or may not be similar to typical eligible apartments as defined by Patel (1982).

Table B-2. Measured air exchange rates in apartments

Apartment type	Sampling month	ΔT^a	Wind speed[b]	Air exchange rate[c]
Low-rise	March	0.5-16.7	2.7-9.8	0.3-0.8
Low-rise	April	3.9-16.7	4.5-8.5	0.7-1.4
Low-rise	May	5.6-11.1	3.6-4.9	1.6-1.7
High-rise	May	1.1-6.7	2.2-4.9	0.9-1.4
High-rise	June	2.8-11.7	3.1-5.8	0.9-1.4
High-rise	June	0.6-5.0	2.2-8.5	0.9-1.2

[a]Temperature difference between indoors and outdoors measured in °C.

[b]Wind speed measured in m/s.

[c]Units are air changes per hour.

Source: Moschandreas et al (1978).

Air exchange rates in small commercial buildings may well be as widely varying as the nature of small businesses themselves. Despite this variety, clearly one common indoor environment in small commercial buildings is the office. In one study, Moschandreas et al. (1980a) found that air infiltration varied from 1.2 to 1.5 air changes per hour in two different buildings. These buildings were both quite large, housing about 100 employees, and may be quite different from eligible buildings as defined by Patel et al. (1982).

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has proposed a standard for ventilation for acceptable indoor air quality (ASHRAE, 1981). Table B-3 presents some ventilation rates calculated from suggested values of ventilation parameters in the ASHRAE standard for a variety of small commercial buildings. With the exception of corridors in large buildings, warehouses, greenhouses, pet shops, meat processing rooms, bank vaults, and libraries, all derived ventilation rates exceed 0.6 air change per hour.

There may be an inverse relationship between the age of a building and the air exchange rate of the structure. In Table B-4, data taken from several studies on single-family detached dwellings have been summarized. In general, studies of older homes found higher air exchange rates. In an attempt to further clarify this relationship, air exchange measurements were gathered from the literature for detached buildings when the wind speed was close to 4.5 m/s (10 mph) and the indoor temperature was about 22.2°C (40°F) above the outdoor temperature. In some cases, the original authors provided an equation

Table B-3. Ventilation rates derived from suggested ASHRAE values

Type of business	Occupancy (persons/10^3 ft^2)	Outdoor air (ft^3/min person)	Ventilation rate (air changes per h)[a]
Laundries			
Commercial	10	15[b]	0.9
Storage/pick-up areas	30	35	6.3
Coin-operated	20	35	4.2
Coin-operated dry cleaners	20	15[b]	1.8
Food and beverage services			
Dining rooms	70	35	15.
Kitchens	20	10[b]	1.2
Cafeterias and fast food	100	35	21.
Bars and cocktail lounge	100	50	30.
Parking garages and auto repair	--	--	9.0
Hotels, motels, etc.			
Bedrooms	5	7.5[c]	2.3
Living rooms	20	3.1[c]	3.7
Baths and toilets	12[c]	50	3.8
Lobbies	30	15	2.7
Conference rooms	50	35	10.
Assembly rooms	120	35	25.
Casinos	120	35	25.
Offices			
Office space	7	20	0.8
Meeting and waiting space	60	35	13.
Public spaces			
Corridors	--	--	0.1
Restrooms	100	1.7[d]	12.
Retail Stores			
Showrooms near ground level	30	25	4.5
Upper level showrooms	20	25	3.0
Storage areas	15	25	2.2
Dressing rooms	2.8[e]	25	5.2
Malls and arcades	20	10	1.2
Shipping and receiving	10	10	0.6
Warehouses	5	10	0.3
Elevators	13.9	15[b]	1.2
Specialty shops			
Barber and beauty shop	25	35	5.2
Health spas	20	15[b]	1.8
Florists	10	25	1.5
Greenhouses	1	5[b]	0.1
Show/repair areas	10	15	0.9
Pet shops	--	--	0.6

Table B-3. (continued)

Type of business	Occupancy (persons/10^3 ft^2)	Outdoor air (ft^3/min person)	Ventilation rate (air changes per h)[a]
Sports and amusement facilities			
Dance areas	100	35	21.
Bowling alley, seating	70	35	15.
Playing surfaces	30	20[b]	3.6
Spectator areas	150	35	31.0
Game rooms	70	35	15.
Swimming pool	--	--	1.5[f]
Swimming pool spectators	70	35	15.
Theatres			
Ticket booths	12[b]	20	1.5
Lobbies and auditoriums	150	35	31.
Stages and studios	70	10[b]	4.2
Public transportation facilities	150	35	31.
Workrooms			
Meat processing	10	5[b]	0.3
Pharmacies	20	7[b]	0.8
Bank vaults	10	5[b]	0.3
Photographic dark rooms	10	20[b]	1.2
Photographic printing rooms[b]	--	--	3.
Educational facilities			
Classrooms	50	25	7.5
Laboratories	30	10[b]	1.8
Training shops	30	35	6.3
Music rooms	50	35	10.
Libraries	20	5[b]	0.6

[a]Ten foot ceilings with smoking allowed were assumed unless stated otherwise.
[b]No smoking conditions were assumed.
[c]Room dimensions of 10' x 10' x 8' were assumed.
[d]Room dimensions of 15' x 15' x 8' with 5 stalls were assumed.
[e]Room dimensions of 6' x 6' x 8' were assumed.
[f]Twenty foot ceilings were assumed.
Source: Calculated from ASHRAE, 1981.

Table B-4. Measured air exchange rates in North American and European homes

Number of homes	Air exchange rate (air changes per hour) Average	Range	ΔT[a] (°C)	Wind speed[b] (m/s)	ΔP[c] (Pa)	Type of house	Comments	Study[e]
4	0.37	0.31-0.42	17	4	—	2 story town-house W/B[d]	Built 1972-3	1
1	0.82	—	17	4	—	2 story W/B detached	Built 1947	1
1	0.50	--	19.4	3.1	—	1 story W/B	Built 1950-55	2
50	1.49	0.35-2.70	—	--	24.9	—	Texas	3
10	0.64	0.37-0.99	4.4	4.5	—	—	Built 1917-43	4
17	0.37	—	--	--	4	--	On the average, built 1950	5
5	0.60	0.09-1.40	--	--	—	--	Tennessee	6
1	0.83	--	34	6.7	—	Mobile home continuous sheath	New	7
1	1.53	—	34	6.7	—	Mobile home caulking	New	7
1	0.46	—	-14	6.7	—	Mobile home continuous sheath	New	7
1	0.91	--	-14	6.7	—	Mobile home caulking	New	7
1	--	0.33-0.68	-14-9	0.5-4	—	One story frame	Built 1964	8
1	0.36	0.15-0.61	5-15	1-5	—	One story frame	Built 1964	9
1	0.11	0.10-0.12	22	4-8	—	Two story frame energy efficient	Built 1977	9
1	0.86	0.64-1.36	4-6	1-2	—	One story frame	Built 1924	9
1	0.59	0.50-0.69	9-10	2-5	—	One story frame	Built 1949	9
1	0.10	0.08-0.13	25-26	3-5	—	Two story frame energy efficient	Built 1978	9
1	0.38	0.31-0.42	18-20	6-8	—	Three story frame energy efficient	Built 1978	9
~100	0.48	--		--	—	—	Less than 2 years old	10
~100	0.86	--	—	--	--	—	More than 2 years old	10
266	1.12	--	—	--	--	—	Low income homes	11

Table B-4. (continued)

Number of homes	Air exchange rate (air changes per hour) Average	Range	T[a] (°C)	Wind speed[b] (m/s)	P[c] (Pa)	Type of house	Comments	Study[e]
1	0.12	--	0	0	--	Four bedroom townhouse	Built 1974	12
1	0.41	--	15	0	--	Four bedroom townhouse	Built 1974	12
1	0.60	0.16-1.57	7-46	1-17	--	One story	Built before 1963	13
2	0.50	0.20-0.70	2-31	<2.7	--	Townhouse	Built 1972	14
9	0.3	0-0.8	--	--	--	--	New homes in Denmark	15
34	1.3	0-3.6	--	--	--	--	Older homes in Denmark	15
1	0.65	--	--	<4	--	--	In England	16
1	1.1	--	0	0	--	Mobile home	Built before 1976	17
1	0.27	0.16-0.41	18-42	0.2-4.3	--	One story W/B	Built before 1960	18
1	0.11	0.06-0.17	-3-3	0.4-3.6	--	One story W/B	Built before 1960	18
1	0.19	0.12-0.28	9-18	0.4-5.4	--	One story W/B	Built before 1960	18
1	0.44	0.24-0.63	3-33	0-4.7	--	One story W/B	Built before 1963	18
1	0.15	0.06-0.23	-2-1	0.2-3.4	--	One story w/B	Built before 1963	18
1	0.45	0.33-0.57	21-39	0.2-5.1	--	One story W/B	Built before 1963	18
1	--	0.5-1.0	-8-23	0.4-2.7	--	Two story	Solar heated	19
1	--	0.2-0.8	-3-19	0.9-4.5	--	Two story W/B	--	19
1	--	0.5-1.2	-6-32	0.9-7.6	--	Two story duplex	Built since 1973	19
1	--	0.6-2.0	-2-31	1.3-8.9	--	Two story duplex	Built 1973	19
1	--	0.8-1.0	0-9	0.4-2.2	--	Two story	--	19
1	--	0.6-1.0	-2-34	0.4-2.2	--	Two story	--	19
1	--	0.1-0.3	-4-22	0-7.6	--	Two story	Electric heat in Chicago	19
1	--	0.4-1.0	19-31	2.2-5.4	--	Mobile home	--	19
1	--	0.3-1.1	5-20	0.9-5.4	--	Mobile home	--	19

[a] Temperature indoors minus temperature outdoors.
[b] Wind speed measured at or near the study site.
[c] Pressure difference between inside and outside.
[d] W/B = with basement.
[e] References for Tables B-4 and B-5 follow Table B-5.

relating air exchange to wind speed and temperature difference. For such cases, infiltration values were calculated. Air exchange versus year of construction is plotted in Figure B-1 and the values are tabulated in Table B-5. Nonparametric rank correlation analysis of the data reveals a statistically significant ($P < 1\%$) inverse correlation. The scatter that remains is due to numerous uncontrolled variables including wind orientation, structural style, occupant behavior, and many others. On the basis of the observed age-dependent air exchange increase in single-family dwellings, it may be assumed that older CACS-covered apartments and small commercial buildings experience higher infiltration rates.

B.2.3 Indoor air quality

Many potential sources of pollutants currently exist in apartments and small commercial buildings. Some of the more noteworthy pollutants include radon, formaldehyde, ozone, respirable particles, carbon monoxide, and nitrogen dioxide. In addition, there is a potentially enormous variety of organic chemicals that may be used in covered small commercial buildings. This section will provide a brief overview of what is known about sources and concentrations of pertinent pollutants.

B.2.3.1 Sources

Radon-222 is a radioactive, noble gas which is generated by the decay of radium-226. Decay of radon in turn gives rise to a series of short-lived radioactive progeny. Since trace amounts of radium occur

ORNL-DWG 83-10565

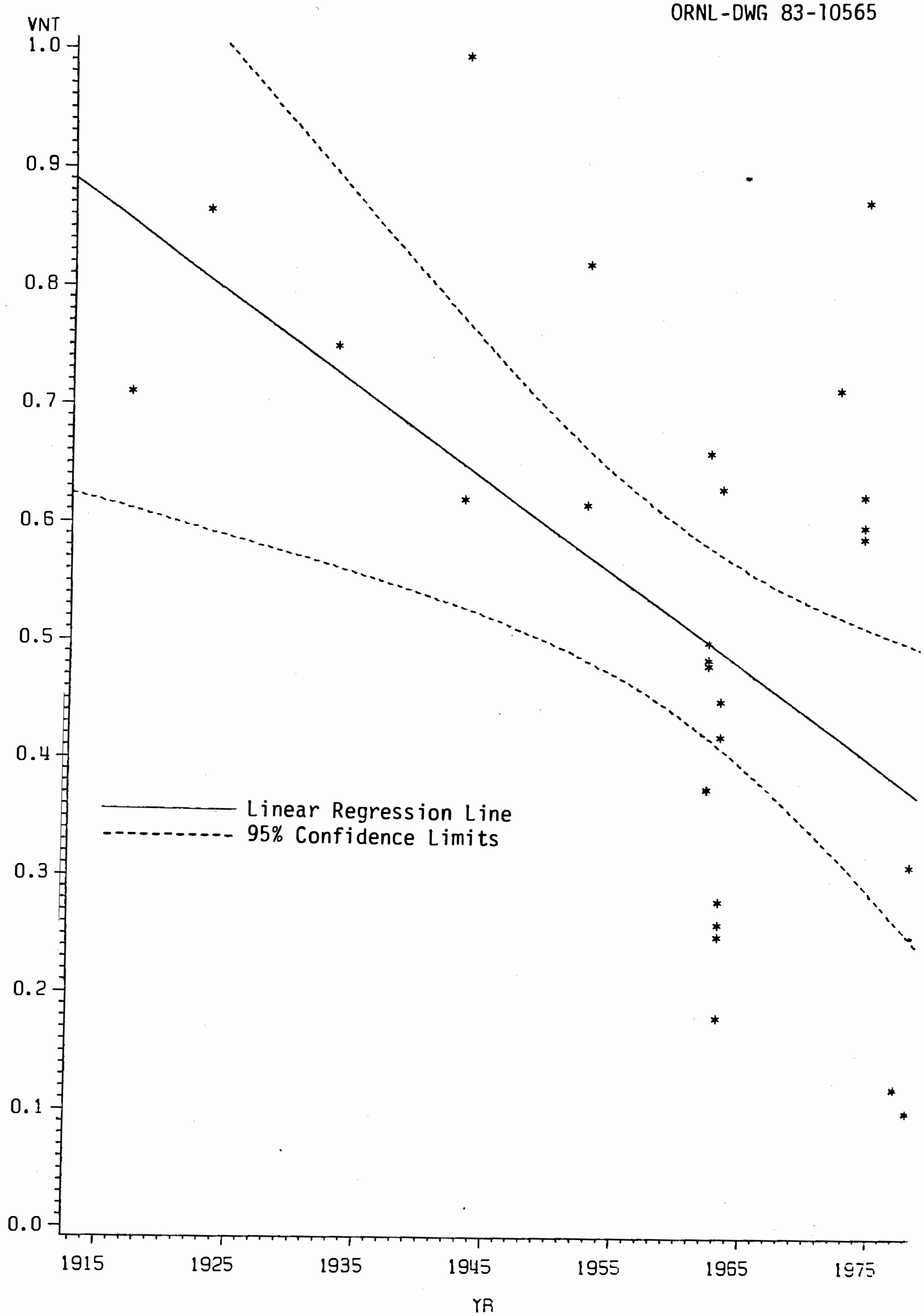

Fig. B-1. Air exchange (VNT) vs year of construction for similar wind and temperature conditions. Data presented in Table B-5.

Table B-5. Air exchange measurements made near 40°F and 10 mph

Year of construction	Air exchange rates (air changes per hour)	State	Temperature difference (°C)	Wind speed (m/s)	Comments	Study[a]
1952.5	0.617	DC	22.2	4.5	Wood frame rambler W/B[b]	2
1952.5	0.820	DC	22.2	4.5	Wood frame rambler W/B after retrofit	2
1963.0	0.180	MN	21.0	4.5	Rambler RH = 29%	13
1963.0	0.260	MN	22.0	5.4	Rambler RH = 25%	13
1963.0	0.180	MN	21.0	3.1	Rambler RH = 25%	13
1963.0	0.250	CAN	23.3	3.7	Wood frame rambler W/B	18
1963.0	0.280	CAN	19.2	5.4	Wood frame rambler W/B	18
1963.0	0.630	CAN	25.0	4.6	Wood frame rambler W/B	18
1963.0	0.450	CAN	21.7	4.1	Wood frame rambler W/B	18
1963.0	0.420	CAN	21.1	4.6	Wood frame rambler W/B	18
1963.0	0.450	CAN	25.5	4.6	Wood frame rambler W/B	18
1977.0	0.120	MN	22.0	4.0	2 Story WD frame energy efficient[c]	9
1978.0	0.100	MN	25.0	4.0	2 Story WD frame energy efficient	9
1978.0	0.310	IA	19.0	6.0	3 Story WD frame energy efficient	9
1972.0	0.715	NJ	22.0	4.0	Townhouse	14
1943.0	0.620	IN	22.2	4.5	1 Story BRK crawl space[d]	4
1933.0	0.750	IN	22.2	4.5	1 Story WD frame W/B	4
1962.0	0.485	IN	22.2	4.5	1 Story WD frame W/B crawl space	4
1943.0	0.995	IN	22.2	4.5	2 Story WD frame W/B	4
1923.0	0.865	IN	22.2	4.5	2 Story WD frame W/B	4
1962.0	0.375	IN	22.2	4.5	1 Story WD frame W/B	4
1917.0	0.710	IN	22.2	4.5	2 Story WD frame crawl space	4
1962.0	0.480	IN	22.2	4.5	2 Story BRK W/B	4
1962.0	0.500	IN	22.2	4.5	1 Story WD frame crawl space	4
1962.0	0.660	IN	22.2	4.5	1 Story BRK slab duplex	4
1974.0	0.625	OH	22.2	4.5	2 Story 4 BRK	20
1974.0	0.599	OH	22.2	4.5	2 Story 4 BRK	20
1974.0	0.875	OH	22.2	4.5	2 Story 4 BRK	20
1974.0	0.589	OH	22.2	4.5	2 Story 4 BRK	20

[a]References for Tables B-4 and B-5 follow Table B-5.
[b]W/B = with basement.
[c]WD = wood.
[d]BRK = brick.

REFERENCES FOR TABLES B-4 and B-5

Study number	Author(s) and year
1	Blomsterberg and Harrje (1979)
2	Burch and Hunt (1978)
3	Caffey (1979)
4	Coblentz and Achenbach (1963)
5	Dickinson et al. (1982)
6	Gammage et al. (1982)
7	Goldschmidt and Wilhelm (1979)
8	Grimsrud et al. (1978)
9	Grimsrud et al. (1979)
10	Grimsrud et al. (1981)
11	Grot and Clark (1979)
12	Hunt and Burch (1975)
13	Luck and Nelson (1977)
14	Malik (1978)
15	Molhave and Moller (1979)
16	Nevrala and Etheridge (1978)
17	Prado et al. (1976)
18	Tamura and Wilson (1963)
19	Moschandreas et al. (1978)
20	Wang and Sepsy (1980)

in soil and rock, radon is found in building materials, drinking water, natural gas, and the air. The indoor levels of radon and its progeny derive from all of these sources.

Formaldehyde is a small, one-carbon, organic molecule which is frequently found in indoor air. Formaldehyde occurs naturally in living organisms and is rapidly metabolized (Borzelleca et al., 1980). Human occupation is an indoor source of aliphatic aldehydes, which may include formaldehyde (Hollowell et al., 1977). Other indoor sources include combustion, particleboard, and certain insulation products.

Ozone, in most instances, is an outdoor pollutant, but may be of special concern in some offices. It rapidly decays indoors in a process catalyzed by many surfaces (Mueller et al., 1973; Sabersky et al., 1973). However, photocopying machines are known to produce ozone (Allen et al., 1978; Selway et al., 1980). Other potential sources include ultraviolet lights and electrostatic precipitators.

Respirable particles are those which are of appropriate size so that, when inhaled, they pass deep into the lungs and are difficult to remove by natural processes. The main source of such particles is combustion of tobacco or other organic materials including coal, wood, natural gas, and kerosene.

Carbon monoxide is another small molecule which arises during the combustion process. Any time that organic matter is burned without sufficient oxygen, carbon monoxide may be produced. Schaplowsky et al. (1974) found elevated carbon monoxide levels in rooms with fuel-burning applicances. Hollowell et al. (1977) found that carbon monoxide was emitted by gas cooking stoves.

Nitrogen dioxide is another combustion product of some concern. Nitrogen dioxide is emitted by gas stoves (Hollowell et al., 1978) and has been found at elevated levels in kitchens during gas stove operation (Hollowell et al., 1977).

Many organic chemicals are formed during combustion processes. It is known that polycyclic organic compounds are emitted from residential wood stoves (DeAngelis et al., 1980), and it is known that stoking of residential wood stoves seems to lead to transient increases in indoor carbon monoxide levels (Moschandreas et al., 1980b). These data suggest that potentially carcinogenic chemicals may be released indoors from combustion of wood or other organic materials. Unburned, volatile hydrocarbons may also be released from refueling of kerosene heaters indoors.

Numerous organic chemicals are used as solvents in small commercial buildings. Organic chemicals are used for many other purposes. It is not feasible to enumerate all potential sources of such pollutants that might be used in apartments and small commercial buildings.

Other more detailed discussions of indoor pollutant sources are found in the RCS environmental impact statement (DOE, 1979). Additionally, other general reviews include those listed in Section B.1.2 of this appendix.

B.2.3.2 Concentrations

Typical indoor concentrations of pollutants vary widely. Such concentrations depend on strength and proximity of sources and on ventilation parameters. Observed concentrations of these pollutants in studies of indoor environments will be summarized below. See Sect. 4.2.1 in the main report for comparison of levels and standards.

Radon concentration is measured in units of Bq/m^3 (1 Bq/m^3 = 1/37 pCi/L) while its progeny are measured in units of working levels (WL). Radon progeny are thought to be responsible for most of the carcinogenic effects seen in workers exposed to radon. Consequently, the WL was developed. One WL is a combination of concentrations of radon progeny yielding, in the decay to Pb-210, a total alpha energy emission of 21 nJ (equivalent to 1.3 x 10^5 MeV) in one liter of air. At radioactive equilibrium between radon and its progeny, air with 37 Bq/m^3 of radon will have 0.01 WL of radon progeny.

Both radon and radon progeny have been measured in indoor environments. NAS (1981) lists several measurements made in residences (but not basements) both in ordinary areas and in areas with elevated levels of radium in the soil:

Soil type	Radon concentration (Bq/m^3)	Progeny concentration (WL)
Ordinary	0.2-1221	0.0008-0.03
Radium-enriched	(no measurements)	0.013-0.02

Ryan (1981) has summarized a comprehensive review of reported radon and radon progeny exposure conditions in houses and other buidings. The geometric mean radon concentration on main floors was 88.8 Bq/m^3 with a geometric (i.e., multiplicative) standard deviation of 4.24-fold. The geometric mean progeny concentration was 0.0066 WL with a geometric standard deviation of 3.45-fold. For measurements in basements, geometric means and multiplicative standard deviations were 239.0 Bq/m^3 ± 3.69-fold and 0.0127 WL ± 3.41-fold. Hollowell et al. (1981) measured radon in new energy efficient houses and in retrofitted houses. For five energy efficient houses the levels ranged from 29.6 to 814 Bq/m^3. After retrofit of three houses, levels were 44, 141 and <37 Bq/m^3; whereas, before retrofit, the levels were <37, 133 and <37 Bq/m^3, respectively. Abu-Jarad and Fremlin (1981) have made measurements in high-rise buildings and found that there is no correlation between apartment elevation above the first level and progeny concentration. They found that ground and first floor measurements had a geometric mean of 0.0033 WL while for the second floor and higher elevations it was 0.0011 WL. On the basis of the data reviewed here, it seems reasonable to postulate that typical radon levels vary quite widely around 100 Bq/m^3 and progeny levels around 0.007 WL. Levels in basements are likely to be two to five fold higher.

Formaldehyde is frequently found in indoor air. NAS (1981) reviewed the literature on formaldehyde levels in residences. The range of measurements was 0 to 4.2 ppm. These authors suggest that average levels in conventional homes are likely to range from 0.01 to 0.1 ppm. Hollowell et al. (1981) measured formaldehyde in five new energy efficient homes and found levels ranging from 0.053 to 0.214 ppm. For three retrofit houses the levels of formaldehyde before retrofit were 0.055, 0.058, and 0.022 ppm, while after the retrofit they were 0.053, 0.051, and 0.019 ppm. In three low-rise apartments in

Pittsburgh, Moschandreas et al. (1978) measured the amount of total aldehydes, most of which is thought to be formaldehyde. The measurements ranged from 0.016 to 0.123 ppm with the averages over 14 days being 0.074, 0.063, and 0.089 ppm. Measurements made in three high-rise Pittsburgh apartments ranged from 0.018 to 0.194 with 14-day averages of 0.045, 0.101, and 0.120 ppm. Gupta et al. (1981) have summarized Consumer Product Safety Commission measurements of formaldehyde levels.

Type of home	Presence of urea-formaldehyde foam insulation	Mean (ppm)	Range (ppm)
Conventional	No	0.03	<0.01-0.08
Conventional	Yes	0.12	<0.01-3.40
Mobile	No	0.34	<0.01-3.99

In response to health complaints, Dally et al. (1981) studied 27 homes: 17 mobiles homes, 5 conventional homes with UF-foam, and 5 other conventional homes. Fifteen homeowners had taken corrective action to lower formaldehyde levels and the others had not. The average level in both these groups was about 0.35 ppm on the second visit and 0.30 ppm on the third visit. On the basis of the data reviewed here, it seems reasonable to assume that typical levels of formaldehyde range up to 0.1 ppm for conventional structures and are about three-to six-fold higher in mobile homes.

Ozone is very short-lived in the indoor environment and is found in low concentrations except around sources. In a study of ten homes in the Boston area, GEOMET (1981) found that on the average, indoor levels were less than 1/5 of those outdoors. For two offices, indoor levels were less than 1/3 of those outdoors. In another paper discussing the same study, Moschandreas et al. (1980a) note that in one office, average hourly concentrations were 9.80 ppb while in another they were 2.62 ppb. Since photocopiers are known to emit ozone, this may reflect the fact that the first office included a reproduction room. In another study of fourteen residences, Moschandreas et al. (1978) found that 95% of the hourly measurements showed that outdoor levels exceeded indoor levels. Hollowell et al. (1981) found levels ranging from 1.7 to 16 ppb in five energy efficient and three retrofit homes. It seems reasonable to assume that ozone is not a problem in the residential environment, but for small commercial buildings with photocopiers, ultraviolet lights, and electrostatic precipitators, there is need for adequate ventilation in the vicinity.

Respirable particles are of great concern in any indoor environment where combustion occurs. Young et al. (1981) reviewed several studies of residential particulate levels. Numbers of respirable particles ranged from 5.2×10^6 to 72×10^6 per cubic meter. The total mass of all particles ranged up to 103 $\mu g/m^3$. When Hollowell et al. (1981) measured particulate levels, they found levels ranging from 6 to 36 $\mu g/m^3$ of respirable particles and from 10 to 77 $\mu g/m^3$ of total particles. Quant et al. (1981) studied three different offices and found hourly levels of particles between 30 and 120 $\mu g/m^3$

with 8-hour time weighted averages of 60 to 82 $\mu g/m^3$. GEOMET (1981) studied two offices and ten residences in Boston. In the offices, levels of total particles were about 30-35 $\mu g/m^3$ on the average which was less than outside. In the residences, indoor levels always exceeded those outside and they ranged from 35 to 145 $\mu g/m^3$. Spengler et al. (1981) have found that levels of respirable particles outdoors were 22 $\mu g/m^3$ while for homes without smokers the level was 24 $\mu g/m^3$. In homes with one or more than one smoker, levels were 43 and 75 $\mu g/m^3$, respectively. Other papers discuss in greater detail the increased levels of particulate matter around smokers (Harke, 1973; Binder et al., 1976; Repace and Lowrey, 1980). From these data, it seems reasonable to assume that particulate levels in buildings with large filtering HVAC systems will be around 20-30 $\mu g/m^3$ and less than outdoor levels. Such buildings will house many of the apartments and small businesses covered by this program. On the other hand, in those cases where the density of smokers is high enough to overwhelm the ventilation, there are likely to be particulate levels which exceed U.S. ambient outdoor air quality standards (75 $\mu g/m^3$).

Another combustion product of some concern is carbon monoxide. NAS (1981) has summarized several studies where carbon monoxide was measured in buildings with sections for smokers. Levels ranged from 2 to 33 ppm in smoking sections and from 1 to 9.2 ppm in other control sections. Young et al. (1981) summarized several residential studies which found levels between 0 and 61.8 ppm. In ten Boston area residences, GEOMET (1981) found the hourly mean concentration to be between 0.7 and 3.3 ppm while for two offices the averages were 3.1 and

2.1 ppm. In four Washington/Baltimore homes, Moschandreas et al. (1978) found hourly average levels of from 0 to 5.2 ppm. Hollowell et al. (1981) found levels between 0.3 and 3.1 ppm in eight energy efficient homes. Typically, residential levels of carbon monoxide will be quite low, less than 1 ppm in the absence of smokers and not in the vicinity of heating or cooking combustion. The local environment around such devices may well approach or exceed threshold limit values (TLV) levels for short intervals. TLVs are levels of exposure for which continuing typical workday exposure are thought to be without risk to the worker. In commercial environments, levels of carbon monoxide will depend on ventilation and smoker density. Typical commercial levels will be two to four fold higher than in residential settings without combustion sources.

When temperatures around flames are high enough, nitrogen in the air can oxidize, therefore, nitrogen dioxide is another indoor pollutant of concern. In eight residences, Moschandreas et al. (1978) found levels of nitrogen dioxide ranging up to 138 ppb. In four homes with electric heating and cooking facilities, GEOMET (1981) found that more than two-thirds of hourly outdoor readings exceeded indoor levels and mean hourly indoor levels were 18, 11, 9 and 9 ppb. In the same study, eight gas-equipped homes were studied. More than half of the indoor levels exceeded outdoor levels and the average values ranged from 22.6 to 38.4 ppb. In two offices, average hourly levels were 17.3 and 18.2 ppb. In studies of typical residences summarized by Young et al. (1981), levels of nitrogen dioxide ranged up to 560 ppb. In studies in experimental chambers which approximate a kitchen with a gas oven and an air exchange rate of 0.24 air changes per hour, nitrogen dioxide levels reached 1500 ppb. NAS (1981) described one study in which seasonal average nitrogen dioxide levels in a gas-equipped Connecticut home were found to range from 26 to 58 ppb. Traynor et al. (1981) found that in a research house with an operating gas stove, peak one-hour average levels of nitrogen dioxide were inversely proportional to the infiltration rate raised to a power between 0.36 and 0.41, depending on where measurements were made. Hollowell et al. (1981) found levels of nitrogen dioxide between 4 and 77 ppb in eight energy efficient homes. Based on the data above, it seems reasonable to conclude that nitrogen dioxide levels in buildings without indoor combustion sources will be determined by outdoor levels and will be around 5 to 25 ppb. Where there is high temperature combustion, levels will be substantially higher, perhaps of the order of 100 ppb.

There is a myriad of organic chemicals likely to be present in trace amounts in the air of CACS-covered buildings. NAS (1981) lists some chemicals detected in offices:

Aliphatics	Aromatics	Halogenated hydrocarbons	Others
n-Hexane	Benzene	Trichloroethane	Hexanol
n-Heptane	Xylenes	Trichloroethylene	Methylethyl-ketone
n-Octane	Toluene	Tetrachloroethylene	
n-Nonane			
n-Undecane			
2-Methylpentane			
3-Methylpentane			
2,5-Dimethylheptane			
Methylcyclopentane			
Ethylcyclohexane			
Methylcyclohexane			
Pentamethylheptane			

Another report from the same research group (Miksch et al., 1981) suggests that there are both larger amounts and larger variety of organics in offices than outdoors and that concentrations of single species can range up to one mg/m^3. Moschandreas et al. (1980a) report that the mean hourly indoor concentration of non-methane hydrocarbons in an office with a print shop was 10.8 ppm whereas in another office it was only 2.8 ppm. In another report, (GEOMET, 1981), the maximum hourly values for two offices were 36.2 and 16.1 ppm, respectively. The National Institute for Occupational Safety and Health (NIOSH) has studied numerous cases of health or indoor air quality complaints in closed office spaces (R. A. Keenlyside and

S. Ahrenholz, personal communication). NIOSH workers studied a New York City office (Baker and Fannick, 1981) and detected hydrocarbons, carbon black, trimellitic anhydride, methylethylketone, Freon-113, and ethylene glycol monoethyl ether. Williams and Tulis (1981) found pentane, hexane, toluene, isopropanol, and benzene in the air of an office and classroom building in Florida. Isopropanol, thought to come from a nearby lithographic printing firm, was found in the air of another office (Hartle, 1981). Ahrenholz and Handke (1982) investigated indoor air quality in a commercial art studio and found the following levels:

Chemical	Near photocopier (mg/m^3)	Reception area (mg/m^3)	In art studio (mg/m^3)
_n_-Hexane	N.D.[a]	5.0	5.4
1,1,1-Trichloroethane	N.D.	7.2	7.9
Total hydrocarbons	19	N.D.	14

[a]Not detected.

In the residential environment, GEOMET (1981) reported that for four electrically equipped residences, maximum one-hour concentrations of non-methane hydrocarbons ranged from 5.2 to 47.2 ppm while for seven gas-equipped residences the range was 5.1-68.4 ppm. Molhave (1979) has identified 38 different chemicals which outgas from one or more of 32 common building materials. Moschandreas et al. (1978) found in a study of 14 residences that 90% of hourly indoor levels of non-methane hydrocarbons were larger than outdoor levels and that indoor levels ranged up to 8.0 ppm. From the above, it seems likely that typical peak residential levels of hydrocarbons will range up to 75 ppm and hourly averages up to 10 ppm. For small businesses very little can be said due to the almost limitless number of possible chemicals, some of which are proprietary, that may be in use.

B.3 Changes Due to Conservation Measures

Energy conservation will cause changes in the American building stock. Indoor air quality can be degraded by virtue of reducing air exchange rates and thereby increasing concentrations of indoor pollutants. In the sections that follow, several subjects will be discussed including changes in pollution sources, changes in infiltration, air quality impacts from conservation measures, and how those impacts may be mitigated.

B.3.1 Changed indoor emissions

The principal effects discussed in this section are those due to building materials and increased traffic of technically knowledgeable people around potentially malfunctioning furnaces.

As mentioned above, building materials emit a wide variety of chemicals (Molhave, 1979). A principal class of building material of some concern includes those materials which contain urea-formaldehyde (UF) resins. Such materials include particleboard, chipboard, and plywood. Urea-formaldehyde foam insulation was cause for concern prior to the Consumer Production Safety Commission (1982) ban against its sale for use in residences. However, at this writing, the ban has been vacated in the courts but the issue has not been legally resolved. Products containing UF-resins tend to emit formaldehyde (Meyer, 1979). The amount of emission depends on air flow, temperature, relative humidity, construction practices, and product specific factors such as length of curing and proprietary additives. Glass (Goldman and Yaniv, 1978) and perhaps other mineral fibers contain trace amounts of radium and hence insulation made from such materials may contribute radon to indoor air. Some building materials may harbor microorganisms. A cellulose-based fireproofing material that was used in construction of a hospital was shown to support the growth of fungal species and emission of fungi led to infection of several cancer patients (Aisner et al., 1976). Dudney et al. (1982) found evidence of several genera of fungi in attic insulation in 57 homes, but it is not clear from those results whether or not the presence of the insulation increased levels of fungi in indoor air.

Some potential situations which cause indoor air pollution may be discovered and corrected by energy auditors and others. For example, it is clear that when furnace flues are blocked, death can result from carbon monoxide poisoning (Kelly and Sophocleus, 1978). Since many of the workmen who will install various conservation measures may be more aware of furnace operation than are owners of buildings, there may be some serendipitous instances where furance malfunctions are noticed and repaired before a serious incident occurs.

B.3.2 Decreased air exchange

Theoretical studies show that decreased air exchange causes both lower rates of energy use for space conditioning (Nevrala and Etheridge, 1978) and buildup of higher concentrations of pollutants with indoor sources (review by NAS, 1981; Esmen, 1978; Ishizu, 1980). Furthermore, many conservation measures will tend to reduce air infiltration although in some studies, measures were found to increase infiltration.

Grot and Clark (1979) found that in 24 low-income homes, fan-induced infiltration was reduced by 30-35% after retrofit weatherization. A research group at Princeton has found a 10-15% reduction in infiltration in 98 detached dwellings after typical retrofits (Howard Ross, personal communication). Tamura and Wilson (1963) measured infiltration in a house during winter on four separate occasions with and without adhesive tape on the perimeter of all windows. Such a measure reduces infiltration as shown by their results which were:

Without Tape			With Tape			
Wind speed (m/s)	Temperature difference (°C)	Infiltration (air exchanges per hour)	Wind speed (m/s)	Temperature difference (°C)	Infiltration (air exchanges per hour)	Percent change
4.1	22	0.45	4.6	21	0.42	-6.7
4.6	25	0.63	4.6	26	0.45	-28.6
3.2	27	0.49	2.2	27	0.45	-8.2
4.6	33	0.55	4.7	33	0.46	-16.4
					Average	-15.0

Blomsterberg and Harrje (1979) report that weatherstripping windows in a 1940's house reduced wintertime infiltration by about 10%. Sinden (1978) finds that weatherization of a townhouse reduces heat loss through infiltration by about 50%. Collins (1979) found about a 30% reduction in fan-induced infiltration in 29 electrically heated homes in Denver after weatherization.

Other studies find very little decrease or even an increase in infiltration after weatherizing. Burch and Hunt (1978) found that after retrofit, infiltration increased about 33% for ambient conditions, 10 mph winds and 40°F indoor-outdoor temperature difference. Dickinson et al. (1982) found no change in infiltration after adding attic insulation and storm windows. More extensive weatherization did reduce infiltration rates.

From the above data, it seems reasonable to assume that infiltration reductions due to weatherization may range up to about 30%. Young et al. (1981) conclude that "retrofitting older homes with common methods can probably reduce infiltration rates by no more than 20-25%." Nero (1981) suggests that a "rather far-fetched upper limit for the effectiveness of infiltration-reduction programs" would be achieving 50% reduction in average infiltration rates. At this time, it is not possible to quantify differences between the above studied residences and CACS-covered buildings.

B.4 Modeling Indoor Air Quality

B.4.1 Ozone

Shair and Heitner (1974) developed a time-dependent model of indoor ozone levels as a function of outdoor levels, ventilation, infiltration, ozone removal by filters, chemical decay, and indoor source strength. That model is described by the following equation:

$$V \frac{dC_i}{dt} = q_o C_o (1-F_o) = q_1 C_i (1-F_1) + q_2 C_o - (q_o + q_1 + q_2) C_i + S - R \quad (1)$$

where:

- V = volume of the room,
- C_i = indoor concentration of ozone,
- C_o = outdoor concentration of ozone,
- q_o = volumetric flow rate of make-up air,
- q_1 = volumetric flow rate of recirculated air,
- q_2 = volumetric flow rate of infiltrated air,
- F_o = fraction of ozone removed from make-up air,
- F_1 = fraction of ozone removed from recirculated air,
- S = mass rate of generation of ozone indoors, and
- R = mass rate of decay of ozone indoors.

The main mechanism of indoor ozone decomposition has been shown to follow first-order kinetics in a surface catalyzed reaction (Mueller et al., 1973; Sabersky et al., 1973). This implies that

$$R = k A C_i ,$$

where k is the surface decay rate constant and A is the total area available to catalyze decomposition.

Shair and Heitner (1974) determined all the pertinent parameter values for a two-room university office in Pasadena, California. The volume of the office was 209.3 m^3, the surface area was 334.4 m^2, and filters used removed none of the ozone. When the air conditioning system was adjusted to minimize the flow of make-up air, the flow rate of make-up air was 251.5 m^3/h, of recirculated air was 1954 m^3/h, and of infiltrated air was 491.0 m^3/h. Mueller et al. (1973) found the surface decay rate constant for offices to be 1.335 m/h.

The two remaining parameters in Equation-1 are C_o and S which are both time-dependent quantities. Shair and Heitner (1974) suggested that the outdoor concentration of ozone might be approximated by a sinusoidal function. Indeed, on five different days in southern California, they measured outdoor levels at various times during the day. In all cases the diurnal profile was a unimodel function, and in most cases it was rather symmetric. For these reasons, it was assumed that $C_o = C_{max}[\sin \omega t]$. C_{max} is the maximum outdoor concentration of ozone. The t is the time in hours since 7:00 a.m. and, by definition, cannot exceed 12 h. The ω is 2π divided by 24 h. With these assumptions, outdoor levels of ozone are modeled so that the level is zero at 7:00 a.m. and 7:00 p.m., and is maximal at 1:00 p.m.

The indoor sources of ozone were thought to be copying machines (Allen et al., 1978). These authors found that the amount of ozone generated per copy ranged as high as 158 μg. Over a seven month period, 120 copying machines produced 18 x 10^6 copies (Bates, 1980). Assuming there are 21.7 workdays per month and using the above figure, it seems reasonable to assume that a typical copying machine produces

19,5 mg of ozone per hour of operation. If it is now further assumed that there is one copying machine in the office described above and that it operates at a constant rate from 8:00 a.m. to noon and from 12:30 p.m. to 4:30 p.m., then the indoor source strength, S, in Equation-1 is now defined.

It is straight forward to solve Equation-1 with all the parameters defined as above. In Fig. B-2, the time-weighted average ozone concentration predicted by this model for a typical workday is presented as a function of infiltration (i.e., q_2) for various peak outdoor concentrations of ozone. In this situation, the amount of fresh air intentionally introduced (i.e., q_0) has been minimized which is the likely action of a building owner seeking to reduce energy usage. Even so, q_0 does not fall below 0.83 air changes per hour. It is clear that for a peak outdoor concentration of about 50 $\mu g/m^3$ the indoor level of ozone is independent of air exchange. For lower levels of outdoor ozone, the indoor level is inversely related to air exchange. For higher levels of outdoor ozone, lower air exchange rates tend to protect office occupants. If the CACS Program results in reducing air exchange from 1.0 to 0.7 air changes per hour, then for a peak outdoor ozone level of 200 $\mu g/m^3$ the time-weighted average workday concentration will be lowered from 100 to 94 $\mu g/m^3$. For higher outdoor levels which may be typical of southern California (Shair and Heitner, 1974), the beneficial effect of reduced air exchange is expected to be even greater.

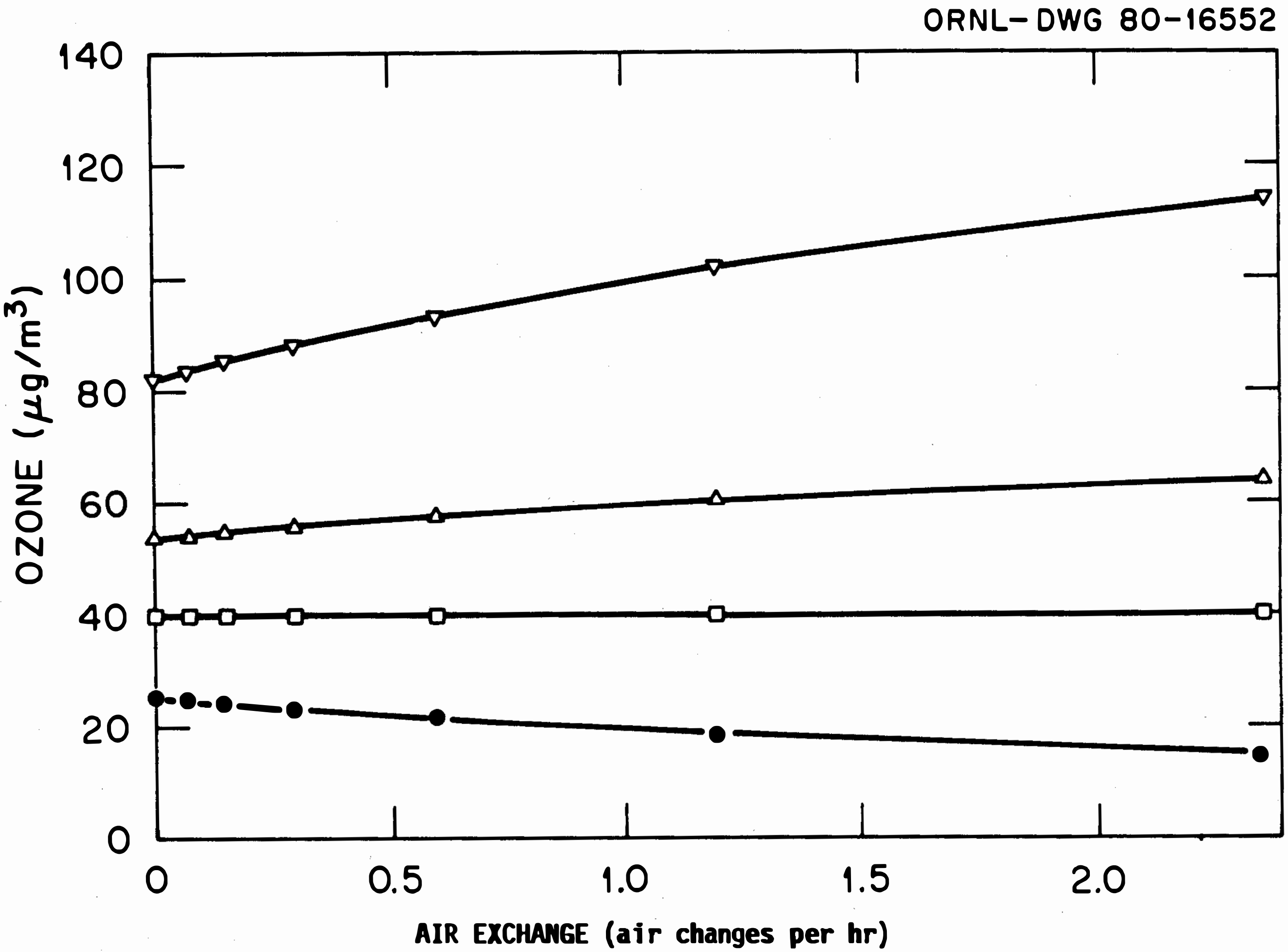

Fig. B-2. Average indoor levels of ozone over an 8-h workday in an office with a copying machine were predicted using Eq. (1). Various outdoor levels of ozone were considered: 200 $\mu g/m^3$ (∇), 100 $\mu g/m^3$ (Δ), 50 $\mu g/m^3$ ($\square$), and 0.01 $\mu g/m^3$ (.).

B.4.2 Radon

In a small commercial building or apartment there are numerous sources of radon. Radon derives from the radioactive decay of radium which may be found in soil, concrete, wallboard, and glass in trace amounts. Guimond et al. (1979) and Hollowell et al. (1979) provide good overviews of the routes of entry of radon into indoor air. Evans (1969) provides an excellent introduction to the field of radon, its short-lived decay products, and the rather unusual unit, the working level (WL), which is used as a measure of airborne levels of these radionuclides. Formally, a working level is any combination of radon's short-lived progeny in a liter of air which yield 20.83 nJ (i.e., 1.3×10^5 MeV) of α-decay energy in the conversion to the isotope lead-210, a longer-lived daughter of radon. If radon and its short-lived progeny are in radioactive equilibrium then 3.7 kBq/L (i.e., 100 pCi/L) each of Po-218/At-218 and Bi-214/Po-214 is equivalent to 1.0 WL. From published results (Evans, 1969; Kusuda et al., 1979), a simple model was developed relating indoor exposure, measured in working levels, to air exchange, indoor source strength, room geometry, and outdoor air concentration. The time rate of change in the number of radon atoms in an office will depend on:

(1) the rate of production of radon by radioactive decay of the parent species,

(2) the rate of destruction by radioactive decay of the subject species,

(3) the rate of air exchange of the subject species to and from the outdoor air, and

(4) the rate of emanation of the subject species from indoor sources.

From these considerations it can be shown that

$$\frac{dN_R}{dt} = -\lambda_R N_R + I(N_R^\circ - N_R) + S \,, \qquad (2)$$

where:

t = time (h),

N_R = indoor concentration of radon atoms (L^{-1}),

λ_R = radioactive decay constant (h^{-1}),

I = infiltration rate (h^{-1}),

N_R° = outdoor concentration of radon (L^{-1}), and

S = emanation rate of radon atoms ($L^{-1}\ h^{-1}$).

An analogous equation for the i^{th} daughter of radon is

$$\frac{dN_i}{dt} = \lambda_{i-1} N_{i-1} - \lambda_i N_i + I(N_i^\circ - N_i), \qquad (3)$$

where:

λ_i, λ_{i-1} = radioactive decay constants for i, i-1 daughters,(h^{-1}), and

N_i, N_{i-1} = indoor concentration of i, i-1 daughter atoms (L^{-1}).

Emanation of daughter atoms from room surfaces is thought not to occur because the daughter atoms are charged ionic species which cannot diffuse from inside a solid material to the indoor breathing space.

If it is assumed that air exchange, indoor source strength, and outdoor concentrations all remain fairly constant for times comparable to the mean lifetime of air in the office, then steady state is achieved and $\frac{dN_i}{dt} = 0$. Although Equations-2 and -3 can be solved without this simplifying assumption, the solution is now easier and is given by

$$N_R^{\infty} = \frac{IN_R^{\circ} + S}{I + \lambda_R} ,$$

$$N_i^{\infty} = \frac{\lambda_{i-1}}{I + \lambda_i} N_{i-1}^{\infty} + \frac{I\, N_i^{\circ}}{I + \lambda_i} ,$$

where N_i^{∞} = the steady state concentration of the i^{th} daughter (L^{-1}). The total working level value is then given by

$$WL = 102.4 \times 10^{-6}\, N_A^{\infty} + 60.61 \times 10^{-6}\, N_B^{\infty} + 60.22 \times 10^{-6}\, N_C^{\infty} ,$$

where:

A = Po-218,

B = Pb-214, and

C = Bi-214.

This model does not account for the effects of human activity patterns. In the case where a room occupant momentarily opens a door or window, this will increase infiltration, allowing an influx of air relatively lean in radon daughters. This will tend to decrease the indoor working level. Thus the assumption of steady state and constant infiltration rate is a case that is worse than usual.

Haque et al. (1965) determined the emanation rate of radon in four typical rooms in England and found values ranging as high as 3.78

Bqm^{-2} Haywood et al. (1980), while studying a former uranium ore sampling plant, found a concrete floor which emitted radon at a rate of 36.9 $Bqm^{-2}h^{-1}$. In the vicinity of that sampling plant, the background emission rate was seven to eight fold lower.

The source term, S, in Equation-2 is the product of emanation rate and the area emitting radon divided by the total volume of the space being ventilated. A case in which reduced infiltration due to the CACS Program may lead to unacceptable levels of radon, is where an office has an exceptionally high emanation rate such as the case described by Haywood et al. (1980). If it is assumed that the floor is the only radon-emanating surface, then S can be calculated as follows:

$$S(L^{-1}h^{-1}) = \frac{36.9\ Bq/m^2\ h^{-1}\ x\ A\ x\ B\ x\ 478.4\ x\ 10^3\ Rn/Bq}{A\ x\ B\ x\ C\ x\ 1000\ L/m^3}$$

where:

A = width of the room (m),

B = length of the room (m), and

C = height of the room (m).

If 2.44-m (i.e., 8-ft) ceilings are assumed, then S is 7.24 x 10^3 $L^{-1}h^{-1}$ for any length and width. For a small office (4.34 m x 3.43 m x 2.44 m or 14.25' x 11.24' x 8') in which all the surfaces emanate radon at a rate equal to the highest reported by Haque et al. (1965), the source term would be calculated as follows:

$$S(L^{-1}h^{-1}) = \frac{3.78\ \text{Bq/m}^2\ h^{-1} \times 478.4 \times 10^3\ \text{Rn/Bq} \times 1.86\ \text{m}^2/\text{m}^3}{1000\ \text{L/m}^3}$$

$$= 3.36 \times 10^3 L^{-1}h^{-1}$$

For a large office (51.82 m x 36.58 m x 2.44 m or 170' x 120' x 8') such as Moschandreas et al. (1980a) emanating radon at the highest rate reported by Haque et al. (1965), the source term would be as follows:

$$S(L^{-1}h^{-1}) = \frac{3.78\ \text{Bq/m}^2\ h^{-1} \times 478.4 \times 10^3\ \text{Rn/Bq} \times 0.913\ \text{m}^2/\text{m}^3}{1000\ \text{L/m}^3}$$

$$= 1.65 \times 10^3\ L^{-1}h^{-1}\ .$$

George (1972) measured the levels of radon and its daughters in New York City outdoor air on eight different summer days. The average of those results were:

	Mean	Standard deviation
Radon-222	6.29×10^{-3}Bq	1.48×10^{-3} Bq
Polonium-218	4.81×10^{-3}Bq	2.22×10^{-3} Bq
Lead-214	2.96×10^{-3}Bq	1.85×10^{-3} Bq
Bismuth-214	1.85×10^{-3}Bq	1.48×10^{-3} Bq
Working level	0.7×10^{-3} WL	0.5×10^{-3} WL

Using the source term derived from the first situations, S - 7.24 x $10^3\ L^{-1}h^{-1}$, and outdoor air with the same relative ratios of radon and its daughters, the indoor working levels were calculated using Equation-3. The results of those calculations are presented in Fig. B-3 for outdoor air of various working levels. If the radon content of the outdoor air is as low as what George (1972) measured, then reducing the air exchange rate from 1.0 to 0.7 air changes per hour raises the indoor working level from 3.5×10^{-3} WL to 5.0×10^{-3} WL. For lower source strength the indoor working levels will be even lower.

B.4.3 Formaldehyde

The most likely sources of public exposure to formaldehyde vapor include photochemical smog, car exhaust, outdoor combustion, cigarette smoke, and products containing urea-formaldehyde resin (Borzelleca et al., 1980). The typical office worker is exposed to the latter two. Resinous products in the office environment include particleboard and plywood which are used in cabinetry, subflooring, and shelving. Fabrics can also be a source of formaldehyde.

Andersen et al. (1975) studied the relationship between indoor formaldehyde levels and various building and meteorological factors. They studied the emission of formaldehyde from particleboard under defined conditions in the laboratory and developed the following mathematical model:

$$E = \frac{(RT + S)\ (aH + b)}{1 + nc/\alpha}, \qquad (4)$$

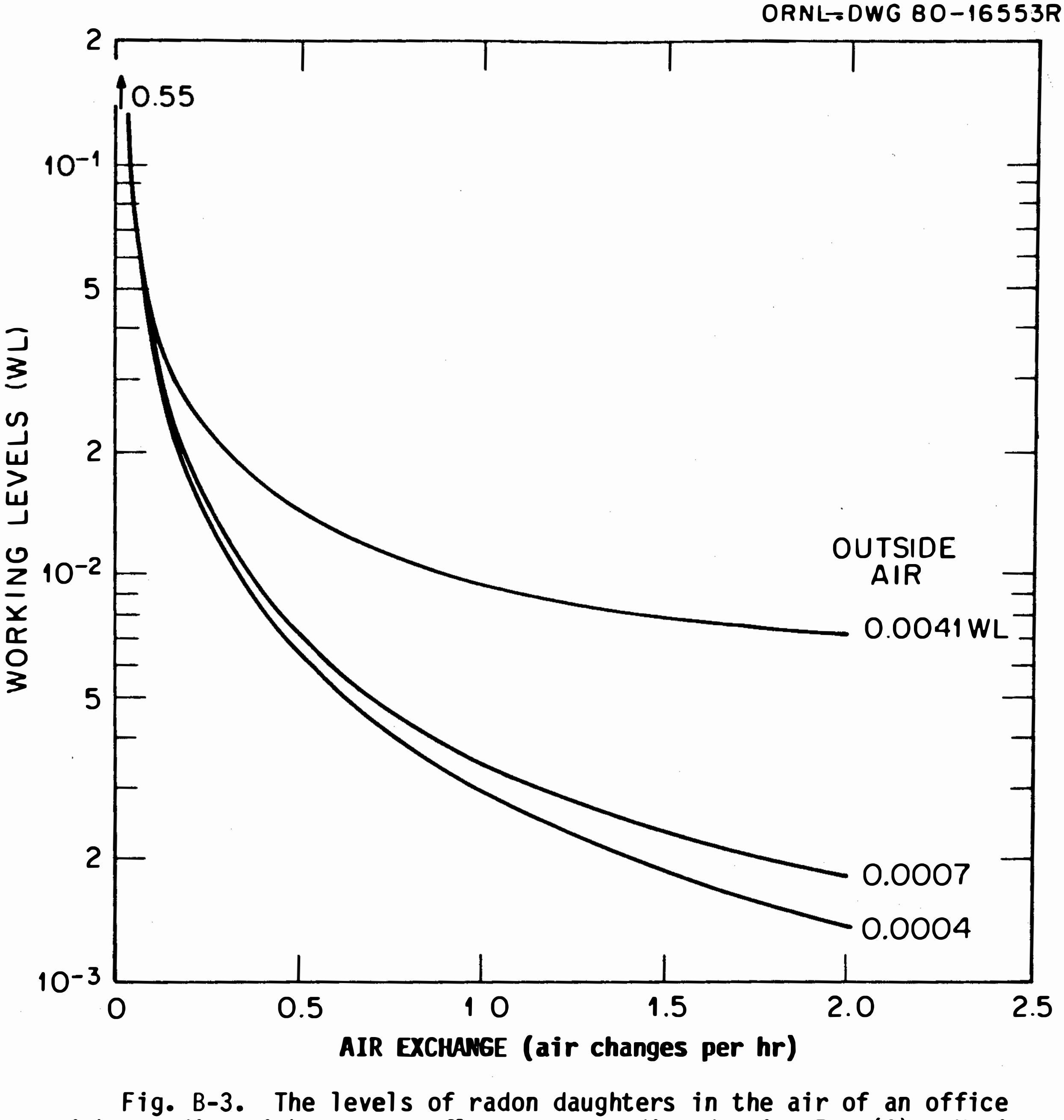

Fig. B-3. The levels of radon daughters in the air of an office with a radium-rich concrete floor were predicted using Eq. (3). Various outdoor levels of radon and its daughters were considered.

where:

E is indoor concentration of formaldehyde (mg/m^3),

a, b, c, S, and R are constants depending on type and surface coating on particleboard in the room,

T is air temperature (°C),

H is humidity (gH_2O/kg dry air),

n is air exchange rate (h^{-1}), and

α is particleboard area/room volume (m^2/m^3).

From field studies of 25 houses, the authors found that R equalled 64 x 10^{-3}. From laboratory studies the authors found a, b, c, and S to be 0.143, 0.048, 0.304, and -0.764, respectively. The ratio of particleboard area to room volume was determined for each house in the field study and the average value was 1.18 m^2/m^3 with a standard deviation of 0.53 m^2/m^3. The average air temperature and humidity found in the field study was 22.8°C and 7.1 gH_2O/kg dry air.

Using the above values of the laboratory-defined constants and the average field study value for temperature and humidity, Equation-4 was evaluated for various infiltration rates and values of α. Figure B-4 presents the results for $\alpha = \overline{\alpha} - \Delta\alpha$, α, and $\overline{\alpha} + \Delta\alpha$. While perhaps such results best apply to Danish residences, they do suggest that reduced air exchange resulting from the CACS Program will not substantially alter the public exposure to particleboard-derived formaldehyde. While the concentration predicted at 1.0 air change per hour, 0.59 mg/m^3, is less than that for 0.7 air changer per hour, 0.63 mg/m^3, both levels are expected to elicit similar biological responses (Borzelleca et al., 1980).

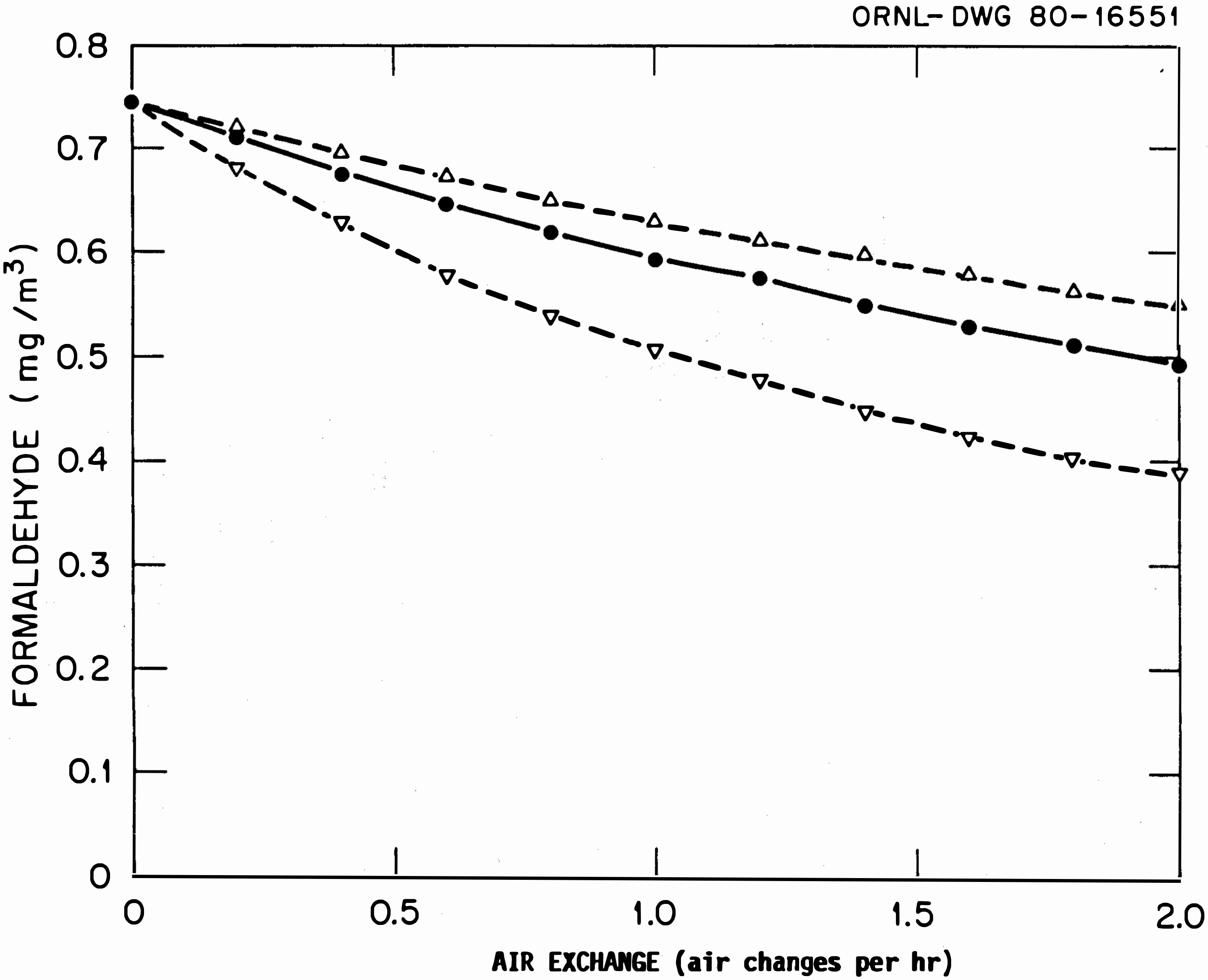

Fig. B-4. Indoor levels of formaldehyde were predicted using Eq. (4). Various ratios of particleboard area to room area were considered: 0.64 m^2/m^3 (∇), 1.17 m^2/m^3 (.), and 1.70 ,$^2/m^3$ (Δ).

B.5 Health Effects

B.5.1 Ozone

The primary health effect due to ozone exposure at concentrations which might be expected in an office environment is irritation of eyes, mucous membranes, and upper respiratory system. Such effects have been demonstrated at very low concentrations (around 1 ppm) and susceptibility to upper respiratory tract infection and tissue damage at higher concentrations. It also acts as a sedative on the central nervous system. A significant aspect of ozone exposure is that particular groups within the population are very sensitive. These groups include the young and possibly those with chronic respiratory ailments such as asthma and bronchitis. There is some evidence that ozone may play a role in the etiology of pulmonary adenomas (Werthamer et al., 1970).

Several authors report symptoms of respiratory irritation, headache and shortness of breath in occupational groups exposed to approximately 1 ppm (Wilska, 1951; Truche, 1951). Challen et al. (1958) report data on heliarc welders. Symptoms of upper respiratory tract irritation were noted in workers exposed daily to concentrations of 0.8-1.7 ppm ozone. When the concentration was reduced to 0.2 ppm, the symptoms disappeared.

Experimental human exposure to ozone has also provided useful information. One investigator exposed himself to 1.5 ppm for one-half hour and 2 ppm for an additional 1.5 hours (Griswold et al., 1957). The subject reported symptoms such as dryness of the mouth and throat, reduced ability to concentrate and think, and lower chest pains. The chest pains recurred periodically for several days and a cough which developed in two days persisted for two weeks. Reductions in standing 3-second vital capacity, total vital capacity, and maximum breathing capacity were noted at the end of the exposure.

Young and Shaw (1964) exposed 12 human subjects to 0.6-0.8 ppm for two hours. Significant changes in diffusing capacity, vital capacity, and forced expiratory volume were observed.

Animal studies have provided much information concerning factors which alter the toxicity of ozone (Stokinger, 1965). Young animals are more susceptible to acute effects than are mature ones. Toxicity or susceptibility to toxicity increases as the temperature increases. Physical exertion during exposure enhances toxicity. Exposure to ozone subsequent to exposure to a bacterial pathogen greatly increases the seriousness of the response to that pathogen. Animal studies have also provided information on effects of chronic exposure to ozone. Chronic exposure to concentrations of about 1 ppm have been shown to cause chronic pulmonary disease, premature aging, and acceleration of lung tumor formation.

B.5.2 Radon

The effect of primary concern from exposure to radon is lung cancer from the radioactivity of radon and its progeny. The first evidence implicating radon in carcinogenesis was the publication of reports of high incidence of lung cancer in uranium mine workers (Lorenz, 1944; Archer et al., 1973). Radon concentrations in the mines were in the range of 10^{-9} curie per liter; background concentrations are in the range of 10^{-12} curie per liter. This in conjunction with the availability of respirable dust particles in the mines for attachment and inhalation of radon progeny suggested a causal relationship. It has been suggested that the lungs of miners are particularly susceptible to carcinogenesis because of the constant irritation of pneumoconiosis and the presence of other air pollutants (Lorenz, 1944).

Animal studies have shown radon to be acutely toxic (Morken, 1955). Chronic exposures resulted in systemic poisoning of the spleen, kidney, and blood-producing tissues. Reduction in life span and body weight were also noted. Workmen's investigations did not elicit lung cancer; however, lesions of the type which often precede lung cancer were produced in the bronchi.

There are several problems involved in establishing a dose-response relationship for radon exposure and lung cancer. Radon itself is inhaled from the atmosphere. In addition, radon progeny attach to dust particles and can be inhaled in this manner, contributing to the tissue dose of alpha radiation. Daughter species may also attach to walls and other surfaces which effectively remove them (and their contribution to lung tissue dosage) from the air. The dose received via radon progeny attached to inhaled particles will be dependent on retention time in the lungs. Since alpha radiation has a very short range, the exact point of deposition is directly relevant to carcinogenesis. Deposition and retention are, in turn, determined by the respiratory physiology and fluid dynamics of the lungs as well as particle size. Moreover, rate of emission of alpha radiation is related to the relative concentration of the various daughter species which are often not in a radioactive equilibrium mixture (Colle, 1980).

Dosimetry refers to methods of numerically relating the concentration of ambient radioactivity and relevant tissue dose. Factors considered in these calculations include transport of radioactive dust in the lungs, the half-life of the radioactivity, the particle size of the dust, breathing rate, ventilation rate, and the geometry of the tissue. Work in the area of dosimetry in association with results of epidemiological investigations of uranium mines has provided a basis for the establishment of regulatory levels. Primary contribution in the area has been made by Parker (1969), Harley and Pasternak (1972), and Desrosiers (1977). For a review, see Holoway et al. (1978).

Risk estimates in terms of excess cases of lung cancer due to radon exposure must be based on extrapolation of dose-response data at high dosages derived from epidemiological investigations of mine workers and animal experimentation. Such quantitative data do not exist for exposures likely to be encountered by occupants of energy-efficient buildings. From high exposure data, UNSCEAR (1977) derived a risk estimate of 200-450 excess cases of lung cancer per million population per working level month (WLM) of exposure (Budnitz et al., 1979). Such estimates are based on a linear extrapolation model. This model involves a directly proportional dose-response relationship. For example, the risk at 1% of a measured dose is 1% of the measured risk at that dose. This is generally accepted as a conservative estimation method of radiation dose-response relationships. In reality, it could be under- or overestimating the true risk, due to the unknown biological response to low doses. Another factor which may confound such an extrapolation is the difference in the occupational atmosphere to which the uranium miners were exposed and the residential environment. For example, particulate matter available for radon attachment may differ in size and concentration. Other pollutants present will differ in type and concentration. In addition, ventilation rates may differ as will breathing rates of individuals exposed while under physical exertion as compared to those at rest or only under occasional exertion. The U.S. Environmental Protection Agency has estimated excess cancer deaths based on a similar procedure (Guimond et al., 1979). The results are as follows:

Lifetime risk of lung cancer per 100,000 persons due to lifetime residency in structures with an average radon daughter concentration of 0.02 WL

Relative risk	Excess cancer deaths	Total years of life lost
Adult and child (sensitivity equal)	2,000	30,000
Child sensitivity (3 times adult)	3,000	50,000
Absolute risk[a] (10 deaths/CWLM[a] for 10^6 person years of risk)	1,000	27,000

[a]CWLM = cumulative working level month.

The data extrapolations described have led to the recommendation of guidelines for exposure to radon and its daughter. The U.S.

Environmental Protection Agency has suggested to the state of Florida for houses on phosphate reclaimed land that action should be taken to reduce levels above 0.02 WL to "as low as reasonably possible," preferably below 0.01 WL (Budnitz et al., 1979). Canada has promulgated similar criterion for houses in four communities associated with uranium mining and processing.

B.5.3 Formaldehyde

Health effects attributable to formaldehyde exposure include respiratory and eye irritation, gastrointestinal irritation, and primary and allergic dermatitis. There is some suggestion, but not hard evidence, that it may be carcinogenic or teratogenic. Most information on adverse health effects in humans due to formaldehyde is derived from occupational exposure. There is no published data on effects in human beings due to long-term exposure to concentrations of formaldehyde below detection thresholds. However, some work on chronic exposure has been done with animals including studies of carcinogenic and teratogenic potential. Effects of acute exposure to a wide range of concentrations of formaldehyde have been studied in animals.

The following is a discussion of individual investigations of response to formaldehyde exposure. Studies on human beings are those in which exposure was quantified and was in the range relevant to the issue of indoor air quality in apartments and small business concerns. Investigations involving chronic exposure in animals are also considered. The discussion is not intended to be exhaustive of all data on the subject. More complete reviews have been published by NIOSH (1976) and the National Research Council (1980).

Ettinger and Jeremias in 1955 (as discussed in NIOSH, 1976) reported eye, nose, and throat irritation in workers handling nylon fabric coated with urea-formaldehyde resins. Employees were exposed to 1-11 ppm gaseous formaldehyde as well as direct contact with the formaldehyde-resin on the fabric. The authors believed the noted effects were due primarily to gaseous exposure.

A controlled exposure of 12 male subjects to 13.8 ppm (17.0 mg/m^3) formaldehyde for 30 minutes was conducted by Sim and Prattle (1957). Subjects experienced eye and nose irritation upon entering the exposure chamber. After 10 minutes in the chamber, the effects were no longer noticeable. The authors point out that their results provide evidence of adaptation to an irritant stress.

Another problem due to treatment of fabric with urea-formaldehyde resins was identified when employees and customers in several dress shops complained of eye, nose, and throat irritation and unpleasant odor. Formaldehyde levels in the shop were found to be 0.13-0.45 ppm (Bourne and Seferian, 1959).

Schuck et al. (1966), in studying the effects on the eye of smog components generated by photooxidation of ethylene and propylene, exposed subjects to the smog mixture in a chamber for five minutes and reported the subjects' feelings of eye irritation. The blinking rate was used as an objective measure of irritation. Subjects readily reported irritation from gas mixtures containing as low as 0.005 ppm formaldehyde. Exposures to gas mixtures generated by photooxidation with ethylene caused more irritation at a given formaldehyde concentration than exposure to mixtures generated by propylene. This emphasized the importance of the presence of varying components in atmospheric exposures.

Melekhina (as reported in NIOSH, 1976) conducted experiments to establish the threshold of odor perception and study the effects of formaldehyde on the central nervous system. Optical chronaxy changes were observed after 15-minute exposures to 0.6-1.3 ppm formaldehyde. The odor threshold was established at 0.06 ppm.

Leonardos et al. (1969) employed a panel of four trained odor panelists to establish the threshold of odor perception at 1 ppm.

Fel'dman and Bonashevskaya (1971, as reported in NIOSH, 1976) reported that some subjects could detect by odor formaldehyde concentrations of 0.074 mg/m^3. Concentrations of 0.053 mg/m^3 produced changes in cerebral electrical activity in these subjects. No such changes were produced in response to concentrations of 0.04 mg/m^3.

Anderson et al. (1979) reported the exposure of 16 subjects to 0.25-1.6 ppm five hours per day for four days. Measures of effects were recorded before, after 1-3 hours and after 3-5 hours of exposure. Nasal mucus flow rate decreased and subjects reported eye irritation as well as dryness of the nose and throat. No changes were observed in pulmonary function or performance of mathematical tests.

Weber-Tschopp et al. (as reported in NRC, 1980) observed a linear relationship for average number of people responding as concentration of formaldehyde increased. Exposure concentrations tested ranged from 0.03-4 ppm. Responses measured included eye, nose, and throat irritation, odor, eye blinking rate, and desire to leave the room. Changes became significant at 1.2 ppm. The authors also reported results suggesting adaptation to the irritant effect.

Several additional reports of occupational exposure yield similar results. Kerfoot and Mooney (1975) reported complaints of eye and upper respiratory tract irritation in funeral home employees exposed to 0.25-1.39 ppm formaldehyde. Paraformaldehyde was also present in the work environment. In another investigation, symptoms of eye, skin, and upper respiratory irritation were more frequent in rubber workers exposed to 0.061 mg/m^3 formaldehyde in the presence of resorcinol and ammonia than in an unexposed control group (Gamble et al., 1976). Baseline lung function measurements were not different among the groups. However, lung function measured before and after shift showed a significant reduction in the exposed group. Schoenberg and Mitchell (1975) studied employees producing filters with fibers impregnated with phenol-formaldehyde. They found that lung function measures were significantly lower in employees working in the exposed area more than five years. Both chronic (chronic cough and excess phlegm) and acute (eye, nose, and throat irritation) symptoms were reported by those exposed at the time of the study. Other substances to which these workers were exposed included phenol and acrylic fiber breakdown products. Of the two formaldehyde concentrations reported (0.4-0.8 and 9.14 ppm) the authors felt the former to be more representative of usual exposure conditions.

Recently, investigations of effects due to formaldehyde released from urea-formaldehyde foam insulation have been conducted in the state of Wisconsin by Mary Ann Woodbury and Dr. Carl Zenz on behalf of the Wisconsin Division of Health (1978) and in the state of Washington by Prof. Peter Breysee from the University of Washington (NRC, 1980). Both studies are limited to investigations of complaints filed and are thus not generalizable epidemiological studies. They do, however, add a relevant dimension to information provided by occupational studies. Prof. Breysee studied primarily mobile homes. He reports the expected symptoms of eye, nose, and throat irritation in addition to indications of central nervous system effects in the form of headaches and drowsiness. Formaldehyde concentrations in the homes of 80% of the complaining individuals were reported by Prof. Breysee to be below 0.5 ppm. Some symptoms were reported in homes with concentrations below 0.1 ppm. His results indicate that young children may be a sensitive population. Breysee acknowledges that there is more than one possible explanation for the occurrence of these symptoms, but the symptoms moderated while the individuals were away from home and recurred in the presence of urea-formaldehyde foam insulation. The Wisconsin study was similar to that in Washington and the results corroborate those of Breysee. Mary Ann Woodbury and Dr. Carl Zenz did, however, address many confounding factors not considered in Breysee's work (NRC, 1980). The individual's physician was contacted and medical and hospital records consulted. Exposure to carbon monoxide, hydrogen sulfide, oxides of sulfur, dust, and infectious agents were considered as were smoking habits. Formaldehyde concentrations were measured in each home. Readings ranged from 0.02-4.8 ppm. Some homes contained only particleboard, some only urea-formaldehyde foam insulation, and one home contained both.

Several investigators have exposed animals to formaldehyde by inhalation for extended periods. Dubreiul et al. (as reported in NRC, 1980) exposed groups of 25 rats to 0.6, 4.6, or 8 ppm of formaldehyde continuously for up to three months. At the lowest concentration, the only effect observed was a yellowing of the fur. The other groups showed, in addition, decreased weight gain along with eye and upper respiratory tract irritation. Several species exposed to 3.8 ppm continuously for 90 days showed interstitial inflammation in the lungs (Coon et al., 1970). Fel'dman and Bonashevskaya (as reported in NRC, 1980) reported a significant decrease in cholinesterase activity and a proliferation of lymphocytes and histiocytes in rats exposed to 2.4 ppm continuously for three months. The cell proliferation was also observed at a concentration of 0.82 ppm. Exposure to 0.0098 and 0.028 ppm yielded no significant findings.

The mutagenicity of formaldehyde has been studied in a variety of organisms. It has been shown that formaldehyde is mutagenic in many species of micro-organisms and some insects. There is not sufficient information to determine the mutagenic potential of formaldehyde in germinal plant and mammalian cells.

Several animal feeding experiments have yielded negative results in terms of potential teratogenic (reproductive) effects in rats and dogs (Guseva as reported in NRC, 1980; Hurni and Ohder, 1973; Sheveleva as reported in NRC, 1980; and Natvig et al., 1971). Work by Gofmekler (reported in NRC, 1980) resulted in differences in the offspring of female rats exposed to 0.8 and 0.01 ppm formaldehyde 10-15 days before and 6-10 days after being placed with male rats. Body weights of offspring of exposed rats were slightly greater than those of control offspring. However, liver and lung weights are less in the exposed groups. Cellular differences were observed only between the controls and those exposed to the higher concentration.

Two studies discussed in NRC (1980), one involving mice and one hamsters, reported early structural changes in respiratory tissue but no tumors. Horton et al. (1963) exposed mice to 83 ppm or 41.5 ppm for one hour per day, three days per week for 35 weeks. They exposed another group to 125 ppm in the same pattern for an additional 29 weeks. Hamsters were exposed to 10 or 50 ppm for five hours per day, five days per week for their lifespan (18 months). Chemical Institute of Toxicology is currently sponsoring lifetime inhalation of mice exposed to 0, 2, 6, and 15 ppm formaldehyde for six hours per day, five days per week. Interim reports provide evidence suggesting that formaldehyde may be an experimental carcinogen. The significance of these preliminary findings cannot be assessed until enough data is collected to perform statistically valid analyses.

The studies described among others have led to the establishment by NIOSH of an occupational exposure standard of a 30-minute duration ceiling value of 1 ppm (1.2 mg/m^3) formaldehyde in air (NIOSH, 1976). Medical surveillance and maintenance of medical records of employees exposed to concentrations greater than 0.5 ppm (0.6 mg/m^3) is also recommended. The American Conference of Governmental Industrial Hygienists (1979) has adopted a time-weighted average for occupational exposure for a 40-hour work week of 2 ppm (3 mg/m^3).

B.5.4 Nitrogen dioxide

The effects of nitrogen dioxide are primarily irritation of eyes and mucous membranes, as well as mechanical and pathological changes in the lungs that lead to increased susceptibility to acute respiratory disease and possibly chronic respiratory disease. There is a plethora of information concerning the health effects of exposure to atmospheric nitrogen dioxide. Discussed below are data on human volunteer laboratory studies, epidemiological studies, and animal laboratory studies. Dose-response data are provided where available.

Human volunteer studies have established an odor threshold of 0.23 mg/m^3 nitrogen dioxide (Henschler et al. as reported in NRC, 1977; Shalamberidze, 1967). The ability of the eye to adapt to dark is altered upon exposure to 0.14-0.50 mg/m^3 (Shalamberidze, 1967). These effects are considered physiological rather than pathological; they are immediately reversible upon removal of exposure. Short-term exposure of human volunteers to nitrogen dioxide has also resulted in various changes in pulmonary function. Although such changes are also reversible they do indicate that adverse changes have been induced. Such changes are of special importance to subgroups such as the elderly and individuals with chronic respiratory or debilitating diseases. Increased airway resistance was demonstated in healthy subjects ten minutes after terminating a 10-minute exposure to 1.3-3.8 mg/m^3 nitrogen dioxide levels in air (Suzuki and Ishikawa as reported in NRC, 1977). A similar effect was noted in subjects at rest 45 minutes after exposure to 5.6 mg/m^3. Subjects with chronic respiratory disease exhibited changes after exposure to 3.8 mg/m^3 while resting and while exercising during exposure to 2.82 mg/m^3 (Rokaw et al. as reported in NRC, 1977).

Epidemiological studies examining adverse health effects due to nitrogen dioxide have considered changes in lung function, incidence of acute respiratory disease, and exacerbation of chronic respiratory disease. Although these studies focus on the concentration of nitrogen dioxide, other pollutants were present in the ambient atmospheres measured which could have produced similar effects.

Four epidemiological studies considered effects of ambient nitrogen dioxide on lung function. A study of two groups of railroad workers in Japan exposed to 0.3-1.13 and 0.34-3.00 mg/m^3 nitrogen dioxide, respectively, showed significant changes compared with unexposed workers (Yamazaki et al., 1969; NRC, 1977). School children in Chattanooga, Tennessee, exposed to average nitrogen dioxide concentrations of 0.15-0.28 mg/m^3 exhibited borderline changes (Shy et al., 1970a,b). No difference in lung function was demonstrated between inner-city Boston policemen and those working in the suburbs who were exposed to 0.10 and 0.08 mg/m^3 nitrogen dioxide, respectively (Speizer and Ferris, 1973a,b). Likewise, no differences in lung function were exhibited between Seventh-day Adventists in Los Angeles and San Diego exposed to average NO_2 concentrations of 0.096 and 0.043 mg/m^3, respectively (Cohen et al., 1972).

Numerous epidemiological studies have been conducted which considered the relationship between incidence of acute respiratory disease and exposure to nitrogen dioxide (Petr and Schmidt, 1966; Giguz, 1968;

Polyak, 1970; Pearlman et al., 1971; Shy et al., 1970b). Although the presence of multiple pollutants in the exposure atmosphere make it difficult to quantify such a relationship, there is strong support for a possible association. Levels as low as 0.10 mg/m^3 have been implicated (Giguz, 1968). A recent study in England concludes that differences in incidence of (acute) respiratory disease in children living in homes in which natural gas was used for cooking as compared to children living in homes in which electricity was used for cooking were due to nitrogen dioxide exposure from use of gas ranges (Melia et al., 1977). Speizer et al. (1979) have reached similar conclusions in the preliminary analysis of their study involving six cities in the United States.

Association between atmospheric exposure to nitrogen dioxide and increased prevalence of chronic respiratory disease has not been so well established (Burgess et al., 1973; Chapman et al., 1973; Cohen et al., 1972; Speizer and Ferris, 1973a,b). Again, problems of multiple exposure make any association between a single pollutant and a given effect extremely hard to quantify.

The primary contribution of laboratory animal studies is strong evidence supporting increased susceptibility of individuals to bacterial and viral infections due to exposure to nitrogen dioxide. Much work has been done toward elucidating the mechanism of this pathological response (NRC, 1977).

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APPENDIX C

COMMENTS SUBMITTED ON THE CACS PROGRAM (DOE/EIS-0050-DS) AND DOE RESPONSES

APPENDIX C

COMMENTS SUBMITTED ON THE CACS PROGRAM (DOE/EIS-0050-DS) AND DOE RESPONSES

The Environmental Impact Statement Final Supplement (EIS-FS) for the Commercial and Apartment Conservation Service (CACS) was filed with the Environmental Protection Agency on ___________, and a notice of its availability published in the Federal Register on ___________. Copies of this document were sent to federal and state agencies, as well as other interested parties which commented on the EIS Draft Supplement (Report DOE/EIS-0050-DS). All comments received on the EIS-DS have been considered and are addressed herein. Comments indicated a need to update discussions on indoor air quality issues.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 23 1981

OFFICE OF
THE ADMINISTRATOR

Ms. Carol Snipes
Office of Conservation and
Solar Energy
Department of Energy
Room 1F-085
1000 Independence Avenue, S.W.
Washington, D. C. 20585

Dear Ms. Snipes:

In accordance with Section 309 of the Clean Air Act, the U.S. Environmental Protection Agency (EPA) has reviewed the Department of Energy's (DOE) proposed rulemaking and draft Environmental Impact Statement (EIS) regarding expansion of the Residential Conservation Service Program to Multifamily and Commercial Buildings (Docket No. CAS-RM-80-125). Presented below are EPA's general comments on the proposed rulemaking and EIS; detailed comments are provided in the enclosure.

EPA strongly supports energy conservation, both as a means for reducing our dependence on foreign oil and avoiding the environmental and economic costs of increasing production. But EPA is also concerned about the adverse impacts, particularly the potential health effects, associated with certain energy conservation measures. EPA has notified DOE of these concerns in connection with earlier rulemakings, and we intend to continue to work closely with DOE in resolving them.

We support DOE's efforts to promote the understanding of indoor air pollution. Additionally, EPA is designing research programs to determine: 1) current exposures to indoor pollutants, 2) effects of building energy conservation programs on exposure levels, 3) health effects and levels of risk of those exposures, 4) technical measures that will effectively reduce exposures, and 5) other Federal actions which might be required to protect human health.

EPA's main concerns are discussed in the enclosure. The EIS should document DOE's careful consideration of special air pollutants, especially tobacco smoke and radon. We believe that the proposed rule should be more specific about the information which should be provided to building managers and occupants. It should incorporate a discussion of indoor air quality into the proposed Tenant's Energy Conservation Information Package.

The same general approach for addressing potential indoor air quality problems now being discussed with DOE in relation to single-family residential buildings should be extended to apply to multi-family and commercial buildings as well. Here, appropriate allowances should be made for differences in physical structures, expected exposure to specific pollutants, and other factors which may influence indoor air quality.

Based on our review of the draft EIS, EPA has reservations concerning the impacts of the proposal and needs additional information concerning these impacts. The EIS has consequently been rated "ER-2". EPA intends to work closely with DOE to resolve the environmental issues associated with the program. If you have any questions concerning EPA's comments please contact Thomas Pierce of this office at 755-0780.

Sincerely yours,

William N. Hedeman, Jr.
Director
Office of Federal Activities

Enclosure

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)
COMMENTS ON DOE'S PROPOSED RULE
AND DRAFT ENVIRONMENTAL IMPACT STATEMENT
ON
EXPANDING THE RCS PROGRAM
TO
MULTIFAMILY AND COMMERCIAL BUILDINGS
DOCKET NUMBER: CAS-RM-80-125

EPA recommends that the following comments be incorporated into the final EIS and be addressed in the final rulemaking:

I. Mitigation Measures

In section 4.2.1.3, of the EIS, it is stated that "A likely action of a building owner seeking to reduce energy consumption may be reducing the flow of intentionally added outdoor air (i.e., make-up air)." Following this, figures 4-1 through 4-3 give the concentration of ozone, radon, and formaldehyde as a function of air change rate. DOE concludes in its impact summary (Section 4.2.1.5) that it does not believe that the health effects due to changes in indoor air quality will constitute a major problem, particularly if mitigative steps which it mentions under Section 4.2.1.4 are utilized. These measures include filtration, proper use of mechanical ventilation systems, and periodic airing out of residences or small commercial buildings. These and other measures have been available under the old, higher ventilation and infiltration rates specified by ASHRAE 62-73, under which existing homes and offices were built. And yet, State and local health authorities are being called upon with increasing frequency to investigate "sick buildings" in which a high percentage of the occupants report the symptoms of indoor air pollution exposure; many of these buildings were modern, tight, energy-efficient office buildings (Kreiss, 1980).

Unfortunately, the specific applicability of many indoor air quality mitigation measures has not been fully explored. Research in this area is continuing. Meanwhile, DOE should make a strong commitment to:

(i) Assure that the people who will manage and and use these buildings are aware of potential pollution sources and health risks posed by building retro-fits;

(ii) Encourage those designing such retro-fits to include mitigation measures where the pollution source presents a significant health risk

On page 4-24 of the EIS Draft Supplement, DOE expresses its intent to "publicize and encourage" the use of mitigation measures. This could best be achieved, at least for tenants

DOE concurs that there is cause for concern about the increasing incidence of reports of building-related illness. (See Section 4.2.1 subheading Building Associated Epidemics for discussion.) Ongoing research programs by CPSC, DOE, and the Center for Disease Control are yielding increasing knowledge of the factors contributing to this problem. DOE feels that as results from these programs become available, they should be evaluated and appropriate changes made in ongoing building energy conservation programs.

Under mitigation measures, it was pointed out that the use of air-to-air heat exchangers is a possible mitigation measure to be considered.

DOE also agrees that owners of buildings with central HVAC systems should be encouraged to investigate the feasibility of installing a heat recovering system in the HVAC system. This is described as a possible mitigating measure in Section 4.2.1 subheading Mitigation Measures.

II. Heating, Ventilation, Air Conditioning

The summary also indicated that some energy conservation measures will have the effect of reducing the amount of the outside makeup air which is introduced intentionally into the building by the HVAC control system.

DOE concurs that some energy conservation measures will result in reduced amounts of outside makeup air in some buildings. In principle, reduced makeup air is a particular example of reduced air exchange, a subject which is discussed at some length in Section 4.2.1 subheading Changes in Air Exchange.

III. Pollutants of Concern

The summary sheet indicated that the list of pollutants should include airborne biohazards (in lieu of bacteria) and particles, especially those from the combustion of cigarettes.

DOE agrees. A discussion on biohazards may be found in Appendix B, Section B.3.1. A discussion on smoking cigarettes is provided in Section 4.2.1 subheading Combustion Products.

that "under the practical range of ventilation conditions and building occupation densities, the RSP levels generated by smokers overwhelm the effects of ventilation and inflict significant air pollution burdens on the public."

Moreover, the very serious public health problems associated with passive smoking are exacerbated by lowered infiltration and ventilation rates (as shown in figure 1, "The Effect of Cigarette Smoking on Office Air Quality at an Occupancy of 10 persons per 1000 sq. ft."). This figure shows that at an effective air exchange rate of 0.4 ach (Table 3-3, DOE's EIS) an office worker would inhale the equivalent of more than 7 low-tar cigarettes (Carleton 70) from the air during an 8 hour shift in an office with an occupancy specified in Table 3-3. It is to be expected that airborne pathogens will also follow such a curve. If the average airchange rate is of the order of one airchange per hour as DOE states, figure 1 shows that decreases in this rate will produce inversely proportional increases in the cigarette equivalents inhaled. Such increases are unacceptable from a public health standpoint.

See comment above.

IV. Radon

In Section 3 of the EIS, more complete data on outdoor radon levels should be cited. (See for example H.H. Harley article in proceedings of an ERDA conference on noble gases: Harley, J.H. "Environmental Radon" Proceedings of Noble Gases Symposium (R.E. Stanley and A.A. Moghissi, eds.) Las Vegas, Nevada ERDA CONF 730915 also to be published by Gessell, T. at U. Texas School of Public Health, Houston).

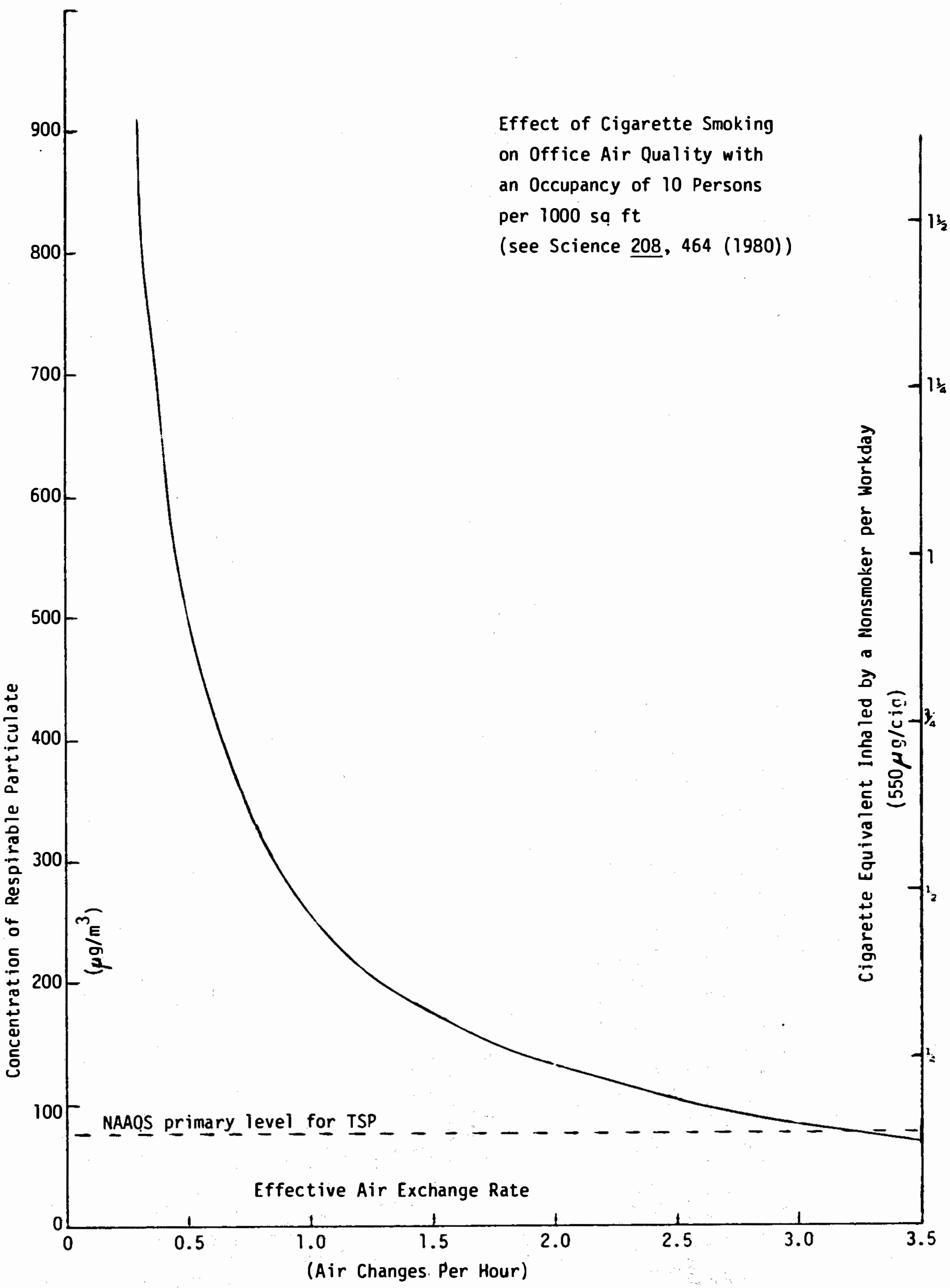
In accordance with CEQ regulations, the EIS-FS refers interested readers to other more detailed reports such as those noted in Section 4.2.1 subheading Radon and Appendix B.

- Data on Indoor levels should be summarized in the EIS. Particular attention should be focused on situations where radon levels are high. (See for example the Radiation Policy Council Report of the Task Force on Radon in Structures, August 1980).

Doe agrees and has attempted to do so in Section 3.3.2.

- Measures to control radon levels should be discussed in greater detail in the EIS. Such information, if given along with conservation advice, could play an important part in minimizing the adverse health impacts of decreased ventilation. (See: EPA 520/4-78-013 "Indoor Radiation Exposure Due to Radium-226 on Florida Phosphate Lands"; and EPA 520/5-77-011 "The Effects of Home Ventilation Systems on Indoor Radon - Radon Daughter Levels." EPA is conducting more extensive research on the effectiveness of air circulation in removing radon decay products and is also investigating measures to prevent radon-rich soil gas from penetrating indoors through cracks in the house foundation.

Such measures are identified among the mitigating measures described in Section 4.2.1 subheading Mitigation Measures.


Effect of Cigarette Smoking
on Office Air Quality with
an Occupancy of 10 Persons
per 1000 sq ft
(see Science 208, 464 (1980))
Concentration of Respirable Particulate
(μg/m3)
0
100
200
300
400
500
600
700
800
900
NAAQS primary level for TSP
Effective Air Exchange Rate
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
(Air Changes Per Hour)
Cigarette Equivalent Inhaled by a Nonsmoker per Workday
(550μg/cig)
1½
1¼
1
¾
½
¼

• The text of the EIS implies that Fig 4-2 represents a worst case situation. Examination of data published in the literature would show that this is a rather typical case. To develop a worst case scenario, DOE should review data on levels associated with Butte, MT; phosphate landa in Florida; radon-rich well water in Maine; or uranium mill tailings use in Grand Junction, CO. (Radiation Policy Council Report cited above; also EPA 520/4-78-013 cited above; and Hess, C.T. et al, "Radon-222 in Potable Water Supplies in Maine" Land and Water Resources Center, University of Maine, Orono).

DOE believes that the situation depicted is a reasonable worst case situation which the authors characterized as "worse than expected". DOE feels that the risk due to radon exposure has been adequately described in Section 4.2.1 subheading Radon.

• EPA's Florida Guidance is misapplied on pg 4-17 of the EIS. The guidance was developed to address a specific problem of high radon exposure in houses built on phosphate lands. Although the guidance suggests that it may not be practical to reduce the radon levels of these high radon houses to levels lower than 0.005 WL above background, it does not imply that raising the radon levels nationally in all houses by 0.005 WL above background should be taken lightly or is without consequence. Any health effects assessment of this level would show a potential impact too large to be ignored.

DOE agrees that the guidance was not stated properly and has corrected it in Section 4.2.1 subheading Radon. However, DOE also believes that the CACS measures will have effects not nearly so large. Many retrofit conservation measures have very little effect on air exchange. Owners of buildings with higher initial air exchange rates will be more economically motivated to retrofit. All these factors will tend to reduce effective changes in average radon progeny levels.

• Regarding the discussion on 4-17 of the EIS on solar rock bed storage, we recommend that DOE's Environmental Measurements Laboratory (EML) be contacted for their experimental findings. Results given at a 1980 workshop at EML showed much higher radon levels than modeled by Rogozen. Also contact Hess at U. Maine for data he has collected on solar houses with granite rock heat storage.

This solar measure is not covered in the program. It is believed the potential for its existence in CACS-covered buildings is so unlikely that there is no need to include solar rock bed thermal storage systems in air analysis.

• Pg C-21: For a more complete review of radon and lung cancer, the following should be consulted:

(1) F.E. Lundin Jr. et. al., Joint Monograph #1, NIOSH-NIEHS, 1971

(2) W.C. Hueper

(a) Occupational Tumors and Allied Diseases C.C. Thomas, Pub, 1942 and

(b) Occupational and Environmental Cancers of the Respiratory Systems, Springer-Verlag, 1966

In accordance with CEQ regulations, the EIS-FS refers interested readers to other more detailed reports. This has been done in Section 4.2.1 subheading Radon and Appendix B Section B.5.2.

• Pg. C-21 & C-22: Morken's studies may not have shown lung cancer because the animals were sacrificed according to experimental protocol before the end of the latent period as suggested by studies at Battelle NWL and France. This discussion should incorporate the results of those studies. For studies on lung cancer in laboratory animals exposed to radon:

(1) W. Bueck, Zierschr, F. Krehsforsch 49: 312, 1939.

(2) B. Rajevsky et. al. Naturwiss. 31: 170, 1943.

(3) F. Unnewehr, Strahlen theropie 108: 421, 1959.

(4) F.T. Cross et. al. PNL-2744, BPNL, 1979; and

(5) Extensive reports of J. Lafuma, R. Masse, J. Chareaud, R. Perraud, J. Chretien and co-workers in France from 1968 through 1980

See last comment.

• Pg. C-22 & C-23: We recommend that more of the randon dosimetry literature be considered. The authors might consult the following sources of references:

(1) C.F. Boloway et. al, Bibliography on the Dosimetry and Radon Daughters ORNL-5284, 1978; and

(2) Proceedings of OEC radon specialist meetings in 1976, 78 and 80.

See laat comment.

• Pg. C-23: Risk estimates are not all derived from high exposure extrapolation. In Canadian and Swedish studies, the lowest reported exposure group, 15 CWLM, has an elevated lung cancer death rate. While the point is not statistically significant it is on the linear extrapolation line through the higher, statistically significant points.

An average of 15 CWLM could be attained during a lifetime of exposure to about 0.01 WL. The statistically significant points on the dose-response curve are a factor no more than 8 higher than 15 CWLM, so extrapolation from these points does not cross a wide range. In addition, linear extrapolation of high LET dose-response curves is not considered conservative and may underestimate the risk (BEIR III).

We recommend that the dose-response studies in the following reports be evaluated to determine whether the low-dose end of the curve is represented:

(1) Cancer/Workshop on Lung Cancer Epidimology and Industrial Applications of Sputum Cytology, Colorado School of Mines, 1979; and

In this report, low exposure is that exposure where exposure-induced health effects occur only marginally more frequently than among unexposed populations. Marginal differences in frequency cannot be statistically reliably observed in finite population studies. For this reason, DOE believes that all risk estimates derive from high exposures. (See Appendix B, Section B.5.2 for further discussion.)

(2) Proceedings of the Park City Environmental Health Conference.

• The statement, on pg C-23 that differences in occupational atmosphere and residential environment "weaken the strength" of dose-response extrapolations must be supported with scientific findings, not speculation. Differences, in mine, residential, and environmental atmospheres were not supported by studies of Jacobi et. al., Beitr. Phys. Atmosphere, 31: 244, 1959.

• Regarding statements on pg C-24, some risk estimates fold in age specific and activity related differences in respiration and expected radon daughter deposition (e.g. EPA 520/4-78-013, 1979; W. Hofmannand, F. Steinhausler, pg-497 in Proceedings of the 4th IRPA Congress, Paris, 1977).

V. Ventilation Rates

In Chapter 3, Section 3.2.2 of the EIS, it is stated that it is generally accepted that the typical air change rate in the average residential office building is about one air change per hour. A discussion follows of the voluntary ventilation standards promulated by the American Society of Heathing, Refrigerating, and Air Conditioning Engineers (ASHRAE) and by the Building Officials and Code Administrators International, Inc. (BOCAI). There are several problems attendant to the EIS's apparent reliance on these voluntary standards for guidance on ventilation:

1. Neither of these standards adequately considers the potential of unsatisfactory indoor air quality, nor do they address methods of alleviating problems when they occur.

2. The EIS discussion of ASHRAE's recommended ventilation standards states that they are protective of human health, but the EIS apparently is referring to ASHRAE Standard 62-73 which has been superseded by ASHRAE Standard 62-73R, Standards for Ventilation Required for Minimum Acceptable Indoor Air Quality. EPA has commented on the latter standard that "with the advent of the proposed standard, individuals may be exposed to excessive levels of radon and its daughter products, tobacco smoke particulates, and formaldehyde" (Hawkins, 1980).

3. The EIS discussion of the BOCAI model building code states on page 3-9 that "one hundred percent recirculation is permitted if the system services only a single family unit." Such an approach

DOE has conservatively attributed all observed lung cancers in uranium miner groups to radon progeny exposure. While the cited study failed to find atmospheric differences, it seems very likely that some carcinogenic substances, such as diesel exhaust emissions, are found in mines, but not in homes or offices. Therefore, the lung cancer risk estimator for radon progeny derived in this way is larger due to additional cases due to exposure to other carcinogens. However, this is true only for occupational groups. (See Appendix B, Section B.5.2 for further discussion.)

DOE believes there are insufficient data to adequately characterize the American population with respect to radon progeny exposure, concurrently with age and physical activity. Hence, such risk estimation procedures have not been introduced (see Appendix B, Section B.5.2).

is incompatible with the maintenance of acceptable air quality within multi-family and commercial buildings with considerably lower infiltration rates, especially where windows are sealed.

EPA recommends therefore, that the EIS discussion of ventilation rates be revised and updated so that the reader will understand the inadequacy of voluntary standards with respect to indoor air quality maintenance. The major concern is that volumetric air change rates per person are not an acceptable surrogate for a direct approach to maintaining indoor air quality. In many circumstances the volumetric approach will fall far short of what is required.

Voluntary standards have contributed to ensuring adequate indoor air quality. In addition, these voluntary standards often influence provisions in model building codes. DOE believes that involuntary standards may prove unduly burdensome and should not be encouraged without definitive data which shows the voluntary approach is not working.

REFERENCES

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Hawkins, D., Letter from D.G. Hawkins, Asst. Administrator, Air, Noise, & Radiation, USEPA, to C.T. Zegers, Manager, Standards, ASHRAE, June 30, 1980.

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Repace, J. & Lowrey, A., "Indoor Air Pollution, Tobacco Smoke, and Public Health" Science 208:464 (1980).

Tager, I., et al., "Effect of parental cigarette smoking on Pulmonary Function of Children", Am. J. Epidemiol. 110:15 (1979).

Kreiss, K., "A Summary of the C.D.C. April 11, 1980 Building Conference", Special Studies Branch, Center for Disease Control Chronic Diseases Division, Atlanta, GA 30333.

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U.S. DEPARTMENT OF ENERGY
COMMERCIAL AND APARTMENT CONSERVATION SERVICE PROGRAM
DOCKET NO. CAS-RM-80-125
COMMENTS ON
PROPOSED RULE
46 FR 4482
JANUARY 16, 1981

In addition to the comments below, comments pertinent to the proposed rule are attached on the Draft Supplement to the Environmental Impact Statement (Pages EIS-1 to 6) and on the Draft Regulatory Analysis (Pages RA-1 to RA-8). Following these comments are additional comments on the Preamble to the proposed rule, many of which relate to more than one Section of the proposed rule.

Section 456.105

In the definition for residential building the term central (heating or cooling) system is used without having a definition for central. A definition is required to avoid confusion regarding what is meant by the term central system. Some people feel that the type of air conditioning equipment ordinarily used in a single family house to condition all rooms is a central system. It can be considered as such to the extent that it serves the entire dwelling unit with a single unit. However, it is possible to use the identical type of equipment for each dwelling unit in a multifamily building, in which case there may be some confusion, since some people will consider that a central system. In order to avoid confusion a central system should be defined as a heating or cooling system that serves more than one dwelling unit.

Section 456.320

The option proposed by DOE is beyond not only the legislative intent of Congress, but also beyond the Law. The Law and legislative history are clear in that Congress intends that multifamily buildings containing 5 or more dwelling units which are either centrally heated or centrally cooled shall be covered under the CACS Program in Title VII. The Law and legislative history are equally clear in mandating that multifamily residential buildings containing 5 or more dwelling units not having a central heating or central cooling system, or both, shall be included in the RCS Program.

Since eligible customers are defined as those who receive a fuel bill from a covered utility, it is clear that even though an eligible customer may occupy an apartment in a building having 5 or more dwelling units, the customer is only eligible for the RCS

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DOCKET NO. CAS-RM-80-125
COMMENTS ON
ENVIRONMENTAL IMPACT STATEMENT
DRAFT SUPPLEMENT
DOE/EIS-0050-DS
DECEMBER 1980

Summary

Page S-2 indicates that the CACS Program involves "the provision of low-cost energy audits . ." Reference to Public Law 96-294 does not indicate any requirement that the energy audits be low-cost.

"low cost" has been deleted.

On page S-3 it is indicated that DOE proposes that individually heated and cooling multifamily dwellings be offered the option of being either under RCS or CACS. Reference to Section 710(b)(3) of Public Law 96-294 indicates that the multifamily dwellings covered by CACS are only those having central heating or central cooling, not individually heating and cooling systems. Therefore the option proposed by DOE is in violation of the Law.

Individually heated and cooled multifamily dwellings are covered by RCS. Centrally heated and cooled multifamily dwellings (five or more units) are covered by CACS.

On page S-5 it is indicated that wood burning devices have not been included as a measure under the CACS Program. Reference to Section 710(b)(5)(J) of Public Law 96-294 indicates that a solar energy system is defined in Section 504(8) of Public Law 96-294 which says that a solar energy system means "energy produced by a wood burning appliance". Therefore the exclusion of wood burning devices by DOE is in violation of the Law. Reference to 458.403 (b)(2)(xvii)(F) of the proposed rule indicates that wood burning devices must be evaluated in commercial energy audits, thus contradicting and overriding the statement on page S-5. Therefore, it is imperative that the environmental impact of wood burning devices be evaluated.

This option was deleted in the final rule. Section 504(8) includes wood stoves in the CACS Program only if they are "in conformity with ... criteria and standards ... prescribed by the board." At this time , the board of directors of the Solar Bank has not issued criteria and standards for wood stoves.Therefore, they are not included in the CACS Program. They are addressed generally, however, under combustion products (see Section 4.2.1 subheading Combustion Products.

Inclusion of wood burning devices will have a dramatic and substantial environmental impact which must be addressed.

See above comment.

These environmental impacts will be not only on ambient and indoor air quality, but also on the fire and safety aspects of these devices and the associated loss and personal injury. For example, the most recent renewal form for my own homeowners insurance policy asked if there is a wood burning stove present. Certainly the reason for this question was not so that I could get a reduction in my exposure or premium.

On page S-6 it is indicated that DOE estimates that one-half of one percent of the eligible buildings will be retrofitted each year between 1982 and 1990. Such an assumption is totally without merit and does not reflect the high degree of activity in the marketplace for energy improvements in covered buildings. DOE has obviously failed to consider the substantial economic motivation that building owners have due to the price of energy alone and the substantial advertising and marketing programs of contractors and manufacturers. It is likely that the penetration and success rate for free enterprise, profitmaking business is going to be far greater than it is with utilities, especially in view of the limited publicity and information requirements imposed on utilities and the general public distrust of utility and Government programs.

DOE considered trends in the installation of CACS-like measures in multifamily residential and small commercial buildings, other programs, incentives, and disincentives to investment in energy conservation, and the availability of information, materials, services, etc., needed to implement a measure, to arrive at the "no-action" adoption rate. The estimated rate was consistent with information made available from 28 utilities and state energy offices as part of the CACS Regulatory Impact Analysis.

Not considered in the Environmental Impact Statement is the increased likelihood of the incidences of accidental hypothermia, which can be brought about by the use of program measures such as automatic energy control systems, load management devices and clock thermostats. These devices are likely to result in lower space temperatures being maintained, especially in multifamily senior citizens housing, with the result that those persons subject to hypothermia may suffer an increased incidence.

The likelihood of hypothermia resulting from installation of automatic energy control systems and load management devices is extremely improbable.

On page S-8 it is indicated that the RCS Program identified five areas of potentially adverse on-site health and safety impacts, yet no discussion is included on how they are to be mitigated. In the RCS Program there are installation and material standards as well as inspections required, yet there are no such provisions in CACS, nor are any such provisions proposed in CACS. Therefore, it is quite likely that there will be adverse health and safety impacts under CACS for:

Wall Insulation
Flue Opening Modifications
Electric and Mechanical Ignition Systems
Small Wind Energy Conversion Systems

DOE does not believe that wall insulation will be an issue of concern because most CACS-covered buildings are of a type that is not conducive to retrofit operations and therefore the implementation rate will be low. Mechanical ignition systems and wind energy conversion systems have been deleted from the list of CACS conservation measures and are therefore non-issues. DOE does not feel that lack of inspections of vent dampers and intermittent ignition devices will significantly increase adverse health or safety impacts.

In Table S-1 on page S-9 it is indicated that the likely adoption rate for automatic energy control systems and equipment in commercial buildings is moderately low. Such an assumption is unwarranted, especially in view of the fact that the vast majority of commercial buildings are not occupied around the clock and would thus benefit the most from automatic energy control systems and equipment.

We concur and have changed the table accordingly.

The conclusion that furnace modifications will have negligible on-site impact in Table S-1 on page S-10 is challenged, especially in view of the fact that no installation standards, material standards or inspection will be provided. If indeed the impact of furnace modifications without standards or inspection is negligible, why then are standards and inspection required in the RCS Program?

No arrangements for purchase, financing, etc. is provided in the CACS Program so standards are believed unnecessary. Also, installation standards, materials standards, and post installation inspections have been removed from the RCS Program because it was concluded that they were unnecessary. The same is true for CACS.

The discussion on pages S-12 and S-13 indicates that there are many unknowns associated with indoor air pollution and that substantial research is still required. Yet, the proposed rulemaking proceeds as if all the questions were answered and all the research were done and it was concluded that there are no adverse environmental impacts. If indeed that is the case, then it is useless to do the research and answer the questions. Until such time as the answers are known with some certainty, any rulemaking by DOE which knowingly has an adverse impact on indoor air quality should be suspended or terminated.

Doe feels that there exists a reasonable large body of scientific data which describes the most important factors contributing to indoor air quality. While there is a need for further work in this area, there is sufficient information to allow implementation of building energy conservation programs. To fail to do so is to forego a substantial opportunity to reduce the rate of consumption of scarce fossil fuels (see Section 4.2.1 for selected summaries and Appendix B).

On page S-13 DOE examines only the adverse health and safety impacts related to insulation when not properly manufactured, installed and utilized. There are numerous other potential adverse safety and health impacts associated with the improper installation and utilization of the other CACS Program measures, especially in view of the fact that there are no material and installation standards and no inspection provided.

All of the foregoing measures have been sufficiently described with respect to their health and safety impacts in Section 3.2.2.1 of the RCS EIS (DOE/EIS-0050, November 1979).

On page S-14 it is indicated that the CACS Program should reduce the incidence of health and safety impacts from heating systems, yet there are no requirements in the CACS Program for examining the health and safety related features of heating systems. Only the energy related features are of concern in CACS.

DOE believes that there may be instances where knowledgeable individuals while making a CACS audit may notice and help correct hazardous situations. This may occur regardless of the purpose of the visit of the knowledgeable individual(s).

On page S-14 it should be noted that there are no ASHRAE Standards concerned with overheating of furnace combustion chambers.

No comment.

Also on page S-14 it should be noted that there are no ASHRAE Standards for vent dampers.

No comment.

On page S-15 no consideration is given to noxious or corrosive fluid leakage from liquid type solar systems or the accumulation of stagnant water, dirt, mold and mildew in air type solar systems and the consequential impact on health and safety.

Health and safety issues (including noxious fluids) pertinent to solar hot water heaters are described in Section 4.2.3.

Moreover, there are no requirements to protect building occupants from structural failure, collector glass breakage and glare from solar collectors. There are no standards requiring "careful" location and installation of collectors. There are no safety standards for the installation of these devices that will prevent injuries during the installation or maintenance of solar systems.

Active solar systems are not included in CACS.

On page S-15 there are no material or installation standards for wind energy systems in connection with the CACS Program, so there is no way of mitigating the adverse impacts mentioned.

Wind energy conversion systems are not included in CACS.

Moreover, no consideration is given to the potential adverse impacts by virtue of radio and television interference that results from the operation of wind energy systems, as well as consideration of the adverse asthetic impact of these devices.

Wind energy conversion systems are not included in CACS.

On page S-17 a related Government Program not mentioned is the Energy Extension Service which provides similar services to multifamily dwellings and small commercial buildings nationwide.

On page S-21 it is indicated that the Law "refers to owners and tenants of commercial buildings in establishing eligibility for the CACS Program". Nowhere in the Law is anything mentioned about owners and tenants. Section 710(b)(2) of the Law defines "commercial building" by the date of completion, its use, exclusions, and energy consumption. Nothing at all is said about individual tenants or individual stores or individual meters.

DOE concurs that the law refers to buildings.

The intent of the energy use limits is quite clear in the Law. Nothing is said about whether the electricity used should be for lighting or for space conditioning or for any other specific purpose. The Law says 4,000 kilowatt hours of electricity.

DOE agrees.

Therefore, if a strip shopping center (including all of the space contained by all of the walls and roof) uses less than 4,000 kilowatt hours of electricity or 1,000 therms of natural gas or the Btu equivalent thereof of any other fuel is a covered building, provided it meets the other requirements of the definition of a commercial building in the Law.

The energy eligability requirement is that the average monthly use must be less than 4000 kWh and 1000 therms of natural gas (or Btu equivalent of other fuel). A discussion of alternative interpretations of the 4000 kWh and/or 1000 therms is provided in Section 2.1.1.

On page S-23 it indicates that DOE permits the States to include RCS Services in the State Plan for the CACS Program, yet nowhere in Public Law 96-294 is this authorized or permitted. Therefore, by DOE giving this permission to the States, they are in violation of the Law.

Public Law 96-294 does not forbid states from using their own authority to establish conservation programs more extensive than CACS.

On page S-25 time of transfer standards are mentioned as an alternative to CACS. There is no legal authorization for such standards. Therefore they should not even be considered.

This is indicated as one alternative to the CACS Program for achieving the energy saving goals of the CACS Program which could be created by a different statute.

Chapter 1 - Introduction

No Comments

Chapter 2 - An Analysis of Alternatives

Beginning on page 2-2 where the No Action alternative is discussed there is no backup or support for the assumptions made about the rate of program goal achievement without the CACS Program.

See response to first comment on page 2.

No information is given regarding the assumptions made when using the Oak Ridge National Laboratory residential and commercial demand models. Those models are not referenced, nor are they available to the public in published form as they were used in this evaluation, in violation of the Administrative Procedures Act.

The ORNL reports have been added to the list of references (see Section 2.2.1).

In general, the alternatives considered as shown in Table 2-1 on page 2-5 are not allowed under the Law, so that comparisons are meaningless.

The alternative section has been extensively rewritten so that program options are compatable with the law.

Chapter 3 - Description of the Affected Environment

In 3.2.2 reference is made to three publications on air change rates implying that they apply to office buildings and thus to all commercial buildings. Such is not the case. The three references cited deal with electrically heated houses, low income housing,

DOE agrees that there is no conclusive data in the commercial sector to establish an air change rate. However, much of the available data has been reviewed and summarized in this EIS-FS (Tables B-2, B-3, B-4, and B-5). DOE feels that the typical buildings eligible for conservation measures under this program will have air exchange rates that range from 0.5 to 1.5 air changes per hour.

and unknown buildings (because the 1977 reference is not publicly available).

In 3.2.2 reference is made to ASHRAE Ventilation Standards. While no specific surveys have been made to determine the extent to which ASHRAE recommended Ventilation Standards have been implemented, there is no evidence that supports any conclusion that their use is at all widespread.

Any conclusion that the existing stock of commercial buildings conforms with the requirements shown in Table 3-3 is purely speculative. In all likelihood any study would demonstrate that the actual ventilation rates in these buildings and the ventilation rates required by the Codes under which these buildings were built are dramatically less than those shown, and in numerous instances are zero.

Table 3-3 has been deleted.

The BOCA Code and its ventilation requirements are similarly not applicable to large numbers of buildings, especially those covered by CACS.

The BOCA code is cited as an example.

Chapter 4 - Environmental Consequences & Mitigating Measures

In 4.2.1.4 there are substantial energy impacts associated with some of the mitigating measures which will cause increased energy consumption, contrary to the intent of the CACS Program.

Installation of filtering devices will require more fan energy consumption. Using mechanical ventilation systems will require additional heating and/or cooling of the ventilation air. Periodic airing of buildings will cause more heating and/or cooling to be required. Use of vents above gas stoves will cause more exfiltration from buildings, which will require replacing that air with outdoor air which must be heated and/or cooled.

We concur that a portion of the energy savings will be offset by some mitigation devices, but there will be a net savings of energy from the CACS Program.

The Environmental Impact Statement fails to consider the adverse environmental impact of certain CACS Program measures which will increase energy consumption, rather than reduce it. By including load management devices and energy storage devices in the definition of automatic energy control systems, it is likely that higher energy consumption will result. These devices are typically used in connection with off peak electric resistance heating systems, and as such qualify for lower cost electricity on many utility company tariffs. Where a choice exists between installing an electric heat pump and an off peak electric resistance heating system, the eligible customer would be encouraged by the CACS Program to select the off peak electric resistance heating system because the automatic energy controls are a covered measure. If on peak electricity costs more than off peak electricity, the use of off peak electric resistance heating can frequently end up being lower in cost than using a heat pump, thus encouraging more use of electric resistance heating, which in turn will result in substantially higher consumption of electricity with its correspondingly higher source energy consumption as well as greater environmental impact.

Insufficient data exist on choice of program measures adopted resulting from CACS audits to estimate these types of impacts.

Another program measure which has substantial environmental impacts that has not been addressed at all is the inclusion of replacement air conditioning as a program measure. All air conditioners today use chlorofluorocarbon refrigerants which are currently under a great deal of criticism by the Einvornmental Protection Agency, who are considering limiting the production of chlorofluorocarbons in order to mitigate the adverse environmental and health consequences of ozone depletion. In order to achieve higher efficiency, newer air conditioners use more refrigerant, thus aggravating this problem.

DOE recognizes that air conditioners use chlorofluorocarbon refrigerants and that ozone depletion is a global environmental problem. DOE feels, however, that additional ozone depletion effects attributable to the CACS Program will be insignificant. New air conditioners on the average should have less leakage of chlorofluorocarbons than older units.

Appendix D - Inventory Methodology

The methodology for determining the inventory for small commercial buildings is described in broad and general terms, with no specifics given. No published reports are referenced. It is indicated that a proprietary source was used for certain information without referring to what that source is. The inavailability of this information is a violation of the Administrative Procedures Act.

Therefore, it is impossible to determine the validity of the methodology utilized.

The methodology for determining the number of small commercial buildings covered by the CACS Program is now described in Section 3.1.2 and appropriate references are cited. Appendix D has been deleted in the EIS-FS.

Appendix E

In E.2.1.1.2 it is assumed that all small commercial buildings will be capable of utilizing ceiling insulation. Such an assumption is not valid, since a substantial fraction of small commercial buildings have flat roofs, frequently without any ceilings at all, therefore making it impossible to install the types of insulation assumed.

DOE agrees that most small commercial buildings will not install ceiling insulation as a CACS measure, because of the reasons cited. Appendix E has been deleted.

Similarly in E.2.1.2.2, few commercial buildings have walls that allow the use of the types of insulation assumed. Therefore the total amount of insulation determined is not valid.

DOE believes that the wall insulation retrofit rate in small commercial buildings will be very low. Appendix E has been deleted.

General

This Draft fails to consider the scope and coverage of buildings intended by DOE in the proposed rule. The Draft only considers entire buildings and not the tenants within numerous additional larger buildings as DOE indicates on page 4489 of the January 16, 1981 Federal Register in the discussion on "Eligible Customer". This will have the result of greatly expanding the number of eligible customers, the area of buildings covered, and the subsequent environmental impact.

The buildings that are covered in the CACS Program are defined in the rule change (Fed. Reg. 47:53236-58, November 24, 1982). The buildings in the EIS-FS are as described in the rule change.

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November 22, 1982

Office of Conservation and
Renewable Energy
Office of Hearings & Dockets, CE-65
Mail Stop 6D025, Room 5F078
Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20505

Attention: CAS-RM-80-125

Re: Commercial and Apartment Conservation Service Program
Docket No. CAS-RM-80-125

Ed. note: These are the only comments relating specifically to the EIS-DS.

Gentlemen:

Following please find my comments on the above proposed rule.

In the discussion of the environmental impact statement it is incorrectly assumed that the Consumer Products Safety Commission has banned ureaformaldehyde foam insulation for all buildings covered by CACS. Rather, the Consumer Products Safety Commission ban covers only some types of buildings such as housing and schools, so that ureaformaldehyde foam insulation can still be used in most types of commercial buildings covered by CACS. In addition, many existing buildings covered by CACS already have ureaformaldehyde foam insulation, and to the extent that infiltration and/or ventilation are reduced in these buildings, the potential environmental impact can be increased.

DOE has corrected its discussion of UF-foam insulation to indicate that the material has been banned by CPSC from residential applications (see Preface). Although it is still possible to install UF-foam insulation in commercial buildings, DOE believes these installations will be significantly reduced as a result of the residential ban;as indicated in the text, the ban has recently been negated by the courts. (See Section 4.2.1 subheading Changes in Indoor Emissions Due to the Program for discussion.)

The discussion on environmental impact goes on to talk about indoor air quality and further accepts the 1981 ASHRAE Standards as valid guidance. It is presumed that the ASHRAE Standards referred to are those in ASHRAE Standard 62-1981 "Ventilation For Acceptable Indoor Air Quality". It should be noted that this Standard has not been accepted as a national consensus Standard. For the first time in history, this ASHRAE Standard was rejected by the American National Standards Institute (ANSI) within the last several weeks. ASHRAE was offered the opportunity to appeal the disapproval by ANSI and did not choose to do so. Therefore, no reliance can be placed on the ASHRAE Ventilation Standards, especially in a regulatory matter or even in the Preamble.

ASHRAE Standard 62-1981 has been published and distributed by ASHRAE, although ANSI has not yet formally accepted the standard because of procedural delays. DOE is unaware of any substantive technical issues preventing such acceptance. More importantly, however, DOE has not used the standard for regulatory requirements. Rather it has been used to calculate the air exchange rates in Appendix B (see Table B-3).

In the Preamble discussion covering comments on the draft CACS supplement it is indicated that comments were made on the potential hazards with active solar systems. The Preamble states incorrectly that neither of these measures is covered under the CACS Program. Reference to Item VII in Appendix I of the proposed rule indicates that active solar domestic hot water heating systems are an applicable program measure under certain conditions. Therefore it is essential that the environmental impact statement address the potential hazard from active solar systems.

Solar hot water heater hazards are discussed in Section 4.2.3.

San Diego Gas & Electric

January 31, 1983

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S.W. Washington, D. C. 20585

Atten: CAS:RM-8-125

Dear Mr. Friedrichs:

Attached are our written comments on the proposed regulations to implement the Commercial and Apartment Conservation Service (CACS) Program.

We appreciate having the opportunity to submit our comments for your review and request that our concerns be given consideration as the Department of Energy develops the rules regarding the CACS Program.

Our company is in the process of documenting the figures to support our statements on the implementation of conservation measures, and will be forwarded under separate cover.

In the future, please direct any comments or questions to:

Lynn Trexel, Conservation Services, (619) 699-5409.

Thank you.

Sincerely,

Jennifer L. Mitchell
Manager, Conservation Systems Department

JLM:LJT:pc

cc: James Rood
California Public Utilities Commission

Karen Griffin
California Energy Commission

The CACS Supplement to the RCS EIS

"DOE is not currently proposing to require auditors to provide information on indoor air quality. However, DOE specifically solicits comments on whether, and if so, how, such information should be provided to customers."

Comment. This information need not be required since air quality will not be affected enough to notice or to adversely impact air quality.

Because DOE does not believe that the CACS Program will have a significant environmental impact, no requirements to address indoor air quality have been included in the CACS Program. However, states and utilities who believe there is a potential for indoor air quality problems are encouraged to address the issue. DOE has published "find and fix the leaks -- A Guide to Air Infiltration Reduction and Indoor Air Quality Control" (May 1981, DOE/CE-0006) and will make it available in the CACS Program for those who wish to use it.

APPENDIX D

DISTRIBUTION LIST

FOR THE EIS-FS

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Below is a list of agencies, organizations and persons to whom copies of the EIS-FS have been sent.

American Gas Association

American Public Power Association

Colorado Springs Department of Public Utilities

Council on Environmental Quality

Edison Electric Institute

Environmental Protection Agency

Lawrence G. Spielvogel, Inc.

Louisiana Power and Light

San Diego Gas and Electric

Sutherland, Asbill and Brennan