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Energy Conservation and Noise Control in Urban Residences: Demonstration Program Plan

David N. Keast and Donna D. Berman

September 1979

Prepared for:
Environmental Protection Agency

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ENERGY CONSERVATION AND NOISE CONTROL IN URBAN RESIDENCES: DEMONSTRATION PROGRAM PLAN

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August 1979

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Under Contract No. 68-01-4488
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Prepared for:

U.S. Environmental Protection Agency
Office of Noise Abatement & Control
Technology & Federal Programs Division (ANR-471)
Washington, DC 20460

Attention: John C. Schettino, Director

SUMMARY

Planning activities have been underway for about five months to design an Energy Conservation and Noise Control Demonstration Program for the decade of the 1980s. This effort has been under the direction of the Environmental Protection Agency, the Department of Energy, the Department of Housing and Urban Development, and the National Bureau of Standards. The resulting plan for conducting the demonstration is discussed in this report.

The synergism between energy conservation and noise control benefits that can be achieved with available technology will be demonstrated in an urban residential building in Chelsea, Massachusetts. The building, located on the grounds of the old Chelsea Naval Hospital, contains two identical dwelling units. One unit, the "reference dwelling," will be renovated and fitted with appliances circa 1970 – 75. The other unit, the "improved dwelling," illustrating noise and energy benefits readily achievable in the decade of the 1980s, will receive the best available treatment to the building envelope and will be fitted with appliances that are selected for energy conservation and for reduced noise emission.

An extensive program of data acquisition and analysis will be implemented to provide a continuous and complete record of the differential energy, noise, and air quality conditions in the two units. A display board in each residence will provide a visual comparison of the energy consumption, noise conditions, and cost benefits in the units. A program of air quality measurement will be conducted to identify the differential air quality levels in and near the residences.

Energy consumption in the reference dwelling (which is almost uninsulated and thus typical of many other urban buildings) is estimated to be about three times that in the improved dwelling. Thus, a 70% energy savings benefit could be demonstrated. In addition, noise levels in the interior of the improved dwelling caused by exterior sources will be reduced by approximately 10 dB(A) compared with levels in the reference dwelling. Furthermore, it is expected that the energy-conserving appliances in the improved dwelling can be selected and installed to be quieter than those in the reference dwelling.

A public information program will be designed to describe the findings of the program to a national audience. The outreach effort will be conducted to reach an estimated one million people. Information materials and special events will be developed to assist in publicizing the program.

It is planned that the demonstration program will be conducted over a 21-month period. The estimated cost for the design and conduct of the program is approximately $500,000.

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1. INTRODUCTION

For some years, the Federal government has sponsored programs directed at improving the urban environment and at restoring the vitality of downtown areas. Over the last six years, programs have been added to minimize energy consumption in buildings because of the rising cost and limited availability of fuels (see Fig. 1).

It is possible with available technology to achieve significant energy conservation in buildings while at the same time helping to overcome a major urban environmental problem: noise (see Fig. 2). Because this opportunity for synergistic benefits is not well understood by people outside the technical fields involved, a demonstration program would be of value to illustrate the benefits to a broader segment of the public.

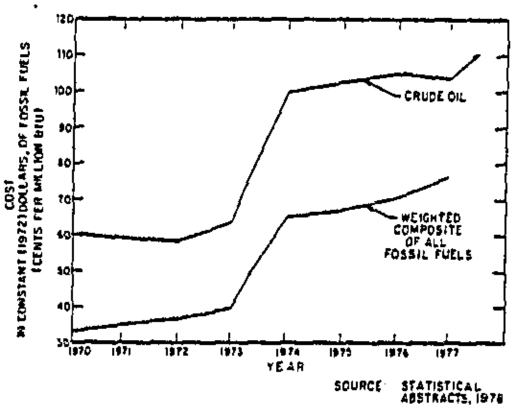

FIG. 1. RECENT FOSSIL-FUEL COST HISTORY.

1.1 Purpose

This report provides detailed plans for a demonstration program that will enhance the public health and welfare by:

- Illustrating the benefits and costs of actions to conserve energy and reduce noise in an urban residence

- Providing information to the public concerning the decreased energy consumption and improved noise environment that can be achieved by applying existing technology in an urban residence
- Demonstrating the synergism between energy conservation and interior noise control benefits in an urban residence
- Gathering data on indoor air quality in energy-efficient residences.

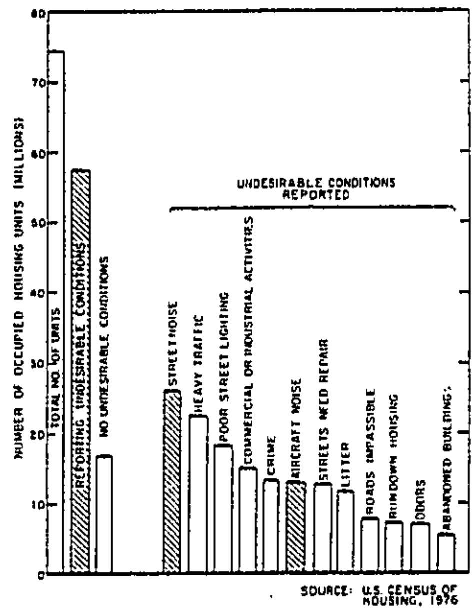

FIG. 1. CENSUS DATA SHOWING THAT NOISE IS THE MOST COMMONLY REPORTED UNDESIRABLE CONDITION IN URBAN NEIGHBORHOODS

The demonstration program will be based upon the fact that both energy consumption and noise within a building depend upon the properties of the building envelope, the mechanical equipment and appliances within the building, and the activities of the building occupants. Closely linked is another familiar urban problem: air quality. The building envelope and equipment control the interchange of air between the inside and outside of a dwelling; furthermore, fuel burning within a building can create its own indoor air quality problems. Additional technical background is summarized in Appendix A.

Outdoor noise and outdoor air quality are major problems for residences located in urban areas. Residential energy consumption is most pronounced in northern climates with high fuel costs. Thus, the demonstration will be most effective if conducted in an urban residence in a northern location. A New England location has been chosen because of its severe winters and heavy dependence on imported fuels (see Fig. 3). The demonstration will be applicable, however, to all northern urban areas with similar heating requirements.

1.2 Planning Process

This plan is based upon a series of meetings held among representatives of the Environmental Protection Agency's Office of Noise Abatement and Control (EPA/ONAC); the United States Department of Energy (DOE); the Department of Housing and Urban Development (HUD); and the National Bureau of Standards (NBS). During these meetings, the objectives and guidelines for the demonstration program were defined, and a building was selected in which the demonstration could be conducted.

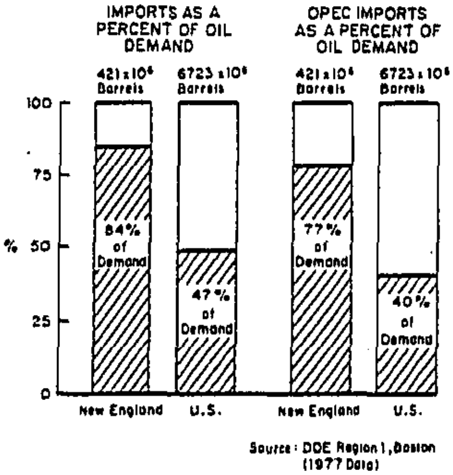

FIG. 3. IMPORTS AS A PERCENTAGE OF TOTAL OIL DEMAND IN NEW ENGLAND AND THE UNITED STATES.

On the basis of a knowledge of the selected building and its location (see Sec. 1.3), Bolt Beranek and Newman Inc. (BBN), as support contractor to EPA, has performed an analysis of the energy and noise benefits that could be demonstrated. These are detailed in Sec. 3 of this report. A plan for the demonstration program has also been developed and is described in Sec. 2; a budget cost estimate is provided in Sec. 4.

1.3 Description of the Demonstration Building

The building selected for the demonstration program is a side-by-side duplex located on the grounds of the old Chelsea Naval Hospital in Chelsea, MA. The building is about 100 ft from the elevated Tobin Bridge (formerly the Mystic River Bridge), a major traffic arterial, as shown in Fig. 4. Originally built about 50 years ago for military family housing, the duplex offers an opportunity for a "before and after" comparison of the noise control and energy conservation benefits that can be obtained through careful design.

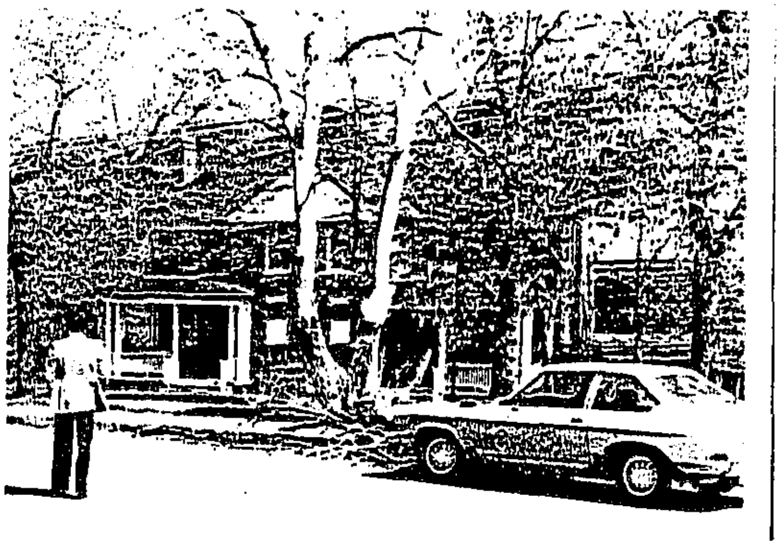

FIG. 4. DEMONSTRATION BUILDING IN CHELSEA, MA.

Since it was declared surplus by the Navy in 1974, the Chelsea Naval Hospital site has been under consideration for an urban redevelopment program. Utilizing over $17 million of seed money from HUD, the Economic Development Administration, and other agencies, the city of Chelsea is about to initiate such a program. The planned redevelopment of this picturesque area within the crowded and economically depressed confines of Chelsea has been favorably received throughout the Boston area (see Fig. 5).

The phoenix beneath the bridge

The city of Chelsea, all 1.8 square miles of it, has been a victim of hard knocks too long. Once known as the "rag shop" because it housed so many peddlars, cut off for years by failure to repair the drawbridge over Chelsea Creek, further isolated and cast in shadow by the creation of the Tobin Bridge, it was almost destroyed by fire in October 1973. Now, at last, the funding and the planning are in place for a $97 million development on the grassy drumlin that housed the Chelsea Naval Hospital.

The effort to make something of the site is not new. Within months of the hospital's closing in 1974, consultants had been called in to make suggestions for its use. Developers from West Germnany and Japan expressed interest. Proposals ranged from a sports complex to an industrial headquarters. There were false starts and disappointing setbacks. But there was also interest and support from House Speaker Thomas P. O'Neill, Sen. Edward Brooke and Gov. Michael Dukakis. In January 1977, Mayor Joel Pressman named former BRA director Robert Kenney to coordinate the drive. Now, according to Chelsea's mayor, all that's needed is a final figure from the Massachusetts Land Bank and approval by the nine aldermen, both expected within a week or two.

Work could start as early as next fall, though it will probably take six years to complete the planned 1200 housing units, the 250-boat marina, the 26-acre waterfront park and the industrial park on the back of the hill. Over 20 governmental agencies have been involved; seven have put up a total of $17 million in public financing; the environmental impact statement has been approved; 350 pages of legal documents have been signed and Chelsea — once considered a dying city, literally looked down on by those who passed overhead between the North Shore and Boston — can look forward to some 3000 jobs, a cut of $39 on its tax rate, the rehabilitation of adjoining neighborhoods through a development-funded revolving loan plan, and new business for its new Mystic Mall and revamped downtown shopping center.

Just goes to show what can be done with persistence and determination. And it goes to show that a town like Chelsea should not be lightly written off.

FIG. 5. *BOSTON GLOBE* EDITORIAL FAVORING THE URBAN REDEVELOPMENT OF THE CHELSEA NAVAL HOSPITAL SITE BY THE CITY OF CHELSEA.

Existing redevelopment plans for the hospital site anticipate that the duplex selected for the demonstration would be renovated and converted to two rental units. The Energy Conservation and Noise Control Demonstration Program is compatible with this objective. As a result, the demonstration program has received the endorsement of the Mayor of Chelsea (see Fig. 6) and of the private developer, Peabody Construction Company.

The duplex itself, designated buildings "T" and "U" on the site plan, is a two-story brick building with a basement and attic. A full-height center fire wall divides the building into two mirror-image dwelling units. Each dwelling unit consists of 1600 ft^2 of living area on two stories, a full basement with laundry room, and a 370 ft^2 finished attic room. The dwellings are in good condition, with high ceilings, hardwood floors, and old double-hung windows. Each has a living room with fireplace, dining room, three bedrooms, two baths, and a kitchen.

The walls of the duplex are of structural brick about 8 in. thick, with furred plaster interior surfaces. The walls appear to be uninsulated. The roof is asphalt shingles over wood sheathing, with about 1 in. of treated paper insulation. The foundation is brick, and the basements are partially heated and uninsulated.

The dwellings currently contain no appliances or equipment. There are no furnaces or hot water heaters, because the building was originally served from a central steam plant. Provision for gas utilization is in place, and plans anticipate the installation

The City of Chelsea Massachusetts

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Office of the Mayor

Joel M. Pressman, Mayor

May 29, 1979

Mr. John C. Schettino, Director
Technology and Federal Programs Division (ANR-471)
Office of Noise Abatement and Control
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Schettino:

The City of Chelsea is most excited about the proposed demonstration project for one of the abandoned properties on the Chelsea Naval Hospital site. We will do everything within our power to assist your office and Bolt, Beranek and Newman, Inc. in making the demonstration a success.

We have discussed the project with the proposed developer, Peabody Construction Company, and they also are excited about the proposal.

We would expect to acquire the site this summer and will make the property available as soon as you desire it. An earlier license could be obtained if necessary.

We look forward to working with your office and will assist in any way that we can.

Yours very truly,

Joel M. Pressman
Mayor

JMP:

FIG. 6. LETTER OF ENDORSEMENT FROM THE MAYOR OF CHELSEA FOR THE ENERGY CONSERVATION AND NOISE CONTROL DEMONSTRATION PROGRAM.

of individual gas-fueled furnaces with baseboard circulating hot-water heat, because the central steam plant is to be torn down during site redevelopment.*

The noise level outside the duplex exceeds an L_{dn} of 77 dB(A), as measured over a 24-hour period. This is due predominantly to traffic on the Tobin Bridge, although the building also lies near the L_{dn} = 72 dB(A) contour for Logan International Airport. Inside an upstairs bedroom, an L_{dn} of about 53 dB(A) has been measured (over a different 24-hour period than the outdoor measurement) with the windows closed.

Calculations indicate that each dwelling unit would require about $300 \cdot 10^6$ Btu/year ($187 \cdot 10^3$ Btu/ft^2) to heat in its present condition. Each unit would consume about 3000 therms of gas at a present cost of about $1200 per year per dwelling.

No data are available on the prevailing air quality around the building. However, because of its proximity to emission sources, the air quality is not expected to be good. Carbon monoxide from vehicles on the nearby bridge, hydrocarbons from extensive oil-storage facilities along Chelsea Creek, SO_2 from a power plant about a mile away, and particulates from demolition and construction on the site will probably all contribute to marginal air quality under some weather conditions. The coastal location, however, will allow periods of respite when sea breezes develop.

*Gas is the most common heating fuel in the U.S., and many New Englanders are now switching from oil to gas as a heating fuel.

2. DEMONSTRATION PROGRAM PLAN

In general, the plan involves the refurbishment of one unit of the duplex to a livable condition, in a form that might have been implemented in the early 1970s. This unit is called the "reference dwelling." The reference dwelling would be renovated without additional insulation and with no particular attention paid to minimizing either energy consumption or noise exposure. It would be representative of many older residences in U.S. urban centers.

The other side of the duplex, known as the "improved dwelling," would be rehabilitated with particular attention to minimizing energy consumption and noise exposure within the dwelling. The improved dwelling would be carefully insulated and the windows treated to minimize energy losses and to discriminate against exterior noises. Appliances and equipment would be selected and installed for minimum energy consumption and reduced noise. The improved dwelling would then be finished and furnished in a manner similar to that of the reference dwelling. Both dwellings would be extensively instrumented, as described below, and a public information program would be carried out during and following the building renovations.

A flow chart of the major elements of the demonstration program is illustrated in Fig. 7. Listed along the left-hand side of Fig. 7 are the principal task areas that would be addressed in the program. Along the top of Fig. 7 are the major activity phases: *analysis*, *design*, *construction*, and *demonstration*. Major tasks are identified by boxes on the flow chart, and the arrows connecting the boxes indicate the interdependency of the tasks. The description below generally follows the flow chart shown in Fig. 7.

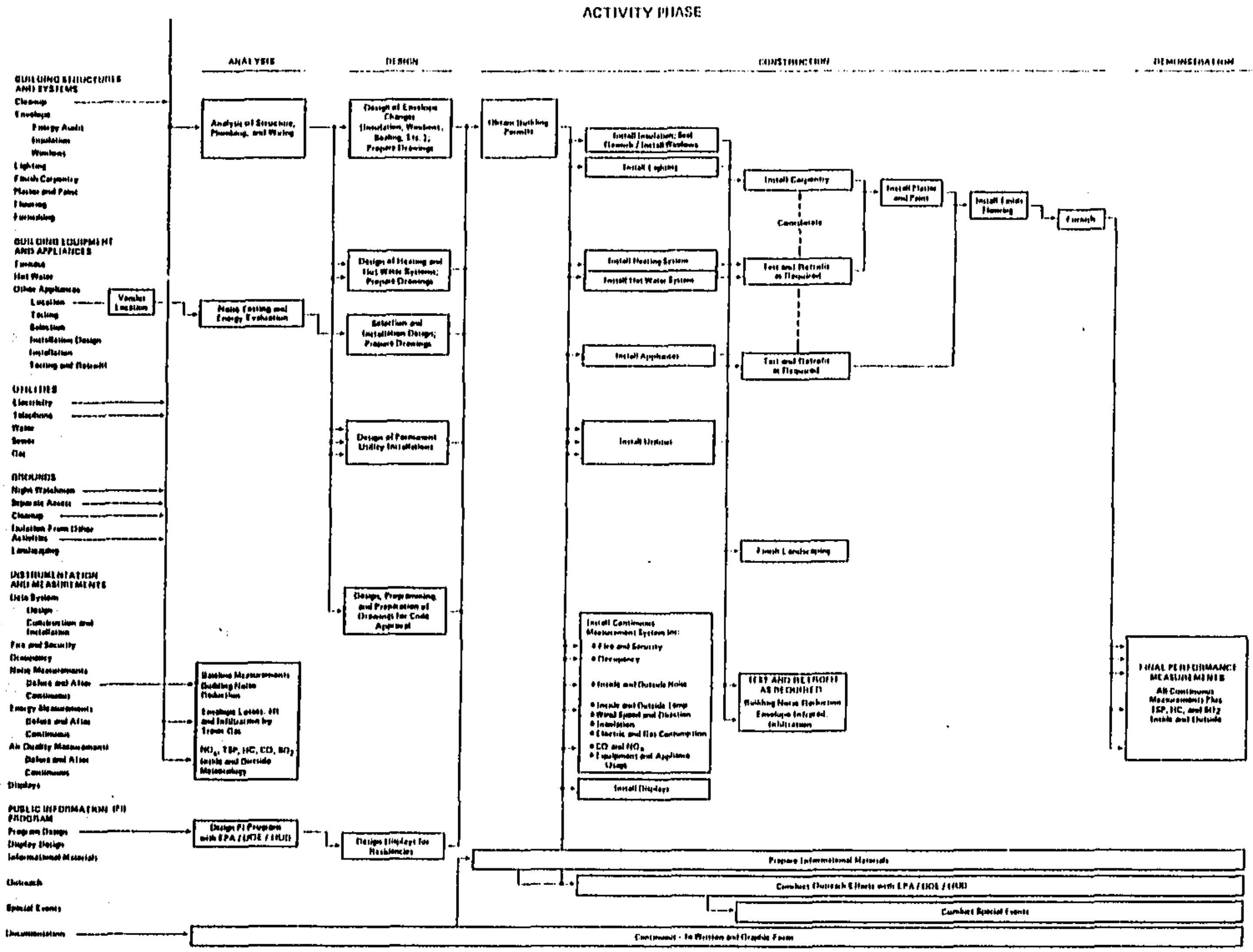

FIG. 7. FLOW CHART OF MAJOR ELEMENTS OF THE DEMONSTRATION PROGRAM.

2.1 Building Structures and Systems

The initial analysis before the retrofit of the building structures and systems will involve a detailed determination of the thermal and acoustic properties of the building envelope. Plumbing and wiring routing would also have to be established. The building energy research group at Princeton University, currently doing research for DOE, will be retained to assist in performing an energy audit of the building envelope. Princeton would do brief tracer-gas studies of infiltration rates and infrared analyses of the building envelope.

Once this information is gathered, it will be possible to design baseboard circulating hot-water heating systems and install insulation and special windows for minimum energy loss and noise transmission. Consideration will be given to window treatments, now available in Europe, that will permit natural ventilation with a minimum intrusion of outdoor noise into the dwelling.

After the issuance of a building permit, the two dwellings will be rehabilitated in accordance with the design, finished, and both will be comfortably furnished with rental furniture. Similar carpeting, drapes, and upholstered furnishings will be used in the two dwellings to provide comparable indoor environments. Following renovation, some rework may be done as indicated by the final performance measurements (see Sec. 2.5).

2.2 Building Equipment and Appliances

The building equipment and appliances that will be used in the dwellings are listed in Table 1. For the reference dwelling, it may be necessary to buy older used equipment. Cooperating

TABLE 1. APPLIANCES/EQUIPMENT FOR EPA/DOE/HUD DEMONSTRATION DWELLINGS.

Item	Reference Dwelling (1970-1975)	Improved Dwelling (1980+)
Furnace (energy, noise, and air quality)	Gas-fired circ. hot water • input/output rating: 150,000/104,300 Btu/hr (sized for heat load of present level of insulation) • two zones • standing (continuous) pilot • uninsulated piping	Same. • input/output rating: 75,000/52,000 Btu/hr • 3 zones • automatic pilot • automatic stack damper • ducted combustion air, if feasible • insulated piping
Thermostat (energy)	Conventional (2 ea.)	2-mode setback clock (3 ea.)
Hot-water Heater (energy)	Gas-fired, 30 gal • moderate insulation (<1975) • standing pilot • uninsulated piping	Same, with same recovery rate • current low-fuel-consumption design with max. avail. insulation • variable firing rate • insulated piping • mixing valve & special high temp. line to dishwasher
Range & Oven (energy, noise, & air quality)	Gas, conventional, with standing pilot	Gas, with automatic pilot (Possibly with oven circulating fan)
Range Hood (noise & air quality)	Conventional, electric	Electric, selected for low-noise • install muffler as required
Dishwasher (noise & energy)	Typical (<1975)	Selected for minimum hot-water consumption, optional electric heater, and low noise • special installation for low noise
Garbage Disposer (noise)	Typical (<1975)	Selected and installed for low noise

TABLE 1 *(cont.)* APPLIANCES/EQUIPMENT FOR EPA/DOE/HUD DEMONSTRATION DWELLINGS.

Item	Reference Dwelling (1970-1975)	Improved Dwelling (1980+)
Refrigerator/Freezer (energy & noise)	Typical 17 ft^3 • auto defrost • continuous stile heater • glass fiber insulation • external fan with condenser coils on bottom	17 ft^3 • auto defrost • switch for stile heaters • foamed-in-place insulation • rear-mounted condenser with no fan • low noise
Clothes Washer (energy & noise)	Conventional, 9 lb warm rinse	9 lb, with adjustable water temp. & level • selected for low noise • suds-saver feature
Clothes Dryer (energy & noise)	Gas: 6½ ft^3 • standing pilot if obtainable	Gas: 6½ ft^3 • automatic pilot, low noise • automatic, moisture-sensing shut off
Window Air Conditioner (energy & noise)	7,500 Btu/hr • EER 5.4	8,000 Btu/hr • EER 8.7 • selected for low noise
Lighting	Incandescent	Fluorescent, where possible
Fireplace	Conventional: wire screen	Glass screen with heat circulator
Other	—	Thermostat-controlled attic fan(s)

vendors who permit simple performance tests and evaluations will be located to facilitate equipment selection. Fortunately, for this purpose, Peabody Construction Company, the developer of the Chelsea site, owns many hundred existing dwelling units with older appliances and equipment. They have offered samples of this equipment for use in the demonstration program in exchange for new replacement units. Lechmere Sales Company, a major Boston appliance retailer, has indicated to DOE an interest in cooperating with appliance energy conservation programs such as this one.

Following selection of the particular items of equipment to be used in the reference and improved dwellings, special attention will be paid to the installation details of particular items of equipment - such as dishwashers, garbage disposers, and range hoods in the improved dwelling - to minimize their noise radiation and energy consumption. Installation detail drawings will then be prepared to obtain building permits.

After appliance and equipment installation, testing and retrofitting may be required to achieve the objectives of the demonstration program.

2.3 Utilities

Electricity and telephone service will be required for the building structural analysis and testing. The actual operation of the demonstration will also, of course, require water, sewer, and gas service. The utility infrastructure on the Chelsea site will be extensively rebuilt as part of the redevelopment program. It is anticipated that this work will start in April 1980 and probably will not be finished until April 1981. This work could involve considerable delay and disruption of the demonstration program. However, because the demonstration building sits at the edge of the Chelsea site, about 200 ft from a public street, temporary utilities can be brought in to serve the demonstration building as early as this fall or winter.

2.4 Grounds

The Chelsea site now has full-time guard services, provided by its present owner, the General Services Administration. Following title transfer to the city of Chelsea, it is anticipated that either Chelsea or the developer will continue to provide night watchmen. Arrangements will have to be made to either share this service or to supply independent night watchmen to ensure security of the unoccupied demonstration dwellings.

The site redevelopment program will involve the layout of new roads and reconstruction of some older roads. This activity could restrict access to the demonstration dwelling. To avoid this problem, it is suggested that separate access be provided to the demonstration dwellings from the nearby public street mentioned in Sec. 2.3. In addition, some sort of visual barrier may be desirable in order to isolate the demonstration building from the demolition and reconstruction activities that will be proceeding on other parts of the street. Finally, a modest amount of landscaping would be desirable to enhance the outside appearance of the demonstration building.

2.5 Instrumentation and Measurements

In general, two classes of technical measurements are anticipated in and around the demonstration dwellings: measurements before-and-after renovation and "continuous" measurements.

The before-and-after measurements would be made, as described below, in order to observe conditions that do not change significantly with time, and to observe parameters that would be very costly to measure continuously. The continuous measurements, on the other hand, would be made throughout the entire demonstration program and would be designed to observe parameters that vary significantly with time.

During the analysis phase of the project, a set of baseline measurements would be made of three phenomena: noise, energy, and air quality. The noise measurements would consist of detailed observations of the noise reduction into various rooms of the building (adjusted for interior absorption) and of noise reduction through the party fire wall separating the two dwelling units. The energy measurements would consist of a detailed energy audit of the unrenovated structure (both dwelling units), including studies of infiltration rates and thermal transmission characteristics of the envelope. It is anticipated that the Princeton group will assist with the performance of these measurements and will provide tracer-gas diffusion and infrared scanning equipment for this purpose.

The baseline air quality measurements will consist of observations of oxides of nitrogen (NO_x), radon, particulates (TSP), hydrocarbons (HC), carbon monoxide (CO), and sulphur dioxide (SO_2), both outside the house and inside each dwelling unit, for a period of several weeks. Correlated measurements of wind speed, wind direction, temperature, and humidity will also be acquired during the baseline air quality study.

During the design phase, an online continuous data system will be designed for installation at the demonstration building. The system will monitor:

- A-weighted sound levels at several locations inside and outside each dwelling unit
- Electricity and gas consumption
- Inside and outside temperatures and humidities
- Wind speed and direction
- Insolation
- Carbon monoxide and oxides of nitrogen both in the kitchens and outside
- Certain events, such as the operation of equipment and appliances.

Fire and security sensors will also be monitored continuously by this system. It is anticipated that all parameters would be sampled at the rate of about once per second.

The continuous data-gathering system will consist of the necessary transducers permanently connected to an LSI-11 processor operating in stand-alone mode in one of the dwelling units. This would be connected over a dedicated phone line to a second LSI-11 located at the BBN offices in Cambridge, MA. The onsite machine program will be capable of being loaded via the communication interface from BBN and will perform the functions of analog-to-digital conversion, events sensing, preliminary averaging, and formatting of data packets for transmission to the host processor at BBN. The host processor would receive the data packets and prepare and update periodic statistics. Records would be stored on floppy disks at BBN. This data base could then be interrogated from ASCII terminals either at the demonstration building or at BBN. A software override would provide alarms at either or both locations should certain unpredictable events, such as a fire, occur. Otherwise, suitably formatted typewritten reports would be produced periodically.

Sharing the sensor array with the continuous data-monitoring system would be a set of real-time displays in each dwelling unit. These displays, which would be designed as part of the public information program (see Sec. 2.6), would indicate current and recent cumulative energy costs, outside and inside noise levels, temperatures, wind speed, and perhaps a simplified measure of air quality. For the energy consumption cost displays, it is anticipated that DOE will be able to provide two Energy Cost Feedback meters, which that agency is now developing.

The real-time displays are intended to be attractively styled and simple to interpret by nontechnical viewers. For more sophisticated inquirers, the onsite terminal can be used to interrogate the data base stored on the continuous data-monitoring system.

Toward the end of the construction phase, an "after renovation" measurement program will be conducted to gather final performance data. This phase will consist of studies by Princeton University of infiltration and envelope leakage, a repetition of the complete air-quality measurement program, and envelope noise-reduction measurements. These measurements may exhibit the need for some rework, which will be done at that time.

2.6 Public Information Program

The public has been subject to so many promotions about building energy conservation that it is doubtful that further voluntary action would be induced by yet another such promotion. This demonstration program has two new and unique aspects, noise isolation benefits and appliance energy efficiency, that should be highlighted. The public information program will be designed to emphasize these features.

Furthermore, the public will want to know the costs to achieve the benefits that are demonstrated by the program. At least for energy savings, the public is well attuned to seeing return-on-investment data in the form of payback periods. Such data will be featured during the public information program.

2.6.1 Program design

In conjunction with the public information staffs of EPA, DOE, and HUD, the public information program for the demonstration will be designed to disseminate information on the energy conservation, noise reduction, and air quality benefits of the program to a wide and varied audience. The program will utilize multiple informational and educational techniques on both the local and national levels. Because of the very graphic and visual nature of the demonstration, the opportunity exists to translate technical information into easily understandable terms for a public audience. Thus, a broad informational program will be structured to appeal to the widest possible range of potential beneficiaries of the program's findings.

In a parallel effort to the design phase of the building renovation, the design activity for the public information program will take place. Through the public information offices of the sponsoring Federal agencies, detailed specifications and a schedule for activities and events that will occur throughout the project will be developed. A variety of informational techniques and special events will be chosen to publicize the project and its findings. These may include visual displays, onsite tours, seminars, technical articles, television and radio news and feature articles, press releases, and other informational techniques. Each technique will be reviewed and evaluated according to specific criteria, such as:

- Effectiveness in reaching target groups
- Cost
- Extent of information provided
- Balance in total package.

Early in this planning, a name for the project will be chosen and a logo or symbol will be designed to provide a thematic unity for all informational activities.

2.6.2 Outreach

The outreach activity will identify target groups of potentially interested persons and develop methods for delivering information about the project to those persons. Although the focus of the outreach program is national, other efforts will be made to reach a local audience that could ultimately visit the demonstration building. Preliminary thinking indicates that the target geographical distribution of the outreach program should be as follows:

- 20% from the Boston SMSA
- 30% from the rest of New England
- 50% from elsewhere in the U.S. where similar heating requirements exist.

The goal of the program is to provide project information to approximately a million people. By referring back to the projected geographical distribution, this would be distributed as follows:

- Boston SMSA: 200,000
- Rest of New England: 300,000
- U.S.: 500,000.

The following distribution reflects our preliminary thinking regarding the overall composition of the target group for the outreach effort:

- 10% from architects and builders
- 5% from utilities
- 5% from state and local officials
- 5% from other special interests
- 75% from the general public.

Information Materials

A variety of informational materials will be produced in conjunction with the demonstration project. They will range from newspaper articles and press releases to television and radio interviews and features. Technical articles and brochures will be prepared and distributed at the project house and at other designated locations.

At each stage of the demonstration project, it will be necessary to prepare written and graphic documentation to assure that an adequate information base is developed for public information materials. This component of the public information program will involve building a complete record of the various project stages from design to final report through written text, photographic or artistic renderings, and television or film records. The goal of this element of the public information program is to assure that no piece of information is missing from the record, which will be useful in describing the program to the public at a later stage of the project or after the project is completed.

The following paragraphs briefly describe some of the information techniques that may be used in the program. Final decisions regarding appropriate choices for the program will be made during the design phase in conjunction with EPA, DOE, and HUD staffs.

Display Board

As the building itself is intended to be a focal point of important public information special events, an information display board will be designed to provide a graphic presentation of real-time data on energy consumption and costs, noise exposure, and air quality. This design effort will be coordinated with the design of the continuous data system (see Sec. 2.5). The display board will be positioned at a central location in the building to provide the visual information to visitors.

Technical Articles

Technical articles on the demonstration project will be prepared for publication in journals, such as *Sound and Vibration* and *Energy and Buildings*. These articles will provide a review of the techniques used to achieve energy conservation and noise reduction and will also describe the energy and noise reduction benefits obtained through the retrofit.

TV and Radio

Radio and TV interview shows are good avenues for publicizing this project and informing the public about the findings. Arrangements will be made for project spokespersons to appear on such programs. In addition, news releases will be prepared for radio and TV news programs, particularly in support of the special events that will be scheduled.

News Articles

Articles will be written to appear in newspapers to publicize special events, such as a statewide Project Week (see Sec. 2.6.3).

Feature Articles

Feature articles will be written for newspaper supplements distributed throughout the United States, as well as for local papers. Other possible outlets for articles are magazines, such as *Better Homes and Gardens*. Efforts will be made to obtain coverage in influential national magazines, such as *Time*, *Newsweek*, and *Fortune*.

Brochures

A primary method for disseminating information about the project will be brochures for distribution at the project residence, mailing to selected lists, and general purpose use. These brochures will be directed to nontechnical audiences and will describe the benefits that can be achieved through the use of the currently available technology in building-envelope treatments and in appliance selection as incorporated in the residences.

2.6.3 Special events

The public information program will devote a significant portion of its resources to designing and sponsoring special events for the general public and for specialized audiences. Three types of special events will be the focus of this effort.

- *Technical Seminars* — Technical seminars will be conducted for state and local officials, building professionals, representatives of utilities, and other professionals. The purpose of these seminars will be to provide additional technical information concerning the project to the professional community. Such seminars could be organized and conducted at universities. Onsite visits to the house may be scheduled in conjunction with seminars in the local area.

- *Television Documentary* — It is hoped that a television documentary, which will reach a wide audience, can be arranged to provide a visual description of the project. An initial contact has been made with Channel 2 in Boston, and this will be followed up during the design phase of the program.

- *Demonstration Project Week* – The Commonwealth of Massachusetts will be asked to designate a statewide Project Week, during which public activities at the demonstration house will be focused. Official activities at the State House and at the project site will be conducted, and an intensive publicity campaign will be mounted in conjunction with the Project Week. During this week, groups of people will be encouraged to tour the project house and to observe at firsthand the comparative treatments and the informational output. A publicity campaign will be mounted in Massachusetts newspapers and on radio and television to encourage the public to view the demonstration house. Special arrangements will be made to staff the house and to provide written and oral information to the public. This week would climax the public information program.

2.7 Technical Evaluation

Continuing technical evaluation of the benefits of the demonstrated technology is, of course, critical to the success of the demonstration program. This is the principal purpose of the continuous data-monitoring system. Technical evaluations may indicate the need for some modifications to the demonstration residences following their initial refurbishment. These modifications are provided for with regard to installation details of appliances (see Fig. 7). Similar work may be required to optimize the performance of the window designs that will allow natural ventilation with a minimum of noise intrusion. Other modifications may become appropriate as a result of initial evaluation of the public information program efforts.

It is anticipated that natural infiltration of the improved residence can be reduced to on the order of one half air change per hour (about 133 ft^3 per min). Indoor air quality will be monitored — particularly for oxides of nitrogen in the kitchen during operation of the gas-burning kitchen range. Despite the intermittent use of a range hood and the absence of a standing pilot, these tests may indicate that this low level of natural ventilation is inadequate. Radon and humidity buildup in kitchens and bathrooms will also be monitored and may be found to be excessive at some times. Should either problem occur, it may be necessary to retrofit mechanical ventilation in the improved dwelling, perhaps with an outflow-to-inflow heat exchanger.

Similarly, it is possible that outdoor air pollution may occasionally be so high that the sealing of the reference dwelling and the provision of special ventilation equipment may be indicated.

Technical documentation of the demonstration will consist of monthly reports and a comprehensive final report providing a history of the project, all data acquired during the project, and an analysis of the benefits observed (including those resulting from the public information program).

2.8 Planning for an Occupancy Phase

The demonstration program outlined here will take place without anyone living in the residences (although residential activities will be simulated by periodic operation of appliances, etc.). This will be somewhat unrealistic, because both the energy consumption and noise exposure within a residence are strongly influenced by the activities and life styles of the occupants.

During the demonstration program, plans will be prepared for a follow-on phase involving controlled occupancy of the two residences – the objective being to examine life-style effects on energy consumption and noise exposure. Additional appliances of a personal nature, such as hand-held hair dryers and television sets, could be introduced for analysis and demonstration during the follow-on occupancy phase.

In addition, a follow-on phase could introduce and demonstrate advanced technology, such as solar heating, greenhouse patios, ventilation through heat exchangers and air-scrubbing equipment.

Opinions expressed by the occupants and remote sensing of their activities (thermostat setting, radio/television volume setting, sleep disturbance, etc.) would generate very useful information from this occupancy phase.

2.9 Time Schedule for the Demonstration Program

The anticipated time schedule for the demonstration program is shown on Fig. 8. This schedule indicates a 21-month program starting in October 1979. The major task items are drawn from those on Fig. 7.

Building analysis, appliance and equipment selection, and baseline measurements would be performed in the fall of 1979 and would require 6 to 8 weeks. Design would require about 2½ months, including interaction with the site developer and his architects, utility companies, and the Chelsea Building Office. It is anticipated that a building permit would be received in January 1980.

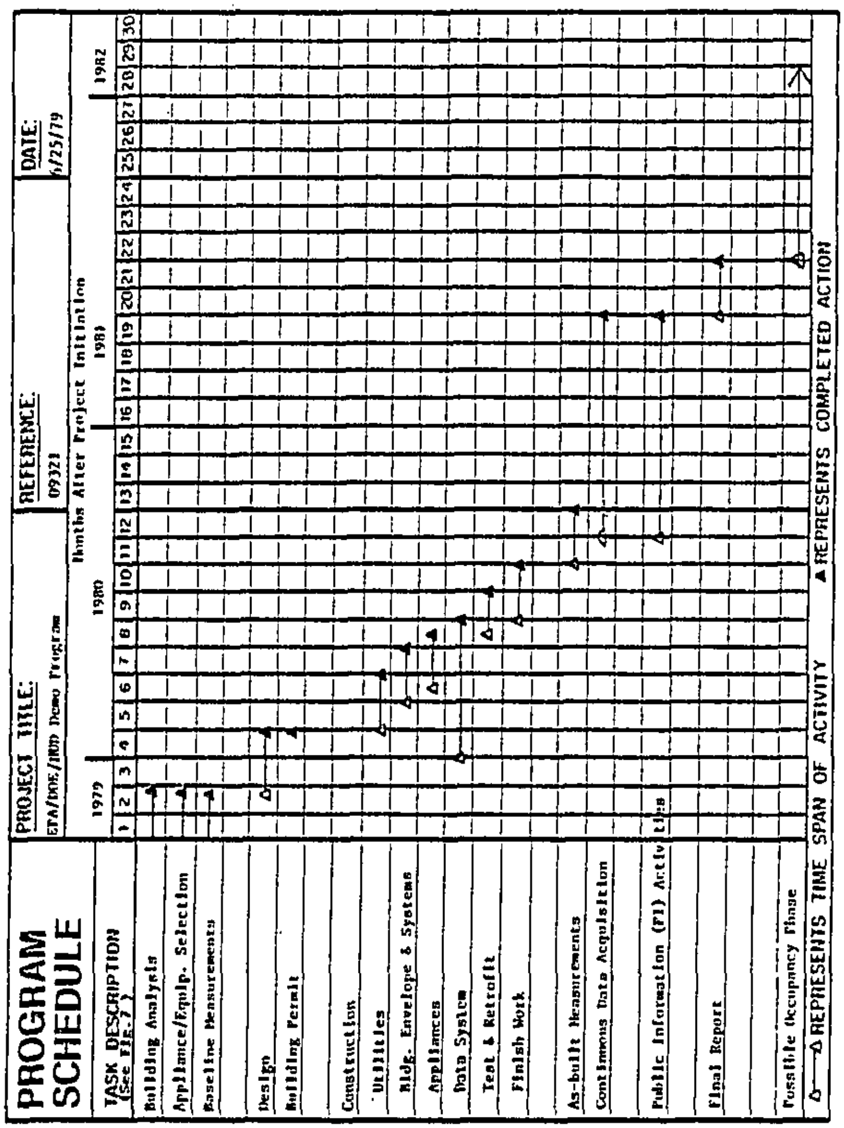

FIG. 8. TIME SCHEDULE FOR DEMONSTRATION PROGRAM

Construction work would start at the end of January 1980 and would last for 6 months, including necessary tests and retrofit activities. Thus, the building would be available for use on the first of August 1980. After a month for "as built" measurements, continuous monitoring and public information activities would occur from September 1980 through the end of April 1981, allowing the accumulation of data on a one-winter cycle of energy consumption and air quality. A final report would then be delivered at the end of June 1981. A follow-on occupancy phase of the demonstration, if desired, could begin in the second half of 1981 and proceed through the winter of 1981-82.

Although a shorter program than that scheduled as shown on Fig. 8 would be desirable, it will still be necessary to acquire at least a full winter's data to demonstrate energy conservation benefits meaningfully. Air quality data should also be acquired under a variety of meteorological conditions. We are advised that it is unrealistic to expect the demonstration building to be renovated in time to gather reliable data during the winter of 1979-80.

3. ESTIMATE OF DEMONSTRATED BENEFITS

An analysis has been made of the benefits that are likely to be demonstrated by the difference between the reference and the improved dwelling units. The results of this analysis and the methods used to carry it out, are described below.

3.1 Noise Reduction Benefits

An estimate of the noise levels that will exist in the demonstration building is shown in Table 2. The differences in noise exposure will occur for two reasons: (1) greater isolation from exterior noise provided by the building envelope of the improved dwelling and (2) reduced noise emission by specially selected appliances within the improved dwelling. The former would be observable primarily in locations like bedrooms that are removed from appliances and when appliances were not operating. The differences in appliance noise levels will be evident to observers going from one residence to the other when the appliances are operating.

Inside the building, the noise level resulting from exterior sources has been measured, with windows closed, at an L_{dn} of 53 dB(A). On the basis of a study in "Energy Conservation and Noise Control in Residences," BBN Report 3903 submitted to EPA in October 1978, it is estimated that an 8-dB improvement can be achieved in this level, for a resulting interior L_{dn} of 45 dB(A) with windows closed. This level is consistent with HUD's indoor noise exposure goal, per 24 CFR 51, Subpart B. The interior noise in the reference dwelling with a window opened 2 ft^2 is estimated (from the "Levels" document, EPA 550/9-74-004) to be 62dB(A). BBN estimates that a special window design could provide equivalent natural ventilation with a noise

TABLE 2. SUMMARY OF ESTIMATED INTERIOR NOISE EXPOSURES IN THE DEMONSTRATION RESIDENCES.

Type	Reference Dwelling	Improved Dwelling	Difference in Level
Through envelope			
closed windows	L_{dn}=53dB 1/	L_{dn}=45dB	8dB(A) 5/
open windows	L_{dn}=62dB 2/	L_{dn}=52dB	10dB(A) 6/
Interior Sources (@ 3 ft) (when operating)			
Furnace	-	-	no change
Hot Water Heater	-	-	no change
Range & Oven	-	-	no change
Range Hood 3/	67dB(A)	55dB(A)*	12dB(A)
Dishwasher 4/	70dB(A)	56dB(A)	14dB(A)
Garbage Disposer 3,4/	88dB(A)	68dB(A)	20dB(A)
Refrigerator/Freezer 3,4/	50dB(A)	37dB(A)	13dB(A)
Clothes Washer 3,4/	71dB(A)	51dB(A)	20dB(A)
Clothes Dryer 4/	63dB(A)	53dB(A)	10dB(A)
Window Air Conditioner 3,4/	65dB(A)	53dB(A)	12dB(A)

Sources:
1. Measured
2. Estimated per EPA 550/9-74-004
3. BBN Report 3791
4. Fig. 3 of EPA NTID 300.1.
5. BBN Report 3903
6. See Sec. 3.1.

*To be installed with muffler

reduction improvement of 10 dB(A). Thus, the noise level within the improved dwelling with windows open would be essentially the same as that in the reference dwelling with windows closed.

Significant differences are not anticipated in the interior noise emission characteristics of the furnaces, hot water heaters, and ranges and ovens in the two dwellings. However, as shown in Table 2, noise emission improvements ranging from 10 to 20 dB(A) should be demonstrable for the other appliances, at a typical listener's distance of 3 ft from each appliance when it is operating. In general, these improvements represent the approximate range between the 90th percentile levels and the 10th percentile levels reported in "Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances," EPA Report NTID300.1; and "Identification and Classification of Noise-Producing Household Consumer Products," BBN Report 3791 (draft). In one case, the range hood fan, it is anticipated that a special muffler would be designed and installed to minimize fan noise. Otherwise, the demonstrable improvement for this appliance would be approximately 6 dB(A).

3.2 Energy Conservation Benefits

The estimated energy conservation benefits that could be demonstrated in the improved dwelling are listed in Table 3. Here again, these benefits fall into two general areas: (1) those associated with thermal losses through the building envelope and (2) those associated with energy consumption by appliances. The envelope losses are by far the most significant, as indicated by the first row of Table 3 entitled "Furnace (Load)."

TABLE 3. PRELIMINARY ESTIMATES OF ENERGY CONSUMPTION & CORRESPONDING SAVINGS FOR DEMONSTRATION RESIDENCES.

Equipment/Appliance Type	Reference Dwelling Consumption (Present Condition)			Improved Dwelling Consumption			Savings		
	Rating	Btu/yr(Gas)	kWh/yr(Elect.)	Rating	Btu/yr(Gas)	kWh/yr(Elect.)	Btu/yr(Gas)	kWh/yr(Elect.)	Percent (%)
Furnace (load)[1/] (eff.)[3/]	150/106.3·10³ [8/] 70%	230·10⁶ 97·10⁶	40	75/52·10³ [8/] 80%	68.2·10⁶ 16·10⁶	60	161.8·10⁶ 81·10⁶	<20>	71.6 83.0
Hot Water Heater (eff.)[4/]	30 gal 3.4·10³ Btu/hr	46·10⁶		30 gal 34·10³ Btu/hr	34·10⁶		12·10⁶		26.0
Thermostat (setback)	Conv.			2-mode Setback	<5.6·10⁶>		5.6·10⁶		7.0[1/]
Range/Oven[5/]	Gas	14.5·10⁶		Gas	6.3·10⁶		8.2·10⁶		56.0
Dishwasher (water)[5/] (elect.)[5/]	850w	Incl.above	176	Optional 750w heater	Incl.above	137		39	22.0
Refrig./Freezer[5/]	17 ft³		1890	17 ft³		1020		870	46.0
Washer (water)[5/] (elect.)[5/]	9 lb	Incl.above	100	9 lb adj.w/ suds saver	<3.6·10⁶>	100	3.6·10⁶		13.9
Dryer[5/]	Gas; 6.5 ft³	6.4·10⁶	20	Gas; 6.5 ft³	4.3·10⁶	20	2.1·10⁶		33.0
Window A/C[3/] (300hr)	7500 Btu EER=5.4		417	8000 Btu EER=8.7		276		141	34.0
Other Equip.			100			100			
Lighting			1000			800		200	
Instrumentation (1 yr)			460			460			
TOTALS		390·10⁶	4183		115.6·10⁶	2953	274.3·10⁶	1230	69.0
Costs (@ $0.40/Therm; & $0.065/kWh)[7/]		$1560.	$272.		$462.	$192.	$1097.	$80.	64.0
		$1832.			$654.		$1177.		

Sources and Notes:
1. Calculation per ASHRAE, "Retrotech," & Mass. Code
2. BBN Handbook
3. ASHRAE 1973 data per Sears Spring/Summer Catalog
4. DOE literature
5. 1979 Sears Spring/Summer Catalog
6. BBN data
7. Typical 5/79 costs in the Boston area
8. Input/output ratios in Btu/hr.

The heating loads of the reference and improved dwellings have been computed using a modified "Retrotech"* technique, conductivity data from the ASHRAE Guide, and design requirements from Article 22 (energy conservation) of the Massachusetts Building Code. The assumptions made in this analysis are as follows:

- The envelope of the reference dwelling will be left essentially unchanged from its present configuration, i.e., with little or no insulation.
- The improved dwelling will have R11 insulation in the walls, R30 insulation in the attic, R11 insulation in the basement, tight storm windows and storm doors, and thorough caulking and weatherstripping.
- Uncontrolled infiltration in the reference dwelling will be two air changes per hour and in the improved dwelling, 1/2 air change per hour.
- Design is for 5634 heating degree days, a 72°F indoor temperature and a +10°F outdoor temperature, as indicated in the Massachusetts State Building Code.

As indicated in Table 3, these changes are estimated to result in more than 71% reduction in the heating load between the reference dwelling and the improved dwelling. The calculations also indicate that the reference dwelling would require a furnace rated approximately 100,000 Btu per hour output and that the improved dwelling would require a furnace rated approximately 30,000 Btu per hour output. The ratings shown for the furnaces

*The Retrotech computation is a simple procedure for determining building heating losses. This procedure was developed by the University of Maine for the Federal Energy Administration. It is widely used, particularly by community service agencies and public utilities.

in Table 3 are the nearest standard sizes to these requirements that are listed in the catalogs available to us.

It has further been assumed, based upon an examination of a handbook provided by the Massachusetts Better Home Heating Council, that the efficiency of the furnace in the reference dwelling would be 70%*, and that of the furnace in the improved dwelling would be 80%*. This results in an additional anticipated savings of 81.10^6 Btu/year.

The anticipated energy savings for the other appliances and equipment are based upon the configurations described in Table 1. Energy estimates are, for the most part, computed from "Energy Saving Design Options Currently Available on Consumer Products" dated May 1978 and provided by DOE. Exceptions to this generalization are based on data in suppliers' catalogs and data provided by the National Bureau of Standards.

The last four rows of Table 3 involve additional assumptions. It has been assumed that the window air conditioners would operate 300 hours per year - about the maximum that is necessary in a coastal New England climate. Other equipment (range hood, garbage disposer) is expected to consume 100 kWh per year. Lighting, considering the unusual occupancy pattern that will be experienced in the demonstration building, is estimated at 1000 kWh per year in the reference dwelling and 800 kWh per year in the improved dwelling. (The latter will have fluorescent lights installed where possible.) Finally, instrumentation and measurement equipment is expected to consume 440 kWh per year in each residence.

*These are effective continuous efficiencies.

In terms of total energy consumption, it is estimated that the improved dwelling will consume approximately 70% less energy than the reference dwelling, using 3412 Btu per kWh as a conversion factor. Utilities for the reference dwelling are estimated to cost $1832 per year (not an unusual cost in the Boston area), and $654 per year for the improved dwelling. These estimates are based on typical present residential rates in the Boston area of 40¢ per therm (100 ft^3 or 100,000 Btu) of gas; and 6½¢ per kWh of electricity.

4. ESTIMATED COST OF THE DEMONSTRATION PROGRAM

A cost estimate for the demonstration program is shown in Table 4. The costs are given in two categories:

- Professional services
  Total: 152 person weeks

- Out-of-pocket cost for purchased items
  Total: $271,000.

Assuming professional services at a present rate of $35 per person hour and allowing 8% inflation of that rate over the 21-month period, the total estimated cost of the program is about $500,000.

The cost breakdown on Table 4 follows the format of the project flow chart, Fig. 7, and provides cost estimates in some detail. The time schedule assumed is that of Fig. 8, with initial construction occurring in the first half of CY 1980. The estimate includes approximately an 8% contingency and some cost items (night-watchman services, lease payments) that perhaps could be reduced.

TABLE 4. ESTIMATED COSTS FOR DEMONSTRATION PROGRAM

Task (See Fig.7)	Professional Labor (Person Weeks)	Purchased Items	Out of Pocket Cost for Purchased Items ($)	Comments
Analysis				
Cleanup bldg. & grounds	0.1	Services	1,000	
Structure	1.0	Travel	100	
IR Mmts. (baseline)	0.2	Instr. Use	250	
Air Quality Mmts. (baseline)	4.0	Instr. Use	5,000	
Envelope Energy Audit	0.2	Princeton Univ. Services	2,000	
Appliance Location Testing & Evaluation	4.0	Instr. Use	1,500	
Design				
Envelope Changes	2.0			
Windows	4.0	Instr. Use & Mat.	1,000	
Heat & Hot Water System	2.0			
Appliance Installation	2.0			
Utilities	1.0			
Data System	12.0			
PI Program	2.0	Consultant	2,500	
Displays	4.0	Materials	500	
Drawings	4.0	Materials	1,000	
Construction				
Building	6.0	Renovation	64,000	3,200 ft^2 @ $20./ft^2
		Inflation on above	9,600	15%
Appliances	4.0	Furnaces (2)	1,500	
		Hot Water Heaters (2)	450	
		Thermostats (5)	250	
		Ranges (2)	1,200	
		Range Hoods (2)	200	
		Dishwashers (2)	650	
		Garbage Disp. (2)	175	
		Refrig./Freezers (2)	1,100	
		Washers (2)	600	
		Dryers (2)	600	
		Window Air Cond. (2)	550	
Utilities: Gas	2.0	Connect & check	1,000	From High St.
Electricity		Supply	1,000	From Chestnut St.
Telephone		2 Lines	200	From Chestnut St.
Water			500	Tap adj. 8" line
Sewer		Clean & check	500	Extg.
Data System	16.0	Sensors	15,000	
		Processing	20,000	
		Line Costs	700	
Display Board	2.0	Instruments	5,000	
Test & Retrofit				
Appliances	2.0	Instr. Use	1,000	
Bldg. IR	2.0	Instr. Use	500	
Envelope Energy	0.4	Princeton Univ. Services	2,000	
Documentation	2.0	Materials	1,000	
Grounds				
Access	0.2	Services	5,000	
Isolation	0.2	Services	5,000	
Landscaping	0.2	Services	1,000	
Night Watchman Services	2.0	16 mo	30,000*	*Could be replaced with alarm or sharing services with Peabody
Furniture Rental	1.0	9 mo	6,000	
Demonstration				
As-built Perf. Mmts.				
Air Quality	4.0	Inst. Use	5,000	
IR	0.2	Inst. Use	250	
PI Program				
Mgmt.	6.0			
Informational Mat.	10.0	Art, printing, filming	10,000	
Special Events	6.0	Materials	10,000	
Other				
Management & Reporting	25.0	Travel, etc.	10,000	
Utilities		1 yr	3,000	
Cleaning & Maint.	4.0	Services	5,000	
Lease		18 mo	18,000†	†Negotiable
Contingency	14.0		20,000	
TOTALS	152.0 person weeks		$271,000.	

APPENDIX A: TECHNICAL SYNOPSES

These synopses summarize the technical interrelationships between noise conditions, energy consumption and air quality in urban residences. The summaries are general and do not necessarily apply specifically to the Chelsea demonstration building.

A.1 Relationships Between Noise Reduction and Energy Loss Through Building Envelopes

There are several ways of reducing the intrusion of noise into a dwelling from outdoors that can also reduce the energy required to heat or cool the building. Similarly, efforts to reduce energy consumption can provide a concomitant benefit in reducing outdoor noise intrusion. Quantitative estimates of these synergistic benefits are provided in "Energy Conservation and Noise Control in Residences," BBN Report 3903 submitted to EPA in October 1978.

A graphic summary of the principal results of that study is given in Fig. A-1. All of the building features illustrated involve reducing the heat energy and the acoustic energy that flows through the building envelope. The single most important step that can be taken to achieve both energy conservation and noise reduction in dwellings is the sealing of air leaks in the building envelope. When done for noise control (which does not require that *all* leaks be sealed), an estimated 15 to 25 percent of the total annual heating/cooling energy requirement of the building can be saved. Although this may not be the most important energy-saving step a building owner can take, it is still quite significant. Correspondingly, if leaks are sealed for energy-conservation purposes, a 5- to 10-dB improvement in

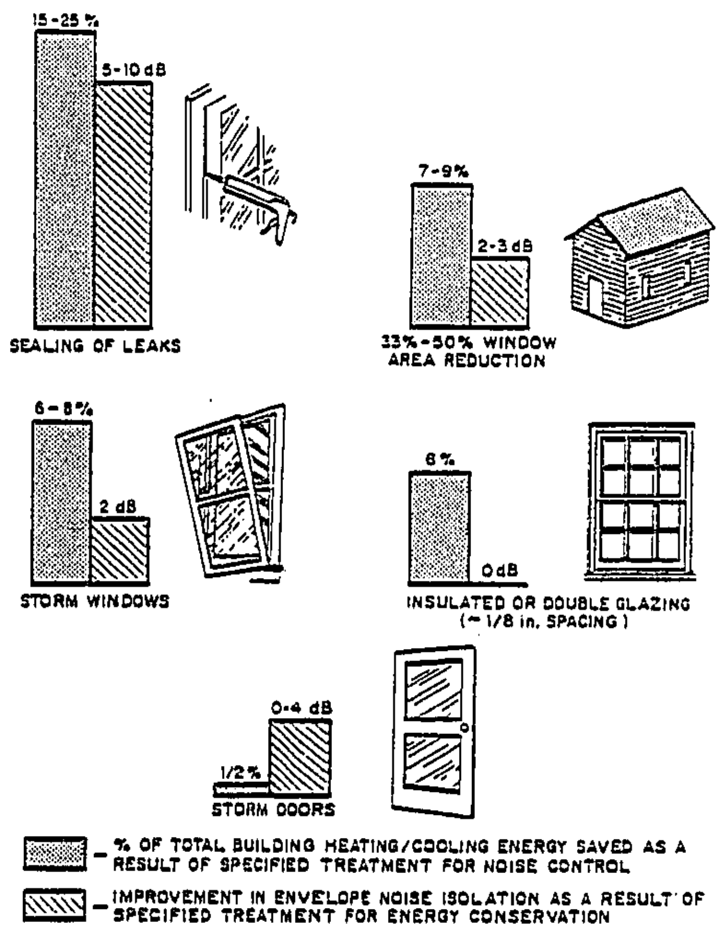

FIG. A.1. SUMMARY OF NOISE-CONTROL AND ENERGY-CONSERVATION BENEFITS RESULTING FROM SELECTED FEATURES OF RESIDENTIAL BUILDINGS.

the interior noise level caused by external noise sources will result. Although this will not solve noise problems caused by indoor sources, it is still a major benefit, particularly in single-family residences.

The use of double glazing, insulated glass, or storm windows will all result in comparable energy savings, 6 to 8 percent of the annual heating/cooling requirement, assuming a modest window-to-wall ratio. However, only storm windows will provide a significant noise-reduction benefit, because of the large spacing possible between the two glass barriers.

Reducing the ratio of window to total wall area by a factor of 33% to 50% will result in both a 7% to 9% energy saving (ignoring insolation effects), and 2- to 3-dB improvement in noise reduction. The use of a storm door (or vestibule) produces a small (½%) energy saving, but as much as 4 dB of additional noise reduction for the room into which the door opens.

It is a common misconception that the addition of thermal insulation to walls will improve their noise-reducing properties. This is generally not true. It is also not true that landscaping around a residence will improve its outdoor noise environment. Both of these things can, however, reduce the energy consumption in a building.

A.2 Relationships Between Energy Consumption and Noise Radiation of Building Appliances and Mechanical Equipment

Much of the noise in residences is caused by appliances and mechanical equipment operating within the building, rather than by the intrusion of outdoor sounds. Such equipment also consumes