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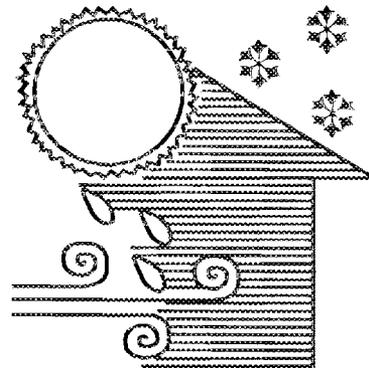
MARTIN MARIETTA

EVALUATION PLAN FOR
THE WEATHERIZATION
ASSISTANCE PROGRAM

Darrell A. Beschen
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Weatherization Assistance Program

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DEPARTMENT OF ENERGY

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**EVALUATION PLAN FOR THE
WEATHERIZATION ASSISTANCE PROGRAM**

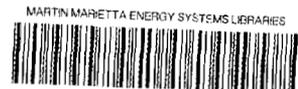
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Prepared for the
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EXECUTIVE SUMMARY

Background

The most recent national evaluation of the impacts of the U. S. Department of Energy (DOE)'s Weatherization Assistance Program (WAP) was completed in 1984 based on consumption data for households weatherized in 1981. WAP regulations and operations have changed substantially since 1981. New funding sources, management principles, audit procedures, and energy-efficiency measures, and an increased emphasis on training, technical assistance, and client education have been incorporated into the program in the last decade. In addition, new initiatives, incentives, opportunities, methods, and technologies are on the horizon. Many of these factors have been studied in isolation or at a local level; however, no recent work has assessed their integrated, national program impact or potential. As a result, a more timely and comprehensive national level evaluation of the WAP is needed to provide policy makers and program implementers with the up-to-date, credible, and reliable information they need for effective decision making and cost-effective operations. DOE's Weatherization Assistance Program Division has asked Oak Ridge National Laboratory (ORNL) to help design and conduct the evaluation.

Evaluation Goals

The national WAP evaluation is designed to accomplish seven goals:

- estimate the energy saved by the program -- one, two, and three years after participation;
- assess nonenergy impacts, such as comfort, safety, and housing affordability;
- assess program cost effectiveness;
- analyze factors that influence energy savings, nonenergy impacts, and cost effectiveness;
- describe the WAP network's capabilities and the innovative weatherization technologies it has employed;
- characterize the WAP-eligible population and the array of federal and non-federal funds that have been used to meet its weatherization needs; and
- identify promising WAP opportunities for the future.

These goals cover many significant issues. They focus on producing the most useful and practical information for program policy, management, and implementation that can be obtained for reasonable costs. Understanding how the program has operated to date, its capabilities, and its client makeup lays the groundwork for planning and operating more effectively in the future at all levels of program decision making. For example, evaluation results should help focus training and technical assistance efforts, identify the client groups that future program efforts should target more specifically, indicate what service delivery procedures are most effective for particular building types, characterize the groups of measures that should be considered in different climate zones, and provide estimates of the level of energy savings that can be expected per public dollar spent.

Each of the major goals is addressed in one or more of the five separate studies that are part of the overall evaluation. Three of these studies focus on principal WAP submarkets:

- single-family fuel-oil homes;
- single-family and small multifamily homes (using gas and electricity); and
- high-density multifamily buildings (all fuels).

The energy savings of homes heated primarily by wood, kerosene, and propane will be studied indirectly by comparing household and program data gathered for those submarkets with results of existing rigorous studies. This is because the additional information provided by collecting energy consumption data for those fuel types would be of limited value in a national study relative to the additional evaluation resources that would be required. For similar reasons, owner-occupied multifamily units and mobile homes will not be studied at the same level of statistical detail as other housing types. Only the largest submarkets (single-family homes, 2-4 unit rentals, and higher density apartment buildings) and the fuels used most widely on a national basis (i.e., gas, electricity, and fuel oil) will be examined using fuel consumption data for a sample of participants, because they will provide the highest impact insights for the available evaluation resources.

The remaining two studies investigate issues that are important for planning and assessing opportunities for innovation, new initiatives, and the incorporation of the DOE conservation program's new directions:

- a description of the WAP network's characteristics and innovations; and
- a profile of eligible clients and resources applied to weatherization beyond federally appropriated funds (leveraging).

The network characterization study will describe the current dimensions and features of the WAP network, thereby providing a frame of reference for shaping future initiatives, policies, and procedures and for understanding the past performance of the program. It will also provide a detailed look at the innovative practices and cutting-edge technologies used in the program. The profile of eligible clients and the WAP resource base will focus on the size and composition of the served and unserved portions of the WAP-eligible population, providing the information needed to assess our accomplishments and sharpen the program's focus on underserved populations. It will quantify and characterize the effectiveness of the WAP in attracting resources to the program over and above those provided by DOE appropriations.

Each of the three submarket studies (fuel oil, single-family, and high-density multifamily) will include a review of recent literature. These reviews will compile and analyze already available evaluation results on low-income weatherization programs operated both by States and utilities to help ensure that key issues are properly addressed by the national WAP evaluation. Each of the five studies is summarized below.

Fuel-Oil Study

The fuel-oil study will estimate the energy savings achieved by the WAP in single-family homes using fuel oil for space heating. The direct measurement portion of the study will be limited to the nine northeastern states and to homes weatherized in 1991 and 1992. Concurrent with direct measurement of fuel use we will collect and compare billing data from which we anticipate development of a methodology to broaden the study scope and findings to a larger sample of homes using fuel oil. (Space cooling is not prominent in this region and therefore will not be measured.) The study will assess the impacts of the WAP on health, safety, comfort, and housing affordability. The assessment of the health, safety, and comfort impacts will be more extensive in this submarket study than in the other studies because these homes will be instrumented and examined both before and after

weatherization. We will meter and gather indoor temperature data, test air-leakage rates, inspect space-heating systems, and gather other information from site visits and measurements conducted both before and after weatherization. Estimates of cost effectiveness of the WAP, parallel to those conducted in the other studies, will be generated for this housing submarket as well.

Single-family Study

The single-family study covers more households than do the other submarket studies because it focuses on the two most commonly used heating fuels (gas and electricity); two major building types addressed by the WAP (single-family homes and 2-4 unit multifamily dwellings); and both rental and owner-occupied housing. In addition, select data collection and analyses will be conducted on the remaining households in the weatherization client base. This study is being designed to provide estimates of program energy savings for homes weatherized in 1989, including savings one to three years after weatherization (directly measured for the gas and electricity study groups and indirectly estimated for the remaining households). In addition, this study will assess nonenergy impacts (e.g., health, comfort, and housing affordability), estimate cost effectiveness, and analyze factors influencing these outcomes. The study will be conducted in three phases.

The first phase will produce statistically rigorous estimates of program energy savings and cost effectiveness for the program as a whole and for three climate regions (very cold with little or no cooling, cold with moderate cooling, and hot with substantial cooling), two fuel types (gas and electricity), and two building types (single-family homes and 2-4 unit multifamily dwellings). Additional climate-region breakdowns (e.g., hot/humid vs. hot/arid climates) will be studied, but at lower levels of statistical rigor. Estimates of energy savings and cost effectiveness are planned for homes that heat with fuels other than gas and electricity, where reliable indirect energy savings estimates are available. A sample of homes weatherized by the WAP in 1989 will be the treatment group for this phase. A control group will be selected from WAP-eligible homes that have not participated in the program.

The second phase of the study involves the collection and analysis of on-site field data. Energy-savings results from phase one will be used to guide the selection of a subsample of treatment and control group homes for this phase. The on-site data will include furnace efficiency testing, blower door testing, a quality assessment, and an occupant interview. This information will be used to interpret the energy savings and benefit/cost results, particularly for homes with especially high or low savings, and to quantify the nonenergy impacts of the WAP.

The third phase of the single-family study will look at the persistence of energy savings over time. Three years of postretrofit energy consumption (1990-92) will be analyzed to assess long-term savings and the influence of household mobility.

High-Density Multifamily Study

A three-phased approach will be employed to provide both national and regional estimates of program energy savings, nonenergy impacts, and cost effectiveness of weatherizing multifamily buildings with 5 or more units. The influence of packages of retrofit measures and other contributing factors also will be assessed.

In the first phase, the nature and number of multifamily weatherization activities in 1989 will be documented, based on the sample of subgrantees surveyed in the single-family

study. The second phase will estimate the energy saved by a sample of units and whole buildings weatherized in PY 1989, based on an analysis of pre- and postretrofit fuel consumption. Cost-effectiveness and programmatic impacts on housing affordability also will be assessed. The third phase will focus on a subset of approximately 10 of these weatherized buildings. Billing and on-site data, and interviews with building owners, managers, and weatherization agencies will provide the necessary information for assessing the effectiveness of alternative service delivery approaches, packages of retrofit measures, and other determinants of impact and effectiveness.

Characterization of the WAP Network

This study will characterize the network of WAP grantees (i.e., State WAP agencies) and subgrantees (i.e., local WAP agencies). The features to be described include:

- the relationships among grantees, subgrantees, and other energy programs and service providers (e.g., brokering);
- the extent of external program relationships;
- the interest and availability of potential partners for future technology demonstrations and DOE initiatives;
- technical assistance, training, and client education skills;
- the range of expertise for diagnosing weatherization needs and installing retrofit measures;
- the ability of subgrantees to provide market information on client needs and to provide feedback on the performance of new technologies; and
- innovations and cutting-edge initiatives being implemented or field tested by the network.

A mail survey of grantees and subgrantees, with a telephone follow-up, will be the major source of data for this analysis. The resulting characterization of the WAP network will provide a valuable frame of reference for describing the WAP's capabilities and shaping future initiatives.

Profile of Eligible Clients and WAP Resource Expansion

This study will focus on the size and composition of the served and unserved portions of the WAP-eligible population and the expansion of WAP resources through leveraging from external sources. It will have two phases.

In the first phase, information will be collected from federal, State, and local agencies and from utilities and utility associations to estimate the numbers and types of eligible homes weatherized with funds provided by DOE/WAP (appropriations and oil overcharge funds), Health and Human Services/Low-Income Home Energy Assistance Program (LIHEAP), State programs, and utilities. Information on brokering and application of non-DOE resources by States and local agencies also will be compiled.

In the second phase, the 1990 Census of Population and the 1990 Residential Energy Consumption Survey (RECS) will be used to provide up-to-date information on the eligible population. Based on these data sources and the results from the first phase, the study will describe the number and type of clients who remain to be served.

By integrating the results of the three submarket studies with this profile, estimates can be made of the energy-savings potential of different socio-demographic segments of the

remaining eligible population. Quantifying the cost-effective, energy-savings potential of low-income weatherization for the nation as a whole will be a key subject of the evaluation's final, comprehensive report. The schedule for each of the five studies and the final comprehensive report is shown in Fig. A-1.

The Working Groups

Two working groups -- a methodology group and a planning and implementation group -- will participate in the evaluation. These groups will be a major source of input to DOE on technical issues, project focus, and application of results. Their advice will ensure that the results of the evaluation are useful and valid and that they reflect the experience and knowledge of evaluation and weatherization experts. In addition, working groups will play a key role in the technology transfer process by helping to make the evaluation methodologies, data, and results available to and understood by users.

The Technology Transfer Strategy

This evaluation plan already has undergone an extensive consultative development process. Program and evaluation experts developed an array of study options; policy makers defined limits, needs, and study parameters; principal stakeholder groups provided additional input; and program and evaluation experts iteratively integrated this input into the proposed evaluation plan. Thus, the technology transfer process has already begun because the evaluation has been designed to reflect the needs of its intended users, including:

- policy makers (e.g., Congress, Governors, State legislatures, DOE, and the Office of Management and Budget);
- program managers and implementers (e.g., DOE program officials, State program directors, and local program implementers);
- utilities and Public Utility Commissions; and
- various business, client, and interest groups.

It is anticipated that the evaluation's methodology will evolve as its constituents' needs change, preliminary results emerge, and opportunities arise. The evaluation's goals and the major features of its five studies are not likely to change, but the methodological details of each study may, in the end, differ from what is described here.

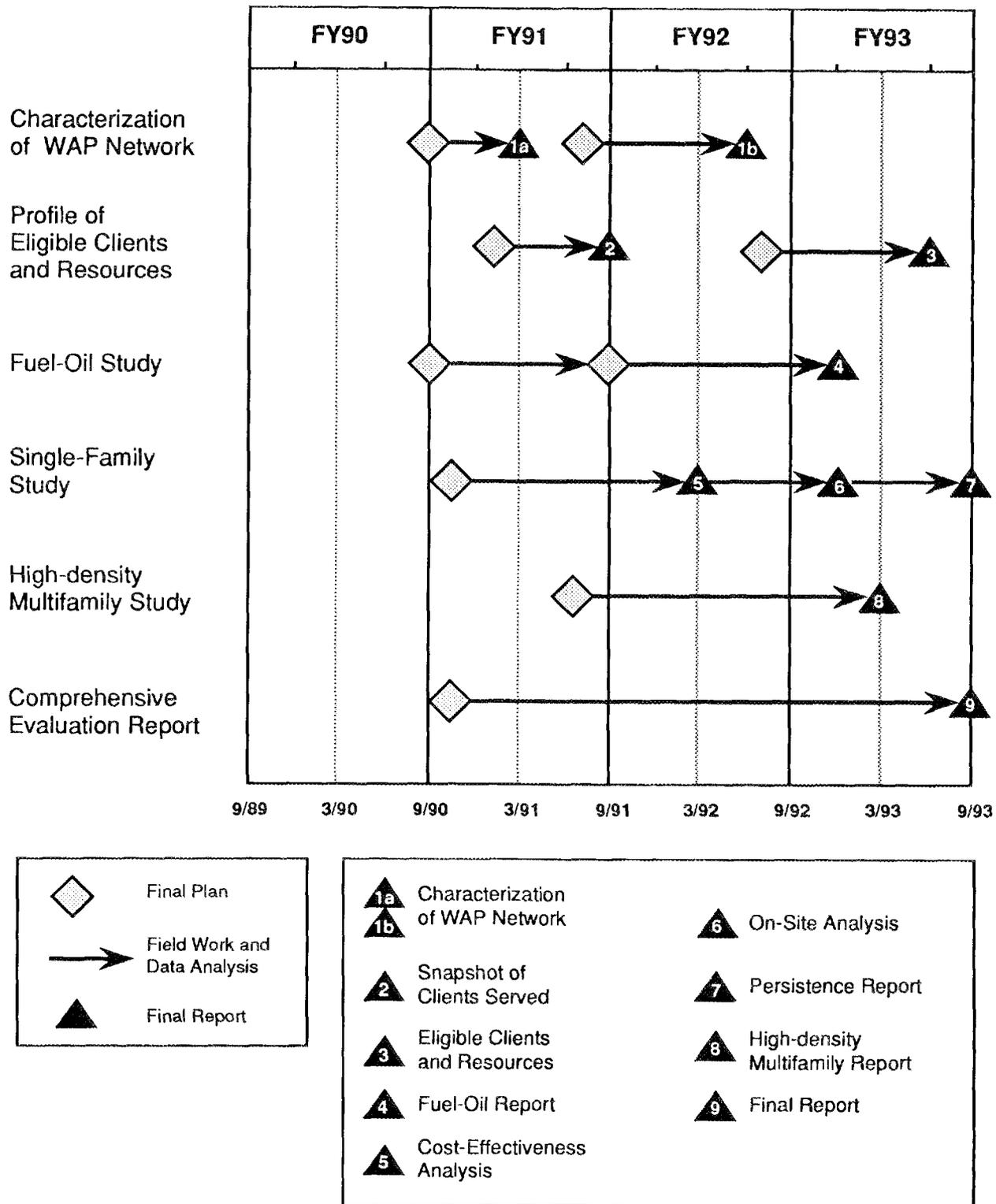


Fig. A-1. Schedule of studies and deliverables.

ABSTRACT

The most recent national evaluation of the impacts of the U. S. Department of Energy (DOE)'s Weatherization Assistance Program (WAP) was completed in 1984 based on consumption data for households weatherized in 1981. WAP regulations and operations have changed substantially over the last decade, and new opportunities are on the horizon. The U.S. Department of Energy (DOE) recognizes the need for a more current national level evaluation of the program and has developed a plan for conducting the evaluation with the support of the Oak Ridge National Laboratory (ORNL).

The national WAP evaluation as currently proposed has seven major goals:

- estimate the energy saved by the program -- one, two, and three years after participation;
- assess nonenergy impacts, such as comfort, safety, and housing affordability;
- assess program cost effectiveness;
- analyze factors which influence energy savings, nonenergy impacts, and cost effectiveness;
- describe the WAP network's capabilities and the innovative weatherization technologies and procedures it has employed;
- characterize the WAP-eligible population and the federal and non-federal funds that have been used to meet its weatherization needs; and
- identify promising WAP opportunities for the future.

The data collection, analyses, and reports are to be completed in phases between 1991 and 1993. The evaluation methodologies vary by fuel type, housing type, and climate zone. For gas and electrically heated/cooled housing units (both single-family and multifamily), the evaluation will focus on weatherization jobs completed in 1989. The analysis of energy savings and cost effectiveness will be based primarily on weather-normalized, retrospective utility billing records (collected for pre- and postretrofit years). For fuel oil heated homes, analysis will be based upon pre- and post-retrofit metered consumption and temperature data collected from homes scheduled for weatherization in 1991 and 1992. The fuel oil study will cover the nine states where fuel oil is most prevalent (New England and New York, New Jersey, and Pennsylvania).

Two supplemental studies will investigate issues that are important for planning and assessing new opportunities for innovation and new initiatives. They will characterize the WAP network of State and local agencies, will profile eligible clients, and will describe the resources used to meet their weatherization needs.

Two working groups, a methodology group and a planning and implementation group, will be part of the project structure. These groups will be a major source of feedback on technical issues, project focus, and applicability of results.

EVALUATION PLAN FOR THE WEATHERIZATION ASSISTANCE PROGRAM

1. INTRODUCTION

The Weatherization Assistance Program (WAP) was established in 1976 by Public Law 94-385 to decrease national energy consumption and to reduce the impact of high fuel costs on low-income households, particularly those of the elderly and the handicapped. In its initial years, the program was managed by the Community Services Administration. In 1979, the U.S. Department of Energy (DOE) became the sole federal agency responsible for operating a low-income weatherization assistance program.

The program has evolved significantly over the past decade from one that emphasized temporary measures and volunteer labor to one in which trained, professional staff install permanent measures. The program has increasingly emphasized training, technical assistance, and client education. WAP regulations and operations have changed substantially, and the program has incorporated new funding sources, management principles, audit procedures, and energy-efficiency measures. In addition, new initiatives, incentives, opportunities, methods, and technologies are on the horizon.

The most recent national evaluation of the energy savings of the WAP was completed in 1984 based on consumption data for households weatherized in 1981 (Peabody, 1984). Since then, many program features have been studied in isolation or at a local level; however, no recent work has assessed their integrated, national program impact or potential. As a result, a more timely and comprehensive national level evaluation of the WAP is needed to provide policy makers and program implementers with the up-to-date, credible, and reliable information they need for effective decision making and cost-effective operations. DOE's Weatherization Assistance Programs Division has asked Oak Ridge National Laboratory (ORNL) to help design and conduct such an evaluation.

The national WAP evaluation is designed to accomplish seven goals:

- estimate the energy saved by the program -- one, two, and three years after participation;

- assess nonenergy impacts such as comfort, safety, and housing affordability;
- assess program cost effectiveness;
- analyze factors that influence energy savings, nonenergy impacts, and cost effectiveness;
- describe the WAP network's capabilities and the innovative weatherization technologies and practices it has employed;
- characterize the WAP-eligible population and the array of federal and non-federal funds that have been used to meet its weatherization needs; and
- identify promising WAP opportunities for the future.

These goals encompass many significant issues. They focus on producing the most useful and practical information for program policy, management, and implementation that can be obtained for reasonable costs. Understanding distinctions about how the program has operated to date, its capabilities, and its client makeup, lays the groundwork for planning and operating more effectively in the future at all levels of program decision making. For example, evaluation results should help focus training and technical assistance efforts, identify the client groups that future program efforts should target more specifically, indicate what service delivery procedures are most effective for particular building types, characterize the groups of measures (e.g., insulation, storm windows and doors, furnace) that should be considered in different climate zones, and provide estimates of the level of energy savings that can be expected per public dollar spent.

Each of the major goals is addressed in one or more of the five separate studies that are part of the overall evaluation. Three of these studies focus on principal WAP submarkets:

- single-family fuel-oil homes;
- single-family and small multifamily homes with gas or electric space heat; and
- high-density multifamily buildings (electricity, natural gas, and fuel oil).

The energy savings of homes heated primarily by wood, kerosene, and propane will be studied indirectly, by comparing household and program data we gather in those submarkets with results of existing rigorous studies. This is because the additional information provided by collecting energy consumption data for those fuel types would be of limited value in a national

study relative to the additional evaluation resources that would be required. For similar reasons, owner-occupied multifamily units and mobile homes will not be studied at the same level of statistical detail as will other housing types. Only the largest submarkets (single-family homes, 2-4 unit rentals, and higher density apartment buildings) and the fuels used most widely on a national basis (i.e., gas, electricity, and fuel oil) will be examined using fuel consumption data for a sample of participants, because this method will provide the most significant insights for the available evaluation resources.

The remaining two studies investigate issues that are important for planning and assessing opportunities for innovation, new initiatives, and the incorporation of the DOE conservation program's new directions:

- a description of the WAP network's characteristics and innovations; and
- a profile of eligible clients and resources applied to weatherization beyond federally appropriated funds (leveraging).

The network characterization study will describe the current dimensions and features of the WAP network of State and local agencies, thereby providing a frame of reference for shaping future initiatives, policies, and procedures and for understanding the past performance of the program. It also will provide a detailed look at the innovative practices and cutting-edge technologies used in the program. The profile of eligible clients and the WAP resource base will focus on the size and composition of the served and unserved portions of the WAP-eligible population -- information needed to assess our accomplishments and improve the program's focus on underserved populations. It will quantify and characterize the effectiveness of the WAP in attracting resources to the program other than those provided by DOE appropriations.

The relationships of each of these five studies to the evaluation's goals are shown in Fig. 1. The national evaluation goals are discussed in more detail in Section 2 of this evaluation plan. In Section 3, the goals and objectives, methods, and outcomes of each of the three principal submarket studies are described. The two related studies are described in Section 4. Finally, in Section 5 the schedule of deliverables is presented, the working groups are discussed, and the proposed technology transfer activities are described.

Evaluation Goals	Principal Submarket Studies:			Related Studies:	
	Fuel-Oil Study	Single-family Study	High-density Multifamily Study	WAP Network Characterization	Eligible Client Profile
Estimate Energy Savings	●	●	●		
Assess Nonenergy Impacts	●	●	●		
Assess Cost Effectiveness	●	●	●		
Analyze Contributing Factors	●	●	●	○	○
Characterize Eligible Population	○	○	○		●
Describe WAP Network Capabilities	○	○	○	●	○
Define Promising Opportunities	○	●	●	●	●

○ = minor focus ● = major focus

Fig. 1. The relationship of the evaluation goals to the five studies.

2. EVALUATION GOALS

2.1 Estimating Energy Savings

A key goal of this evaluation is to estimate the energy saved by the WAP. Annual savings will be estimated for gas and electrically heated homes weatherized in 1989 and for fuel-oil homes weatherized in 1991 and 1992. Results for three years of energy savings, 1990-92, will be analyzed in the single-family study to estimate the persistence or durability of savings. Estimates of the total amount of energy saved by the program and the potential for even greater savings can be developed from these annual savings estimates. In addition, the estimates of national energy savings for 1989 and for fuel-oil homes weatherized in 1991-92 will be compared to the savings of homes weatherized in 1981 to assess the impact of program changes.

Estimates of energy savings are key to accomplishing several goals of the evaluation, such as analyzing cost effectiveness (Sec. 2.3) and analyzing factors influencing savings and cost effectiveness (Sec. 2.4). The assessment of nonenergy impacts (e.g., comfort, safety, and housing affordability) also is closely related to the estimation of energy savings because improvements in the affordability of housing and in comfort and safety may be a direct result of improvements in energy efficiency.

Because estimating energy savings is a key goal and is essential to accomplishing several other goals of the evaluation, it will be addressed in each of the three major submarket studies. The fuel-oil study will estimate savings for single-family buildings in the Northeast. The single-family study will estimate energy savings for three years following weatherization in 1989 for the U.S. as a whole (excluding Alaska and Hawaii), for three climate regions, and for both single-family and low-density (2-4 units) multifamily buildings. The high-density (5 units or more) multifamily study will assess the energy savings achieved in larger buildings.

The methodologies used for estimating energy savings will differ by building and fuel type (Fig. 2). Fuel-oil savings will be estimated with three months of pre-retrofit heating season data and three months of postretrofit heating season data for homes weatherized in January of 1991 and 1992. On-site metered data will be collected because dealer records can be unreliable for fuel-oil analysis. For gas and electrically heated single-family and 2-4 unit

Fuel-Oil Study

- Homes weatherized in 1991 and 1992
- Sample of approximately 250 homes weatherized by 25 to 50 subgrantees
- Sample of approximately 150 control group homes from the same subgrantees
- Random assignment to treatment/control groups
- Sample stratification by State
- Furnace submetering: pre- and postretrofit
- Indoor and outdoor temperature monitoring
- On-site visits and diagnostics
- Possible expansion of sample size through collection of data from fuel-oil dealers
- Single-family buildings only
- Nine northeastern States

Single-Family Study

- Buildings weatherized in 1989
- Sample of approximately 20,000 dwelling units weatherized by 400 to 450 subgrantees
- Control group of approximately 10,000 eligible dwelling units
- Sample stratification by climate zone and subgrantee size
- Supplemental sample of exemplary subgrantees and subgrantees with cooling programs
- Single-family and 2-4 unit multifamily buildings
- Retrospective billing data from utilities
- On-site visits to a subsample of homes
- Analysis of the persistence of savings -- one to three years after weatherization
- Secondary analysis of energy savings for fuels other than gas and electricity

High-Density Multifamily Study

- Buildings weatherized in 1989
- Control group of similar buildings
- Sample of units and buildings stratified by climate zone
- Multifamily buildings with 5 or more units
- Retrospective billing data from utilities
- Data collection from building owners, managers, and weatherization agencies
- Different evaluation methods for master vs. individually metered buildings

Fig. 2. Approaches of different energy-savings analyses.

multifamily homes, analysis will be based on utility billing records (collected for pre- and postretrofit years) and the Princeton Scorekeeping Method (PRISM). The high-density multifamily study will use a variety of methods including billing history analysis and simulation techniques.

Each of these studies (fuel-oil, single-family, and high-density multifamily) will include a review of recent literature. These reviews will compile and analyze already available results of evaluations of low-income weatherization programs operated both by States and utilities. Because careful literature reviews will help ensure that key issues are properly addressed by the national WAP evaluation, this task will begin before data collection is initiated. Findings from these reviews will be compared with the results of the three major submarket studies. For the single-family study, the literature review will gather information that can be used for a secondary analysis of energy savings in dwellings that heat with wood, propane, or kerosene, and in mobile homes.

2.2 Assessing Nonenergy Impacts

The second goal of the evaluation is to assess nonenergy impacts of the WAP. The following nonenergy impacts will be explored:

- enabling low-income families to spend a smaller percentage of their income on energy;
- improving thermal comfort and promoting healthier and safer homes, especially for elderly and handicapped individuals who often have special health needs;
- reducing the environmental impacts of energy production and consumption;
- stimulating local economies by providing jobs and commerce in weatherization materials (i.e., indirect economic benefits);
- increasing the availability of affordable housing; and
- reducing utility arrearages, nonpayments, and fuel cut-offs.

On-site occupant surveys and dwelling unit inspections will play a key role in these assessments. In addition, data from secondary sources will be gathered to assess some of the indirect environmental and economic impacts of the WAP.

The 1976 legislation establishing the WAP stated the importance of reducing the impact of high fuel costs on low-income households, particularly

those of the elderly and handicapped. An assessment of program-induced improvements in the affordability of heating and cooling will be conducted by combining the fuel cost data (collected in all three studies) with information on household income (collected from local agencies or occupant surveys). If information on rent and mortgage payments is available, it will be possible to estimate the impact of the WAP on the percent of household income spent on housing costs. The result should be a thorough description of the energy burden of low-income households and an assessment of the impact of the program on this burden. Fuel-oil and utility billing data also will be used, where possible, to examine the impact of low-income weatherization on fuel assistance payments, fuel cut-offs and utility customer arrearages and nonpayments.

Impacts on safety, health, and comfort also will be assessed. Safety and health will be evaluated by collecting data on the incidence of unsafe and unhealthy conditions (such as cracked heat exchangers, unvented gas-fired water heaters, and carbon monoxide problems caused by incomplete fossil fuel combustion) and remedial actions recommended or taken during weatherization. Pre- and postretrofit safety conditions will be compared in the fuel-oil study; the single-family study will compare conditions in weatherized homes with those of a control group.

Comfort will be assessed through occupant surveying and on-site inspections and monitoring. Indoor temperatures will be monitored in the fuel-oil study to identify changes in indoor temperatures after weatherization and to address the issue of "take-back". Low-income households may take back weatherization efficiency improvements in the form of increased comfort and more heated or cooled living space (Dinan and Trumble, 1989). Therefore, quantitative data on indoor temperature and the amount of space that is heated or cooled will help interpret the energy savings estimates and identify the full range of program benefits. Blower-door test results from both the fuel-oil and single-family studies will provide quantitative estimates of the program's ability to reduce the air leakage of homes. Impacts on air leakage areas will be assessed by comparing blower-door testing results before vs. after weatherization (in the fuel-oil study) and in weatherized vs. control group homes (in the single-family study).

Energy savings estimates will be translated into environmental impacts by using the results of existing research on the fuel-specific environmental

externalities of power production and consumption. Some of the indirect economic costs and benefits of the WAP will be estimated by applying an input/output methodology similar to the one being developed for the State of New York's Weatherization Assistance Program. The impact of weatherization on the longevity of affordable housing will be investigated by comparing levels of investment in rehabilitation and rates of demolition for weatherized vs. control group dwelling units.

Finally, the impact of weatherization on utility arrearages, nonpayments, and cut-offs will be explored in the single-family, high-density multifamily, and fuel-oil studies.

2.3 Analyzing Cost Effectiveness

Analysis of cost effectiveness will combine the assessment of energy and nonenergy impacts with program cost data to produce cost-effectiveness indicators such as benefit/cost ratios, estimates of the cost of conserved energy, and net present value. Cost data per job will be collected (where available) at the subgrantee and State levels for the following categories: direct material costs, direct labor costs, program support, and administrative costs. The result will be an assessment of energy savings (both percent and absolute) vs. investment on a dwelling-by-dwelling basis. To the extent that nonenergy impacts can be measured in monetary terms, these will be incorporated into the cost-effectiveness analysis. A variety of assumptions concerning future fuel prices, retrofit lifetimes, and discount rates must be made for this analysis. Each of the three submarket studies will generate cost-effectiveness measures, and these measures will be produced for each of the major climate regions, housing types, and fuel types.

2.4 Analyzing Factors That Influence Savings and Cost Effectiveness

The fourth goal of the evaluation is to analyze factors that may cause the energy savings and cost effectiveness of weatherization to vary across homes. This issue will be investigated by the single-family, fuel-oil, and high-density multifamily studies, using a variety of methods. Each study will attempt to identify the best opportunities for achieving the most cost-effective results for the weatherization dollars expended.

There are three main approaches to the analysis: First, individual factors will be examined as potential determinants of energy savings and cost effectiveness, including:

- regional differences: e.g., fuel prices, cost of living, and climate (heating and cooling degree days);
- dwelling unit characteristics prior to weatherization: e.g., levels of insulation, energy consumption, and age of unit;
- occupant characteristics: e.g., thermostat setpoint temperatures and household demographics;
- packages of retrofit measures installed: e.g., the inclusion of furnace retrofits and the extensiveness of house tightening and insulating;
- service delivery differences: e.g., audit procedures, contractors vs. in-house crews, and client education offered;
- methods of client selection, outreach, and marketing: e.g., identifying high priority clients (such as the elderly or high energy users) vs. selecting at random from waiting lists; and
- use of sophisticated diagnostic procedures: e.g., blower doors and infrared scanners.

These explanatory factors will be cross-tabulated with energy savings and cost-effectiveness measures to test their effects.

The second approach to this analysis will use multivariate statistical models to estimate the independent influence of single variables, controlling for the influence of other factors. Results can be used to compare the importance of variables in determining the effectiveness of the program. For example, regression results might show that energy savings are more closely related to client selection methods than to audit procedures.

Energy analysis software packages will be used in the third approach to simulate energy savings. The simulated energy savings will be compared with measured savings for a subset of homes to identify any systematic discrepancies and to estimate the impacts of different groups of retrofit measures (e.g., insulation, storm windows and doors, and furnace measures). Comparisons between simulated and actual savings can provide several types of useful information that will assist in the interpretation and explanation of results. For example, if homes with certain types of weatherization measures consistently save less than predicted while homes without those measures save close to predicted values, assumptions about the value of the weatherization measures should be reexamined, as should the assumptions on

which the predictions were based. A different pattern that has been observed in studies of furnace replacement, for example, is that average predictions may agree with average savings, but individual houses may save much more or less than predicted. A case-by-case analysis of discrepancies between predicted and actual savings may identify significant interactions among occupant behavior, dwelling unit characteristics, groups of measures, and service delivery techniques.

2.5 Describing the WAP Network's Characteristics

Another goal is to describe the WAP network of State and local agencies and its ability to broker, demonstrate, evaluate, and accelerate the market penetration of new energy-efficient, cost-effective building technologies. The network's capabilities will be characterized in several areas. The ability of the subgrantee network to attract resources for low-income weatherization from federal, State, utility and other sources outside of the WAP will be described. In addition to quantifying these outside funding contributions, this study will describe the extent of cooperation among organizations in shared outreach efforts (i.e., client identification and recruitment) and shared resources (e.g., equipment, staff time, and data). The availability of technical assistance, training, and expertise also will be documented. Demonstrated network capabilities to date in delivering less traditional, innovative, or cutting-edge weatherization technologies such as compact fluorescent light bulbs, energy-efficient air conditioning, and high-density wall insulation -- sometimes with outside funds -- will be examined as well. Finally, the possible roles of subgrantees as sources of market information and feedback on the performance of new technologies will be assessed.

2.6 Characterizing the WAP-Eligible Population and WAP Resource Expansion

For planning, DOE requires reliable estimates of the number of income-eligible households that have been weatherized and the number remaining to be served. These estimates will come from a separate study (the eligible client profile and resource expansion study) that will be conducted in phases over the three-year evaluation period. This study will characterize the weatherized and the remaining population in terms of housing type, ownership status, weatherization provider, funding source, and program-related demographics

(e.g., elderly or handicapped). This information will be particularly valuable when combined with information on factors influencing energy savings and cost effectiveness (from the three submarket studies). In combination, these studies will offer insights about how to best serve the remaining households and about the savings potential of the different components of this unserved population.

2.7 Identifying Promising Opportunities

To be fully successful, the national WAP evaluation must provide a window to the future -- a vision of those cutting-edge technologies and state-of-the-art practices that may enable improvements in the program's future performance. It is not sufficient simply to describe the program's recent accomplishments because these may become vestiges within a matter of years.

Several evaluation activities will facilitate the kind of forward thinking that is needed. First, both the single-family and high-density multifamily studies will examine the activities and impacts of innovative and promising programs that are nominated by experts for inclusion in the evaluation. The energy savings and cost effectiveness of the approaches used by these programs will be estimated to confirm (or refute) the claim of superior performance. Superior approaches also may be identified among the randomly sampled programs that comprise the bulk of the data for the single-family and high-density multifamily studies. Together, these exemplary programs offer models for future replication. It is likely that there will be several different types of exemplary program models, since the effectiveness of any one approach typically depends upon the context in which it operates. Detailed information will be provided on a selection of programs representing exemplary program types.

All of the studies will contribute information on advanced technologies and practices. These will result in a compendium of innovative ideas and an assessment of their current levels of use and effectiveness. The compendium can be used as a guide to technologies and practices that may warrant monitoring, evaluation, and possibly promotion in the years ahead.

2.8 Secondary Outcomes

The national WAP evaluation will undoubtedly generate information on topics that are important to the management of the WAP but that are not

included in the primary goals of the evaluation and do not require additional funding. Some of these likely secondary outcomes include:

- a better understanding of low-income occupant turnover rates and their effects on energy savings;
- the identification of information gaps that should be addressed by future research;
- improvements in weatherization program evaluation methods that can make future evaluations more useful;
- a model evaluation plan that can be used by States as a starting point for their own evaluations; and
- sharing of data from the national WAP evaluation with public agencies or utilities interested in conducting additional analyses.

In addition, there probably will be a number of unanticipated benefits from the evaluation.

3. PRINCIPAL SUBMARKET STUDIES AND THEIR METHODOLOGIES

The principal submarket studies -- fuel-oil, single-family, and high-density multifamily -- are designed to evaluate the WAP as applied to the program's largest WAP submarkets. Among all U.S. low-income households (with incomes less than 125% of the poverty level) the main heating fuels are fuel oil (9.5%), natural gas (55%), and electricity (16.5%). Thus, 81% of low-income households use one of these three fuels for heating (Energy Information Administration, 1989). Use of fuel oil for heating is concentrated in the Northeast. In the Northeast about 40% of all households heat with fuel oil, and 70% of all U.S. households that use fuel oil as their main heating fuel are located here. Therefore, the fuel-oil study, which requires primary collection of fuel consumption data, will be conducted only in the Northeast. Use of electricity for heating is concentrated in the Pacific Northwest and the Southeast. Natural gas is used by over 40% of households in each of the four Census regions and by 75% of the households in the Midwest (Energy Information Administration, 1989). The single-family study, which is nationwide in its coverage, will collect data on both electricity and natural gas in roughly the proportions that are typical of each region.

The building types for which primary data will be gathered to generate specific energy-savings estimates -- single-family homes, 2-4 unit multifamily dwellings, and high-density (5 units or more) rentals -- include 93% of WAP-eligible households. Only 7% of eligible households live in mobile homes or owner-occupied high-density (5 units or more) multifamily buildings (Economic Opportunity Research Institute, Inc., 1986). Energy-savings estimates based on the primary data collected in the submarket studies therefore will not be possible for these two specific building types.

3.1 Fuel-Oil Study

3.1.1 Goals and Objectives

The fuel-oil study will be limited to single-family dwelling units (owned and rented) located in nine States in the northeast Census region. These nine States include about 55% of all U.S. households (single-family and multifamily) with incomes below 125% of the poverty level that use fuel oil (and kerosene) (Energy Information Administration, 1990).

The fuel-oil study will estimate the energy savings achieved by the Weatherization Assistance Program in single-family homes using fuel oil for space heating. The direct measurement portion of the study will be limited to homes weatherized in 1991 and 1992. Concurrent with direct measurement of fuel use, we will collect and compare fuel-oil delivery data from which we anticipate development of a methodology to broaden the study scope and findings to a larger sample of homes using fuel oil. Space cooling is not prominent in this region and therefore will not be measured. The study will assess the impacts of the WAP on health, safety, comfort, and housing affordability. The assessment of health, safety, and comfort impacts will be more extensive in this submarket study than in the others because the sampled homes will be instrumented and studied both before and after weatherization. We will meter and gather indoor temperature data, test air-leakage rates, inspect space-heating systems, and gather other information from site visits and measurements conducted both before and after weatherization. Estimates of cost effectiveness of the WAP, parallel to those conducted in the other studies, will be generated for this housing submarket as well.

Factors that may cause savings and cost-effectiveness to vary will also be assessed to the extent possible. However, this assessment may be more limited than that performed in the single-family study primarily because many factors (e.g., audit procedures, the inclusion or exclusion of furnace retrofits, and other service delivery differences) may not vary sufficiently among the limited number of subgrantees to be used in the fuel-oil study. In addition, these factors may be so highly inter-correlated that it is impossible to disentangle their independent effects given the limited sample of weatherized homes.

3.1.2 Methodology

Because fuel-oil delivery records can be unreliable and often are unavailable, on-site metered data will be collected for this study. The reliability and availability of fuel-oil delivery records will be assessed by collecting all available delivery records for the study homes. Energy consumption and savings determined from the delivery records will be compared with metered results to assess the extent of agreement. If the agreement is close and sufficient resources exist, a methodology will be

developed and implemented to improve the accuracy of this study's results by enlarging its sample through the analysis of delivery data from fuel-oil dealers. Dealers also will be relied upon to provide fuel-oil price data.

Four hundred houses located in the service territories of 50 WAP subgrantees will be monitored during the study. The experimental design involves split-winter testing during two different winters. Half of the 400 houses will be sampled from 25 subgrantees and will be monitored during the 1990-91 winter. The treatment group portion of these will be weatherized in January 1991, and the control group portion will be weatherized at the end of the winter. The remaining houses will be sampled from some combination of the same subgrantees and from some different subgrantees. They will be monitored during the 1991-92 winter, with weatherization occurring in January 1992 (for the treatment group), or at the end of the winter (for the control group).

This design was selected, in part, because it requires the control group homes to wait no longer than six to eight months before they are weatherized (Fig. 3). Due to the inconvenience of on-site monitoring, all 400 participating homes will receive a small gratuity. Control group households will receive an additional small gratuity at the end of the experiment to compensate for the delay in weatherizing their homes.

Preliminary analysis indicates that the mean savings of the weatherized houses will be estimated within an error relative to the mean of approximately 25% at a confidence interval of 90%. This assumes a 25% attrition rate and a standard deviation 1.5 times greater than the mean. Cluster sampling using States as a stratification variable will be used to ensure a representative sample.

Space-heating fuel consumption and indoor and outdoor temperatures will be recorded hourly and will be collected weekly for all houses during the winter test periods. The following additional information will be collected for all of the homes:

- occupant characteristics;
- dwelling unit characteristics;
- house air-leakage rates (measured using a blower door) for pre- and postretrofit periods; and
- space-heating system safety information including steady-state efficiencies during the pre- and postretrofit periods.

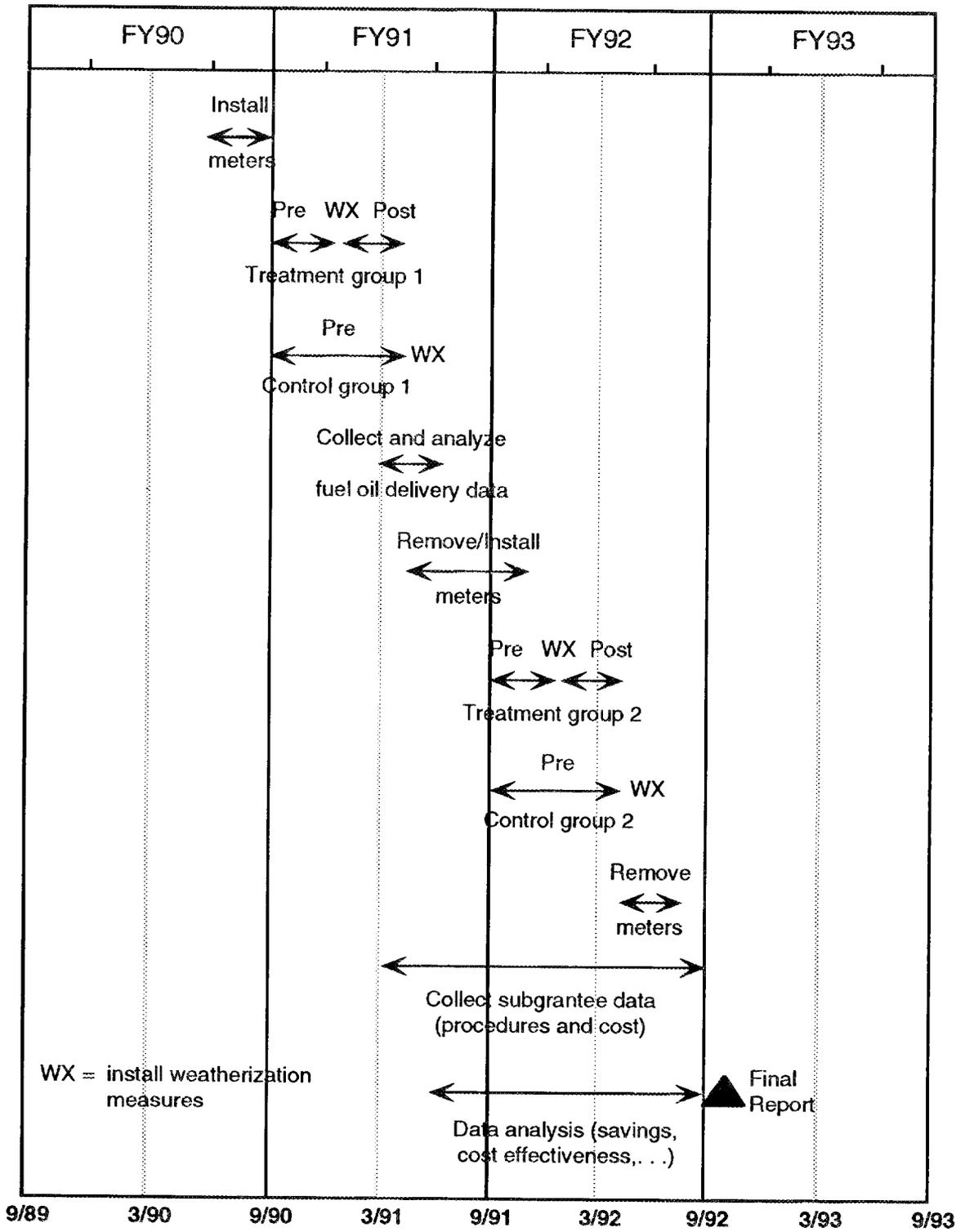


Fig. 3. Timetable of the fuel-oil study.

Information on subgrantee practices such as client recruitment, selection, and education will be collected along with the measures installed in the study houses and the weatherization costs. As in the other submarket studies, some of this information will be quite detailed, including data on specific products used, the use of blower doors to guide air-leakage control efforts, and whether the heating distribution system was balanced or the ducts sealed.

The study will rely on the cooperation of the local subgrantees who will identify houses and help install monitoring instruments. Subgrantees also will provide information on their program's operation, the measures installed, and weatherization costs. To maximize consistency and the ability to integrate findings, the protocol used to collect this information will be similar to the protocols used in the other two submarket studies. An energy consulting firm will be contracted to install and maintain instrumentation and collect all field data.

3.1.3 Outcomes

The study's final report will describe the results of the evaluation and will address each of the study's four goals. First, it will provide a region-wide estimate of the fuel oil saved by the WAP in the Northeast during 1991 and 1992. Second, nonenergy impacts will be assessed, including health, safety, comfort, and housing affordability. Third, cost effectiveness of the WAP, as it has operated in this submarket, will be estimated. Finally, factors influencing the program's performance will be identified. When combined with the results of the eligible client profile, these findings will enable an assessment of the potential energy savings available to the WAP in the fuel-oil submarket. It also will identify fuel-oil market segments that future program efforts should target and will provide insights into how to best serve these segments.

3.2 The Single-Family Study

3.2.1 Goals and Objectives

The single-family study covers more households than the other submarket studies because it focuses on two major building types (single-family homes and 2-4 unit multifamily dwellings), the two most commonly used heating fuels (gas and electricity), and select data collection and analyses on the remaining households in the weatherization client base (i.e., mobile homes and homes heated primarily by kerosene). It is being designed to

provide estimates of program energy savings for homes weatherized in 1989, including savings one to three years after weatherization (directly measured for gas and electrically heated homes and indirectly estimated for the remaining households). In addition, this study will assess nonenergy impacts, cost effectiveness of the program, and factors influencing the program's outcomes.

3.2.2 Methodology

This study will be conducted in three phases, as illustrated in Fig. 4. The **first phase** will produce statistically rigorous estimates of program energy savings and cost effectiveness for the program as a whole and for three climate regions (Fig. 5), two fuel types (gas and electricity), and two building types (single-family homes and 2-4 unit multifamily buildings). We plan to estimate energy savings and cost effectiveness for remaining homes, where reliable indirect energy savings estimates are available. The climate regions shown in Fig. 5 are an approximation of the three climate regions to be analyzed, based on the closest State boundaries that reflect the predominant statewide heating and cooling degree day conditions. Local climates may cause particular subgrantees and their weatherized homes to be classified differently from the State in which they are originally identified. The sample is being designed so that program-induced energy savings for each of the three climate regions can be estimated with a relative error of 10% and a 90% confidence level. More detailed climate regions (e.g., hot/humid and hot/arrid) also will be examined, but at less rigorous levels of precision.

A sample of homes weatherized by the WAP in Program Year (PY) 1989 (typically April 1, 1989 to March 31, 1990) will be the treatment group for this phase. A control group will be selected from WAP-eligible homes that have not participated in the program. These homes will be sampled from waiting lists of income-eligible households.

Both gross savings and net savings will be presented. Gross savings are based on the weather-adjusted results for the treatment group alone. Net savings are obtained by comparing changes in control group consumption with those of the treatment group. Because control group consumption may increase or decrease during the study period, net savings may be either higher or lower than gross savings. This phase also will contain a preliminary

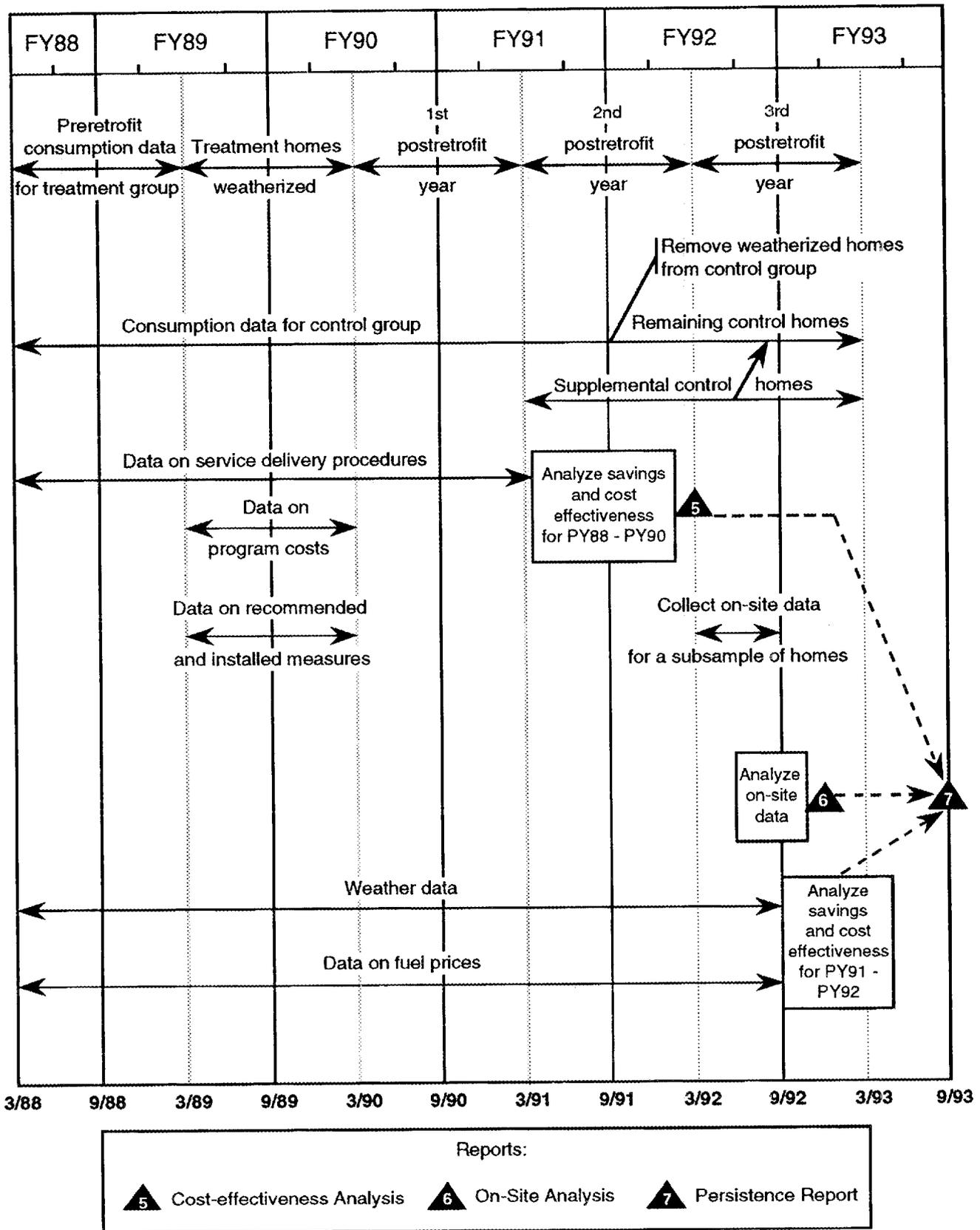


Fig. 4. Timetable of the single-family study.

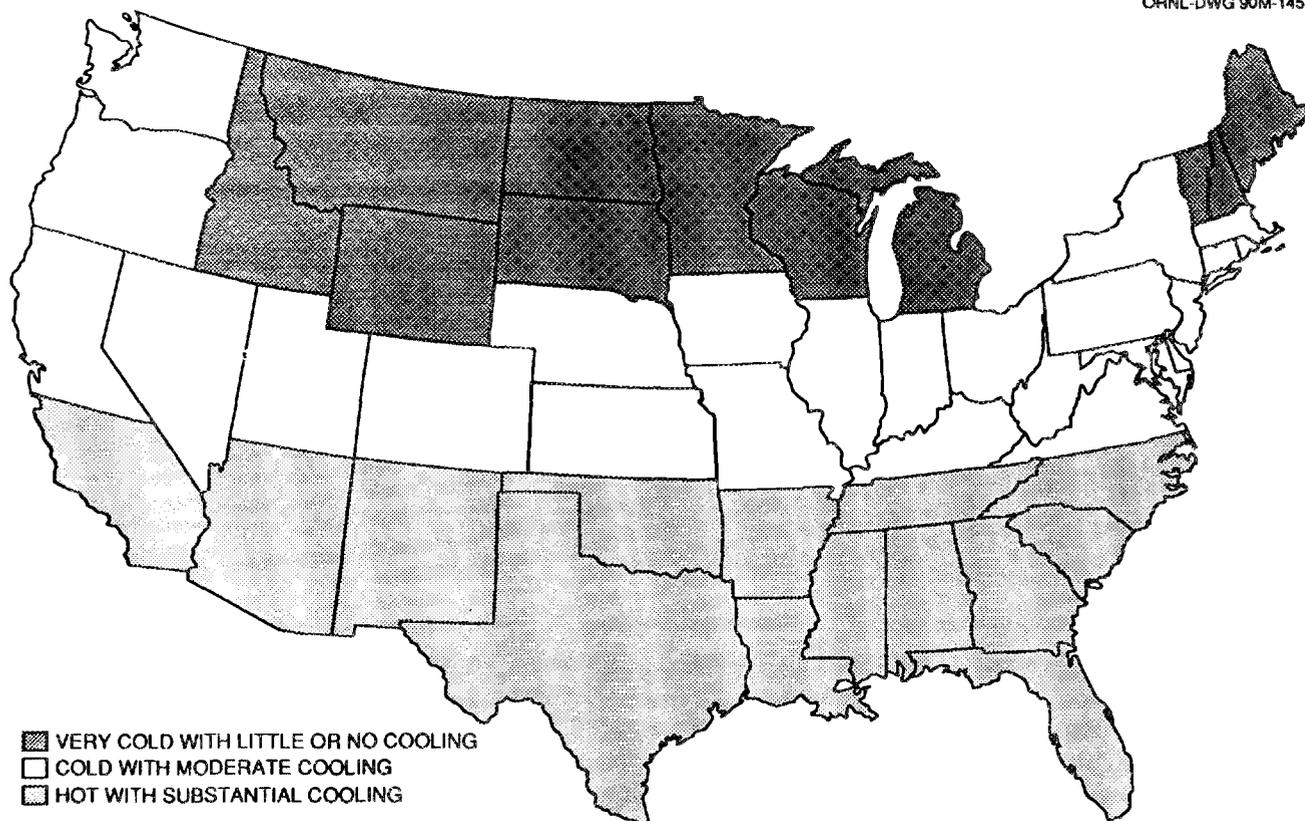


Fig. 5. Climate regions for the national WAP evaluation.

analysis of factors that explain variations in savings and cost effectiveness, and an examination of some nonenergy impacts such as housing affordability.

The process of designing the sampling frame and determining the necessary sample sizes for the first phase of this study is underway. Stratification by climate region and subgrantee size (in number of housing units weatherized in PY 1989) is planned. Subgrantees will first be sampled; then housing units will be selected from the sampled subgrantees.

Preliminary analysis, based on formulas for the selection of a simple random sample from the population of all households weatherized in a study year, suggests that approximately 20,000 treatment households and about 10,000 control group households should be selected from a sample of 400 to 450 subgrantees. With typical levels of sample attrition, about 6,500 treatment households and 4,000 control group households that heat with natural gas or electricity will remain in the final sample used for estimating energy savings. Housing units located in high-density multifamily buildings will be dropped from this study's final sample. In addition, homes will be

dropped that have incomplete or unavailable utility bill histories. The required sample size estimates are based on the assumption that the standard deviation of energy savings is about twice the mean for the treatment group and about equal to the mean energy savings for the control group (Hirst, et al., 1985; Elmroth, Forslund, and Rølen, 1984; Goldberg, 1986).

A small sample of exemplary subgrantees will be included in this sample to enable innovatively and highly effective programs to be analyzed (see Section 2.7). An effort also will be made to include all subgrantees that install air conditioning measures. Only the random sample of subgrantees will be used to estimate program-wide measures of performance.

The first phase requires several major data collection efforts:

- fuel consumption and fuel price data for the sample of 20,000 treatment homes and 10,000 control group homes that heat with gas or electricity will be obtained from utilities;
- weather data will be obtained from the National Oceanic and Atmospheric Administration (NOAA);
- data on program costs will be obtained from subgrantees and State program offices;
- data on service delivery procedures will be based primarily on a survey of subgrantees being conducted as part of the Characterization of the WAP Network (see Section 4.1); and
- data on recommended and installed measures will be obtained for each sampled housing unit from the subgrantees.

The fuel consumption and weather data will be analyzed with PRISM. To obtain all the information required for the PRISM analysis, several steps are required. First, subgrantees must be contacted and asked to supply lists of 1989 weatherized homes and waiting lists of income-eligible households (names, addresses, and utility companies). Second, bill waivers must be obtained for each household to allow access to utility bills. In most cases, these will be available from subgrantees. Third, the utility company must be contacted and asked to supply the billing records. Fourth, weather data must be obtained from nearby weather stations. Fifth, data entry, cleaning, and analysis must be completed.

Analysis of cost effectiveness requires using the PRISM results along with data on fuel prices and program costs. In addition, appropriate assumptions concerning discount rates, life expectancies of weatherized homes

and energy conservation measures, and fuel price escalation rates must be developed. Several scenarios will be explored as part of a sensitivity analysis.

The **second phase** of the study involves the collection and analysis of on-site field data. Energy-savings results from phase one will be used to guide the selection of a subsample of 500 treatment homes and 300 control group homes for this phase. The original control group sample must then be purged of homes that have been weatherized; a supplemental control group sample based on current waiting lists may then be needed. Approximately 200 treatment homes with especially high or low savings will be selected for inclusion in the on-site subsample along with 300 randomly sampled treatment homes.

The on-site data will include furnace efficiency testing, blower door testing, and an occupant interview. This information will be used to interpret the energy savings and benefit/cost results, particularly for homes with especially high or low savings, and to quantify the nonenergy impacts of the WAP. The on-site test results also will be used to characterize the energy efficiency of WAP weatherized homes vs. homes not yet weatherized. Along with information on reductions in the proportions of household budgets spent on fuel costs, these data will help quantify nonenergy impacts of the WAP.

A major goal of this study is to analyze factors that influence energy savings and cost effectiveness. Data from both phases one and two will be used in this analysis. Measures of program performance will be cross-tabulated with a variety of potential contributing factors to find patterns of variation. Multiple regression models and other multivariate techniques also will be developed to rank the importance of factors in determining program effectiveness.

This second phase also will generate simulated savings and benefit/cost ratios and compare them with measured savings and cost effectiveness for a subset of homes. The energy analysis software has not yet been selected. However, the selected software will 1) consider a wide range of mechanical system and envelope measures, 2) include both heating and cooling, 3) analyze interactions among the savings of different weatherization measures, 4) apply to both single-family and small multifamily buildings, and 5) be based on state-of-the-art algorithms. Results of this analysis will be used to identify any systematic discrepancies and to estimate the impacts of different groups of retrofit measures.

The **third phase** of the single-family study will look at the persistence of energy savings over time. Three years of postretrofit energy consumption (1990-92) will be analyzed to assess long-term savings and the influence of household mobility. Substantial attrition from the original sample can be expected by this stage of the study, thereby limiting the analysis to a subsample of the initial treatment group. The control group will probably be severely depleted at this stage (by the removal of weatherized homes), and a supplemental sample of control group homes will be necessary. A survey of occupants will be conducted in this phase to provide information on occupant turnover and energy-related changes in the households. Because transience is a fact of life for many low-income households, houses with occupant turnover will not be dropped from the analysis. A standard of "comparable use" may be defined, and houses dropped only if they experience radical changes in number of occupants, income level, or other key determinants of energy use.

Altogether, the single-family study depends on a very extensive data collection effort that includes information on: (1) billing histories and fuel prices from numerous utilities, (2) program costs, recommended and installed measures, service delivery procedures, and other data from about 400 to 450 subgrantees, (3) occupant characteristics based on a survey of a subset of households in the sample, and (4) building characteristics from on-site visits. These data will be screened carefully and subjected to data quality checks. Like the data collected in the other studies, they will be organized in well-documented data bases that can be made available to interested parties in such a manner that the identity of individual households remains anonymous.

3.2.3 Outcomes

Three reports will be produced corresponding to the three phases of the study (Fig. 4). The first report will estimate program energy savings and cost effectiveness for the year following weatherization in 1989. Estimates of energy savings and cost effectiveness will be reported at the national level and for a variety of market segments, including three different climate zones, two fuel types, and two building types. A variety of possible determinants of energy savings and cost-effectiveness will be examined. In addition, program-induced improvements in energy affordability will be assessed.

The second report will explain in detail the energy savings and cost-effectiveness results by analyzing on-site data. These data also will be used to

help quantify nonenergy impacts including safety (e.g., through an analysis of the incidence of unsafe conditions) and comfort (e.g., through an assessment of air infiltration rates, interior temperatures, and the incidence of unheated rooms). In addition, program impacts on fuel assistance payments, fuel cut-offs, and utility customer arrearages and nonpayment will be estimated using utility information, when available.

The third report will examine the persistence of energy savings by measuring the amount of energy saved two and three years after weatherization. Information on the durability of energy savings is important for assessing WAP's long-range effectiveness and potential.

3.3 The High-Density Multifamily Study

3.3.1 Goals and Objectives

Approximately one-third of all WAP-eligible homes that are renter-occupied are located in multifamily buildings with 5 or more dwelling units (Economic Opportunity Research Institute, Inc., 1986). Possible energy savings for efficiency measures in multifamily buildings are significant, typically ranging from 10% to 30% of existing consumption (Goldman, Greely, and Harris, 1988). This study will be limited to renter-occupied buildings, which constitute the vast majority of WAP-eligible high-density multifamily housing.

The high-density multifamily study will provide both national and regional estimates of program energy savings and cost effectiveness for this submarket. Program impacts on energy affordability, reliance on fuel assistance payments, occurrence of fuel cut-offs, and instances of utility customer arrearages and nonpayments also will be quantified. The influences of groups of retrofit measures on energy savings and cost effectiveness will be identified, and a variety of other contributing factors will be assessed.

3.3.2 Methodology

The study of energy savings in high-density multifamily buildings weatherized by the WAP is complicated by many factors, including:

- incomplete weatherization (i.e., in many instances, only one or a few units in a building are weatherized);
- vacancies and turnover;
- occupant behaviors;
- variable building operations and maintenance procedures;

- type of metering (i.e., master-metering vs. thermostatically controlled and individually metered units); and
- central heating systems vs. individual heating, ventilating, and air conditioning (HVAC) units.

The research design for the high-density multifamily study will account for these “complicating” factors in addition to considering the impacts of weather variation and a range of occupant and building characteristics. The study will be conducted in three phases (Fig. 6).

During **phase one**, high-density multifamily WAP activities will be characterized, based on the same sample of subgrantees used in the single-family study. Data on the nature and number of multifamily units weatherized in PY 1989 will be collected and summarized. Information on recruitment practices, audit procedures, service delivery, and measures installed also will be collected.

At the same time, previous multifamily weatherization evaluations will be reviewed to identify research methodologies that are most promising and factors that have influenced the success of past programs. We propose a relatively lengthy period for developing the evaluation methodology for this study because of the sparseness of prior research on energy consumption in large multifamily buildings.

During the **second phase**, energy savings and cost-effectiveness will be analyzed for a sample of units in multifamily buildings weatherized in PY 1989 by the sample of subgrantees examined in the Single-Family Study. These units will be drawn from the sampled subgrantees to represent the types of high-density multifamily weatherizations that were completed in PY 1989. The sample of units will represent different climate regions, sizes and ages of buildings, individual unit and whole building retrofits, and types of heating systems.

Three comparisons or control group designs are being considered. (1) The sample of units could be their own control group, by simply comparing weather normalized energy consumption before weatherization vs. after weatherization. (2) A sample of units on the waiting lists of the same subgrantees could be the control group for the sample of units weatherized in 1989. A variation on this design would match key characteristics (e.g., fuel type and size of building) of the weatherized and control group sample.

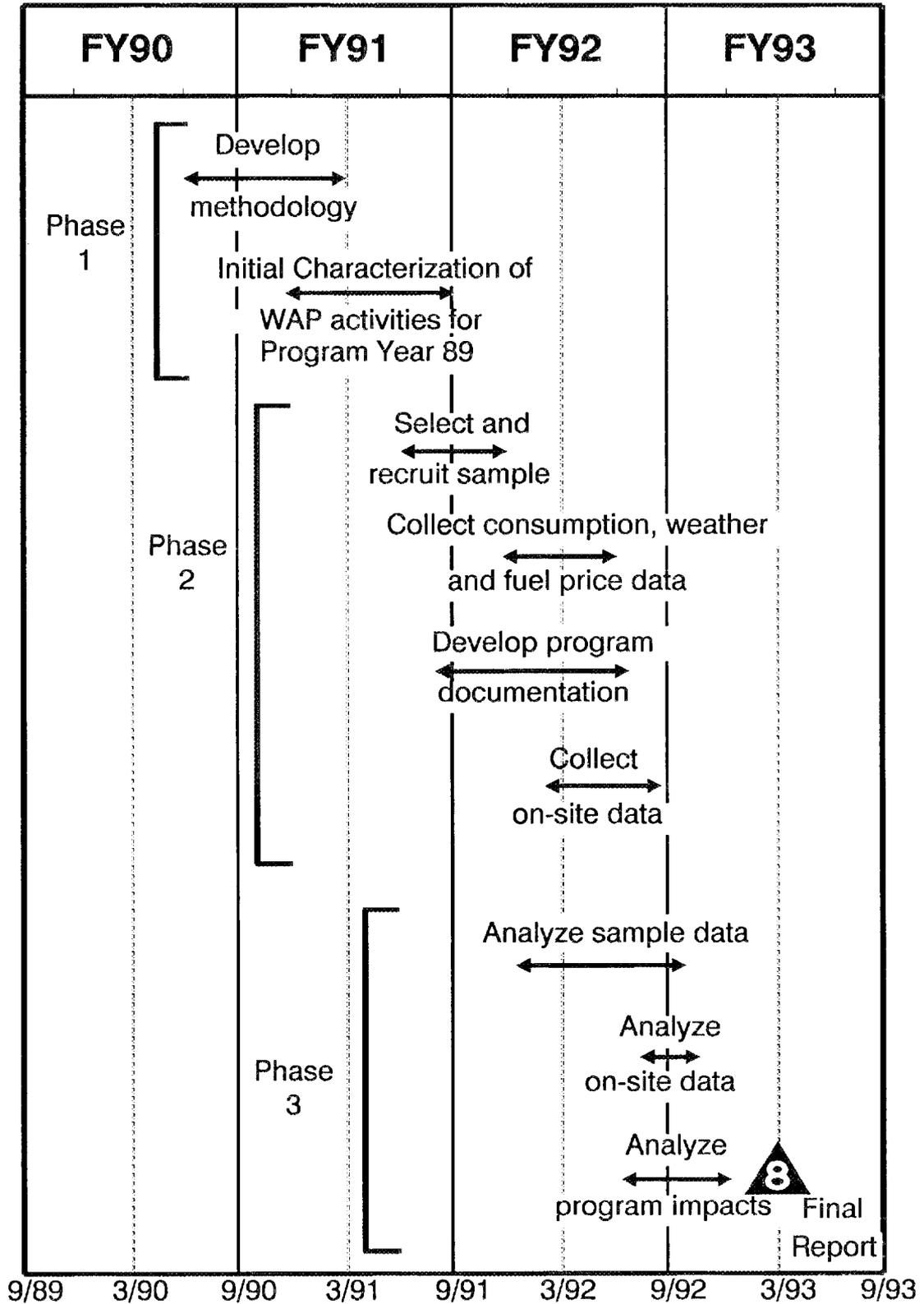


Fig. 6. Timetable of the high-density multifamily study.

(3) Nonweatherized units located in the same apartment complex as the sampled weatherized buildings could serve as a matched control group. This alternative might be feasible when portions of a complex are retrofitted over a period of several years. The second control group option (with matching) is deemed most desirable.

Sampled buildings would be recruited by working closely with subgrantees, local utilities, and building owners and managers. For master-metered buildings, the cooperation of the building owner and manager is essential for obtaining utility billing records. For individually metered buildings, utilities would be asked to provide billing histories for tenants. Billing histories might be easier to obtain where the weatherization was conducted as a joint project between a local agency and a utility. Only as a last resort will an attempt be made to collect bill waivers directly from individual tenants.

Analysis of the billing histories and subgrantee data will follow procedures that are similar to those used in the single-family study. Differences will include checking for vacancies and turnover.

During **phase three**, a subset of approximately 10 buildings will be selected for on-site data collection. In addition, the building owners (or managers) will be asked to provide information on their buildings and on their experiences with the WAP. For instance, how did the building owners become aware of and interested in WAP participation? What were their primary motivations for participation? What changes to the buildings and their occupants have occurred during the study period that might affect energy consumption levels? What changes occurred as a result of the weatherization? This subset of buildings will be selected to closely represent the population of weatherized high-density multifamily buildings.

3.3.3 Outcomes

This study will characterize the multifamily weatherization activities funded by the WAP in terms of the number and types of units and buildings that have participated in the program. By comparing these results with the findings of the eligible client profile discussed in Section 4.2, we can also profile the types of units and buildings that have usually not been served by the WAP to date.

National and regional estimates of energy savings and cost effectiveness for this submarket will be important products of the study. In addition, the energy savings and cost effectiveness of different groups of measures will be estimated, and a variety of other contributing factors will be assessed. Program impacts on energy affordability, reliance and fuel assistance payments, occurrence of fuel cut-offs, and instances of utility customer arrearages and nonpayments also will be quantified.

4. RELATED STUDIES

4.1 Characterization of the WAP Network

This study will describe the current dimensions and characteristics of the WAP network of States and subgrantees to provide a frame of reference for understanding the impacts and cost effectiveness of the Weatherization Assistance Program and for shaping future policies and procedures. The features to be described include:

- the relationships between grantees, subgrantees, and other energy programs and service providers;
- the extent of external program relationships;
- the interest and availability of potential partners for future technology demonstrations and DOE initiatives;
- technical assistance, client education, and training skills;
- the range of expertise for diagnosing weatherization needs, installing retrofit measures, and delivering related services;
- the ability of subgrantees to provide market information on client needs and to provide feedback on the performance of new technologies; and
- innovations and cutting-edge initiatives being implemented or field tested by the network.

By understanding the size, scope, skills, and capabilities of the current WAP network, DOE can better work with the network to enhance program performance and establish links with other private- and public-sector programs aimed at promoting energy efficiency in the nation's building stock.

This study is divided into two phases. Phase one will involve data collection from all current WAP grantees and subgrantees. A mail survey with a telephone follow-up, will be the major source of data for this analysis. Phase two will entail a more in-depth study of a small number of selected grantees, subgrantees, and associated agencies to explore in greater detail the technologies, initiatives, and energy efficiency marketing potential of the WAP network. Funding for this second phase is contingent on the findings of the first phase, and whether the more detailed analysis of the second phase is warranted.

In sum, the Characterization of the WAP Network will provide all levels of WAP management with the necessary information to enhance delivery mechanisms, further leverage federal resources, foster collaborative activities, and promote advanced energy-efficient technologies.

4.2 Profile of Eligible Clients and WAP Resource Expansion

This study will focus on the size and composition of the served and unserved portions of the WAP-eligible population. It also will document the extent that WAP resources have been expanded through external sources to better serve the program's clients. The study will have two phases.

In the **first phase**, information will be collected from federal, State, and local agencies and from utilities and utility associations to estimate the numbers and types of eligible homes that have been weatherized with funds provided by DOE/WAP (appropriations and oil overcharge funds), Health and Human Services/Low-Income Home Energy Assistance Program (LIHEAP), State programs, and utilities. Information on brokering and application of non-DOE resources by States and local agencies will be compiled. Funds from many sources often are integrated into the WAP, providing enhanced training for weatherization crews, a broader range of weatherization services to clients, and services to more clients.

In the **second phase**, the 1990 Census of Population and the 1990 Residential Energy Consumption Survey (RECS) will be used to provide up-to-date information on the eligible population, and thereby better characterize the number and type of housing units that remain to be weatherized. The unserved population will be characterized by examining the differences between the eligible population and the served population described in the first phase.

One of the challenges of this study will be to eliminate double counting of homes weatherized by multiple sources. The definitions of "weatherized" and "eligible" also will require careful consideration. The analysis is complicated by the fact that a household remains income-eligible regardless of whether the dwelling unit has received weatherization services. If the unit has been previously weatherized, a unit remains ineligible for weatherization services even if the income-eligible occupants have never received WAP services. Recognizing that people move in and out of the WAP-eligible population as incomes change, occupants of households change, and eligibility

rules change, the study also will examine the dynamics of this client profile, drawing partially on the results of the on-site interviews from the single-family study.

5. MANAGEMENT ISSUES

5.1 Schedule of Deliverables

Figure 7 lists the nine reports that will result from the five studies, including their planned completion dates. The first report, characterizing the WAP network's capabilities, will be completed in March 1991. The entire evaluation will be concluded with the comprehensive, ninth report in September 1993.

5.2 Role of the Working Groups

Two working groups, a methodology group and a planning and implementation group, will participate in the evaluation. These groups will be a major source of input to DOE on technical issues, project focus, and application of results. Their advice will ensure that the results of the evaluation are useful and valid and that they reflect the experience and knowledge of evaluation and weatherization experts. In addition, the working groups will play a key role in the technology transfer process, first helping guide the development of the evaluation (the technology) from conception to final reports and then helping to make the evaluation methodologies, data, and results available to and understood by users (the transfer).

The members of both working groups were selected through a nomination process. Briefings on the proposed evaluation were given to major trade and professional organizations representing the primary constituents of the evaluation. These organizations then were asked to nominate individuals to participate in the working groups. Balanced representation of regions across the United States was sought during the process of selecting members from the larger list of nominations.

The role of the methodology group (composed of weatherization and residential conservation evaluation experts) will be to review the study design and methods to ensure that the desired evaluation outcomes are obtainable from the data to be gathered and are rigorous in their statistical underpinnings. This group will meet four times during the first year of the project. Each of the first three meetings will focus on one of the three submarket studies, and the fourth will discuss any remaining methodological planning issues.

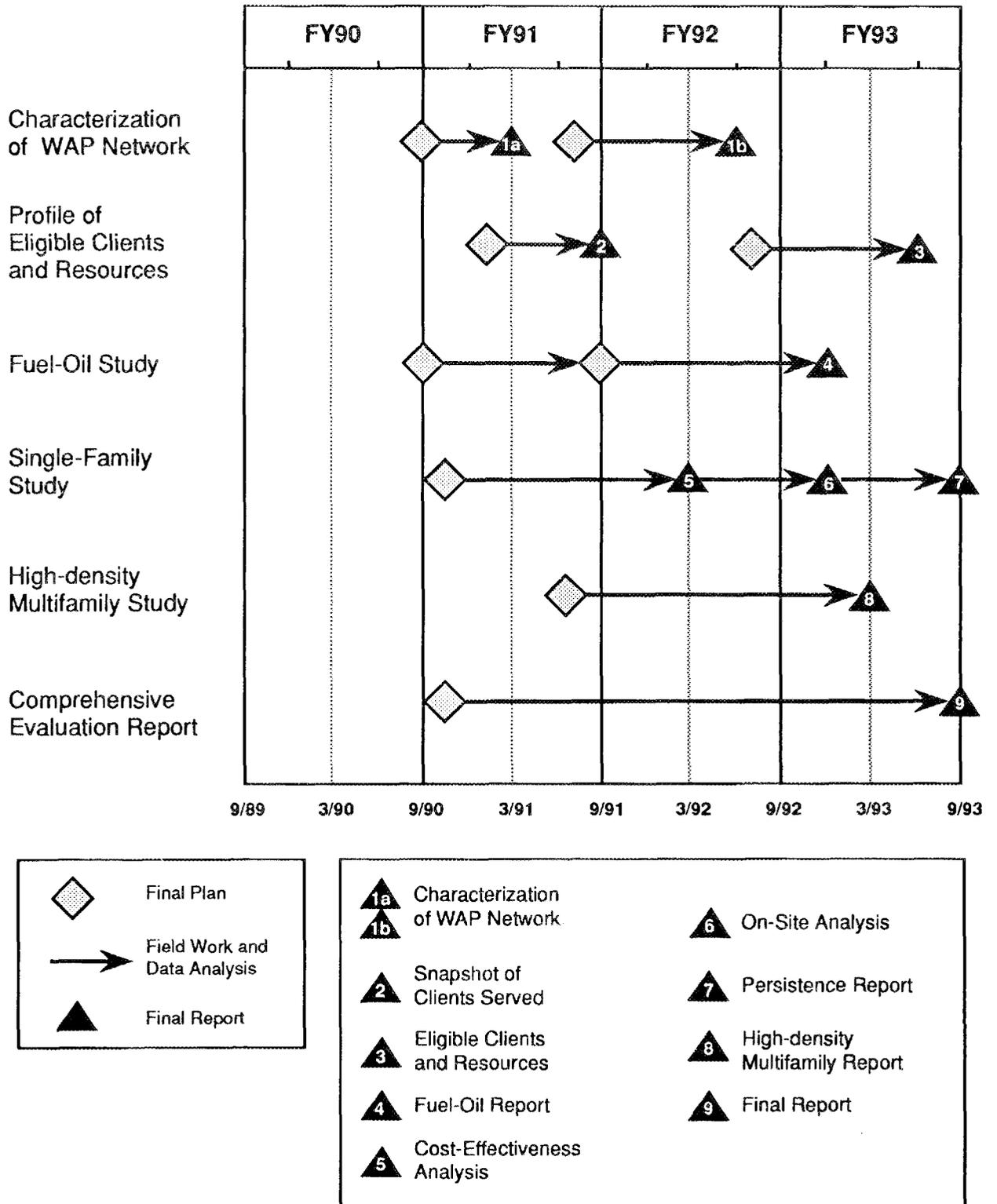


Fig. 7. Schedule of studies and deliverables.

The planning and implementation group is composed of persons knowledgeable about weatherization programs, services, opportunities, issues, and management. Its purpose is to ensure an objective, credible, and appropriate study and to ensure that the materials developed provide policy makers, program managers, and program implementers the key information needed to guide, manage, and operate the program in a cost-effective manner. The group will meet quarterly during the first year of the project and semiannually thereafter.

5.3 Technology Transfer Strategy

This evaluation plan has already undergone an extensive consultative development process. Program and evaluation experts developed an array of study options; policy makers defined limits, needs, and study parameters; principal stakeholder groups provided sensitivities and additional focus to the lines of inquiry; and program and evaluation experts iteratively integrated this input into the proposed evaluation plan. Thus, the technology transfer process has already begun because the evaluation has been designed to reflect the needs of its intended users.

The proposed evaluation will benefit a variety of groups:

- policy makers (e.g., Congress, Governors, State legislatures, DOE, and the Office of Management and Budget);
- program managers and implementers (e.g., DOE program officials, State program directors, and local program implementers);
- utilities and Public Utility Commissions; and
- various business, client, and interest groups.

Policy makers will want to know how effectively the program has addressed its objectives of conserving energy and reducing the impact of high fuel costs on low-income households, whether the benefits have exceeded the costs, and what the future potential benefits are. Program managers and implementers will be interested in the evaluation's conclusions about what types of service delivery procedures, client selection, outreach and marketing, audits, retrofit measures, and households have achieved the greatest savings and cost effectiveness. Utilities will want to know what lessons they can apply to their own demand-side management programs and how low-income weatherization

might fit into their integrated resource planning. Business groups will want to know in what areas the program is likely to expand markets or need products. Client and interest groups will want to know who has been served, what the benefits of participation have been, and who remains to be served.

A technology transfer strategy will be designed to support the transfer of the evaluation's results to each of the types of potential users described above. The strategy will deliver results to policy makers, program implementers, and business and interest groups through a variety of informational and technical assistance mechanisms and media. It is likely that the planning and implementation working group will play an active role in this technology transfer process.

It is anticipated that the evaluation's methodology will evolve as its constituents' needs change, preliminary results emerge, and opportunities arise. The evaluation's goals and the major features of its five studies are not likely to change, but the methodological details of each study may, in the end, differ from what is described here.

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