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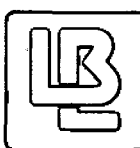
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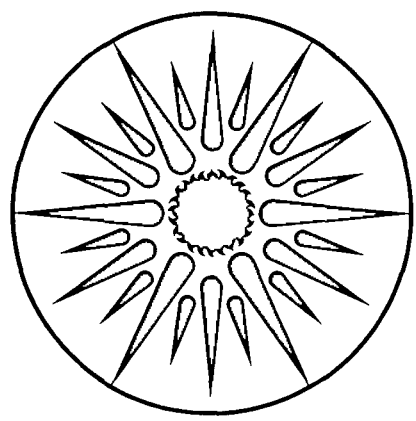
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A RESIDENTIAL CONSERVATION DATA BASE
FOR THE PACIFIC NORTHWEST
Documentation and Appendixes

A. Usibelli, B. Gardiner, W. Luhrsen,
and A. Meier

November 1983

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A RESIDENTIAL CONSERVATION DATA BASE FOR THE PACIFIC NORTHWEST

DOCUMENTATION AND APPENDIXES

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This volume contains the documentation and appendixes for Parts 1 and 2 of this report, which are available as Lawrence Berkeley Laboratory Report, LBL-17055.

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PART THREE
Space Heating Measure Documentation

Residential Electric Space-Heating End-Uses and Conservation Measures

Introduction

Space heating accounted for 32.0 % of 1980 total residential electricity use in the Pacific Northwest (BPA, July 1982, p 71). The following documents the space heating end uses and conservation measures used in the data base of conservation measures. Each of the end uses and conservation measures is described in separate sections below. We first describe our overall approach in modelling the electric space heating sector, along with our major assumptions.

Methodology

We based our analysis on "typical" cases (or prototypes), each representing a specific portion of the Pacific Northwest's electrically heated housing stock. We aggregated these typical cases to obtain average conditions and energy savings. The typical case approach permits greater realism and accuracy and easier updating in the future. The philosophy is that the stock should be divided into a sufficient number of prototypes to accurately determine the conservation potential for various measures. For example, the typical case approach permits us to distinguish between houses that can accept R-38 insulation and those that can only accept R-11. Refer to the technical appendices for additional details on the typical case methodology.

We divided the residential electric space-heating sector into four major groups containing 24 separate categories. (see table III-1).

Table III-1 Space Heating Enduses			
Major Group	Stocktype/Zone	ID Code	Typical Cases
Mobile Homes			
	New, Zone 1	EN11100E00	2
	New, Zone 2	EN11200E00	2
	New, Zone 3	EN11300E00	2
	Old, Zone 1	EO11100E00	1
	Old, Zone 2	EO11200E00	1
	Old, Zone 3	EO11300E00	1
Single Family-Detached			
	New, Zone 1	EN12100E00	3
	New, Zone 2	EN12200E00	3
	New, Zone 3	EN12300E00	3
	Old, Zone 1	EO12100E00	15
	Old, Zone 2	EO12200E00	15
	Old, Zone 3	EO12300E00	12
Single Family-Attached			
	New, Zone 1	EN13100E00	2
	New, Zone 2	EN13200E00	2
	New, Zone 3	EN13300E00	1
	Old, Zone 1	EO13100E00	9
	Old, Zone 2	EO13200E00	9
	Old, Zone 3	EO13300E00	5
Multi-Family Units			
	New, Zone 1	EN15100E00	1
	New, Zone 2	EN15200E00	1
	New, Zone 3	EN15300E00	1
	Old, Zone 1	EO15100E00	1
	Old, Zone 2	EO15200E00	1
	Old, Zone 3	EO15300E00	1

The 4 major groupings; single family-detached, mobile home, multi-family, and single family-attached conform to the divisions in the BPA forecast documentation (BPA, May 1982) and, therefore information on numbers of units and average annual growth rates were readily available. We separated single family-attached housing from single family-detached housing because the former have a substantially higher percentage of rental units (thus making conservation measure penetration more difficult). Single family-attached houses are more difficult to model due to adjoining walls and floors; there is also

¹ Single family-attached structures include all units classified as semi-detached, attached on 2 sides, 2 to 4 units detached, 2-4 units 1 side attached, and 2 to 4 units with 2 sides attached. Multi-family units includes single units contained in a building with five or more total units. The responses to question 1 part d in the Regional Survey were used to break out housing stock. Note that these definitions of housing type may differ from that used by the region's utilities or other residential studies.

substantially less information available on single family-attached insulation levels than for detached units. There was no data in the Regional Survey for mobile homes and multi-family units insulation levels and only limited supplemental sources.

The typical cases for each of the four end uses were developed from several sources. Most of the "old" stocktype typcases came from the Pacific Northwest Residential Energy Survey (hereafter, referred to as the "Residential Survey" or simply the "Survey") conducted by the firm of Elrick and Lavidge, during late 1979 and early 1980 (Elrick and Lavidge, Volume 1 p. 7). The objectives of the Residential Survey were:

"provide a data base which could describe the principal demographic, family, dwelling, weatherization and appliance characteristics of residential customers within the four state [Idaho, Oregon, Montana, and Washington] and four climate zones and the Pacific Northwest."

Nearly all of the typcases were developed from special computer runs of the Survey using the Statistical Package for the Social Sciences (SPSS) Version 7 (dated April 30, 1979) available on the LBL CDC 6000/7000 system. This was necessary because the published volumes did not provided sufficient information on electrically heated homes by housing type and climate zone.

The analysis for "old" stocktype units was developed based on the response to question 15, "What fuel is used by the main heating equipment for your (house) (apartment)?". That is, the fuel that heats most rooms or the largest space". If the response was number 5 (electricity) these units were selected for further analysis. This yielded a total of 1662 cases (unweighted) out of a total of 4029 survey responses or approximately 41% of the total sample. The weighted average, which allowed for over and under sampling of states, increases the the total to 44 %. We did not include those residences having non-electric fuels as their main heating source, but used electric as a supplemental fuel (question 31) because there was no method to determine how much the electric heat contributed to total space heating requirements.

We further excluded from the analysis houses that were only seasonally occupied. Many of these houses, especially vacation homes, may have electric space heating but we lacked sufficient information to estimate the potential for electricity savings. Based on the occupancy responses in the Residential Survey, however, this should have a very small effect on our analysis.

Climate

The climate of the Pacific Northwest has a broad range of temperature conditions. In the heavily populated Puget Sound Basin 4500 to 5000 degree-day per year are typical. In contrast, sections of sparsely populated northern Idaho and western Montana can experience temperatures as low as -37°F and near 8000 degree-days annually. We chose to use three climate zones for our analysis. Although this means we have lost something in terms of fine detail the nature of the the Survey data coupled with a desire to keep the number of typical cases considered within managable bounds, lead to this decision.

These zones also correspond to those delineated by Battelle (Battelle, Working Paper 2, Feb 1982)

Lacking a population weighted degree-day value for each of the zones, however, we selected one "representative" city in each of the regions: Zone 1 - Portland, Oregon; Zone 2 - Spokane, Washington, and Zone 3 - Missoula, Montana. These cities have hourly temperature data available and were large population centers in the climate zone. The WORK4 program also can generate savings estimates for several other cities in the region. These include Seattle, Washington; Boise, Idaho; Astoria, Oregon; and Lewiston, Idaho.²

U-values and Areas

The principal selection factor for developing typical cases (or "typ-cases") was the amount of insulation in the ceiling/attic area, largely because of the availability of data, and its importance as a heat loss path in the house. The key selection factor for "old" stocktype typcases (single family detached and attached units) was ceiling insulation. For example, we divided the single family detached units into typcases with ceiling/roof insulation values of; less than R-4, R4-11, R12-19, R19-27, R28-37, and greater than R-38. When there were insufficient numbers of sample cases in the Survey to warrant these divisions, we grouped the insulation levels into larger units.

We calculated the R-values of the ceiling and roof combination using the responses to Survey questions 101 and 102, namely, the amount of insulation in the ceiling and under the roof. We calculated the insulation levels using the following formula:

$$\begin{aligned} \text{R-value of ceiling/roof insulation} = & (\text{battcei} \times 3.2) + \\ & (\text{loosecei} \times 2.2) + (\text{rigidcei} \times 6.0) + (\text{battraf} \times 3.2) \\ & + (\text{looserf} \times 2.2) + (\text{rigidrf} \times 6.0) \end{aligned}$$

Where:

battcei = inches of fiberglass batt insulation in ceiling
loosecei = inches of loose fill insulation in ceiling
rigidcei = inches of rigid board insulation in ceiling
battraf = inches of fiberglass batt insulation in roof
looserf = inches of loose fill insulation in roof
rigidrf = inches of rigid board insulation in roof

numerical entries are the R-value multipliers³

This formula was then applied to each case in the selected group and the results were binned into the insulation level categories indicated above. We then used the mean value for each of the groupings (combining groups when the standard error of the mean exceeded 1.5) to determine the U-value entry of each typcase. For uninsulated houses we assumed a typical U-value of .19 (R-5.2).

The dwelling were further described by six major heat loss paths, ceiling/roof, walls, floor, volume of air and air exchange rate, windows, and doors. For each of these paths an area was calculated from the sample and the total u-value determined (insulation plus building material contribution). The sections below describe how the area and U-value for each path was determined.

Floor and Ceiling Area of Dwelling

Questions 8 A and B, respectively, indicate the occupants estimates of the area of the dwelling (in square feet) and the proportion of the total area which is regularly heated. These estimates exclude garage, unfinished basement, and unfinished attic areas. If the respondent failed to answer the floor area question, the surveyor measured it. Roughly one-half of the householders were able to estimate their floor area, but there was a noticeable disparity between the householder responses and the measured area for the dwelling. In nearly all cases the measured area responses indicated a smaller square footage than the verbal responses, some as low as 71% of the verbal estimate. However, since there is no indication in the published Survey material of a comparison between occupants estimates and actual square footage measurements we cannot verify the accuracy of the verbal estimates. Note also that heated floor area is only reported for cases where question 8A was answered. When the floor area was measured no estimate of the heated portion was made. Consequently, there is no cross check available on the validity of heated area estimates. In general, the heated portion of the home was 90% to 95% of the total floor area. Variations around the mean square footage, i.e., the standard error, ranged from approximately 5 to 15 %. We calculated the floor area for each typical using a weighted average of the verbal and measured area responses. We made no corrections for a smaller heated area because close agreement between the floor area and the heated area values. The ceiling area of the dwelling was assumed to be identical to the floor area.

Wall and Door Area and Insulation

The wall area of each dwelling unit was calculated based on the floor area. We assumed that the dwellings were square, one story units with standard eight-foot walls. Thus the wall area was the product of the square root of the floor area times four (the number of walls) times eight (the average wall height). We then subtracted from this gross wall area the wall space taken up by windows and doors to obtain a net wall area. For single family-attached units we assumed that, on average, one wall adjoined another unit. For multifamily, we assumed that there were two adjoining walls. In both instances the adjoining walls area was excluded as a heat loss path and the area of the wall was discounted accordingly. All walls were assumed to be of standard 2"x4" construction with 16" centers, leaving a wall cavity of 3.5".

We assumed that the house has on average two exterior doors (excluding sliding glass doors which are included in the glazing area) with an average area of 20 ft² each, or a total of 40 ft².

Windows

The average window area estimates are based on responses to question number 11 which asked for the number of windows by size category: small, medium, and large. The large category also included sliding glass doors. We then estimated the average size for each category of window (or sliding glass door). Large windows were assumed to be 45 ft², medium windows 25 ft², and small windows 8 ft². These values were then used to calculate a total glass area in the unit based on the following formula:

$$A = (L \times 45) + (M \times 25) + (S \times 8)$$

Where

A= total window area
L= # of large windows
M= # of medium windows
S= # of small windows

The standard error of the mean area ranged from 5 to 20 %.

After estimating the average window area for each typical case we then determined the window U-value. Question 12 indicates the percentage of each category of window that had either double glazing or storm windows. Although there is a slight difference in the U-values and infiltration characteristics of double glazed and storm windows (ASHRAE 1981 Fundamentals, pp 27-10/11) we assumed the same U-Value for each. The variation within the category, e.g. double glazing with a 1/2 inch air space versus double glazing with a 1/4 inch air space, outweighs the glass/storm window differences. We employed simple estimates rather than calculating the percentage of double glazing in each category because a relatively large fraction of the household did not respond to this question. We suspect that most of the non-respondents did not have double glazing or storm windows, so our assumption that the respondents percentage applied to all units in the typcase category may overestimate the actual glazing level. No information on either triple glazing (i.e., triple pane windows or double storms) or quadruple glazing is given in the survey. However, such levels of glazing are seldom encountered in current building practice, we therefore assumed a zero penetration.

Question # 14 asked whether the household had "Plastic covering over windows or doors". We did not use this question in our calculation of glazing levels because doors were also included and because the responses were limited to "all", "some", or "none", and the quality and durability of the plastic covering were not indicated.

Air Infiltration

The final major heat loss path, air infiltration, is the most uncertain. Infiltration cannot be easily estimated without elaborate and time consuming procedures (e.g., a blower door or tracer gas). None of the broad surveys conducted in the region, including the Pacific Northwest Regional Survey, the Oregon Department of Energy's residential survey, and a number of utility audit and weatherization programs include valid cross-sectional data on infiltration. In addition two infiltration studies conducted by the Lawrence Berkeley Laboratory are often cited as source for Pacific Northwest housing infiltration (Dickinson, Feb. 1982, and Lipshutz, Aug 1981). These studies were conducted on homes in Eugene, Oregon and Midway, Washington. However, these samples were not intended to be representative of any regional average and cannot be extrapolated to regional averages. This data limitation is a major shortcoming since infiltration can contribute as much as 40% to building's energy losses. The effective U-value for infiltration in each house is the product of the infiltration rate and the heat capacity of the air within the building. We used the gross building volume to estimate the heat capacity.

Table 3-2 contains some representative U-values.

Floor Area	Effective U-Value ^a
750 ft ²	108
1000	144
1250	180
1500	216
1750	252

^a Values based on 8-foot interior walls and an average heat capacity of 0.018 BTU/ft³.

Average Temperature in Pacific Northwest Dwellings

The heating energy use in a dwelling is very dependent on the indoor temperature. This is especially true for milder (and heavily populated) portions of the region west of the Cascades, where large numbers of the total heating hours in the year occur at moderate temperatures. Thus a small reduction in indoor temperature will substantially reduce the the total number of furnace hours. We used data from the Residential Survey to determine the average daily inside temperatures for existing dwellings. We assumed that inside temperatures for newer, more thermally "tight" dwellings to be higher than the average temperature in existing structures because the improved thermal efficiency of the new units make it less costly for the occupants to maintain a higher temperature setting. The temperature assumptions for the typical cases temperature assumptions can be easily and rapidly modified.⁴

For existing dwellings, the average daily temperature was calculated from responses to questions number 28, 29, and 30 in the Regional Survey. The questions were:

"Please think about the the temperature at which you will keep your (house) (apartment) during this fall and winter [1979-1980]. In answering the next questions, give your estimate of the average for all of the heated areas.

28. What temperature will your house be during the day?

² See Appendix B for a discussion the subroutine HOURH which uses the weather data to determine energy use and measure savings. WORK4 is designed to accept additional weather data for other cities, not included in the current list.

³ R-values are taken from the Office of Technology Assessment, Residential Energy Conservation, Volume 1, 1979 pp.277 et seg.

29. What temperature will it be during sundown and bedtime (bedtime is defined as about 11:00 p.m.)?

30. And what will the temperature be during sleeping hours or approximately 11:00 p.m. to 7:00 a.m.?"

We assumed a 12 hour daytime period, a 4 hour evening period, and an 8 hour nighttime period. These estimates were then used to arrive at an average weighted indoor temperature. There was little difference between the daytime and evening temperatures reported and thus our estimates of average temperature were largely insensitive to changes in the daytime/evening hour allocations. The typical range of standard errors in temperature estimates from the Survey was from 0.4°F to 1.5°F. In some instances where average energy consumption values were low, e.g. multi-family "old" stock we increased the indoor temperature about 1°F; still within the range of the standard error.

It is important to note that none of the temperature estimates in the survey were verified by temperature recording devices. The surveyor assumed that the occupant's responses were accurate; the occupant's estimates also may be in error. Comparison of occupant estimates of indoor temperature and chart-recorder measured temperatures in Davis, California indicate a number of disparities⁵ This disparity was shown in several instances to be several degrees. The thermostat temperature settings also may inaccurately reflect the actual temperature of the dwelling unit, either as a result of zone heating or that the thermostat itself is inaccurately measuring the temperature. Again we have found no information on the accuracy of Pacific Northwest thermostats or the prevalence of zone heating.

Because of the importance of indoor temperature on space heating energy use and the likelihood of temperature estimation errors high priority should be given to long term temperature measurements and examination of the prevalence of zone heating in a representative sample of Northwest housing. This would go far to improve that quality of energy consumption data analysis.

⁴ The minor data base inputs can also accept mid temperature and mean outside temperature assumptions. The mid temperature values are only used in the modelling of hot water energy use and are ignored in space heating runs. Similarly, the mean outside temperature has not been used, but has been replaced by the hourly temperature calculation procedure described in Appendix B (HOURH subroutine). We found that a conventional degree-day calculation gave misleading results.

⁵ Unpublished data provided by Dr. Ed Vine, Lawrence Berkeley Laboratory, Energy and Environment Division, Energy Analysis Program. Dr. Vine's analysis indicated no particular pattern in the occupants estimates versus the temperature records, i.e. the occupant was just as likely to overestimate the indoor temperature as to underestimate it.

Electricity Consumption Data in the Regional Survey

Utility billing data for the period from August 1978 to July 1979 (November 1979 for fuel oil) was included as part of the Regional Survey. Approximately 64 percent of the survey participants also provided electricity consumption data (2578 of 4020 respondents). Initially we had hoped that the electricity billing data would validate the Work4 results for the typical cases. We constructed several computer programs to access and format the billing data, remove those cases with missing information or poor quality coding, transform the data from billing periods to calendar months, and determine a base usage (i.e., non-space conditioning electricity use). After deleting cases with missing values or coding errors, the number of remaining cases for any given typical case was not sufficient to yield a statistically valid estimate. Consequently, we were not able to use the billing information as a cross check on our typical case estimates.⁶

Internal Gains

The heat generated by the operation of appliances and activities of people (called "internal gains") contributes a significant proportion of the heat needed to maintain a comfortable temperature inside a home. Solar radiation through windows is sometimes also included in internal gains, but in this report we have treated it separately (see below). The operation of an appliance thus provides two amenities, that for which it was originally intended (such as lighting or refrigeration) and space heating. On many cool days, the internal gains provide sufficient heat so that no furnace output is needed. We estimate that internal gains contributes about one-fourth of the total space heating requirements of the average home in the BPA region. (see below)

As the appliances inside a home become more efficient (either through retrofit or replacement), they produce less heat and the furnace must supply more offsetting heat. A new, efficient refrigerator, for example, will use less electricity for refrigeration. At the same time, it produces less waste heat, so the furnace will operate longer. This interaction between appliances and space heating complicates the accounting of energy savings because conservation measures cannot be treated independently. Ignoring the interaction results in overestimates of potential energy savings from appliance conservation measures and underestimates of savings from space heating conservation measures.

There are two strategies to incorporate interactions in the estimates of conservation potential. These strategies differ in the treatment of the internal gains. In the first case, internal gains are coupled to specific appliances; in the second, internal gains are coupled to space heating. This distinction is best described in terms of an appliance conservation measure:

⁶ The computer programs that we developed to perform these functions have not been included in this package of material, however, they are available to BPA on request.

1. Net Energy Savings Strategy. Subtract the increase in space heating from the expected savings of the measure. The listed savings (on which economic calculations would be based) will thus always be net energy savings.
2. Adjusted Internal Gains Strategy. List the savings as if they were measured by a kWh-meter placed on the specific appliance. At appropriate intervals (say, 500 - 1000 kWh), reduce the amount of the assumed internal gains used in making space heating energy consumption estimates.

Neither strategy is the correct one because we must separate the two end uses for within the CPS 2.0 model. Our goal here is to avoid double-counting (or under-counting) energy savings in as simple a manner as possible.

How important is the interactions effect? We can make some rough calculations for one appliance and then for the total internal gains to gauge the significance of the effect. The size of the interaction may determine the strategy to be adopted.

Consider a very inefficient refrigerator. It will use about 2000 kWh/year, and contribute the same amount in internal gains. With a six-month heating season, however, the refrigerator would contribute only 1000 kWh of useful heat. The most efficient refrigerator with similar features currently available uses 900 kWh, or 450 kWh of useful internal gains. The net decrease in internal gains is $(1000 - 450) = 550$ kWh/year, although this greatly depends on the length of the heating season. If the home is resistance heated, then the furnace must supply an additional 550 kWh per year. On the other hand, if the home is heated with a heat pump whose COP is 1.8, only $(550/1.8) = 306$ kWh will be used. This interaction effect for this extreme case will be significant with either heating system because, it represents 1.5 - 4.0% of the typical space heating consumption (which ranges from 7 - 20,000 kWh/year).

A typical home in the Pacific Northwest will have approximately 7000 kWh/year of internal gains due to appliances and occupants, and about 4500 kWh occurring during the heating season.⁷ Our research suggests that most homes could reduce the appliance energy consumption by 50% to 75% through retrofit measures and replacement with more efficient appliances. This includes more efficient refrigerators and freezers, lighting systems, water heater insulation and hot water conservation measures. Roughly 2,250 to 3,375 kWh/year of useful internal gains would be lost as these measures were implemented. The amount of additional furnace output to offset this loss depends on the type and efficiency of the furnace.

⁷ Estimates of internal gains are based on CIRA simulations of "free heat." These figures are based on a 1350 square foot house in Portland, with 3 occupants, a water heater set at 140°F located in the heated space, a refrigerator using 1600 kWh/year, and a normal complement of additional appliances. For comparison, Palmiter (p. 19) estimates internal gains at 5133 kWh/year while acknowledging that a 50% variation among different homes is not unusual.

The first technique (net energy savings) is initially simpler but has several drawbacks. By listing only the net energy savings, many assumptions are made about the location of the appliance, the heating system and the climate in which the home is located.

We must treat appliances located in unheated areas separately because those in unheated areas provide no useful heat. The refrigerator in the garage, for example, must be reckoned differently than the one in the kitchen. With the exception of water heaters, we have no data on appliance location. About 44% of the electric water heaters are located in unheated areas. (See water heater documentation.) Even a simple measure, such as installing a water heater blanket, must be divided into at least two measures to reflect differences in the water heater's location.

Next, one must make assumptions regarding the type and efficiency of the heating system. If the home is heated with natural gas, then there is no increase in electricity consumption. At least with respect to estimating electricity conservation potential, the interactions question does not exist for gas-heated homes. Roughly 56% of BPA homes are not electrically heated. (PNWRS, Vol. I, p.41) A higher efficiency light bulb or refrigerator in electrically-heated and gas-heated homes must therefore be treated differently. Even among electrically heated homes, one must distinguish between homes with heat pumps, baseboard resistance, and those with electric furnaces (because each has a different efficiency). Finally, the net savings for appliance conservation measures will be larger in warmer regions than in colder regions (because the heating season is shorter).

This strategy also ignores the interactions between space heating conservation measures and the amount of internal gains. As furnace output increases to offset more efficient appliances, the energy savings from insulation and other space conditioning conservation measures likewise increases.

Our analysis of conservation potential does not include air conditioning, because it constitutes only 0.8% of total residential electrical consumption (BPA July 1982 Forecast, p. 73). Here internal gains work against the cooling system. Reducing appliance energy use lowers air conditioning requirements. The Net Savings Strategy becomes especially complicated if air conditioning is added in the future. The net savings are added (rather than subtracted as in space heating).

The alternative strategy, adjusting internal gains in the space heating end use as the appliance conservation measures are implemented, has somewhat different problems. Reducing the internal gains from the appliance measures at the appropriate places in the sequence of space heating conservation measures is possible and could be done by our program Work4. It involves, however, hundreds of incremental adjustments in the internal gains to reflect the effect of each appliance improvement.

We can simplify this procedure by sacrificing the linkage of reductions in internal gains to specific conservation measures. The incremental reductions are lumped together and the internal gains are scaled down in relatively large blocks. Each block thus represents a combination of measures. The block reductions in internal gains can be introduced at the appropriate level of cost-effectiveness. For example, there may be several appliance conservation

measures with costs of conserved energy (CCE) between 2 and 3 cents/kWh, including a refrigerator improvement, a few lighting measures, and a clothes dryer measure. The total reduction in internal gains from these measures would depend on many factors related to the house and its location. At 3 cents/kWh internal gains for houses in the coldest climate zone would be cut 600 kWh to reflect appliance improvements with costs of conserved energy between 2 and 3 cents/kWh. Space heating consumption would actually rise at 3 cents/kWh to reflect the loss of this supplementary heat source. In the warmest region, the internal gains would be cut only 400 kWh between at 3 cents/kWh due to the shorter season and different locations of appliances.

Many of the the drawbacks of the net savings approach are avoided by adjusting internal gains in the space heating end use. Gas heated homes and different climate regions can be treated individually. Likewise, the varying efficiencies of electrical heating systems can be incorporated.

We prefer to use the latter strategy. The appliance data will be "cleaner" because it permits us to use energy savings data obtained from standard testing procedures without further, and complicated, corrections for internal gains. On the other side, adjusting in internal gains is a commonly accepted element of space heating calculations.

The loads program built-in to CPS 2.0, Work4, will accept "negative" conservation measures, that is, a loss of free heat through appliance improvements. Enter a negative energy savings and a negative cost in the measure data base. (The result is a positive CCE.) Select the appropriate cost so that its CCE falls in the desired range.

Quantification of Internal Gain Effects

We have attempted to quantify the changes in space heating energy use (using the adjusted internal gains strategy) in two steps. First, the CPS 2.0 model was run with internal gains for each of the typical case cut in half (e.g. 3,500 kwh/yr rather than 7,000 kwh/yr). From this modification we determined that approximately 50% of the decrease in 'free heat' is 'captured' by increased savings for the space heating measures. Table III-3 presents these results.

Table III-3 Effect of Internal Gains "Adjustment" on Space Heating End Uses (GWh/year)								
Year	W/O "Adjustment" ^a			"W/ "Adjustment" ^b			Difference	
	Baseline	Potential	Difference	Baseline	Potential	Difference	Baseline	Potential
1980	18893	16657	2236	22375	19834	2538	3482	3177
1985	19747	8240	11507	23550	10489	13061	3803	2229
1990	20773	6910	13863	24941	9158	15783	4168	2248
1995	21994	6875	15119	26577	9266	17311	4583	2391
2000	23436	6886	16550	28492	9442	19050	5036	2500

^a This case represents the CPS 2.0 results reported in Part 1

^b This case is identical to the first except that the internal gains are halved.

The second part of our analysis involved the calculation of the change in internal gains for both appliances and water heating. The formula for calculating the internal gains offset at a given cutoff price (cce) is:

$$\text{Usage} = \text{MSave} * \text{Sat} * \text{Lfrac} * \text{Adj} * \text{COP}$$

where:

Usage = The internal gains that are **not** 'captured' by the space heating measures.

MSave = Cumulative Total Savings (column I) from the Conservation Measure Output Table at a given cutoff price.^k

Sat = The percentage of electrically-heated households with either electric water heating or electric appliances.

Lfrac = The percentage of appliances that are located within the heated portion of the house.

Adj = Adjustment factor determined in step one.

COP = The overall coefficient of performance of the electric heating system.

For our analysis we have taken the the MSave from the water heating or appliance conservation measure tables. The Sat for water heating and electric appliances are 0.81 and 0.41, respectively. The Lfrac for water heating is 0.44 and is assumed to be 1.0 for appliances. The Adj factor is 0.50, and the

overall COP is assumed to be 1.0 Table III-4 presents the results of our analysis.

Table III-4 Internal Gains Results			
Cutoff Price (\$/kWh)	Total Savings (TWh)	IG change (TWh)	(MW Avg)
Water Heating 2000			
0.01	6.5	1.2	137
0.02	7.0	1.3	148
0.03	8.7	1.6	183
0.15	11.9	2.1	240
Water Heating 1995			
0.01	5.8	1.0	114
0.02	6.3	1.1	125
0.03	7.3	2.3	274
0.15	10.5	1.9	320
Water Heating 1990			
0.01	5.3	1.0	114
0.02	5.7	1.0	114
0.03	6.8	1.2	136
0.15	9.0	1.6	182
Water Heating 1985			
0.01	4.8	0.9	102
0.02	5.1	0.9	102
0.03	5.9	1.0	114
0.15	7.0	1.3	148
Appliances 2000			
0.01	9.5	1.9	217
0.02	10.3	2.1	240
0.03	11.5	2.4	274
0.15	13.1	2.8	320
Appliances 1995			
0.01	7.3	1.3	150
0.02	7.8	1.4	160
0.03	8.3	1.5	171
0.15	10.3	1.8	205
Appliances 1990			
0.01	5.0	0.9	102
0.02	5.3	1.0	114
0.03	5.6	1.0	114
0.15	7.2	1.3	148
Appliances 1985			
0.01	2.5	0.4	46
0.02	2.6	0.5	57
0.03	2.8	0.5	57
0.15	4.0	0.7	80

Solar Gains

We also used CIRA to calculate average solar gain contributions for our typical homes. Estimates of solar gains are substantially more difficult to make on a generalized basis than internal gains. This is because they are heavily dependent on such factors as house orientation, amounts of glazing area, landscaping, and use of curtains. We were unable to obtain any of this type of information from the Regional Survey and consequently, were dependent largely on CIRA default values, and reasonable estimates of house configurations. For example, we assumed equal glazing on all sides of the home. Based on this admittedly crude analysis, we estimated that solar gains, in a sample of Northwest cities, ranged upward to 9000 kwh/year. We used this value as a guideline, generally discounting it by 1000 to 2000 kwh to be conservative in our estimates. However, the solar gains values remain one of the most uncertain inputs in our analysis.

Electric Space Heating Systems

The electric space heating equipment is divided into into three types: baseboard electric resistance, electric heat pump with a duct distribution system, and electric furnace with forced-air ducts. Other electric systems include portable space heaters, radiant electric heat, and central boilers "fueled" by electricity. Although the Regional Survey indicates some use of these latter systems, they generally represented a maximum⁸ of only few percent of the total systems, consequently we have ignored them.

The division among the three heating systems is made for several reasons: 1) there are often efficiency losses associated with duct distribution of heated air, 2) heat pumps have a coefficient of performance (COP) significantly greater than 1.0, 3) retrofit installation of heat pumps in houses with distribution ducts already in place is substantially cheaper than installation in houses without ducts, and 4) duct insulation is an important conservation measure for many units.

Single family attached and detached homes had all three types of units. Mobile homes were assumed to be electric furnace only. Multi-family units were assumed to have only electric baseboard.

"New" Stocktype Prototypes.

The new stocktype prototypes were developed mainly for sources other than the Regional Survey. The most significant data source was the the material published by Housing Industry Dynamics Inc. (HID, 1976-1981). Each year HID conducts a national survey of active homebuilders to "determine the characteristics of new housing and construction practices of new homebuilders" (HID, "Survey Methodology" (unpublished) available from HID, Crofton, MD). HID claims that the 4,000 to 5,000 usable response represent 10 to 12% of the nation's annual housing starts. The survey controls for responses by state and by size of builder and then generates a series of "average" units of

⁸ Portable electric heaters were the largest proportion of this secondary category and are indistinguishable from baseboard electric heat, with the possible exception of more zone heating with portable heaters.

building products per house. The averages are disaggregated by state and housing type: single family-detached, single family-attached (2-4 unit structures or townhouses), and multi-family low-rise (5 or more units and three stories or less). HID indicates that "within the confines of acceptable research error and the size of the sample, the annual usage rates calculated from the survey are assumed to be a statistically valid representation of total product usage". Nonetheless, because the survey is voluntary, and there appears to be no provisions for pre-screening of responses, the data on building characteristics may be biased. For example, builders who tend to heavily insulate their dwellings may be more likely to respond. There also is no indication in the survey material that the builders responses are checked for accuracy, or that there is any check on the quality of construction or component installation. We tried to check the validity of the HID data by comparing it with samples from the Regional Survey's 1976 through 1979 constructed units. However, when we selected for housing type, age, and use of electric space heating the Survey sample size became so small we felt it was no longer a valid comparison.

HID data for the Pacific Northwest are available for each year from 1976 through 1981. For single family-detached units all four states in the region are included, for attached structures Montana is excluded, and for multi-family units there is only Oregon and Washington data. Although the number of units constructed in this time period varied substantially, the sampling was able to maintain a roughly 10% response rate, i.e. builders responsible for constructing 10% of the total number of units in each state were included in the published sample.

We used the HID data to help determine five of the six major heat loss paths used in the WORK4 modelling: floor, ceiling, walls, doors, and windows (there was no HID data on infiltration). In all case we used the "mean" or "average" values for U-values, and areas. Floor, ceiling, and wall R-values are reported directly, without any explanation of how they were calculated. We assumed that these values represented the total R-value of the building component included the insulation and the building shell material. Door and window R-values were not reported, however we assumed a standard value from ASHRAE for door insulation and used the glazing layers information to calculate a weighted average window resistance. For additional information refer to the appropriate end use documentation sections.

COSTS

Two major sources were used to determine regional cost data for space heating conservation measures: The National Association of Home Builders Research Foundation Inc.'s Installed Costs of Energy Conservation Measures, (June 1980) and Ecotope's estimates included in Potential for Conservation for Electrical Energy in Northwest Residences, (June 1982). Both of these studies were based on phone surveys of conservation supply contractors located in the Pacific Northwest. The NAHB survey obtained cost estimates for conservation measure installation in newly constructed residences in Boise, Idaho; Portland, Oregon; and Seattle, Washington. The Palmiter work covered both installations in new homes and retrofit conservation measures in existing structures with phone contacts centered in the Seattle and Portland areas.

In addition to these two major sources of cost information, supplemental sources included the Sears Roebuck Catalog, the Computerized Instrumented Residential Audit (CIRA) computer program, the Residential Conservation Service, and a variety of utility estimates.

More details on specific measure costs are included in the appropriate conservation measure sections, however, a few points deserve particular note.

- 0 The NAHB cost survey show little variation in new house conservation measure costs among the three cities surveyed in the region. Consequently, we have assumed that each of the three climate zone divisions used in the analysis have the same measure costs.
- 0 Although there is only a limited variation in typical costs for insulation material and installation, the range of costs for window glazing measures can be very large (Palmiter, June 82, p. 29 and NAHB, June 1980, p. 4). These cost variations are due, in large measure, to the variety of frame materials, the type of window, and the quality of the window. In addition custom designed windows can be much more expensive
- 0 A standard 22 percent builder overhead and profit figure has been added to new construction.
- 0 Although Palmiter's survey indicated that installation of conservation measures in new buildings are more expensive than retrofits, we find the assumption difficult to accept. We believe that physical constraints imposed in retrofitting are greater than in new construction and that retrofitting will entail higher labor costs. We have, therefore, used the lower NAHB estimates for new construction.
- 0 All costs are in 1980 dollars. We have not used the Palmiter procedure to revise the cost to 1982 dollars via a GNP inflator. All of our analysis is based on 1980 as the conservation potential program start-year.

Wood Consumption

Another factor that influences the accuracy of our estimates is the contribution of wood heating to the total energy use of Pacific Northwest homes. Fireplaces and wood stoves have become a major source of supplemental heating for many of the regions residences. Even if we know the amount of wood burned, its contribution to the house's total heating load is difficult to estimate because there are enormous variations in fireplace efficiency and the wood's heating value.⁹ In addition, fireplaces and wood stoves often provide zone heating. The fireplace may cause a net decline in efficiency of home heating if the combustion air is drawn from inside the house.

⁹ M.P. Modera and R.C. Sonderegger, Determination of In-Situ Performance of Fireplaces, LBL-10701, August 1980, is a good source of information of the problems of determining the contribution of wood heat to the space heating requirements of a home. Also see U.S. Department of Energy, "What about Fireplaces" Pub 313 for a simple guide to fireplace efficiency.

The Residential Survey includes several questions on the use of wood in the region. These include information on the number of stoves or fireplaces, the presence of fireplace doors, the presence of heat exchangers on the fireplace, the number of cords of wood consumed during the preceding year [1978], and the sources for the wood¹⁰. In addition, question 34 in the Survey asks for the number of rooms heated by the additional heating equipment. However, there is no information on what percentage of the total floor area these rooms represent, or whether the central heating system is turned off when the supplemental source is being used.

The Oregon Department of Energy's Residential Energy Conservation Survey (ODOE, March 1979) provides some gross data for the entire state. Fifty eight percent of the state's households burned some wood, with the average annual 1978 consumption being 2.7 cords. Unfortunately, this information was not available by housing type and, consequently, was of little use.

Notwithstanding all of the uncertainties involved, we have attempted to make some rough estimates for the contribution of wood heating total space heating. Our estimates have been added to the total internal gains of the house. However, we have not tried to take into account the effects of zone heating which can very significantly reduce total heating requirement. Only the single family-detached case provided enough data to be able to estimate wood consumption.

We assumed that a cord of medium density wood (such as douglas fir), semi-seasoned would produce about 18 million BTUs of heat or the equivalent of 5200 kwh. Further we assumed that a typical fireplace in the region would deliver about 7% of the the heat generated to the house and that a stove would provide about 50%. In zone 1 about 10% of the homes have a stove, and about 40% have and use fireplaces. Mean annual consumption is approximately 2 cords. For zone 2 the percentages are 10% and 50%, respectively, with mean consumption at 2.2 cords. Finally for zone 3, the penetration of stoves in single family detached units reaches 20% while fireplaces are present in 40% of the remaining units. Average consumption is 3.0 cords/year. We estimate 1000 kwh/year of equivalent heat is provided by wood in zones 1 and 2 and nearly 2,000 kwh/year-equivalent provided in zone 3. Wood contributes from 10 to 20 % of the internal gains of a single family detached home.

Data Limitations and Uncertainty

As with the appliance and water heating sections of this report the space heating analysis is heavily dependent on detailed end-use data. The Regional Survey has provided much of this data for existing residences while the HID surveys served as a major source for new construction practices. Although both of these source have much useful information they remain incomplete. For example, the Regional Survey contains no information on multi-family and mobile home insulation characteristics, although they are vital elements in determining both heat loss and potential for conservation measures. Additionally, the size of the samples that remain after selecting for a number of characteristics such as climate zone, insulation amounts, and type of heating

¹⁰ See Regional Survey questions 33 through 39.

system are often quite small. Extrapolation of small sample sizes to the larger population of homes in the region can introduce a large range for potential error.

Validation of the various survey results is also of major importance. Neither the PNW Regional Survey nor the HID surveys included a sample validation procedure. This should receive a high priority in any future surveys.

Additional Assumptions

- 0 All conservation materials and installation procedures are of high quality, e.g. we assume that blown-in wall insulation contractors leave no unfilled gaps.
- 0 Only physical constraints to conservation implementation are included in our eligible fraction estimates.
- 0 We have not attempted to estimate any additional "administrative" costs associated with program implementation.

Start Year and Roll in Rate and Stop Year

Each conservation measure in the analysis requires a measure start year and a roll in rate. The start year is the year that the measure will begin to be added into the applicable housing stock and the roll in rate (specified in years) is the amount of time required for the measure to be implemented in the end use up to the level of the eligible fraction. For example, a wall insulation measure with a start year of 1980, a roll in of 8 years and an eligible fraction of 45 %, will begin to enter the model's conservation potential calculations in 1980 and will be in 45 % of the dwellings present in 1988. The stop year is the year when a conservation measure begins to rollout of the stock (this is not used in the space heating analysis). For additional information on these parameters refer to Appendix A.

The start year for all space heating measures is 1980, the same year as the program start year. We have chosen 1980 for several reasons. First, most of the data that is available on housing stock characteristics is 1980 information. Secondly, all space heating conservation measures we have included are currently available. There are no "future" technologies involved. Finally, we have no replacement of measures by new future measures.

The roll in time we have used is dependent on the end use sector (single family-detached, single family-attached, multi-family, and mobile home) and the stocktype ("old" or "new"). Within a given sector and stocktype all measures are assumed to have the same roll in time. For conservation measure in new housing we use a one year rollin regardless of the end use sector. This is done to reflect the fact that measures will be added at the time of construction of the house and needed not be rolled in over time as is the case with "old" stock. The eligible fraction for new housing is then used to reflect the percentage of the stock constructed each year that will have the conservation

measure installed.

Recall that the roll in time is defined as the shortest period of time that conservation measures can be implemented with disruption to the supply market. "Disruption" being defined as noticeable increases in the real cost of insulation measures. In addition we have tried to account for consumer constraints in the roll in estimate. For "old" stock we have used the single family-detached end use as the benchmark with roll in time of five years. Traditionally, the penetration of conservation measures into single family dwellings has been the most rapid. This is reasonable considering most of these homes are owner occupied and the occupants are able to benefit directly from conservation investments. Accordingly, we have assumed a longer roll in time for those sectors having a higher percentage of renters. Roll in time for single family attached units is 7 years, for mobile homes 8 years, and for multi-family residences 10 years.

Space Heating Enduse Descriptions

The following contains more detailed information on the space heating end uses. For the sake of brevity we have grouped end uses together by climate zone. New stocktype mobile homes in all three climate zones, for example, are described under a single end use heading. Each of the sections include a description of the end use with emphasis on unique characteristics, a discussion of the derivation of the initial stock values, and the addition and decay (replacement) rates. In addition, we include references and discussions of other related studies and caveats in interpretation of the data. Refer to the introductory discussions for additional material on methodology and general assumptions.

In order to make full use of this documentation the reader should have a detailed copy of the CPS 2.0 model output available. * The outputs provide substantial detail on the typical cases used to derive aggregate end uses and conservation measures. Briefly, the typical case output for space heating end uses contains useful information in two locations, the "Initial Conditions" section, and the "Measure Effects" section.

The "Initial Conditions" section contains all of the primary inputs that WORK4 uses to calculate an initial UA/efficiency and consumption value for each typcase. The "Initial Primary U-values" are, from left to right on the printout, ceiling/roof, walls, floor, glazing, the heat capacity of the interior air, and doors. The primary areas or volumes are expressed in square feet, except for the infiltration path which is in air changes per hour (ach). The efficiencies are given for the primary heating system (baseboard, furnace, or heat pump) and the forced air ducting systems (if applicable). The initial fixed consumptions, entered as negative values, give the internal gains and solar gains estimates in kwh/year (note that wood heating would be included in the internal gains entry). The inside temperature is the heating season average in degrees Fahrenheit. The city indicated is the one from which the weather data is taken (Portland is #1, Spokane #2, and Boise #3).

The "Measure Effects" section presents the total electricity consumption, the initial and subsequent UA values for the dwelling unit, the difference between the balance temperature and the outside temperature, the contribution of free heat (both internal gains and solar) to the heating season, and the heating system efficiencies.

* The CPS 2.0 model will generate different amounts of output depending on the setting of qualifier on the "DIAGNOSTIC" control card. The control card should be set to level "2" for maximum information (See A-22 for details).

END USE EN11100E00 EN11200E00 EN11200E00 Space Heating
Mobile Home New Stocktype Zones 1 2 3

END USE DESCRIPTION

The most detailed information on new mobile home characteristics is provided in a study by Steven Winters Associates, An Analysis of Energy Conservation Options for Manufactured Housing (DOE-Steven Winters, Nov 1982). Based on this source we have divided the new housing stock in each of the three climate zones into two prototypes, a single wide (or single section) prototype with 924 square feet of floor space (14' x 66') accounting for 70% of the new stock and a double wide (or double section) prototype with 1344 square feet of floor area and representing the remaining 30% of the new stock. We assumed uniform insulation and glazing characteristics for all three climate zones (refer to the typical case outputs for more details). We also assumed that the mobile homes were heated by electric furnaces, but because the ducts were well insulated and enclosed within the trailer shell there were no duct losses. The Winters' prototype are based on national manufacturing trends, divided into three national climate zones. All of the Pacific Northwest falls into their zone 2; hence we have assumed that the prototypes are the same throughout the entire region. When more data become available we will be able to improve our analysis accordingly.

INITIAL STOCK

The total initial stock of new mobile homes is entered as 159,000. By climate zone the breakdown is 79,000 zone 1; 68,000 zone 2; 12,000 zone 3. This represents the total stock of units present in the program start year (1980) and is used by the model to calculate the incremental additions of new mobile homes and replacement of "old" mobile homes.

UEC

From the prototypes developed for new mobile homes we used WORK4 to calculate a region-wide average UEC of 8179 kwh/year. This is approximately 87% of the estimated space heating electricity consumption in existing mobile homes. In large measure this decrease in UEC reflects the increased insulation levels assumed for the newly constructed units. The aggregate UEC is composed of a 5949 kwh/year consumption for zone 1 units, 9860 kwh/year usage for zone 2, and 13,575 kwh/year for zone 3. These zone estimates are based on WORK4 calculations of energy use and assume that the relative proportions of single and double-wide units are constant in each zone (30% double, 70% single). Sales weighted data from the major cities in each region would help to improve the quality of the UEC estimates.

ADDITION RATE

The addition rate is 0.038, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). The addition rate is assumed to be the same for all three climate zones. No data were available with which to determine zone-specific additions.

The mobile home stock is the fastest growing end use sector. Note that we have assumed that the addition rate in the BPA forecast is valid for the stock of electrically heated homes. We have not included any accounting for fuel switching.

REPLACEMENT RATE

The replacement rate (i.e. construction of new houses to replace the retired part of the existing stock) is 0.042, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). The replacement rate is assumed to be the same for all three climate zones. No data were available with which to determine zone specific additions. This replacement rate is derived from an assumed 23.8 mean lifetime for mobile homes (Refer to BPA, Appendix 1 for additional details). The replacement (decay) rate also assumes a constant percentage saturation of electrically heated mobile homes.

OTHER STUDIES

Two other studies provide prototype for new Pacific Northwest mobile homes, Palmiter (June 1982) and Synergic Resources Corporation, (Jan 1982). The Palmiter prototype was the same for all three climate zones and had the following characteristics:

Walls	939 ft ²	R 11
Roof/Ceiling	1040 ft ²	R 19
Floor	1040 ft ²	R 11
Glazing	125 ft ²	Double Pane
Door	36 ft ²	R 2
Infiltration	0.6 ach	

For the Synergic Resources study the prototype was taken from the U.S. Department of Energy, "Mobile Homes", Appendix C Economic Analysis, Energy Performance Standards for New Buildings, DOE/CS-1029, January 1980. The units had R-14 ceiling roof insulation, R-11 floor insulation, and R-11 walls with some double glazing. Four sizes were examined ranging from 720 ft² to 1960 ft². Palmiter's analysis estimated a new mobile home UEC of 9615 kwh/year.

CAVEATS

Data on characteristics of new mobile homes in the region are limited. The HID surveys which provided us with useful data on the other "new" building stocks does not include any

analysis of mobile homes. The building prototypes need to be verified by regional survey information. See above for additional details.

END USE E011100E00 E011200E00 E011300E00 Space Heating
Mobile Home-Old Zones 1 2 3

END USE DESCRIPTION

Information on existing mobile homes both nationally and in the Pacific Northwest is very limited. Although the Residential Survey provides some general information on mobile home characteristics, it does not include any data on amounts of insulation. To the best of our knowledge there is no other region specific information on the thermal characteristics of mobile homes in the Pacific Northwest. This is a serious data limitation particularly because the mobile home sector is the fastest growing housing sector in the region (BPA, Appendix 1, May 1982) and, consequently, will assume an increasingly larger share of total housing stock.

Notwithstanding the lack of information on insulation characteristics the Regional Survey does provide information on the basic physical structure of mobile homes. The Survey indicates that slightly more than 63% of all mobile homes in the region use electricity as their primary fuel source (volume 4 p 61). This electrically heated sector has the following characteristics: the average mobile home is 1000 ft² (950 to 1060 ft² in the .95 confidence interval). Zone 1 homes have a modelled area of 960 ft², zone 2 homes have 1000 ft², zone 3 homes have an area of 1100 ft². The area of glazing in each climate zone was particularly large ranging from 248 ft² in zone 1 to 185 ft² in zone 2. This high percentage might be attributable to the prevalence of large sliding glass doors.

For the WORK4 prototype insulation levels, we assumed that the ceiling contained R19, and the walls were not insulated for all cases in zones 1 and 2 (equivalent to R7), and only in a few cases for zone 3 (average R9 wall value). Because more than 85% of the mobile homes contained a crawl space, presumably covered with a skirting, we used a mean R-value for uninsulated crawl space (provided by the CIRA computer program) of R-13. Double glazing and storm windows is uncommon in zone 1, but quite common in zone 3, with zone 2 having intermediate levels.

INITIAL STOCK

The total initial stock of old mobile homes is entered as 159,000. This represent the total stock of units present in the program start year (1980) and is derived from BPA data (BPA, Appendix 1, May 1982) based on the saturation of electric heating in mobile homes. By climate zone the breakdown is 79,000 in zone 1; 68,000 in zone 2; and 12,000 in zone 3. We apportioned the stock into climate zones based on the percentage of electrically heated mobile homes in each zone as indicated by the regional survey. The estimates were corrected to include case weighting and to accurately reflect

the BPA service territory portion of Montana.

UEC

New mobile home UEC were "corrected" to conform as closely as possible with the BPA estimated electric space heating consumption figure of 9391 kwh/year (BPA, Appendix 1, May 1982). The WORK4 calculation of consumption is 9435 kwh/year with zone 1 units using 7760 kwh, zone 2 units 10,549 kwh, and zone 3 units 14,145 kwh. Note that the BPA baseline consumption does not include any estimate of zone specific energy consumption, only a regional total.

ADDITION RATE

The stocktype "old", as we have defined it, has no addition rate. All additions are included in the "new" stocktype.

DECAY RATE

The decay rate (i.e. removal of existing houses from the stock) is 0.042, based on BPA forecast stock changes (BPA, Appendix 1, May 1982).

OTHER STUDIES

The Palmiter existing mobile home prototype has 1000 sq ft of floor space, (20x50x8), 125 sqft of glazing, wood-frame walls with 1/4 quarter inch masonite interior finish, and metal exterior siding. It has uninsulated skirting, and two hollow core doors (R2). The ceiling of the unit is insulated to R 19, the floors to R 11, and there is no insulation in the walls. Infiltration is assumed to be 0.6 air changes/hour (ach) and the window glazing ranges from 70 % double glazed in climate zone 1 to 88 % double glazed in climate zone 3 (Palmiter, 1982)

The Synergic Resources study (Jan 1982) briefly describes mobile homes in the region, and estimate the average annual energy use for space heating to be 7,962 kwh/year. Their prototype is based on Seattle City Light's Copper Creek Alternative Study (April 1981). The study estimates that the typical mobile home in the region is approximately 1,028 square feet. However, it does not contain specific information on insulation levels.

The Natural Resources Defense Council Model Plan (NRDC, 1982) derives their prototype from BPA data. Their unit has 960 square feet of floor space, 144 square feet of glazing (15 % of the floor area), and a gross wall area of 1024 square feet (40'x 24'x 8').

CAVEATS

See discussion above.

END USE EN12100E00 EN12100E00 EN12100E00 Space Heating Single
Family-Detached New Stocktype Zones 1 2 3

END USE DESCRIPTION

The single family-detached "new" stocktype is modelled much more simply than the corresponding "old" stocktype because we have assumed that the new units added to the stock are substantially more homogeneous than those currently present in the region. For our analysis we have made a number of assumptions:

- 1) One prototype can be used to describe all of the new additions in each of the three climate zones. This is a 1350 ft² unit with 146 ft² of glazing.
- 2) New homes will be constructed with three types of electric heating systems: baseboard (30%), electric furnace (50%), and heat pump (20%). The percentage saturation of each type of heating system is derived from the HID material.
- 3) The internal gains in new homes will be slightly less than those in "old" homes because of new more efficient appliances and water heaters.
- 4) The mean daily temperature settings in new homes will be higher than in existing homes: 68°F versus a range of of about 63 to 67°F.
- 5) Insulation levels in new homes are, on average, greater than in existing structures. Ceiling levels are R19 to R30, walls R11, floors R20, and glazing from single to double pane depending on region. (Note that we have assumed new windows are aluminum frame and, therefore have a lower R-value than comparable wood frame windows in the "old" stock.)
- 6) New homes with either forced air electric furnace, or heat pumps have highly insulated ducting systems with an average efficiency of .98 compared to our estimate of .85 in older homes.

For further details on typical UA values, etc. refer to the program output.

INITIAL STOCK

The 640,000 units in this end use were split into the three climate zones with 337,000 in zone 1 (52%), 254,000 in climate zone 2 (40%), and the remaining 49,000 (8%) in climate zone 3. The initial stock values were calculated from the 1980 single family stock average estimates of BPA (BPA, May 1982) by multiplying by the percentage saturation of

electrically-heated homes. The divisions into climate zones were based on the percentage of cases in the regional survey, using the weighted number of cases (to correct for over and under sampling of states) with the Montana values further reduced to include only that portion of Montana which is actually in the BPA service territory (about one-third of the state's total housing stock) These values represent the total stock of units present in the program start year (1980) They are used by the model to calculate the incremental additions of new single-family detached homes and replacement of "old" single-family detached homes.

UEC

Based on the prototypes we have chosen for the new homes we have calculated a region-wide UEC of 10211 kwh/year for space heating or about two-thirds of the consumption of the existing stock average home. In climate zone terms this breaks down into 9304 kwh, 10,815 kwh, and 13,316 kwh.

ADDITION RATE

The addition rate is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982).

REPLACEMENT RATE

The replacement rate (i.e. construction of new house to replace existing stock that has been removed (decayed)) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982).

OTHER STUDIES

The area characteristics of our prototype new units are based on the Palmiter analysis (Palmiter, June 1982) and have been checked against the Housing Industry Dynamics data (HID 1976-1981) for reasonableness. The HID data was used as the basis for determining the average insulation levels. Washington/Oregon data were used for zone 1, Idaho data for zone 2, and Montana data for zone 3. Our estimate of approximately 10,000 kwh for new housing agrees closely with the Palmiter analysis.

CAVEATS

The limitations of HID data on which we depended for a large part of this analysis are discussed in the introductory section.

END USE EN13100E00 EN13200E00 EN13200E00
Space Heating Single Family-Attached-New Stocktype Zones 1 2 3

END USE DESCRIPTION

New single family-attached units were modelled with only a single typical case for each climate zone. This 1200 ft² unit was developed largely from HID survey data. The survey indicates that new units are being constructed to a very high level of thermal efficiency with a UA around 310. This is a significant increase from the existing stock values and may represent inaccuracies in the HID data. Additional details can be found in the typical case outputs.

INITIAL STOCK

The initial stock of "new" single-family attached homes is 374,000. By climate zone the entries are 224,000, 101,000, and 49,000. This represents the total stock of units present in the program start year (1980) and is used by the model to calculate the incremental additions of new single-family attached homes and replacement of "old" single-family attached homes.

UEC

The UEC of "new" single family-attached structures is calculated by WORK4 to be 7892 kwh/year.

ADDITION RATE

The addition rate is 0.022, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). This rate is assumed to be the same for all three zones.

REPLACEMENT RATE

The replacement rate (i.e. construction of new house to replace existing stock that has been removed (decayed)) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). This rate is assumed to be the same for all three zones.

OTHER STUDIES

Single family-attached structures have generally not been considered apart from the single family category in other Pacific Northwest studies.

CAVEATS

See the introductory section for a discussion of the HID data.

END USE E013100E00 E013200E00 E013300E00 Space Heating Single
Family-Attached Old Stocktype Zone 1 2 3

END USE DESCRIPTION

The single family-attached category includes all units classified, in the regional survey, as semi-detached, attached on 2-sides, 2 to 4 units detached, 2-4 units 1-side attached, and 2 to 4 units with 2-sides attached (question 1d). We have divided this end use from the single family detached category for three reasons. First, the presence of adjoining walls, floors and ceilings in attached houses units make accurate modelling more difficult. If we were to include these units in the detached category the reliability of our analysis would be diminished. Second, nearly 50% of the attached units are renter occupied while less than 17% of the detached structures have renters. This indicates that the rate of penetration of conservation measures can be expected to be slower in attached stock. Finally, only a portion of the attached structures have data on insulation levels.

The "old" stocktype analysis is built upon 23 typical cases, 9 each in climate zones 1 and 2, and 5 in zone 3. Because of the lack of detailed insulation data, we have condensed the insulation categories in three groupings: low (less than R4 ceiling), medium (R4-19), and high (greater than R20). This division was further disaggregated to accommodate the three electric heating system types. We found a wide range in the floor area estimates for this stock: from 892 ft² to 1671 ft². Similar variation also was present for glazing area. Although the standard error of the estimates was in the same percentage range as for detached structures, the small number of typical cases may not provide a sufficiently large base for extrapolation to the regional population. For additional details refer to the typical case outputs.

INITIAL STOCK

The initial stock of "old" single-family attached homes is 374,000. By climate zone the entries are 224,000, 101,000, and 49,000. This represents the total stock of units present in the program start year (1980). The total stock value is from BPA (Appendix 1, May 1982) and the division into climate zones is based on the percentage of typical cases in the Regional Survey.

UEC

The BPA forecast projections do not include a separate UEC estimate of single family-attached units apart from the single family value of 15028 kwh/year (BPA, Appendix 1, May 1982). Therefore, we had no specific baseline UEC with which to "validate" our estimate. We have used essentially the same value as the single family-detached estimate, i.e.,

approximately 15,000 kwh/year. Our rationale for this estimate is that internal gains for attached residences might be significantly less than for detached, because of shading effects, fewer appliances, less wood heating, etc. Nonetheless, a random sampling of utility bills in this sector would significantly increase the validity of estimate.

ADDITION RATE

The stocktype "old", as we have defined it, has no addition rate. All additions are included in the "new" stocktype.

DECAY RATE

The decay rate (i.e. removal of existing houses from the stock) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982).

OTHER STUDIES

The Palmiter and NRDC studies did not break out single family attached units from the single family category.

CAVEATS

Note that our division of housing stock between single family-attached units and single family-detached may differ from that used by other regional studies or utilities. Additional problems with data quality and sample size are indicated above.

END USE EN15100E00 EN15200E00 EN15300E00 Space Heating
Multi-Family New Stocktypes Zone 1 2 3

END USE DESCRIPTION

The multi-family "new" prototypes (one for each climate zone) were developed largely from data provided by the HID surveys. The HID information is available only for Washington and Oregon and we have assume it can be applied to the entire region. We have² assumed that the units have an average floor area of 1000 ft², have two adjoining walls, 100 ft² of glazing area (including sliding glass doors). Insulation levels in zones 2 and 3 are R-20 ceiling, R-11 walls, R-11 floors, double glazed windows, and an average infiltration rate of 0.6 ach. The levels in zone 1 are slightly lower, particularly because we assume only single pane glass will be installed. Additionally all units will continue to use electric resistance baseboard as their main heating system.

INITIAL STOCK

The total initial stock of electrically heated multi-family units in the region is 274,000. (BPA, Appendix 1, May 1982). There are 214,000 units in zone 1, 57,000 in zone 2, and only 3,000 in zone 3. This represents the total stock of units present in the program start year (1980) and is used by the model to calculate the incremental additions of new multi-family units and replacement of "old" multi-family units.

UEC

We have estimated that new residences in the region will use an average of 6885 kwh/year, or roughly the same amount of energy used by existing units. The reason for this agreement is that the increased floor area of new units are assumed to be offset by improved thermal integrity.

ADDITION RATE

The addition rate is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). The addition rate is assumed to be the same for all three climate zones.

REPLACEMENT RATE

The replacement rate (i.e. construction of new house to replace existing stock that has been removed (decayed)) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). The replacement rate is assumed to be the same for all three climate zones.

OTHER STUDIES

Palmiter's prototype for new multi-family units has similar levels of insulation and roughly equivalent areas.

CAVEATS

The data taken from the HID survey only covers the states of Oregon and Washington and may not accurately represent multi-family construction practices in Idaho and Montana.

Accurate modelling of heat loss in multi-family units is difficult due to adjoining walls, floors, and ceiling. Unlike models such as DOE 2.0 the heat loads subroutines in CPS 2.0 are not designed to model multi-zone heating. Consequently, the conclusions concerning changes in heating load due to implementation of conservation measures should be viewed as general indicators of savings and not as precise estimates.

END USE E015100E00 E015200E00 E015300E00 Space Heating
Multi-Family-Old Stocktype Zones 1 2 3

END USE DESCRIPTION

The "old" stock side of multi-family residences is similarly constrained by data availability. The Regional survey does not contain data on insulation characteristics. Consequently, we have made use of the for data on areas, glazing layers, and heating systems. To determine the insulation levels we relied on the data developed by Palmiter. However, as was the case with existing mobile homes the lack of insulation information make such estimates highly suspect. We hope that in future regional survey work, insulation estimates, with on-site measurements will, be included as for the multi-family and mobile home sectors as well as for single family residences.

INITIAL STOCK

The total initial stock of electrically heated multi-family units in the region is 274,000. (BPA, Appendix 1, May 1982). In zone one there are 214,000 units, in zone two 57,000, and in zone three there are only 3,000 electrically heated units.

UEC

The BPA forecast uses an average consumption of 6752 kwh/year per multi-family dwelling unit. The WORK4 calculation for the region yields a result of 6708 kwh/units. The values are 6108 kwh for zone 1, 8869 kwh for zone 2, and 8452 kwh for zone 3. Note that zone 3 has a lower average consumption than zone 2. This result is most probably due to the lower area of zone 3 units, and our estimate of slighter greater thermal efficiency. However, because zone 3 represents such a small percentage of the total stock, the value has little influence on the stock average.

ADDITION RATE

The stocktype "old", as we have defined it, has no addition rate. All additions are included in the "new" stocktype.

DECAY RATE

The decay rate (i.e. removal of existing houses from the stock) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). This decay rate is assumed to be the same for all three climate zones

OTHER STUDIES

Refer to the Palmiter analysis (June 1982) for more information.

CAVEATS

Data on insulation levels is essentially nonexistent in any region-wide statistically valid sense. In addition there is little data available on the range of prototype multi-family units that are present in the Northwest. Finally there is a need for correlation between insulation levels, occupancy patterns, and energy consumption levels in these units as a check against modelling exercises.

Conservation Measure Descriptions

The following sections contains descriptions of the conservation measures that have been applied to the space heating end uses. In most instances we have combined similar measures, in different climate zones, under a single description. For example, additions of triple glazing in new single-family detached homes in climate zones 1, 2, and 3 are described under one entry. This was done to decrease the amount of redundant descriptive information and because the measure descriptions and costs are often identical or very similar.

For a rapid comparison of measure costs, lifetimes, eligible fractions, savings, and costs of conserved energy (cce) refer directly to the CPS 2.0 typical case outputs. The "Measure Ranking Table" contains this information for each typical case while the "Averaged Data" section immediately at the end of each end use output contains the result for all typical case in the end use. Appendix C provides a brief explanation of the column labels in each section.

CONSERVATION MEASURE(S) MN11100E0001 (112, 113)
Space Heat Mobile Home-New Stocktype 2-3 Glazing

MEASURE DESCRIPTION

In the typical cases for new mobile homes we assumed that all of the units, regardless of climate zone, had double-glazed windows installed as part of their standard equipment. Consequently, the units would only be eligible to add triple or quadruple glazing (see measure MN11100E002, below). The windows would be installed as factory equipment.

MEASURE COST

Cost estimates for installation of conservation measures in new mobile homes are taken from the An Analysis of Energy Conservation Options for Manufactured Homes (DOE-Steven Winters, Nov 1981). Glazing cost are \$1015 for double wide units, and \$ 855 for single wide units. These are factory installed measures.

AVERAGE SAVINGS

The average savings for this measure are 676 in zone 1, 1150 in climate zone 2, and 1507 kwh in climate zone 3. The savings are calculated by WORK4 assuming each layer of glass increases the effective R-value of the window by approximately 1. For comparison, Steven Winters' estimates a savings of approximately 660 /year in the Seattle area.

LIFETIME

The lifetime for the measure is 25 years thus we assume that the windows will not have to be replaced over the lifetime of the mobile home. This value is based on minimum lifetime requirements for conservation measures as set forth in the BPA Zero Interest Loan Weatherization Program- Energy Conservation Agreement (September 1981, attachment 7 pp 5). The document states that "components shall be designed to meet or exceed minimum life expectancies as follows: 1) 25 years for: insulation, windows, completely new sliding doors."

START YEAR

For all conservation measures implemented in the residential space heating sector, both in new and in old stock, we assume implementation will begin in 1980. This is because all of the measures are currently available in the market place.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

In all climate zones we estimate that 95 % of the units will be eligible for installation of triple glazed windows. This estimate assumes that for various design reasons 5 % of the stock cannot add triple glass.

CAVEATS

Implementation of the conservation measure may be particularly difficult because it assumes factory installation. Many of the new mobile home purchased in the Pacific Northwest are constructed outside of the region. Presumably, region wide construction standards would have to be established, similar to the State of California's appliance efficiency and auto emission standards. We have not attempted to make any estimate of the feasibility of such implementing such standards in the manufactured housing sector. One would expect that the approximate \$7000 cost of implementing all of the measures considered for new mobile homes would greatly increase the producers' reluctance to implement the measures.

CONSERVATION MEASURE(S) MN11100E0002 (112, 113)
Space Heat Mobile Home-New Stocktype 3-4 Glazing

MEASURE DESCRIPTION

The installation of quadruple glazing is merely an extension of the triple glazing measure described above. We assume factory installation.

MEASURE COST

The cost of quadruple glazing is the same as triple glazing except that we have added \$1 to guarantee that the measures will appear in the correct order in the WORK4 ranking.

AVERAGE SAVINGS

The additional savings from adding an additional layer beyond the triple glazed window are, by climate zone 216 , 422 kwh, and 568 kwh.

LIFETIME

The lifetime for quadruple glazing is 25 years, the same as triple glazing.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have also assumed that 95% of the mobile homes are eligible for quadruple glazing. The constraints to adding quad glass are assumed to be identical to those associated with triple glass.

CAVEATS

There may be problems obtaining quad glazed windows for new construction. We have no information available on the manufacture of such windows. It may be necessary to add an exterior or interior storm window in place of a 4-layer window.

CONSERVATION MEASURE(S) MN11100E0003 (112, 113)
Space Heat Mobile Home-New Stocktype Ceiling Insulation Add R16

MEASURE DESCRIPTION

This measure is simply the addition of an effective R-16 level of insulation to the ceiling/roof area of new mobile homes. The Winters' analysis indicates that this is the maximum feasible additional insulation that can be added without costly redesign of the roof. The R-16 values includes the effect of insulation compression.

MEASURE COST

The costs of installing an additional R16 insulation in the ceiling are \$480 in the double-wide prototype and \$402 in the single wide unit (DOE-Steven Winter, Nov. 1981) The weighted average cost is \$425.

AVERAGE SAVINGS

The WORK4 calculation of savings are 735 in zone 1, 1045 in zone 2, and 1330 kwh in zone 3.

LIFETIME

We generally assume that the lifetime of protected interior insulation is 30 years, but because the average lifetime of mobile homes is only 25 years, we have used the shorter lifetime here.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that the ceiling insulation measure can be added to 100 % of the new mobile homes.

CAVEATS

CONSERVATION MEASURE(S) MN11100E0004 (112, 113)
Space Heat Mobile Home-New Stocktype Wall Insulation Add R7

MEASURE DESCRIPTION

This measure involved increasing the value insulation in the interior the wall from R-11 to R-13 and then adding an exterior sheathing with an insulating value of approximately R-5.

MEASURE COST

The additional material and labor costs for wall insulation are \$615 for both single and double wide units. The reason that both costs are the same is because there is no significant difference in the net wall area for single and double wide units. The major cost component is the exterior sheathing which accounts for almost \$500.

AVERAGE SAVINGS

The average energy savings calculated by WORK4 are 885 , 1438 kwh, and 1820 kwh.

LIFETIME

We generally assume that the lifetime of protected interior insulation is 30 years, but because the average lifetime of mobile homes is only 25 years, we have used the shorter lifetime here.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that the ceiling insulation measure can be added to 100 % of the new mobile homes.

CAVEATS

CONSERVATION MEASURE(S) MN11100E0005 (112, 113)
Space Heat Mobile Home-New Stocktype Reduce Inf 0.3 ach

MEASURE DESCRIPTION

Reduction for infiltration in residences is described in other applicable sections of this documentation. We have assumed that careful construction at the factory can cut the air change rate in half. There is little empirical information to support such a reduction in mobile homes. Experiments should be undertaken to validate our assumptions. Specific measures could involve installation of a continuous vapor barrier, additional weatherstripping and caulking around doors and windows, sealing of wall, floor and ceiling penetrations, and installation of tongue and groove subflooring.

MEASURE COST

The cost of infiltration reduction is based on estimates developed for retrofit "house doctoring". We have used the same cost estimates for all entries in the data base regardless of stocktype or house size. Instead, we varied the level of reduction, assuming that new houses will be able to do a better job of infiltration reduction than retrofit houses. (Dickinson, et al., Feb. 1982)

AVERAGE SAVINGS

The average savings for infiltration reduction are calculated to be 1536 , 2173 kwh, and 2698 kwh.

LIFETIME

It is very difficult to estimate the lifetime of infiltration reduction measures; however, we believe a 15 year lifetime is realistic for new housing.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that the infiltration reduction can be implemented in 100 % of the new mobile homes.

CAVEATS

Many factors influence the effectiveness of infiltration reduction. First, if the transportation and on-site setup procedures are poorly conducted the factory installed infiltration reduction measures may be circumvented. For example, in double-wide units the seam may not be made air tight. Secondly, reduction of the ach rate to 0.3 may increase indoor air quality problems, and consequently be precluded or require the addition of an air-to-air heat exchanger. Finally, we have no empirical information indicating the effectiveness of infiltration on energy reduction in new mobile homes

CONSERVATION MEASURE(S) MN11100E0006 (112, 113)
Space Heat Mobile Home-New Stocktype Floor Insulation Add R9

MEASURE DESCRIPTION

Average insulation levels for new mobile homes in the Pacific Northwest are approximately R-11. Construction of the floor is such that the insulation level can be increased to between R-19 and R-20 with no design changes.

MEASURE COST

Installation of an additional R9 insulation in the floor of a mobile home is projected to cost \$240 in the double wide unit and \$176 in the single wide unit for an average cost of \$195 (DOE-Steven Winter, Nov. 1981)

AVERAGE SAVINGS

The average savings calculated by WORK4 are 566 , 772 kwh, and 956 kwh.

LIFETIME

We generally assume that the lifetime of protected interior insulation is 30 years, but because the average lifetime of mobile homes is only 25 years, we have used the shorter lifetime here.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that the floor insulation measure can be added to 100 % of the new mobile homes.

CAVEATS

CONSERVATION MEASURE(S) MN11100E0007 (112, 113)
Space Heat Mobile Home-New Stocktype Insulate Door

MEASURE DESCRIPTION

This measure requires the installation of a two highly insulated doors in place of the uninsulated doors normally installed on new mobile homes. The change in door would be from honeycomb hollow-core units to aluminum skin insulated foam core type.

MEASURE COST

The cost additional cost of an insulated door is approximately \$100 (DOE-Steven Winter, Nov. 1981). Thus two doors would add \$200 to the cost of the mobile home.

AVERAGE SAVINGS

Because of the relative low cost of this measure it generally is implemented earlier in the sequence of WORK4 measures. The savings are 555 , 799 kwh, and 960 .

LIFETIME

We assume that the insulated doors will last for the lifetime of the mobile homes; 25 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that the insulated doors can be added to 100 % of the new mobile homes.

CAVEATS

CONSERVATION MEASURE(S) MN11100E0008 (112, 113)
Space Heat Mobile Home-New Stocktype Heat Pump

MEASURE DESCRIPTION

Apparently few, if any, new mobile homes have heat pumps installed as standard equipment. The preference for those units with electric heat is for electric furnaces. For climate zone one the seasonal cop is assumed to 1.9; for zone 2, 1.8; and for zone 3, 1.7.

MEASURE COST

We have assumed that the additional cost of installing a heat pump in place of an electric furnace is \$3250 in a double wide unit and \$500 less in an existing unit. Cost are estimates adapted from the Sears Roebuck catalog (Winter, 1981).

AVERAGE SAVINGS

The savings attributable to the efficiency increase available from a heat pump addition may appear less than expected. The reason is that the high cost of the heat pump measure forces it downward in the WORK4 calculation procedure, after the UA value of the mobile home has been reduced by roughly a factor of two. In zone 1 the heat pump saves only 341 . For zones 2 and 3 the savings are 925 and 1538 kwh, respectively.

LIFETIME

The average lifetime of a typical heat pump is generally 15 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

- For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that all units that can have electric furnaces installed will also be able to accept a heat pump. Therefore, the eligible fraction is 100 % of the new mobile homes.

CAVEATS

In general the heat pump measures are implemented near the end of the list of applicable measures. This means that the heat pump will be installed in a low UA house and the corresponding savings

will be less. Consequently, they usually appear at or above the \$0.15 CCE cut-off price and therefore so not lower the UEC calculation.

CONSERVATION MEASURE(S) MN11100E0009
Space Heat Mobile Home-New Stocktype Change Roof Color from Light to Dark

MEASURE DESCRIPTION

This measure is taken directly from the DOE analysis (DOE- Steven Winters, November 1981). We have added this measure only in the first climate zone under the assumption that heat savings attributable to dark roof color will be offset by increases in summer cooling requirements in this zone.

MEASURE COST

The additional cost of this measure is estimated at \$200 by the DOE report. The cost increased results from installation of a prepainted aluminum (0.019") roof instead of a galvanized steel roof.

AVERAGE SAVINGS

The measure is not modelled directly in the WORK4 procedure but is assumed to save 200 based on DOE simulations for the Seattle, Washington. This measure does not appear in the final conservation supply potential because its CCE is greater than \$0.15

LIFETIME

The lifetime of the measure is based on an average lifetime for roofing.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

For the purpose of this example measure we have assumed that all new mobile homes sold in climate zone 1 can implement this measure. It is unlikely, however, that such a subregion specific marketing will be feasible.

CAVEATS

This measure is added to the analysis chiefly as an illustration of one aspect of the WORK4 model, namely the addition of a measure with fixed savings. The model cannot directly accommodate changes in solar gains or losses through its

UA/efficiency procedures.

CONSERVATION MEASURE(S) M011100E0001 (112, 113)
Space Heat Mobile Home-Old Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in existing mobile homes can take a variety of forms including installation of interior or exterior storm windows or replacement of the entire window with a double glazed unit. For the purpose of conservation savings analysis, the differences in savings are not significant.

MEASURE COST

We have relied on the Palmiter cost estimate of approximately \$4.00/ft². This would be the typical cost for a storm window installation. Cost for replacement of the window would be substantially higher.

AVERAGE SAVINGS

Savings calculated for this measure range from 1442 to 2279 kwh.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

For all "old" mobile home measures the roll in time is eight years (see introduction)

ELIGIBLE FRACTION

The eligible fraction is based on Regional Survey responses. In all three climate zones we have estimated that approximately 60 percent of the homes already have double glazing or equivalent.

CAVEATS

Costs for window conservation measure vary greatly, and depend on the window type, amount of labor required for installation, and the quality of the material desired. We have used the Palmiter estimates with the assumption that they are a reasonable "average" value. The conservation savings estimates do not include the effects of storm windows on infiltration reduction. We also have not decreased the

savings to account for decreases in solar gains due to reduced transmission. As a rule-of-thumb each additional layer of glass diminishes the solar gains through the window by about 10% (CIRA computer calculations).

CONSERVATION MEASURE(S) M011100E0002 (112, 113)
Space Heat Mobile Home-Old Stocktype 2-3 Glazing

MEASURE DESCRIPTION

This measure is identical to the one above except we increase the glazing to three layers.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

Savings from adding an additional layer of glass to a double layer window are much less than those from the initial double layer retrofit, ranging from 390 to 729 kwh.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years, and is based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all "old" mobile home measures the roll in time is eight years (see introduction)

ELIGIBLE FRACTION

We have assumed that the the penetration of triple glazed windows in existing mobile homes is essentially zero. Consequently, we have assumed an eligible fraction of .95, excluding 5% of the stock for those homes that might be physically unable to add a third glazing layer.

CAVEATS

We have not included a quadruple glazing measure as an option in the mobile home retrofit market.

CONSERVATION MEASURE(S) M011100E0003 (112, 113)
Space Heat Mobile Home-Old Stocktype Ceiling Insulation R-11

MEASURE DESCRIPTION

Addition of R-11 ceiling insulation to existing mobile homes is the largest amount we feel can be accommodated, without unacceptable compression.

MEASURE COST

The cost to retrofit ceiling insulation is approximately \$0.33 per square foot. This estimate is adapted from Palmiter.

AVERAGE SAVINGS

Average savings for insulation retrofits are calculated by WORK4 to range from 246 to 814 kwh/year. The relatively small savings, reflect the fact that we have assumed that most of the mobile homes in the region already have R-19 insulation in place.

LIFETIME

The lifetime for all interior insulation measures in mobile homes is the same as the average lifetime of the mobile home-25 year.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all "old" mobile home measures the roll in time is eight years (see introduction)

ELIGIBLE FRACTION

We have assumed that all but 5% of the homes will to implement this measure.

CAVEATS

Data on insulation levels of existing mobile homes is very sparse; consequently our estimate of an average of R-19 may be an overestimate. Thus we may be underestimating the savings potential from retrofit ceiling insulation.

CONSERVATION MEASURE(S) M011100E0004 (112, 113)
Space Heat Mobile Home-Old Stocktype Reduce Inf 0.2 ach

MEASURE DESCRIPTION

This infiltration reduction measure is similar to those described for other housing stocks. Because of the diversity of measures which will be required to reduce infiltration (weatherstripping, caulking, fixing broken windows, etc.) we have only indicated a general savings and cost. Based on the infiltration reduction research that has been conducted at the Lawrence Berkeley Laboratory (see for Dickinson, et al, Feb 1982; Lipschutz, et al, Aug 1981, Fisk Feb 1982) For a detailed discussion of the infiltration reduction techniques refer to The House Doctor's Manual, Energy Performance of Buildings Group, Lawrence Berkeley Laboratory, February 1982.

MEASURE COST

Measure cost are described in the "new" mobile homes section above.

AVERAGE SAVINGS

Savings from infiltration reduction ranged from 621 to 1318 as calculated by WORK4.

LIFETIME

See "new" mobile homes section.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all "old" mobile home measures the roll in time is eight years (see introduction)

ELIGIBLE FRACTION

We have no specific information available on infiltration rates in Pacific Northwest mobile homes. We have assumed, based on LBL studies (see above) that .65 ach is a feasible baseline infiltration rate and that on average mobile homes can reduce this level to 0.45 ach.

CAVEATS

We have not included an provisions for interior dehumidifiers or air-to-air heat exchangers in our analysis. Addition of either of these would increase the cost of measure without affecting the savings.

CONSERVATION MEASURE(S) MO11100E0005 (112, 113)
Space Heat Mobile Home-Old Stocktype Floor Insulation Add R-19

MEASURE DESCRIPTION

We assume that "old" stocktype mobile homes have no floor insulation and therefore can physically accommodate six-inch batts (R-19)

MEASURE COST

Cost of installation are approximately \$0.40 per gross square foot of floor area. (adapted from Palmiter, 1982)

AVERAGE SAVINGS

Saves calculated by WORK4 range from 1318 to 2835 kwh/year. These large savings are attributable to the lack of floor insulation in most units and the relatively low cost per R-value of insulation.

LIFETIME

All interior insulation in mobile homes is assumed to last for the 25 year average life of the mobile home.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" mobile home measure is 8 years (see introduction for details)

ELIGIBLE FRACTION

We have assumed that all mobile homes in the region have no underfloor insulation and that 100% can add it. This may be an overestimate give the fact that approximately 15% of the units are slab-on-grade. However, slab-on-grade units might make use of equivalent perimeter insulation.

CAVEATS

(See above)

CONSERVATION MEASURE(S) MO11100E0006 (112, 113)
Space Heat Mobile Home-Old Stocktype Insulate Door

MEASURE DESCRIPTION

This measure is identical to the "new" stocktype measure except that we have added an additional \$50 to account for labor.

MEASURE COST

The cost of this measure is based on a per door material cost of \$100 and installation cost of \$25 for a total of \$250.

AVERAGE SAVINGS

Refer to the typical case outputs for savings values.

LIFETIME

We assume that exterior insulated doors will last for 25 years (see corresponding "new" measure above)

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

ELIGIBLE FRACTION

We have assumed that all mobile homes are eligible for this measure.

CAVEATS

CONSERVATION MEASURE(S) M011100E0007 (112, 113)
Space Heat Mobile Home-Old Stocktype Wall Insulation Add R-11

MEASURE DESCRIPTION

This measure calls for the addition of R-11 blown-in wall insulation. The R-11 figure is the typical insulating value for 3 1/2" of blown-in insulation.

MEASURE COST

The cost of insulation is approximately \$0.52/ft².

AVERAGE SAVINGS

The savings for the wall insulation range from 2042 to 3237 kwh, as calculated by WORK4.

LIFETIME

The interior insulation in mobile homes is assumed to last for the 25 year average lifetime of the mobile home.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" mobile home measures is 8 years (see introduction for details)

ELIGIBLE FRACTION

The eligible fraction is assumed to be 100%.

CAVEATS

The assumed insulation levels for existing mobile homes are based largely on supposition, since the Regional Survey only provides a small amount of information on whether the wall have or do not have any insulation. Better stock characteristic data would help to improve this estimate.

CONSERVATION MEASURE(S) M011100E0008 (112, 113)
Space Heat Mobile Home-Old Stocktype Heat Pump

MEASURE DESCRIPTION

The heat pump measures use a seasonal COPs of 1.9, 1.8, and 1.7, respectively.

MEASURE COST

Our cost estimates for heat pumps are based on values adapted from the Sears/Roebuck catalog.

AVERAGE SAVINGS

(refer to program outputs)

LIFETIME

We have assumed that the typical life of a heat pump is approximately 15 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" mobile home measures is 8 years (see introduction for details).

ELIGIBLE FRACTION

The penetration of electric heat pumps, as indicated by the Regional Survey, is essentially zero. Therefore, we have assumed that all units can accept a heat pump retrofit.

CAVEATS

The quality of the estimates for this measure would be improved by the availability of more regional season heat pump performance data. Note that our estimates for COPs may be high especially since the heat pump is added after a number of conservation measures have been implemented. Evidence from the BECA-A analysis indicates that heat pumps in heavily insulated homes will only be needed during cold periods, i.e. when the temperature falls below 40°F. At such temperatures the COP of heat pumps begins to approach 1.0 (they operate essentially as resistance heaters). Our estimates of savings may thus be high, and the heat pump may move substantially farther above the \$0.15 cut-off energy price.

CONSERVATION MEASURE(S) MO11100E0009 (112, 113)
Space Heat Mobile Home-Old Stocktype Duct Insulation

MEASURE DESCRIPTION

Ducts losses occur for both electric furnaces and heat pump distribution systems. Based on the Survey responses to duct location and insulation we have calculated that typical losses in the "old" housing stock are probably about 15%, i.e., the efficiency of the ducting system is .85. For this measure we have assumed that an additional 1 to 2 inches of duct insulation are added and that this will result in an increase in distribution efficiency to .95. The calculation of original duct efficiency and improvements is derived from the CIRA computer program calculations. The CIRA procedure includes efficiency estimates for ducts location and amount of insulation.

MEASURE COST

Costs for duct insulation are taken from CIRA and are estimated to be \$1.00 dollars per linear foot. We have assumed that the average mobile home will have approximately 250 linear feet of ducts. This cost assumes that the ducts are easily accessible.

AVERAGE SAVINGS

Savings for duct insulation are 37 , 166 kwh, and 835 kwh. The savings are calculated by WORK4 as an improvement in system efficiency.

LIFETIME

We assume that duct insulation will be effective for 30 years.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for this measure is 8 years.

ELIGIBLE FRACTION

The eligible fraction is calculated based on the assumption that all mobile homes with electric furnaces are eligible for duct insulation. The regional survey did not provide sufficient data to determine the extent of actual duct insulation in mobile homes. Refer to the program output for additional details.

CAVEATS

We have assumed that all ducts are accessible for addition of insulation. We have assumed that all mobile homes with electric furnaces can utilize insulation.

CONSERVATION MEASURE(S) MN12100E0001

Space Heat Single Family-Detached New Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in new single family units assumes double pane windows will be installed at the time of construction of the house. This measure is only applied in zone 1 homes as all other single family homes are assumed to have double glazing installed as a standard feature.

MEASURE COST

The measure cost (from Palmiter) is \$2.00 per square foot.

AVERAGE SAVINGS

Climate zone 1 savings are calculated to be 2375 /year.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have determined that approximately 20% of the homes in zone 1 have double glazing (HID data). Consequently, the eligible fraction is .80

CAVEATS

CONSERVATION MEASURE(S) MN12100E0002 MN12200E0001 MN12300E0001
Space Heat Single Family-Detached New Stocktype 2-3 Glazing

MEASURE DESCRIPTION

Triple glazing in new single family units assumes triple pane windows will be installed at the time of construction of the house. This measure is applicable in all three climate zones.

MEASURE COST

The measure cost (from Palmiter) is \$2.50 per square foot.

AVERAGE SAVINGS

(refer to program output)

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have assumed that 5% of the homes will be physically unable to implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MN12100E0003 MN12200E0002 MN12300E0002
Space Heat Single Family-Detached New Stocktype 3-4 Glazing

MEASURE DESCRIPTION

Quadruple glazing in new single family units assumes quadruple pane windows will be installed at the time of construction of the house. This measure is applicable in all three climate zones.

MEASURE COST

The measure cost (from Palmiter) is \$3.50 per square foot.

AVERAGE SAVINGS

(refer to program output)

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have assumed that 5% of the homes will be physically unable to implement this measure.

CAVEATS

END USE E012100E00 E012200E00 E012200E00
Space Heating Single Family-Detached-Old Stocktype Zones 1 2 3

END USE DESCRIPTION

The single family-detached housing type is the largest electric space heating sector both in terms of numbers of units (640,000 units) and in absolute consumption. For this reason the sector has received particular attention in our analysis. Fortunately, the sector also has the most data available on housing characteristics, including insulation amounts. In order to make use of this data to the fullest extent possible we have used a large number of typical cases in the analysis, 15 each for climate zones 1 and 2, and 12 for climate zone 3. As noted in the introduction we have used the amount of ceiling/roof insulation to select typical cases (less than R4, R4-11, R12-19, R20-27, R28-38, and greater than R38 insulation levels). These cases were further subdivided by type of main heating system: electric furnace, baseboard electric resistance and heat pump.

Floor area is a critical determinant of the total energy use of the houses, as it is used to calculate the area of three of the six major heat loss path; floor, ceiling/roof, and walls. Palmiter in his analysis of single family units estimated the average size of the region's dwelling to be 1350 ft². Although this appears to be a reasonable value, particularly since single family attached structures are included, we discovered a large variation in housing size. The range in housing size for each of the climate zone's typical cases were:

Climate Zone 1	1284 ft ²	to	1743 ft ²
Climate Zone 2	1230 ft ²	to	1987 ft ²
Climate Zone 3	1202 ft ²	to	1837 ft ²

The standard error around these values ranged from 5 to 15%. Window area for these single family units also ranged widely.

INITIAL STOCK

The 640,000 units in this end use were split into the three climate zones with 337,000 in zone 1 (52%), 254,000 in climate zone 2 (40%), and the remaining 49,000 (8%) in climate zone 3. The initial stock values were calculated from the 1979 single family stock average estimates of BPA (BPA, May 1982) and were divided into climate zones based on the percentage of cases in the regional survey. The percentage allocation was based on the weighted number of cases (to correct for over and under sampling of states) with the Montana values further reduced to include only that portion of Montana which is actually in the BPA service territory (about one-third of the state's total housing stock)

UEC

Our objective in modelling the cases was to match as nearly as possible the 1979 baseline energy consumption values for the sector used in the ORNL residential model runs. BPA estimates that single family units (including both attached and detached) consume 15,028 kwh/year for electric space heating. In our runs we calculated a usage of 15,306 kwh for the entire region. This was derived from an aggregate average usage of 11356 kwh in zone 1, 19942 kwh in zone 2, and 21028 kwh in climate zone 3. The internal and solar gains inputs were used to correct our estimates to conform with the BPA baselines

ADDITION RATE

The stocktype "old", as we have defined it, has no addition rate. All additions to single family detached stock are included in the "new" stocktype.

DECAY RATE

The decay rate (i.e. removal of existing houses from the stock) is 0.018, based on BPA forecast stock changes (BPA, Appendix 1, May 1982). This value was used for all three climate zones, and while correct in the aggregate may over or underestimate the actual stock changes in a specific region.

OTHER STUDIES

Refer to the Palmiter, Synergic Resources, and NRDC studies for details. In all of these studies, however, there were at most three prototypes considered, not the 42 used in this analysis. Consequently, while these studies do provide some comparative values, they were of limited value in our development of prototype units.

CAVEATS

Many of the caveats associated with the analysis are covered in the introductory material.

CONSERVATION MEASURE(S) MN12100E0004 MN12300E0003 MN12200E0003
Space Heat Single Family-Detached New Stocktype Ceil. Insulation
Add R-38
Space Heat Single Family-Detached New Stocktype Ceiling Insula-
tion Add R-30
Space Heat Single Family-Detached New Stocktype Ceiling Insula-
tion Add R-30

MEASURE DESCRIPTION

The measure is the addition of insulation to the ceiling of the dwelling. In zone 1 we estimate that the house can accept an additional R-38 of insulation (about 1-foot). In zones 2 and 3 where the initial insulation levels are greater, we have only considered an R-30 measure. In all instances we have continued to discount the effective insulation level by 15% to account for possible compression (see "old" single family detached R-49 ceiling insulation measure for details). The R-38 has an R-32 value and the R-30 has an R-26 value.

MEASURE COST

Costs for installation of insulation in new homes are based on the NAHB cost survey. The costs are approximately \$0.35/ft² of gross ceiling area.

AVERAGE SAVINGS

Refer to the typical case outputs for measure savings calculations.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have assumed that all new housing will be able to physically implement this measure, therefore the eligible fraction is 1.00.

CONSERVATION MEASURE(S) MN12100E0005 MN12300E0004 MN12200E0004
Space Heat Single Family-Detached New Stocktype Wall Insulation
Add R12

MEASURE DESCRIPTION

This measure calls for the addition of a Thermax exterior wall sheathing with an R-value of 12. This measure would be installed at the time of construction and would not require that the house be resided.

MEASURE COST

The cost projections are derived from the NAHB cost survey for new building construction. They indicated that a regional cost of approximately \$0.75 per net square foot of wall area is realistic.

AVERAGE SAVINGS

The average savings for this measure range close to 1600 /year for each of the three climate zones. The greater savings for this measure in new units as compared to existing occurs because of the much lower cost. This makes it more economically feasible to implement the measure before other measures have substantially improved the building UA.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have used an eligible fraction of .900 for this measure. This assumes that approximately 10 percent of the new homes will not be able to add exterior wall sheathing because of design or materials constraints, e.g., the house is constructed of brick.

CONSERVATION MEASURE(S) MN12100E0006 MN12300E0005 MN12200E0005
Space Heat Single Family-Detached New Stocktype Reduce Inf 0.25
ach

MEASURE DESCRIPTION

See the single introduction and the single family detached "old" descriptions for details. The new dwellings have a lower initial ach rate than existing units (.60 versus .65). In addition, we have assumed that infiltration measures installed in new units will be more effective than retrofit installations and that a reduction of 0.25 ach is feasible.

MEASURE COST

Refer to the single family detached discussion.

AVERAGE SAVINGS

The average computed savings for infiltration reductions were 1535 , 2418 kwh, and 2289 kwh.

LIFETIME

We have assumed that 15 years is a reasonable lifetime for infiltration reduction measures which are installed with some care.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

All new houses are assumed to be eligible for this measure.

CAVEATS

We have not included any provisions for dehumidifiers or air to air heat exchangers, although the final infiltration rate falls to 0.35 ach.

CONSERVATION MEASURE(S) MN12100E0007 MN12300E0006 MN12200E0006
Space Heat Single Family-Detached New Stocktype Floor Insulation
Add R-11

MEASURE DESCRIPTION

This is standard addition of insulation to the area under the floor, done at time of construction. The R-11 insulation brings the total insulation level to R-30.

MEASURE COST

The costs, again taken from the NAHB, are about \$0.31/ft².

AVERAGE SAVINGS

The computed savings ranged from 696 to 1141 .

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have assumed that all new houses will be able to add an additional R-11 of underfloor insulation.

CAVEATS

Slab-on-grade units will not be able to implement this measure, however, they have perimeter insulation available as an option.

CONSERVATION MEASURE(S) MN12100E0008 MN12300E0007 MN12200E0007
Space Heat Single Family-Detached New Stocktype Insulate Door

MEASURE DESCRIPTION

See description for "old" stocktype.

MEASURE COST

The cost of this measure is based on a per door material cost of \$100 and no additional labor charges This makes the total cost \$200.

AVERAGE SAVINGS

The savings computed were 540 , 905 kwh, and 754 kwh.

LIFETIME

The lifetime of insulated doors is assumed to be 30 years.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

We have assumed that approximately 50% of the houses now being constructed have well-insulated doors installed as standard practice (HID, 1980-1981). Therefore we assume an eligible fraction of .500 in all three climate zones.

CONSERVATION MEASURE(S) MN12100E0009 MN12300E0008 MN12200E0008
Space Heat Single Family-Detached New Stocktype Heat Pump 1

MEASURE DESCRIPTION

This measure calls for the installation of a new heat pump with COP of 1.9 (zone 1), 1.8 (zone 2), and 1.7 (zone 3). This measure is applied to homes which were originally designed for either baseboard or forced air electric heating systems.

MEASURE COST

The costs of the heat pump is \$3025 for new homes that were planning on installing electric furnaces and \$4200 for those planning on electric baseboard. The former figure is lower as it does not include the additional cost of installing ducts. Cost estimates are adapted from Sears/Roebuck.

AVERAGE SAVINGS

(refer to program output)

LIFETIME

We assume that all heat pumps will last for 15 years.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

Based on the number of installations of electric furnace and baseboard heat, we have set the eligible fractions at .64, .40, and .80.

CAVEATS

Refer to the heat pump measure descriptions for old and new stock mobile homes for additional details.

CONSERVATION MEASURE(S) MN12100E0010 MN12300E0009 MN12200E0009
Space Heat Single Family-Detached New Stocktype Heat Pump 2

MEASURE DESCRIPTION

This measure is an upgrade in the efficiency of an existing heat pump. We estimate that the upgrade can improve the COP of the units by .6 in each of the climate zones.

MEASURE COST

We estimate cost of the measure at \$500.

AVERAGE SAVINGS

Consult the program outputs.

LIFETIME

We assume that all heat pump measures will have a 15 year lifetime.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time time for all "new" conservation measures is one year.

ELIGIBLE FRACTION

The eligible fractions for this measure are .2, .5 and .2.

CAVEATS

CONSERVATION MEASURE(S) M012100E0001 (122, 123)
Space Heat Single Family-Detached Old Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in existing single family homes can take a variety of forms including installation of interior or exterior storm windows or replacement of the entire window with a double glazed unit. For the purpose of conservation savings analysis the difference in savings are not significant.

MEASURE COST

The cost of this measure is taken from Palmiter and is computed at the rate of \$5.00 per square foot of glazing area.

AVERAGE SAVINGS

Refer to the program output for information on savings from double glazing retrofits.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction for double glazing in zone 1 is .589. For zones 2 and 3 the fractions are .444 and .170, respectively. The eligible fractions are derived from Regional Survey Data.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0002 (122,123)
Space Heat Single Family-Detached Old Stocktype 2-3 Glazing

MEASURE DESCRIPTION

This measure is identical to the double glazing measure except that a third layer of glass is added.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

The savings from triple glazing retrofits are substantially smaller than those for double glazing. One of the chief reasons is that they occur far down on the list of implemented measures. Refer to the program output for details. Note also that triple glazing measures often fall near or above the cut-off price of \$0.15 per kwh.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction).

ELIGIBLE FRACTION

Survey data give no indication of triple or quad glazing, therefore we have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) M012100E0003 (122,123)
Space Heat Single Family-Detached Old Stocktype 3-4 Glazing

MEASURE DESCRIPTION

This measure is identical to the previous measure except that a fourth layer of glazing is added.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

The remainings savings available from adding an additional layer of glass to an existing triple pane window are quite small (see output for details). In all cases the quadruple glazing is above our cut-off price.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

Survey data give no indication of triple or quad glazing, therefore we have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0004 (122,123)
Space Heat Single Family-Detached Old Stocktype Ceiling Insulation Add R-49

MEASURE DESCRIPTION

There are five possible ceiling insulation retrofit levels available for "old" single family detached housing. Only one level of insulation is used in each typical case, all others are "not applicable", i.e., they have an eligible fraction of 0.0. We have chosen only one retrofit level in order to illustrate the maximum feasible conservation potential, not the range of levels available below the maximum. For example for houses in the less than R4 category we added R-49 insulation in one step rather in lesser increments. In those cases where the insulation approached near-maximum levels, the R-38 + typical cases, only R-11 was added. In general, we tried to raise the level of insulation in all single family-detached homes to approximately the R-49 to R-55 range. The insulation material is assumed to be fiberglass insulation batts and would be approximately two feet deep. Not all homes have sufficient ceiling/attic capacity to accept two feet of insulation, especially near the eaves. Consequently, we have decreased the effective R-value for all insulation retrofits by 15 %, thus the R-49 insulation is assumed to have an effective R-42 resistance.

MEASURE COST

The cost of the measure is calculated based on a cost of approximately \$0.75 per gross square foot of ceiling area. The cost average cost for zone 1 is \$986, for zone 2, \$1067 and for zone 3 \$821.

AVERAGE SAVINGS

R 49 ceiling insulation is added only to those houses that have no insulation. These houses have a very high UA and space heating electricity consumption. Savings in the three zones were calculated to be 4101 , 7125 , and 8006 kwh. In all three climate zones this measure was the single largest energy saver by nearly a factor of two over the next largest saver.

LIFETIME

As with all interior insulation measures, except for mobile homes, we have used a lifetime of 30 years. This estimate is consistent with BPA program requirements, CIRA calculations, and several other conservation sources.

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction is calculated based on typical case measure fractions. In nearly all instances we have assumed that measure fraction, i.e. the percentage of units within a typical case that can implement the measure, is 100%. In a few case where Regional Survey information indicated that some of the houses could not add additional insulation the measure fraction is less (refer to the input data for details).

CAVEATS

Increasing the ceiling insulation level to more R-49 may exceed ceiling load bearing regulations. We have not allowed for this limitation in our analysis.

CONSERVATION MEASURE(S) MO12100E0005 (122,123)
Space Heat Single Family-Detached Old Stocktype Ceiling Insulation Add R-38

MEASURE DESCRIPTION

This measure is the same as the R-49 measure except it is implemented in homes with low to moderate levels of existing insulation. The R-38 value is entered as R-32 to account for compression near the eaves of the house.

MEASURE COST

R-38 insulation costs are taken from Palmiter and are about \$0.62 per gross square foot.

AVERAGE SAVINGS

Refer to program output

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is determined based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) M012100E0006 (122,123)
Space Heat Single Family-Detached Old Stocktype Ceiling Insulation Add R-30

MEASURE DESCRIPTION

This measure is the same as the R-49 measure except it is implemented in homes with moderate levels of existing insulation. The R-30 value is entered as R26 to account for compression near the eaves of the house.

MEASURE COST

R-30 insulation costs are taken from Palmiter and are about \$0.46 per gross square foot.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction is determined based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0007 (122,123)
Space Heat Single Family-Detached Old Stocktype Ceiling Insulation Add R-19

MEASURE DESCRIPTION

This measure is the same as the R-49 measure except it is implemented in homes with moderate to high levels of existing insulation. The R-19 value is entered as R16 to account for compression near the eaves of the house.

MEASURE COST

R-19 insulation costs are taken from Palmiter and are about \$0.35 per gross square foot.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction is determined based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) M012100E0008 (122)
Space Heat Single Family-Detached Old Stocktype Ceiling Insulation Add R-11

MEASURE DESCRIPTION

This measure is the same as the R-49 measure except it is implemented in homes with high levels of existing insulation. The R-11 value is entered as R11 to account for compression near the eaves of the house. In some homes with greater than R-49 insulation we do not add any additional insulation, both because of physical limitations and the very small energy savings.

MEASURE COST

R-11 insulation costs are taken from Palmiter and are about \$0.21 per gross square foot.

AVERAGE SAVINGS

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year for all conservation measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction is determined based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0009 (122) MO12300E000
Space Heat Single Family-Detached Old Stocktype Wall Insulation
R-11-Fill

MEASURE DESCRIPTION

One method of improving the thermal efficiency of walls is to add insulation to the interior, uninsulated wall cavity. Installation of fiberglass batts is not a feasible retrofit option, however, holes can be drilled in the wall and blown-in cellulose insulation added for moderate costs. Note that we are assuming cellulose and not urea-formaldehyde foam will be added, as the latter has been banned because of air quality problems

MEASURE COST

The measure costs are approximately \$0.52 per net square foot of exterior wall. This yields \$766, \$761, and \$813 for the climate zones.(Palmiter, June 1982)

AVERAGE SAVINGS

The savings for this measure are calculated by WORK4 as 1977, 2878 kwh, and 2600 kwh.

LIFETIME

We have assumed that all interior protected insulation will last for 30 years.

START YEAR

The start year for this measure is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is calculated by WORK4 from the measure fractions and applicable typical case fractions. Our estimates of percentage of dwellings that could add R-11 blown-in insulation were developed based on Regional Survey data. Only those houses that indicated "none" as the amount of wall insulation were assumed to be able to add this measures. Refer to the typical case inputs for details on specific measure fractions. In the aggregate, .312, .234, and .175 of the zone 1, 2, and 3 homes were determined to be eligible for this measure.

CAVEATS

Addition of blown-in wall insulation requires the insulation contractor to drill a number of holes into the side of the dwelling. Often the home owner finds this unsightly and may wish to delay adding the insulation until the house is ready to be painted. We have not included this constraint in our analysis. Additionally, there may be some problems of insulation settling with time, however, we were not able to quantify this effect and have not included it

CONSERVATION MEASURE(S) MO12100E0010 (122) MO12300E0010
Space Heat Single Family-Detached Old Stocktype Wall Insulation
R12-Side

MEASURE DESCRIPTION

A more involved and vastly more expensive wall insulation option is the addition of R12 Thermax insulation to the outside of a dwelling. This measure can only be added to the house when the house is resided.

MEASURE COST

The cost estimate for this option is taken from Palmiter (June, 1982) and is \$2.30 per net square foot of wall area. This high cost represents the cost of residing the house at the time of measure installation.

AVERAGE SAVINGS

The very high cost of this measure causes it to appear near the end of the list of measures implemented by WORK4, consequently, the potential savings are low and the cost of conserved energy is very high. In zone 1 WORK4 calculates a savings of only 193 , in zone 2 only 334 kwh, and in zone 3 only 506 .

LIFETIME

We are assuming that this measure will have a 30 year lifetime.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction, i.e. the percentage of units that can physically accommodate a conservation measure, is quite high-.800 in all three zones. We arrived at this value based on our estimates of the number of wood frame houses with siding in the region, derived chiefly from the Regional Survey.

CAVEATS

The very high cost of this measure makes it highly unlikely that homeowners will be willing to implement it. In addition the high CCE places the measure far above the energy cut off

line of \$.15 per .

CONSERVATION MEASURE(S) M012100E0011 (122) M012300E0010
Space Heat Single Family-Detached Old Stocktype Reduce Inf 0.2
ach

MEASURE DESCRIPTION

Infiltration reduction is described in the introductory sections. From studies on "house doctoring" conducted by LBL we have determined that 0.2 ach is a realistic infiltration reduction estimate for existing residences. (Dickinson, 1982; Fisk, 1982,) We assume that the infiltration measure will require a pressurization/depressurization of the home with a blower door, a two-person house doctor team, and approximately 10 total man hours of labor. The actual conservation procedures that will be implemented will vary substantially from house to house (see the LBL, House Doctor Manual).

MEASURE COST

Our estimate of cost for infiltration reduction is based on work performed at Midway, Washington and is assumed to be \$381 per house.

AVERAGE SAVINGS

The average computed savings for infiltration reduction are 1104 , 1907 kwh, and 2448 kwh.

LIFETIME

Although it is difficult to estimate the lifetime of an infiltration reduction measure because of the wide range of measures that can be used to reduce air infiltration, we have assumed that good quality workmanship would last for 15 years. There is little evidence for the long term durability of infiltration reduction measures especially based on pressurization measurements. This is an area which warrants additional study.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

Without actual pressurization measures of individual homes it is very difficult to determine the air infiltration rates. We have used a very general figure of 0.65 as our initial region-wide average infiltration rate. Similarly we have

assumed that a reduction of 0.2 can, on average, be implemented in all homes. As more infiltration measurements are made in the region one can begin to revise the eligible fraction estimates.

CAVEATS

As noted above there has been little work performed on infiltration rates and potential for reductions in the Pacific Northwest. The Eugene, Oregon (Lipschutz, Aug. 1981) and Midway, Washington (Dickinson, Feb. 1982) studies conducted by the Lawrence Berkeley Laboratory are the most often cited examples for the region. However, the sample sizes were small and not necessarily representative of the "average" building stock in the region. Consequently, our estimates of conservation potential from infiltration reduction remain highly uncertain.

CONSERVATION MEASURE(S) MO12100E0012 (122) MO12300E0011
MO12100E0013 (122) MO12300E0012
Space Heat Single Family-Detached Old Stocktype Floor Insulation
Add R-19 or Add R-30

MEASURE DESCRIPTION

Retrofit floor insulation has been split into two measures. For the purposes of our analysis we have assumed that all houses in the region are built with a crawl space and that the underfloor area has approximately 10 inches of space available for insulation. In those homes that indicated they had some floor insulation in place (Regional Survey) we assumed that it was R-11 and that an additional R-19 could be added. For homes indicating no underfloor insulation we applied the R-30 insulation measure. We have assumed that the insulation will be fiberglass batts held in place with either nylon netting or wire prongs.

MEASURE COST

The cost of retrofitting underfloor insulation are adapted from Palmiter (June, 1982) and are \$0.50 for the R-19 and \$0.62 for the R-30.

AVERAGE SAVINGS

The WORK4 program orders the measures by CCE and therefore because of its lower costs the R-19 measure was implemented in the typical case before the R-30 measure consequently the savings for the R-30 measure are less than those of the R-19. This can be corrected by a recalculation of the eligible fraction and use of only one measure in a given typical case. Nonetheless the aggregate savings for the two measures implemented are roughly correct. Refer to program output for details.

LIFETIME

The lifetimes for these two measures are 30 years.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is calculated from the Regional Survey based on the factors described above. In Zone one .203 and .516 of the house can accept R-19 and R-30 respectively. In zone two the fractions are .203 and .433, and in zone three they are .287 and .410.

CAVEATS

As noted above the implementation of these measures assumes the existence of a crawl space under the house (a basement would also work, however, the savings effects would be different). To the extent that we have included slab-on-grade units in our analysis of potential we have overestimated conservation potential. However, perimeter insulation on slab can also yield substantial savings at comparable costs.

We have assumed that all houses have an underfloor area of 10 inches where insulation can be added. This may not be the case in a number of homes because of the use of underfloor sheathing, etc. We know of no source of data on the extent to which this is a constraint on floor insulation in the region.

CONSERVATION MEASURE(S) M012100E0014 (122) M012300E0013
Space Heat Single Family-Detached Old Stocktype Insulate Door

MEASURE DESCRIPTION

This measure requires the installation of two highly insulated doors in place of the uninsulated doors normally installed on single family residences.

MEASURE COST

The additional cost of an insulated door is approximately \$100 (Palmiter, June 1982, Sear/Roebuck Winter 1981), thus two doors would cost \$200. We have added an additional \$50 to the cost as the labor charges for adding the two doors.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

We assume that these doors will have an average lifetime of 30 years.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction).

ELIGIBLE FRACTION

We have assumed that approximately one half to two-thirds of the homes in the region have doors with slight insulation on the order of R-2, but that the penetration of highly insulated doors, up to R-13 is almost zero. Consequently, we have used an eligible fraction of 1.0 in all cases.

CAVEATS

The door replacement options assumes that: 1) there are, on average only two exterior doors on a home (not including sliding glass doors which are included in the windows path), 2) the exterior doors are of standard size and construction, and 3) the occupants would be willing to change their doors.

CONSERVATION MEASURE(S) MO12100E0015 (122) MO12300E0014
MO12100E0016 (122) MO12300E0015
Space Heat Single Family-Detached Old Stocktype Heat Pump 1 Space
Heat Single Family-Detached Old Stocktype Heat Pump 2

MEASURE DESCRIPTION

See the discussion above for details.

MEASURE COST

The cost of the heat pump is \$3025 for existing homes that have on installed electric furnaces and \$4200 for those with electric baseboard. The former figure is lower as it does not include the the cost of installing ducts. Cost estimates are adapted from Sears/Roebuck.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

We assume that all heat pump measures will have a 15 year lifetime.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

The eligible fraction for this measure is calculated from Regional Survey data.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0016 (122) MO12300E0015
Space Heat Single Family-Detached Old Stocktype Heat Pump 2

MEASURE DESCRIPTION

This is an upgrade in the performance of an existing heat pump by a COP of .6

MEASURE COST

The cost of the measure is \$500.

AVERAGE SAVINGS

See program output for details

LIFETIME

We assume that all heat pump measures will have a 15 year lifetime.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

Only those dwelling units which have a heat pump already in place are eligible for this measure.

CAVEATS

CONSERVATION MEASURE(S) MO12100E0017 (122) MO12300E0016
Space Heat Single Family-Detached Old Stocktype Duct Insulation

MEASURE DESCRIPTION

Duct losses occur for both electric furnaces and heat pump distribution systems. Based on the Survey responses to duct location and insulation, we have calculated that typical losses in the "old" housing stock are probably about 15%, i.e., the efficiency of the ducting system is .85. For this measure we have assumed that an additional 1 to 2 inches of duct insulation are added and that this will result in an increase in distribution efficiency to .95. The calculation of original duct efficiency and improvements is derived from the CIRA computer program calculations. The CIRA procedure includes efficiency estimates for ducts location and amount of insulation.

MEASURE COST

Cost for this retrofit are taken from CIRA and are approximately \$1.00 per linear foot of ducting. We have assumed that a standard 1200 square foot home would have about 250 linear feet of ducting. This estimate was then scaled appropriately for different house sizes. The average costs by zone are \$268, \$281, and \$250. Note that this estimate assumes all ducts are easily accessible.

AVERAGE SAVINGS

The average savings for duct insulation are calculated by WORK4 as an efficiency improvement. Savings are 1091, 1971, and 2179 kwh.

LIFETIME

We assume that duct insulation will be effective for 30 years.

START YEAR

The start year for all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family detached stock is five years (see introduction)

ELIGIBLE FRACTION

We have calculated the eligible fraction for addition of duct insulation based on responses in the Regional Survey. Only those house with ducts and indicating no insulation we deemed

eligible. Hence the eligible fractions for this measure are very small: 0.010 in zone 1, 0.050 in zone 2, and 0.026 in zone 3.

CAVEATS

Implementation of this measure assumes that all ducts are accessible.

CONSERVATION MEASURE(S) MN13100E0001 (132, 133)
Space Heat Single Family-Attached New Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Installing double glazing in new single family units assumes double pane windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$2.00 per square foot.

AVERAGE SAVINGS

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0002 (132, 133)
Space Heat Single Family-Attached New Stocktype 2-3 Glazing

MEASURE DESCRIPTION

Retrofitting triple glazing in new single family units assumes triple pane windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$2.50 per square foot.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0003 (132, 133)
Space Heat Single Family-Attached New Stocktype 3-4 Glazing

MEASURE DESCRIPTION

Retrofitting quadruple glazing in new single family units windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$3.50 per square foot.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0004 (132, 133)
Space Heat Single Family-Attached New Stocktype Ceiling Insulation Add R-30 (R-38 in zone 3)

MEASURE DESCRIPTION

This is a standard ceiling insulation measure. R-38 has a effective R-32 insulating value and R-30 has an effective R-26 value. Note that we the HID data indicates a lower average installation

MEASURE COST

Cost are derived from the NAHB data (see single family detached)

AVERAGE SAVINGS

Refer to the program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

CAVEATS

CONSERVATION MEASURE(S) MN13100E0005 (132, 133)
Space Heat Single Family-Attached New Stocktype Wall Insulation
Add R12

MEASURE DESCRIPTION

This measure calls for the addition of a Thermax exterior wall sheathing with an R-value of 12. This measure would be installed at the time of construction and would not require that the house be resided.

MEASURE COST

The cost projections are derived from the NAHB cost survey for new building construction. They indicated that a regional cost of approximately \$0.75 per net square foot of wall area is realistic.

AVERAGE SAVINGS

The average savings for this measure range from just over 500 in zone 1 to more than 1400 in climate zone 3. The greater savings for this measure in new units as compared to existing occurs because of the much lower cost. This makes it more economically feasible to implement the measure before other measures have substantially improved the building UA.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that this measure can be added to all new single family-attached units.

CONSERVATION MEASURE(S) MN13100E0006 (132, 133)
Space Heat Single Family-Attached New Stocktype Reduce Inf 0.25
ach

MEASURE DESCRIPTION

This is a standard infiltration reduction measure. We have increase the reduction potential from 0.20 ach (old stock) to 0.25 ach.

MEASURE COST

We have used our standard cost estimate of \$381. See infiltration measures, above, for more details.

AVERAGE SAVINGS

Refer to program output for details.

LIFETIME

We have used a lifetime of 15 years for carefully installed infiltration reduction measures.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

The eligible fraction is 100%.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0007 (132, 133)
Space Heat Single Family-Attached New Stocktype Floor Insulation
Add R-11

MEASURE DESCRIPTION

This assumes that new housing can add an additional R-11 layer of insulation to an existing R-19 insulation.

MEASURE COST

Cost are derived from the NAHB data (see single family detached)

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that all houses in the region can accept and addition R-11.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0008 (132, 133)
Space Heat Single Family-Attached New Stocktype Insulate Door

MEASURE DESCRIPTION

MEASURE COST

The cost of this measure is based on a per door material cost of \$100 and no additional labor charges. This makes the total cost \$200.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

We have assumed that insulated doors will last for 30 year.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have used an eligible fraction of 0.50 under the assumption that approximately one-half of the new homes have insulated doors installed as standard equipment.

CAVEATS

CONSERVATION MEASURE(S) MN13100E0009 (132, 133)
Space Heat Single Family-Attached New Stocktype Install Heat Pump

MEASURE DESCRIPTION

This measure involves the installation of a heat pump in new single-family attached house. See the single family detached description for details.

MEASURE COST

The cost of the heat pump is \$3025 for new homes that were planning on installing electric furnaces, and \$4200 for those planning on electric baseboard. The former figure is lower as it does not include the the cost of ducting. Although we have used a slightly smaller prototype of new single-family attached than we have for the new single-family detached, we did not feel a significant cost reduction was warranted.

AVERAGE SAVINGS

LIFETIME

All heat pump measures are assumed to have a 15 year lifetime.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) M013100E0001 (132, 133)
Space Heat Single Family-Attached Old Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in existing single family homes can take a variety of forms including installation of interior or exterior storm windows or replacement of the entire window with a double glazed unit. For the purpose of conservation savings analysis the differences in savings are not significant.

MEASURE COST

The cost of this measure is taken from Palmiter and is computed at the rate of \$5.00 per square foot of glazing area.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0002 (132, 133)
Space Heat Single Family-Attached Old Stocktype 2-3 Glazing

MEASURE DESCRIPTION

This measure is identical to the double glazing measure except that a third layer of glass is added.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

Survey data give no indication of triple or quad glazing, therefore we have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0003 (132, 133)
Space Heat Single Family-Attached Old Stocktype 3-4 Glazing

MEASURE DESCRIPTION

This measure is identical to the triple glazing measure except that a fourth layer of glass is added.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

Survey data give no indication of triple or quad glazing, therefore we have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0004 (132, 133)
Space Heat Single Family-Attached Old Stocktype Ceil.Insulation
Add R-49

MEASURE DESCRIPTION

We have applied retrofit ceiling insulation measures of attached housing in the same manner as detached housing, namely a single incremental addition based on the initial level of insulation. Refer to the description of the measure "Single Family-Detached Old Stocktype Ceiling Insulation Add R-49" above for details. Note that we have entered the R-49 measure as an effective R-42 in our calculations to allow for compression.

MEASURE COST

R-38 insulation cost are taken from Palmiter and are about \$0.75 per gross square foot.

AVERAGE SAVINGS

Refer to the program outputs.

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is determined based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0005 (132, 133)
Space Heat Single Family-Attached Old Stocktype Ceil.Insulation
Add R-38

MEASURE DESCRIPTION

(See Measure MO13100E0004, above). The effective insulation level is R-32

MEASURE COST

R-38 insulation cost are taken from Palmiter and are about \$0.62 per gross square foot. AVERAGE SAVINGS

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0006 (132, 133)
Space Heat Single Family-Attached Old Stocktype Ceil. Insulation
Add R-30

MEASURE DESCRIPTION

(See Measure MO13100E0004, above). The effective insulation level is R-26

MEASURE COST

R-30 insulation cost are taken from Palmiter and are about \$0.46 per gross square foot.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is based on the amount of insulation present in the typical case.

CAVEATS

CONSERVATION MEASURE(S) M013100E0007 (132, 133)
Space Heat Single Family-Attached Old Stocktype Ceiling Insulation Add R-19

MEASURE DESCRIPTION

(See Measure M013100E0004, above). The effective insulation level is R-16

MEASURE COST

Cost are derived from the Palmiter data (see single family detached)

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

Refer to the program outputs

CAVEATS

CONSERVATION MEASURE(S) M013100E0008 (132, 133)
Space Heat Single Family-Attached Old Stocktype Ceiling Insulation Add R-11

MEASURE DESCRIPTION (See Measure M013100E0004, above). The effective insulation level is R-9

MEASURE COST

Cost are derived from the Palmiter data (see single family detached)

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

Refer to the program outputs

CAVEATS

CONSERVATION MEASURE(S) MO13100E0009 (132, 133)
Space Heat Single Family-Attached Old Stocktype Reduce Inf 0.2
ach

MEASURE DESCRIPTION

This is a standard infiltration reduction measure.

MEASURE COST

We have used cost of \$381 for all infiltration reduction measures.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

We have assumed that carefully installed infiltration reduction measures will be effective for 15 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

All existing homes are eligible for this measure.

CAVEATS

CONSERVATION MEASURE(S) M013100E0010 (132, 133)
Space Heat Single Family-Attached Old Stocktype Floor Insulation
Add R-19

MEASURE DESCRIPTION

This is a standard floor insulation measure.

MEASURE COST

Cost are adapter from Palmiter data.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0011 (132, 133)
Space Heat Single Family-Attached Old Stocktype Floor Insulation
Add R-30

MEASURE DESCRIPTION

MEASURE COST

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0012 (132, 133)
Space Heat Single Family-Attached Old Stocktype Insulate Door

MEASURE DESCRIPTION

MEASURE COST

The cost of this measure is based on a per door material cost of \$100 and installation cost of \$25 for a total of \$250.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

We have assumed that insulated doors will last for 30 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0013 (132)
Space Heat Single Family-Attached Old Stocktype Heat Pump 1

MEASURE DESCRIPTION

This measure is identical to the single-family detached measure described above.

MEASURE COST

The cost of the heat pump is \$3025 for new homes that were planning on installing electric furnaces and \$4200 for those planning on electric baseboard. The former figure is lower as it does not include the the cost of ducting. Cost estimates are adapted from Sears/Roebuck.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

All heat pump measures are assumed to have a 15 year lifetime.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is calculated from those homes that do not have an existing heat pump.

CAVEATS

CONSERVATION MEASURE(S) MO13100E0014
Space Heating Single Family-Attached Old Stocktype Heat Pump 2

MEASURE DESCRIPTION

This is a heat pump upgrade measure. Consult the single family detached measure for details.

MEASURE COST

(see single family detached)

AVERAGE SAVINGS

Refer to program output

LIFETIME

Heat pump measures should last, on average, about 15 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

Only those homes which already have a heat pump in place are deemed eligible for this measure. The saturation of heat pump homes has been computed from special SPSS runs of the Pacific Northwest Regional survey.

CAVEATS

The heat pump discussion for mobile homes highlights many of the caveats.

CONSERVATION MEASURE(S) MO13100E0015
Space Heating Single Family-Attached Old Stoctype Duct Insulation

MEASURE DESCRIPTION

This measure is identical to the one described for single family detached units.

MEASURE COST

We have assumed that insulation will cost approximately \$1.00 per linear foot of ducting. This estimate is taken from the CIRA computer program. There is no data that we know of on the typical length of Pacific Northwest home ducting, however, we have calculated that 250 feet is reasonable for 1200 to 1300 ft² dwelling. We have adjusted the distance slightly for larger and smaller homes and computed an average cost for each typical case.

AVERAGE SAVINGS

Refer to the typical case outputs for details on measure savings.

LIFETIME

We have assumed that duct insulation will last an average of 30 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for all "old" single family-attached conservation measure is 7 years (see introduction).

ELIGIBLE FRACTION

The eligible fraction is computed for those houses in the Regional Survey having ducting system located in unheated space with little or no insulation.

CONSERVATION MEASURE(S) MN15100E0001 (152,153) Space Heat
Multi-Family New Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in new multi family units assumes double pane windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$2.00 per square foot.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

For this measure and all other measures in the space heating sector we have assumed that rollin can begin in the base year, i.e., 1980. All of the technologies we have included in the analysis are available in the current market place.

ROLL IN TIME

For all new measure installations we have defined the roll in time to be one year. This is because we are assuming that installation of conservation measures occur at the time of construction.

ELIGIBLE FRACTION

We have assumed that all multi-family homes can accept double glazing. CAVEATS

CONSERVATION MEASURE(S) MN15100E0002 (152,153) Space Heat
Multi-Family New Stocktype 2-3 Glazing

MEASURE DESCRIPTION

Retrofitting triple glazing in new single family units assumes triple pane windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$2.50 per square foot.

AVERAGE SAVINGS

Refer to the program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed all but 10% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MN15100E0003 (152,153)
Space Heat Multi-Family New Stocktype 3-4 Glazing

MEASURE DESCRIPTION

Retrofitting quadruple glazing in new single family units assumes quadruple pane windows will be installed at the time of construction of the house.

MEASURE COST

The measure cost (from Palmiter) is \$3.50 per square foot.

AVERAGE SAVINGS

Consult the program output for details.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed that approximately 20% of the new multi-family units cannot utilize quad glazing because of physical constraints such as space limitations.

CAVEATS

CONSERVATION MEASURE(S) MN15100E0004 (152,153)
Space Heat Multi-Family New Stocktype Ceiling Insulation Add R-
11

MEASURE DESCRIPTION

This is a standard ceiling insulation measure.

MEASURE COST

Cost are taken from the NAHB study.

AVERAGE SAVINGS

Refer to program outputs

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We have assumed an eligible fraction of 1.0

CAVEATS

CONSERVATION MEASURE(S) MN15100E0005 (152,153)
Space Heat Multi-Family New Stocktype Reduce Infil 0.25ach

MEASURE DESCRIPTION

See prior infiltration reduction descriptions for details. Because measure is implemented in new housing we have increased the reduction from 0.2 (old) to 0.25 and have used a lower initial infiltration rate of 0.60 versus 0.65.

MEASURE COST

See above.

AVERAGE SAVINGS

Refer to the program output for details.

LIFETIME

We have assumed that careful installed infiltration reduction measures can have an effective lifetime of 15 years.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

We assume all new units are eligible for this measure.

CAVEATS

There has been very little empirical work on infiltration rates and in multi-family units. Communication of air between adjoining units has made pressurization tests difficult. The Energy Performance of Buildings Group at the Lawrence Berkeley Laboratory is currently researching this issue and should be a valuable source of information for future improved infiltration reduction estimates.

CONSERVATION MEASURE(S) MN15100E0006 (152,153) MN15100E0007
(152,153)
Space Heat Multi-Family New Stocktype Floor Insulation Add R-11
Space Heat Multi-Family New Stocktype Floor Insulation Add R-11

MEASURE DESCRIPTION

These are standard floor insulation measures added in two steps (see above)

MEASURE COST

Costs are from the NAHB cost surveys.

AVERAGE SAVINGS

Refer to program output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

For all new measures the roll in time is one year (see introduction)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0

CAVEATS

CONSERVATION MEASURE(S) MO15100E0001 (152,153)
Space Heat Multi-Family Old Stocktype 1-2 Glazing

MEASURE DESCRIPTION

Retrofitting double glazing in existing multi-family homes can take a variety of forms including installation of interior or exterior storm windows or replacement of the entire window with a double glazed unit. For the purpose of conservation savings analysis the difference in savings are not significant.

MEASURE COST

The cost of this measure is taken from Palmiter and is computed at the rate of \$5.00 per square foot of glazing area.

AVERAGE SAVINGS

Refer to output for specific numbers.

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time for retrofitting conservation measures in old (i.e., existing) multi-family units is 10 years. We know of no comprehensive region-wide data to support a more precise roll-in figure and have used ten years as simply our best judgement.

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) M015100E0002 (152,153)
Space Heat Multi-Family Old Stocktype 2-3 Glazing

MEASURE DESCRIPTION

This measure is identical to the double glazing measure except that a third layer of glass is added.

MEASURE COST

The measure costs, based on Palmiter, are approximately \$6.00/ft²

AVERAGE SAVINGS

Refer to program outputs

LIFETIME

The lifetime of window glazing measures is assumed to be 25 years based on BPA minimum lifetime requirements.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time is 10 years. (see above)

ELIGIBLE FRACTION

Survey data give no indication of triple or quad glazing, therefore we have assumed all but 5% of the units can implement this measure.

CAVEATS

CONSERVATION MEASURE(S) MO15100E0003 (152,153)
Space Heat Multi-Family Old Stocktype Ceiling Insulation Add R-11

MEASURE DESCRIPTION

This is a standard ceiling insulation measure.

MEASURE COST

Cost for this measure are taken from Palmiter.

AVERAGE SAVINGS

Refer to output.

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time is 10 years. (see above)

ELIGIBLE FRACTION

See program outputs.

CAVEATS

CONSERVATION MEASURE(S) MO15100E0004 (152,153)
Space Heat Multi-Family Old Stocktype Wall Insulation Add R8

MEASURE DESCRIPTION

We have assumed that multi-family dwellings have little or no wall insulation, and that an amount equal to R-8 could be blown in.

MEASURE COST

The costs are based on Palmiter data.

AVERAGE SAVINGS

Refer to output

LIFETIME

The lifetime of all interior insulation measures is assumed to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time is 10 years. (see above)

ELIGIBLE FRACTION

We have assumed that all units in the region are eligible for wall insulation.

CAVEATS

CONSERVATION MEASURE(S) MO15100E0005 (152,153)
Space Heat Multi-Family Old Stocktype Reduce Infl 0.2 ach

MEASURE DESCRIPTION

This measure is a standard infiltration retrofit.

MEASURE COST

All infiltration costs are assumed to be the same, only the amount of infiltration reduction changes.

AVERAGE SAVINGS

See output.

LIFETIME

For well installed air infiltration reduction measures we believe a lifetime of 15 years is reasonable.

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time is 10 years. (see above)

ELIGIBLE FRACTION

We have assumed that all units in the region are eligible for retrofits.

CAVEATS

CONSERVATION MEASURE(S) MO15100E0006 (152,153) MO15100E0007
(152,153)

Space Heat Multi-Family Old Stocktype Floor Insulation add R8
Space Heat Multi-Family Old Stocktype Floor Insulation Add R-11

MEASURE DESCRIPTION

See discussion under new stocktype

MEASURE COST

Cost are adapted from Palmiter.

AVERAGE SAVINGS

Refer to output

LIFETIME

The lifetime of all interior insulation measures is assumed
to be 30 years (see above).

START YEAR

The start year of all measures is 1980.

ROLL IN TIME

The roll in time is 10 years. (see above)

ELIGIBLE FRACTION

We have assumed that all units in the region can accept these
measures.

CAVEATS

PART FOUR
Water Heating Measure Documentation

WATER HEATING DOCUMENTATION

The water heating end-uses appear in both the major and minor data bases. The WORK4 program calculates the baseline UECs for water heating, and the average costs and savings for hot water measures, using the "typical" cases entered into the minor data base. (See the WORK4 documentation for a full explanation of the program.)

Water heating is divided into three end-uses: single-family, multi-family, and mobile home. No division into different climate zones was made because there was little evidence that energy consumption for water heating varies significantly among different climate zones. The water heating end-uses can be expanded later to include separate climate zones if BPA decides that this would be a useful feature.

Documentation for the water heating end-uses includes explanation of the "minor" data base inputs and the "major" data base inputs. For the "minor" data base, parameters for the typical cases (such as the amount of hot water consumed and the temperature of the water), and the measure data associated with each typical case (for example the measure cost and the effects of the measure on the typical case parameters) are specified and documented under "Minor Data Base Documentation". For the "major" data base, the parameters applicable to the entire end-uses (not just a single typical case) are explained (for example the stock, growth, and decay values). See below under "Major Data Base Documentation".

Additionally, the documentation includes comparisons of our savings estimates with other sources, including submetered data in the region. See "Analysis of Savings Results" below.

MAJOR DATA BASE DOCUMENTATION

Water Heating End-Uses

WATER HEATING-SINGLE FAMILY DWELLINGS EE34000E00

End-Use Description

This end-use is the electrical energy used to heat water in single-family homes. Both standby losses and heating requirements are included. Energy used to heat water for all hot water uses is in this end-use; laundry, dishwashing, showers, and miscellaneous other uses.

UEC

The baseline unit energy consumption used by the CPS program is the 1980 baseline UEC that BPA has determined through use of ORNL runs.

For single family residences this number is 4515 kWh/year (1981 Technical Review of ORNL, BPA Forecast Appendix 2, August, 1982).

The WORK4 program also calculates a baseline UEC from the typical cases in the minor data base. This number is compared with the major data base UEC in a consistency check. If there is more than a five percent discrepancy between the two figures, a warning flag appears. This is to make sure that the typical cases being used to calculate average savings from the conservation measures are representative, in the aggregate, of the baseline stock.

Initial Stock

The initial stock is the 1980 stock of single-family homes with electric water heaters. We have used the Pacific Northwest Residential Survey to get an estimated saturation of electric water heating in single family units of 0.8015 (Elrick & Lavidge, 1980, Volume 4, p. 121, using single family attached and detached columns). This saturation is then applied to the total single family occupied housing stock of 2391 thousand (see demographics documentation) to get an initial stock of 1916 thousand single-family units.

Addition Rate

The addition rate is 0.019, based on BPA forecast stock numbers (BPA, Appendix 1, August 1982).

Decay Rate

This is not applicable since we have not split water heating into "new" and "existing" units. (See appendix A for explanation of new and existing.)

WATER HEATING-MULTI FAMILY DWELLINGS EE35000E00

End-Use Description

This is water heating in multi-family units. At this point we have not separately evaluated the usage of central building water heaters.

UEC

The baseline unit energy consumption used by the CPS program is the 1980 baseline UEC that BPA has determined through use of ORNL runs.

For multi family residences this number is 2730 kWh/year (1981 Technical Review of ORNL; BPA Forecast Appendix 2, August 1982).

The WORK4 program also calculates a baseline UEC from the typical cases in the minor data base. (See explanation above, under "Water Heating-Single Family.")

Initial Stock

The initial stock is the 1980 stock of multi-family homes with electric water heaters. We have used the Pacific Northwest Residential Survey to get an estimated saturation of electric water heating in multi family units of 0.872 (Elrick & Lavidge, 1980, Volume 4, p. 121, using multi-family column). This saturation is then applied to the total multi family occupied housing stock of 327 thousand (see demographics documentation) to get a total initial stock of 285 thousand multi-family units.

Addition Rate

The addition rate is 0.018, based on BPA forecast stock numbers (BPA, Appendix 1, August 1982).

Decay Rate

See explanation above under "Water Heating-Single Family."

WATER HEATING-MOBILE HOMES EE31000E00

End-Use Description

This is electric water heating in mobile homes.

UEC

The baseline unit energy consumption used by the CPS program is the 1980 baseline UEC that BPA has determined through use of ORNL runs.

For mobile homes this number is 4225 kWh/year (1981 Technical Review of ORNL; BPA Forecast Appendix 2, August, 1982).

The WORK4 program also calculates a baseline UEC from the typical cases in the minor data base. (See explanation above, under "Water Heating-Single Family.")

Initial Stock

The initial stock is the 1980 stock of mobile homes with electric water heaters. We have used the Pacific Northwest Residential Survey to get an estimated saturation of electric water heating in mobile homes of 0.819 (Elrick & Lavidge, 1980, Volume 4, p. 121, using mobile home column). This saturation is then applied to the total mobile home occupied housing stock of 232 thousand (see demographics documentation) to get a total initial stock of 190 thousand mobile homes.

Addition Rate

The addition rate is 0.038, based on BPA forecast stock numbers (BPA, Appendix 1, August 1982).

Decay Rate

See explanation above under "Water Heating-Single Family."

MINOR DATA BASE DOCUMENTATION

Typical Cases Used For Water Heating

Generally, the typical cases were chosen to model a variety of plausible ("typical") residences with electrically heated water. Thus, one single-family typical case has a clothes washer and a dishwasher, with the water heater unwrapped and in a heated area, while a second typical case has a clothes washer but no dishwasher, with the water heater in an unheated area and the pipes insulated, etc.

However, we weighted the typical cases such that in the aggregate, there is agreement with the saturations of different characteristics pertinent to water heating. In other words, since 86.4 % of single-family homes have clothes washers, the sum of the weighted fraction of typical cases with clothes washers should approximate 86 %.

The table below shows the saturations of the water heating characteristics in the three end-uses. These were obtained from SPSS runs made at LBL of the Pacific Northwest Residential Survey (Elrick & Lavidge, 1980).

Table IV-1

SATURATIONS (in %) IN RESIDENCES WITH ELECTRIC WATER HEATING

CHARACTERISTIC	TOTAL	SINGLE-FAMILY	MULTI-FAMILY	MOBILE HOME
Water Heater:				
heated	56.1	54.0	75.3	56.4
unheated	43.9	46.0	24.7	43.6
wrapped	22.0	19.7	16.0	51.4
pipes insul.	27.1	24.3	12.3	65.7
Residence:				
showers restr.	19.5	19.3	18.3	22.1
clothes washer	77.8	86.4	12.3	77.5
dishwasher	51.0	51.7	54.6	39.3
# of residents	2.7	2.83	1.82	2.51

Note: totals may vary due to rounding.

Additionally, other characteristics must be specified for each typical case. These include:

- gallongage use for showers, laundry, dishwashers, and other
- areas and u-values for heater tank sides & top, bottom, and pipes
- hot water temperature
- incoming, cold water temperature
- ambient air temperature outside the heater tank

There are no Elrick & Lavidge survey data on these characteristics. However, there are data available from other regional and national sources on averages and ranges for these characteristics. We have tried to use some of this data to create reasonable typical cases which have "average" values for these characteristics, but which show some range of "typical" values.

For example, Seattle City Light survey data (Seattle City Light Dept., May, 1981) shows the average hot water temperature setting to be 144 degrees F, but also shows a range of settings from 110 degrees F to 165 degrees F. In addition to the varied settings, stratification of the heated water in the tank causes the temperature to vary, even at a certain temperature setting. Thus, we have included a range of values in our typical cases which averages to about 145 degrees F.

Similarly, since the majority of water heater tanks are 52 or 66 gallon tanks (Seattle City Light, May, 1981 for example), we calculated the areas of the walls, top and bottom of these sized tanks for use in our typical cases.

The initial u-value of the sides, top, and bottom of the water heater tank, and the pipes must be specified as inputs for the typical cases. We assumed that most unwrapped water heaters have about R-5 thickness walls and top. This corresponds to a u-value of 0.2. There is a heated air film around the water heater which makes the effective difference in temperature between the hot water temperature and the ambient temperature less than the actual difference. We have decreased the u-values of the sides of the water heater slightly to account for this phenomenon, hence we used u-values of 0.15 - 0.20 in the typical cases. The u-value for the water heater pipes was estimated to be about 0.80.

The annual average ambient temperature used for water heaters in unheated areas ranged from 50 to 55 degrees F. See p. 7, Ek, The Effects of External Insulation on Electric Water Heaters, BPA, Feb., 1982. This report cites average annual ambient temperatures in the BPA service area as 52.1 degrees F in the Western area, 50.7 degrees F in the Eastern area, and 41.6 degrees F in the mountain area. Since most of the BPA population is in the Western area, and since we suspect that the ambient temperature for water heaters in unheated areas may be slightly higher than the outdoor air temperature, we have used 55 degrees F for most of the typical cases in unheated areas. We used 50 degrees F for a few of the typical cases. For typical cases involving water heaters in conditioned areas, we used 65 - 70 degrees F as the local ambient temperature.

The average annual incoming (cold) water temperature is another variable. We have used values around 50 degrees F. Seattle City Light reports that Water Department records show the average annual water temperature in the Seattle area is 47 degrees F. (Seattle City Light Dept., May, 1981).

We used the formulas for water consumption given in an analysis of hot water consumption (Clear and Goldstein, 1980) with the number of persons/household information from the Elrick & Lavidge survey to get some average estimates for gallonage usage requirements.

Additionally, Palmiter (May, 1982) gives data on gallons used/occupant from several utility sources:

	Seattle	EPRI	WHIP	Tacoma
Daily Gallons/Occupant	24.2	18.7	17.9	12.4

Often, per capita hot water consumption is assumed to be about 20 gallons per day. (See, for example, Wall, Seattle City Light, Feb., 1982, p.11). Our per-capita values are less, for most of the typical cases. Lower values seemed reasonable, based on the Clear & Goldstein report (1980) and the Palmiter data cited, and in matching the baseline electricity consumption values. We have varied the amounts in our typical cases, but they average less than 20 gallons/person/day.

CONSERVATION MEASURES

Complete documentation on the water heating measures follows. This includes detailed descriptions of the measures, their costs, lifetimes, and eligible fractions.

Savings from the measures are generated through use of the WORK4 program (see documentation for this program in Appendix B). Inputs to the program for each of the measures in each typical case must include the cost, lifetime, and eligible fraction for that typical case, as well as the changes in the typical case parameters which are caused by implementation of the measure.

For example, for the measure to decrease the hot water temperature to 120 degrees, two changes must be entered for each typical case. These are: the degrees drop in hot water temperature and the increased gallonage for showers and other which would occur. (Showers are taken at a temperature which is the result of mixing hot and cold water. If the difference between these two temperatures is reduced, the amount of hot water needed to result in an equal amount of shower-temperature water will increase.)

Consider the measure "install low flow showerheads." This measure results in a decreased volume of hot water for showers. The percentage decrease must be entered for each typical case for which the measure is applicable (some typical cases may already have low flow showers).

We have included the option of installing a solar water heater. Currently it is being treated as a change in the heating efficiency.

Hot Water Measures Documentation

CONSERVATION MEASURE ME34000E0001 (350, 310)

NAME

Temperature setback to 140 Degrees F

MEASURE DESCRIPTION

This is a no cost measure to set back the thermostat of the water heater to 140 degrees F. In homes where there are electric automatic dishwashers, there is some concern that the performance of the dishwasher is degraded by use of hot water at temperatures lower than 140 degrees F.

Improved detergents may eliminate the need for temperatures above 140 degrees for automatic dishwashing. All hot water thermostats could then be set to 120 degrees F. Sears, for example, now sells a detergent for low-temperature dishwashing. We are concerned by the lack of experimental data, and the high phosphate levels that may be an environmental problem. While more investigation is done on the effects of reduced hot water temperatures on dishwashing performance, we will conservatively assume that in homes with automatic dishwashers, the hot water temperature is set back only to 140 degrees F. If new low-temperature detergents prove to be safe and effective, a simple change in the Work4 program can be made to include homes with automatic dishwashers in the eligible fraction for the "setback to 120 degrees F" measure.

Setting back the hot water temperature increases the gallonage usage. Thus, for each typical case, the inputs to the WORK4 program for this measure are: (1) the number of degrees the hot water will be setback, and (2) the increases in volume for showers and "other" uses.

COST

This is a no-cost measure.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is the same as the lifetime of the water heater, 13 years. (ADL/CPES March, 1982).

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

This measure only requires a change in the temperature setting on the water heater. We assume that the measure can be rolled-in over a 5 year period.

ELIGIBLE FRACTION

The eligible fraction is calculated by the WORK4 program as an average of the eligible fractions in the typical cases. In filling in this measure for the typical cases, we assume that water heaters in all homes with dishwashers where the hot water temperature is above 140 degrees F are eligible for temperature setback.

CONSERVATION MEASURE ME34000E0002 (350, 310)

NAME

Water Heater Wrap-Walls

MEASURE DESCRIPTION

This measure is to add a R-11 wrap to the walls and top of the electric water heater.

COST

The cost for this measure is estimated to be \$25.

This is based on regional utility cost data. (See for example the May, 1982 Seattle City Light Conservation Planning report, p.47) We have not included all the labor costs quoted in this report since many utilities have programs for implementing these measures, and/or consumers can retrofit them. (Additionally, new appliances may have the added insulation on the walls, top, and bottom and labor costs would be inappropriate.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is estimated to be 10 years. (See, for example, BPA Appendix 2, August, 1982, p. A-60).

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

This measure has a roll-in time of 5 years.

ELIGIBLE FRACTION

The eligible fraction is calculated by the WORK4 program as an average of the eligible fractions in the typical cases. In making up the typical cases, we attempted to have the fraction of typical cases with heaters already wrapped match the Pacific Northwest Residential Survey data on existing wrapped water heaters. These wrapped water heaters would not be eligible for this measure.

CONSERVATION MEASURE ME34000E0003 (350, 310)

NAME

Insulating Bottom Board

MEASURE DESCRIPTION

This measure is to insulate the bottom of the water heater tank with an insulating bottom board. We have assumed the R-value of the board to be about R-11, based on use of HO-43001 Styrofoam, as suggested by Seattle City Light. (See Seattle City Light, May, 1982, p.46).

COST

The cost of this measure is \$10.

This is based on the cost data given in the Seattle City Light Conservation Planning report (Seattle City Light, May, 1982, p.47) We have not included all the labor costs quoted in this report since many utilities have programs for implementing these measures, and/or consumers can retrofit them. (Additionally, new appliances may have the added insulation on the walls, top, and bottom and labor costs would be inappropriate.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is assumed to be 10 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

We are assuming that this measure is rolled in over 5 years.

ELIGIBLE FRACTION

All electric water heaters are assumed to be eligible for this measure, so the eligible fraction (as calculated by the Work4 program) is 1.0

CONSERVATION MEASURE ME34000E0004 (350, 310)

NAME

Low Flow Showerheads

MEASURE DESCRIPTION

We have started with the assumption that a typical showerhead has a flow rate of about 5 gallons per minute. (See for example Wall, Seattle City Light, Feb. 1, 1982, p. 9, which uses typical shower flow as 6 gpm; Wright et al, LBL, which cites the CEC as assuming a pre-standard shower flow rate of 4.5 gpm, NRDC, 1982, technical appendix cites 5 gpm, etc.) This measure is to install a low-flow showerhead that uses 2.5 gpm. The California Energy Commission (CEC) adopted standards for plumbing fittings that became effective on December 22, 1978.

	Test Pressure	Maximum Flow Rate
Showerheads	20-45 psig	2.75 gpm
	45-80 psig	3.00 gpm

(psig = pounds/square inch gauge; gpm = gallons per minute)

The CEC lists showerheads meeting this standard, and thus eligible for sale in California. There are several models that have a flow rate of 2.5 gpm or less. (See CEC Directory of Certified Showerheads and Faucets, August, 1982.) This would save one-half of the hot water used for showering. Thus, the input needed to the Work4 program for this measure is a percentage decrease of 0.5 (50%) in the volume of hot water used for showers.

Additionally, Minuse company manufactures a very low-flow showerhead which has a flow rate of only 0.5 gpm. (See CEC Directory of Certified Showerheads and Faucets, August, 1982, p.100.) This showerhead is very expensive, but may be included as a separate water heating measure in future revisions of this data base.

COST

The cost for this measure includes the showerhead cost and the labor cost for installing the showerhead. In homes where there is more than one showerhead, all showerheads are assumed to be retrofitted with low flow showerheads. Thus, although the cost for a single showerhead may be only \$10 (see, for example, Wright et al, LBL, January, 1981), we have used \$40 as the total cost for this measure since there may be labor costs, and there may be more than one showerhead per residence. (Note that in new homes, there would not be a labor cost, but since the water heating end-use has not been divided between new and old housing stock, there is no adjustment for this.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The low flow showerhead is estimated to have a lifetime of 20 years. (BPA, Aug., 1982, Appendix 11, p. A-6*).

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

We are assuming that this measure is rolled in over 5 years.

ELIGIBLE FRACTION

The eligible fraction is calculated by the WORK4 program as an average of the eligible fractions in the typical cases. In making up the typical cases, we attempted to have the fraction of typical cases ineligible for this measure match the Pacific Northwest Residential Survey data on residences which have shower restrictors. These residences would not be eligible for this measure.

CONSERVATION MEASURE ME34000E0005 (350, 310)

NAME

Cold Water Laundry

MEASURE DESCRIPTION

This measure is to have residences with a clothes washer do half of the loads in cold water. For each typical case, the input to the WORK4 program for this measure is a 50% reduction in the volume of hot water used for laundry. This measure also extends the life of clothes.

COST

This is a no-cost measure.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is assumed to be the same as for clothes washing machines- 10 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

We assume that this measure is rolled in over 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is based on the fraction of homes with clotheswashers. We have assumed that this measure is applicable to 90% of homes with clothes washers.

CONSERVATION MEASURE ME34000E0006 (350, 310)

NAME

Efficient Clothes Washer

MEASURE DESCRIPTION

The input to Work4 for this measure is a percentage reduction in the volume of hot water used for laundry of 30%. (See Statt & Coggins, August, 1980; and SERI/A New Prosperity, p. 72.)

COST

The cost for this measure is estimated to be \$30. (See, for example, SERI, A New Prosperity, which cites \$25 as the cost for improving the efficiency of the clotheswasher and decreasing water use by 30 %.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is 10 years, based on the estimated lifetime of the clothes washer.

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

This measure is assumed to roll in as the appliance is replaced. The lifetime of clotheswashers is 10 years, and since they are assumed to decay linearly, the roll-in time is 10 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is based on the fraction of homes with clotheswashers. Work4 calculates the eligible fraction based on the percentage of typical cases with clotheswashers.

CONSERVATION MEASURE ME34000E0007 (350, 310)

NAME

Efficient Dishwasher

MEASURE DESCRIPTION

The input to Work4 for this measure is a percentage reduction in the volume of hot water used for washing dishes of 30%. (See Statt & Coggins, August, 1980.)

COST

The estimated cost for this measure is \$30. (See SERI, A New Prosperity, which cites a cost of \$50 for a 50 % water use reduction. We are assuming a 30% reduction based on Statt & Coggins, and we assume that the cost will be about \$30, but this is only an estimate.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is 10 years, based on the estimated lifetime of the dishwasher.

START YEAR

The start date for this measure is 1980.

ROLL-IN-TIME

This measure is assumed to roll in as the appliance is replaced. The lifetime of dishwashers is 10 years, and since they are assumed to decay linearly, the roll-in time is 10 years.

ELIGIBLE FRACTION

The eligible fraction is calculated by the WORK4 program as an average of the eligible fractions in the typical cases. In making up the typical cases, we attempted to have the fraction of typical cases eligible for this measure match the Pacific Northwest Residential Survey data on residences which have dishwashers.

CONSERVATION MEASURE ME34000E0008 (350, 310)

NAME

Heat Pump Water Heater

MEASURE DESCRIPTION

This measure is to install a heat pump water heater instead of the conventional electric resistance water heater. BPA has projected a regional average C.O.P. (coefficient of performance) of 2.0, but has also noted that utility data thus far show heat pump water heater performance to be somewhat lower. (See Biemer, "Heat Pump Water Heating- A Status Report for the Pacific Northwest," 1982.)

We have estimated the average C.O.P. to be 1.9 based on BPA's projections, modified slightly to account for the lower performance seen by utilities thus far.

The input to WORK4 which is made for this measure is to increase the efficiency 0.9, from 1.0 to 1.9.

COST

We have estimated the cost of purchase and installation of a heat pump water heater to be \$1200. Cost data for the heat pump water heater show a wide range. (See, for example Biemer, "Heat Pump Water Heating- A Status Report for the Pacific Northwest," which cites a range of costs from \$900 to \$1800, installed.) As more heat pump water heaters are sold, the costs may decline.

Since the heat pump water heater is assumed to be installed at the time of replacement of a conventional electric water heater, the replacement cost must be subtracted from the heat pump water heater cost. We have assumed \$200 as the cost of a conventional electric water heater, thus the cost for this measure is $1200 - 200 = \underline{\$1000}$.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The estimated lifetime for this measure is 15 years. (BPA, Aug., 1982, Appendix 11, p. A-63).

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

The roll-in time is 13 years, because the heat pump water heaters are assumed to roll in as the resistance water heaters are replaced linearly over a lifetime of 13 years. This measure is replaced in 1990 by a high COP heat pump water heater.

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.5. Electric water heaters could potentially be replaced by heat pump water heaters or solar water heaters, but presumably not both. We have arbitrarily assumed for this analysis that half could be heat pump water heaters and half solar water heaters.

CONSERVATION MEASURE ME34000E0009 (350, 310)

NAME

Temperature Setback to 120 Degrees F

MEASURE DESCRIPTION

This is a no cost measure to set back the thermostat of the water heater to 120 degrees F.

Setting back the hot water temperature increases the gallonage usage. Thus, for each typical case, the inputs to the WORK4 program for this measure are: (1) the number of degrees the hot water will be setback, and (2) the increases in volume for showers and "other" uses.

COST

This is assumed to be a no-cost measure. If a contractor were needed to setback the thermostat, there could be labor costs involved. However, we have assumed that the setback is done by the consumer, or as part of a utility program.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is assumed to be the same as for the electric water heater, 13 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

We assume that this temperature setback measure is rolled in over 5 years.

ELIGIBLE FRACTION

The eligible fraction is calculated by the WORK4 program as an average of the eligible fractions in the typical cases. We have assumed that all residences that do not have dishwashers are eligible for this measure, if the temperature setting is above 120 degrees.

CONSERVATION MEASURE ME34000E0010 (350, 310)

NAME

Pipe Insulation/Anti-Convection Valve

MEASURE DESCRIPTION

This measure is to insulate the hot water pipes, and/or install an anti-convection valve or thermal traps. Since the savings for these measures are interrelated, we chose to model them as one measure. As more research is done on the interactions between the anti-convection valve and pipe insulation, this measure should be re-evaluated.

The pipe area is 1.0 square feet (about 6 lineal feet of 0.5 inch diameter pipe). We assume that this length is insulated with R-5 insulation.

COST

The cost of this measure is estimated to be \$30. This is for labor and materials for insulating the pipe, or putting in an anti-convection valve or thermal traps.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime of this measure is estimated to be the same as the lifetime of the electric water heater- 13 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

We assume that this measure will be rolled in over 5 years.

ELIGIBLE FRACTION

This measure is assumed to be applied to all units which do not already have pipe insulation.

CAVEATS

The savings from insulating pipes and/or installing an anti-convection valve are related to the geometry of the pipes, the hot water and ambient temperatures, and the frequency and amount of hot

water use. More research needs to be done on these factors and their interrelationships. By combining the two measures, we have avoided double-counting savings.

CONSERVATION MEASURE ME34000E0011 (350, 310)

NAME

Solar Water Heater

MEASURE DESCRIPTION

This measure is to add a solar water heating system. The cost and effectiveness of solar water heating vary greatly. The number of panels, the weather and other variables influence the amount of the water heating load that can be supplied by a solar system. We treat the solar hot water measure as a change (improvement) in the water heating system efficiency. This is a simple way to model the effect of a solar system that supplies an estimated fixed proportion of a household's hot water needs. We increased the efficiency 0.7 (from 1.0 to 1.7). This assumes that the system will supply 40-45 percent of the demand. This may be overly conservative (in California, systems are often estimated to supply 60 % of the demand), but due to the uncertain weather conditions for solar in much of the Northwest, we think that conservatism is warranted.

COST

The estimated cost for a solar water heating system is \$2000.

Since the solar water heater is assumed to be installed at the time of replacement of a conventional electric water heater, this replacement cost must be subtracted from the solar water heater cost. We have assumed \$200 as the cost of a conventional electric water heater, thus the cost for this measure is $2000 - 200 = \underline{\$1800}$.

The \$2000 cost is based on a small system, including panel, storage tank, pump, pipes, framing, controller, and labor costs. (See Wright et al, LBL, January, 1981, p. 73.)

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The estimated lifetime for this measure is 20 years. (BPA, Aug., 1982, Appendix 11, p. A-63).

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

The roll-in time for this measure is 13 years, because the solar water heaters are assumed to roll in as the conventional water heaters are replaced linearly over a lifetime of 13 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.5. Electric water heaters could potentially be replaced by heat pump water heaters or solar water heaters, but presumably not both. We have arbitrarily assumed for this analysis that half could be heat pump water heaters and half solar water heaters.

CONSERVATION MEASURE ME34000E0012 (350, 310)

NAME

Additional Insulating Wrap

MEASURE DESCRIPTION

This measure is to add an additional R-11 insulating wrap to a water heater that is already insulated.

COST

The estimated cost for this measure is \$26. Presumably the cost for this measure would be the same as for the water heater wrap measure above—\$25. We have added one dollar to the cost so that this measure will have a slightly higher CCE and thus will follow the other measure in the program calculations.

AVERAGE SAVINGS

This is calculated by the WORK4 program and is not an input. See "Technical Description" above for an explanation of the inputs to the WORK4 program.

LIFETIME

The lifetime for this measure is estimated to be 10 years. (See explanation under the original wrap measure.)

START YEAR

The start year for this measure is 1980.

ROLL-IN-TIME

This measure is assumed to roll in over 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, because the additional wrap could be applied to a water heater that already has insulated walls.

CONSERVATION MEASURE ME34000E0013

NAME

High COP Heat Pump Water Heater

MEASURE DESCRIPTION

We assume that by 1990 heat pump water heaters achieve a field COP equal to the best obtained in the standard testing procedure. The GAMA Directory of Certified Water Heater Efficiency Ratings (Gas Appliance Manufacturer's Association, January 1983) lists two 52 gallon heat pump water heaters with a Energy Factors of 3.4. The heat pump water heater industry is a few years behind the air conditioner market with respect to the rapid increase in efficiencies. (There, the COP of the best model nearly doubled in 5 years and is still climbing.) We believe that a model with an energy factor higher than 3.4 will soon appear on the market, and will perform at about 3.4 in the field. Nevertheless, we do not phase in this model until 1990.

This measure replaces the less-efficient heat pump measure. From 1990 onwards, all single family homes receive the high COP model, either as a replacement for a conventional resistance water heater or a retired heat pump.

COST

We believe that the heat pump should not cost more than the most expensive units currently on the market, e.g. \$1800. The consumer must in any event buy a water heater tank, so we have subtracted \$200, leaving a net cost for this measure of \$1600.

AVERAGE SAVINGS

The savings are calculated by Work4 and depend on the measures implemented prior to the heat pump installation. Work4 treats this measure as a 2.4 improvement (1.0 - 3.4) in energy efficiency to avoid possible double-counting of energy savings when replacing a less-efficient heat pump.

LIFETIME

We estimate the water heater heat pump to last 10 years.

START YEAR

This measure is introduced in 1990.

ROLL-IN TIME

The roll-in time is 13 years, because the high COP heat pump water heaters are assumed to roll in as the resistance water heaters or lower COP heat pumps are replaced linearly over a lifetime of 13 years.

ELIGIBLE FRACTION

We believe that all single-family homes will be eligible for this measure, hence the eligible fraction is 1.0.

Electricity Savings from Hot Water Measures: Our Results Compared With Engineering and Empirical Data

There have been numerous measurements of water heater consumption (principally for time-of-use information) but, until recently, very few measurements of savings from conservation measures. We present below a summary of empirical data for water heater conservation measures. These savings must be interpreted with caution since a variety of testing conditions were used. For example, the low savings obtained by Consumer Reports for a water heater wrap are a result of the original water being very well insulated and the ambient air temperature quite high. The references are given below the table, along with a a discussion of pertinent factors.

Table 1V-2

MEASURED SAVINGS FROM HOT WATER CONSERVATION MEASURES
(KWH/YEAR)

	Measure				
Source:	full wrap	bottom board	temp. setback	low flow showerhead	pipe ins./ anti-conv.
LBL Results-					
SF	547.	64.	596.	781.	113.
MF	457.	43.	414.	422.	105.
MH	584.	51.	549.	813.	95.
BPA (1)	565.				29./105.
BPA (2)	420.				30.
BPA (3)	1045.				
BPA (4)	435.			400.	
Seattle City Light	400.	90.	485.		150.-180.
Palmiter	480.	110.			180.
Consumer Reports	71 - 250.				482.
Alabama Power	482.				
GAMA					403.

BPA (1). The Effectiveness of Anti-Convection Devices in Reducing Standby Losses From Domestic Water Heaters, Ek & Miller, BPA ERGH-82-36, August 3, 1982.

These are results based on laboratory tests. Assumptions are that the water temperature is 60 degrees C (140 degrees F); the ambient temperature is 15 degrees C (59 degrees F); and the tank size is 197 liters (52 gallons).

BPA (2). The Effect of Electric Water Heater Tank Insulation Modifications and Water Pipe Insulation on Standby Power Consumption, Ek, BPA, ERGH-82-35, July 27, 1982; These are results based on laboratory tests. For the tank insulation (wrap), a 52 gallon electric water heater was used, with 133 degree F water, and an ambient temperature of 64 degrees F. R-11 insulation was applied. Lesser savings resulted when the terminal cover was left exposed. For the pipe insulation, the water temperature was 144 degrees F, and the average ambient temperature was 78 degrees F. 5 feet of pipe were wrapped, but the R value of the wrap is not specified.

BPA (3). The Problem of Standby Tank Losses From Water Heater Storage Tanks, BPA, December, 1982. The Effect of External Insulation on Electric Water Heaters, Ek, BPA, February, 1982. The annual savings are for an R-11 wrap and a 78 degree F difference between water and ambient temperature.

Note that supplemental (February 1982) tests conducted for an average temperature differential between water and ambient of 69 degrees F showed that standby losses with a full R-11 wrap were 65.6 % of base (no wrap). This is a significantly different result than the 56.4% savings that resulted in the 1045 kwh/year savings figure given above, and may explain the lower savings figures cited in the more recent BPA reports.

BPA (4). Conservation Sourcebook, Appendix, January, 1983, Table 1, Appendix E. Only shower flow restrictors were installed and no assumptions were listed. Flow restrictors are generally less effective than low-flow showerheads, possibly accounting for the small savings.

Seattle City Light data are from: Conservation Planning Process: A status report, May, 1982, Table 3, p. 27.

Palmiter data are from -- Palmiter, Larry, Potential For Conservation of Electrical Energy In Northwest Residences, Draft Report, June 28, 1982, p. A20.

Consumer Reports, (Oct. 1981). These are an average of 12 laboratory measurements of high-efficiency (i.e., well-insulated) 52-gallon, water heaters and a warm (70 F) ambient air temperature. Water temperature was maintained at 140 F. R-values of the insulation blanket varied from

R-4 to R-11. Anti-convection valves were placed on both hot and cold pipes.

Alabama Power, EPRI Rept. #137 (1980). These measurements were conducted over 12 months on 6 water heaters, mostly located in unheated areas in typical homes. An R-11 blanket was installed.

GAMA, Gas Appliance Manufacturers Association Directory of Certified Water Heater Efficiency Ratings (January 1983). Efficiencies for several electric heat pumps are listed with and without thermal traps; this value was typical.

PART FIVE

Appliance Measure Documentation

End Uses

REFRIGERATORS AND REFRIGERATOR-FREEZERS

We divided refrigerators and refrigerator-freezers into five end-use types: single-door manual defrost refrigerators; partial-automatic defrost refrigerator-freezers; top-freezer automatic defrost refrigerator-freezers; bottom-freezer automatic defrost refrigerator-freezers; and side-by-side automatic defrost refrigerator-freezers. See below for a complete description of these end-uses.

We assumed that the proportion of frostfree refrigerators will increase during the next 20 years. This is a national trend that we assume also holds in the Northwest. However, we assumed that the refrigerator size would remain constant because we lacked stock data for a more detailed analysis. (Moreover, the frozen efficiency forecast does not distinguish between new and old refrigerators.) The forthcoming Pacific Northwest residential survey will provide information on the type and size of refrigerators owned by Northwest residents. These new data should be used to re-evaluate the refrigerator end-uses. Our electricity savings may be high because they are based upon a higher future saturation of frostfree models. See documentation under "Initial Stock" below for the explanation of how we estimated the stocks of the five refrigerator types.

END USE EE40001E00 REFRIGERATORS-SINGLE DOOR MANUAL

End-Use Description

This end-use type includes all refrigerators that have a single outside door enclosing a compartment for refrigerated food storage at a temperature of above 32 degrees Fahrenheit. The refrigerator may include a compartment at a temperature between 8 degrees Fahrenheit and 32 degrees Fahrenheit for temporary frozen food storage.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register, 42FR46140, September 14, 1977).

UEC

The DOE/ADL CPES report (ADL, March 1982) shows the 1980 baseline unit for this type to have an energy factor of 7.2 with a UEC of 708 kWh/year. This is a baseline for units being shipped in 1980 and thus is not representative of 1980 stock average. Over the last few years there has been a decrease in the energy consumption of refrigerators and refrigerator-freezers, thus the average UEC for the 1980 regional stock would be expected to be higher than 708 kWh/year.

Shipment weighted energy factors for the different types of refrigerators and refrigerator-freezers (AHAM Industry Data and SAI calculations) show that for manually defrosted refrigerators with 15 degree freezer, the shipment weighted energy factor was 6.62 in 1972, increasing to 7.65 in 1980. The energy factor is defined to be the corrected volume divided by the annual energy consumption. (The volume correction is made to adjust units with various ratios of refrigerated compartment volumes to freezer compartment volumes to a common base). Thus, for units with similar corrected volumes, the energy consumption has been decreasing.

In their forecast, BPA, using the adapted ORNL model, uses 1980 average existing stock estimates of

Single Family	1687 kWh/year
Multi Family	1387 kWh/year
Mobile Home	1676 kWh/year

(BPA/ORNL, December 1981, August, 1982). The average stock UECs for the refrigerator types we are using should correspond to these BPA baseline estimates.

Using the shipment weighted data mentioned above, (AHAM/SAI) we did a preliminary estimate of 1980 stock average UECs by calculating the ratio of the 1972 shipment weighted average energy factors, and applying this ratio to the 1980 shipment weighted energy factors to the ADL 1980 baseline unit (ADL/CPES, March, 1982). Then we adjusted these preliminary estimates to be consistent with the BPA/ORNL baseline estimates for single family, multi family, and mobile home.

Thus, for single-door, manual defrost units, the preliminary estimate was 818 kWh/year. [1972 energy factor = 6.62; 1980 energy factor = 7.65, and ADL baseline UEC = 708 kWh/year: $7.65/6.62 (708) = 818$].

For partial automatic defrost units, the preliminary estimate was 1407 kWh/year. [1972 energy factor = 4.29; 1980 energy factor = 5.51, and ADL baseline UEC = 1096: $5.51/4.29 (1096) = 1407$].

For the top freezer, bottom freezer, and side by side type categories, we used the models without ice features, since these accounted for the majority of units shipped. Thus, for top freezer, the preliminary estimate was 1980 kWh/year. [1972 energy factor = 3.66; 1980 energy factor = 5.37, and baseline UEC = 1350: $5.37/3.66 (1350) = 1980$]. For bottom freezer, the preliminary estimate was 3048 kWh/year. [1972 energy factor = 3.49; 1980 energy factor = 5.69, and ADL baseline UEC = 1870: $5.69/3.49 (1870) = 3048$]. For side-by-side, the preliminary estimate was 2890 kWh/year. [1972 energy factor = 3.49; 1980 energy factor = 5.69, and ADL baseline UEC = 1770: $5.69/3.49 (1773) = 2890$].

The preliminary estimates for the five refrigerator end-uses were:

single-door	818
partial automatic	1407
top freezer	1980
bottom freezer	3048
side-by-side	2890

These figures were then adjusted to be consistent with the BPA/ORNL baseline figures (see below). An "average" unit was calculated from the BPA estimates and occupied housing stock figures to use 1659 kWh/year.

(1687 x 2391 single-family units	x 1.186 saturation =	4,783,870
1387 x 327 multi family units	x 1.011 saturation =	458,538
1676 x 232 mobile home units	x 1.070 saturation =	416,050
	total =	5658458 /3410 units = 1659).

Note that the refrigerator saturations are different for the individual housing types. These data are based on examination of our runs of the PNW survey data. Using these saturations and the housing stocks gives a total refrigerator stock of 3415 thousand units. This varies slightly from the 3410 thousand that is obtained from using the survey results for all housing types together. We assume that this slight discrepancy is due to rounding and survey weighting. It is not a significant discrepancy.

Adjusting the preliminary estimates downward by 8-9% to:

single-door	750
partial automatic	1300
top freezer	1825
bottom freezer	2800
side-by-side	2650

gives a stock weighted "average" unit use of 1656 kWh/year which is thus consistent with the BPA/ORNL baseline.

We realize that the above method is fairly crude: the corrected model volumes may not have remained the same during the 1972-80 period; 1972 is just a general estimate of the average age of the refrigeration stock (the lifetime is 19 years, but there has been stock growth since 1972), etc. We used this method to get an idea of the different unit energy consumptions of the various types, which we then adjusted to match an "average" BPA baseline unit.

The upcoming second survey on residential energy consumption in the Pacific Northwest will have more data on saturations of refrigerator types. The new data will be useful in estimating saturations of the various refrigerator types.

Initial Stock

The initial stocks of the different refrigerator and refrigerator-freezer types were estimated by using data from the Pacific Northwest Residential Survey (Elrick & Lavidge, July, 1980), and the DOE/ADL CPES

report (ADL, March, 1982).

The residential survey results (Elrick & Lavidge, 1980) show that refrigerator saturations in the Northwest are 0.6788 frostfree and 0.4772 nonfrostfree, for a total of 1.156.

The nonfrostfree category must be divided into two types- single door manual and partial automatic. Lacking data for the Northwest on the division between these two types, we have used the production statistics given in the DOE/ADL CPES report (ADL, March, 1982) to divide the non-frostfree stock between manual and partial-automatic. Similarly, these manufacturing statistics were used to divide the frostfree units into the three categories of top freezer, bottom freezer and side-by-side.

Using the ratio of single-door manual to partial-automatic from the production data given in the ADL/CPES analysis, and applying it to the non-frostfree saturation given by the survey, and then multiplying by the occupied housing stock figure (see demographics) gives the following stocks:

$$(.3264) (.4772) (2950) = 460$$

$$(.6736) (.4772) (2950) = 947$$

Single Door Manual Defrost 460 thousand

Partial-Automatic Defrost 947 thousand

The stocks for the automatic defrost ("frostfree") types are similarly calculated:

$$(.7593) (.6788) (2950) = 1520$$

$$(.0577) (.6788) (2950) = 116$$

$$(.1830) (.6788) (2950) = 366$$

Top Freezer Automatic 1520 thousand
Defrost

Bottom Freezer Automatic 116 thousand
Defrost

Side-By Side Automatic 366 thousand
Defrost

Addition Rate

According to the BPA forecast data, refrigerators grow at approximately the same rate as new housing, about 2% per year. Since we have divided refrigerators into types, we decided that although the total addition rate for refrigerators should be consistent with the 2% growth rate, the saturation of single door manual defrost units seems likely to decline

relative to the saturation of frost free units. (As the single door, manual defrost units wear out they may be replaced by a frostfree model).

To account for this, we have decreased the addition rate for single door manual defrost units to 1%, while increasing the addition rate for the top freezer category to 2.3%. The addition rates for the other two categories remain at 2%.

Decay Rate

This is not applicable since we have not divided the refrigerator/freezer stock into "new" and "old" units for this draft.

Since we are evaluating savings as compared to a "frozen efficiencies" forecast, where the unit energy consumptions of the appliances are frozen at the existing 1980 stock average, we have not treated the new stock as different from the existing stock.

When a frozen efficiencies case is available, which separates new stock at the lower energy consumption levels, the refrigerator/freezer end-uses should be revised accordingly.

END USE EE40002E00 REFRIGERATORS-PARTIAL AUTOMATIC DEFROST

End-Use Description

A partial automatic defrost unit has both a refrigeration compartment and a freezer compartment. The freezer compartment is at a temperature lower than 8 degrees F and has a separate outside door. The refrigerator compartment does not need manual defrosting but the freezer compartment does.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register, 42FR46140, September 14, 1977).

UEC

The baseline existing unit energy consumption for partial automatic refrigerator-freezers was estimated to be 1300 kWh/year (see explanation above in the "UEC" section under "Refrigerators - Single Door Manual").

Initial Stock

The initial stock of partial automatic defrost refrigerator-freezers is estimated to be 947 thousand. See explanation above in the "Initial Stock" section under "Refrigerators-Single Door Manual"

Addition Rate

The addition rate is 2.0% (see explanation above under "Refrigerators-Single Door Manual").

Decay Rate

This is not applicable (see explanation above under "Refrigerators-Single Door Manual").

END USE EE40003E00 REFRIGERATORS-TOP FREEZER

End-Use Description

This end-use includes refrigerator-freezers which have a freezer compartment with a separate outside door, located above the refrigeration compartment. The freezer compartment is at a temperature below 8 degrees F.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register, 42FR46140, September 14, 1977).

UEC

The baseline existing average unit energy consumption for this category of refrigerator-freezers is estimated to be 1825 kWh/year. (See explanation above in the "UEC" section under "Refrigerators-Single Door Manual").

Initial Stock

The initial stock of top freezer, automatic defrost refrigerator-freezers is estimated to be 1520 thousand units. See explanation above in the "Initial Stock" section under "Refrigerators-Single Door Manual."

Addition Rate

The addition rate for this end-use is 2.3% (see explanation under "Refrigerators-Single Door Manual").

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE40005E00 REFRIGERATORS-BOTTOM FREEZER

End-Use Description

This end-use includes refrigerator-freezers which have a freezer compartment with a separate outside door, located below the refrigeration compartment. The freezer compartment is at a temperature below 8

degrees F.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register, 42FR46140, September 14, 1977).

UEC

The baseline existing average unit energy consumption for this category of refrigerator-freezers is estimated to be 2800 kWh/year. (See explanation above in the "UEC" section under "Refrigerators- Single Door Manual").

Initial Stock

The initial stock of bottom freezer, automatic defrost refrigerator-freezers is estimated to be 116 thousand units. See explanation above in the "Initial Stock" section under "Refrigerators-Single Door Manual."

Addition Rate

The addition rate for this end-use is 2.0% (see explanation under "Refrigerators-Single Door Manual").

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE40004E00 REFRIGERATORS-SIDE BY SIDE

End-Use Description

This end-use includes all refrigerator-freezers with the freezer compartment, (with a separate outside door), on one side of the refrigeration compartment. The freezer compartment is at a temperature of 8 degrees F or below. Some models have through the door ice and water features however, we have not included the data for these models.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register, 42FR46140, September 14, 1977).

UEC

The baseline existing average unit energy consumption for this type is estimated to be 2650 kWh/year. (See explanation above in the "UEC" section under "Refrigerators- Single Door Manual").

Initial Stock

The initial stock of side-by-side units is estimated to be 366 thousand units. See explanation above in the "Initial Stock" section under "Refrigerators-Single Door Manual."

Addition Rate

The addition rate for this end-use is 2.0% (see explanation under "Refrigerators-Single Door Manual").

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

FREEZERS

Freezers have been divided into three end-uses: chest freezers with manual defrost; upright freezers with manual defrost; and upright freezers with automatic defrost.

END USE EE50001E00 FREEZERS-CHEST MANUAL DEFROST

End-Use Description

A chest freezer is a cabinet designed for the storage of food at 0 degrees F or below, in a chest configuration with a door opening at the top of the unit. No chest freezers currently offer an automatic defrosting feature.

UEC

The baseline unit energy consumption for the manual defrost chest freezer is 1475 kWh/year.

The DOE/ADL CPES report (ADL, March 1982) shows the 1980 baseline unit for this type to have an energy factor of 11.13 with a UEC of 851 kWh/year. This is a baseline for units being shipped in 1980 and thus is not representative of 1980 stock average. Over the last few years there has been a decrease in the energy consumption of freezers, thus the average UEC for the 1980 regional stock would be expected to be higher than 851 kWh/year. (Sources-SAI/AHAM)

BPA, using the adapted ORNL model, uses 1980 average existing stock estimates of

Single Family	1971 kWh/year
Multi Family	1611 kWh/year
Mobile Home	1971 kWh/year

(BPA/ORNL, Dec. 1981). The average stock UECs for the freezers types we are using should correspond to these BPA baseline estimates.

An "average" unit was calculated from the BPA estimates and occupied housing stock figures to use 1967 kWh/year.

(1971 x 2391 single-family units x .596 saturation = 2,808,746
1611 x 327 multi family units x .107 saturation = 56,367
1971 x 232 mobile home units x .508 saturation = 232,294
total = 3,097,407/1575 units = 1967).

Note that the freezer saturations are different for the individual housing types. These are data from our runs of the PNW survey data. Using these saturations and the housing stocks gives a total refrigerator stock of 1578 thousand units. This varies slightly from the 1575 thousand which results from using the survey results for all housing types together. We assume that this slight discrepancy is due to rounding and survey weighting. It is not a significant discrepancy.

Shipment weighted energy factors for the different types of freezers show that for manual defrost chest freezers, the shipment weighted energy factor was 8.86 in 1972, increasing to 11.32 in 1980. The energy factor is defined to be the corrected volume divided by the annual energy consumption. Thus, for units with similar corrected volumes, the energy consumption has been decreasing.

Using the shipment weighted information, and the ADL baseline figures, (which it should be noted have some discrepancies between tables 2.1 to 2.3 and table 2.12), we estimated preliminary baseline figures for the freezer types.

The preliminary baseline estimates:

Chest Freezer-Manual Defrost	1087 kWh/year
Upright Freezer-Manual Defrost	1303 kWh/year
Upright Freezer-Automatic Defrost	2298 kWh/year

give a stock weighted "average" unit use of 1458 kWh/year which is too low. (The BPA baseline that we attempted to match has an average UEC of 1967 kWh/year as calculated above). These preliminary figures were then rounded up by about thirty percent to give baseline figures of:

Chest Freezer- Manual Defrost	1475 kWh/year
Upright Freezer-Manual Defrost	1750 kWh/year
Upright Freezer-Automatic Defrost	3100 kWh/year

These give a stock weighted "average" unit use of 1968 kWh/year, which is consistent with the BPA/ORNL baseline.

Initial Stock

The stock figure was obtained by first applying the PNW residential survey (Elrick & Lavidge, 1980) saturation figure of 0.534 to the total occupied housing stock to get a total number of freezers. (.534) (2950) = 1575 Then, this stock of freezers was divided among the three freezer types by using the PNW residential survey division between frostfree and nonfrostfree, and the ADL/CPES (ADL, March, 1982) data on product

shipments by type.

We have taken the ratio of frostfree to nonfrostfree provided by the residential survey (0.243 to 0.757 or 383 thousand frostfree units and 1192 thousand non-frostfree units) as the best estimate of the division, and then used the ADL/CPES shipment data to further disaggregate the nonfrostfree portion of the stock into chest freezers and upright freezers.

According to the shipment data, but excluding compact freezers which accounted for 24.5% of the total, chest freezers were 46.9%, upright manual freezers were 41.7%, and upright automatic freezers were 11.4%.

Note that this shows a ratio of manual to automatic of 0.886 manual to 0.114 automatic, compared to 0.757 to 0.243 given by the residential survey. However, it must be remembered that the survey was done for existing stock, while the shipment figures are for 1980 shipments only. Thus, we have used the survey figures to make the division between frostfree and nonfrostfree units, and the shipment data to further divide between upright freezers with automatic defrost and upright freezers with manual defrost.

$(.534) (2950) = 1575$ thousand freezers.

$(.243) (1575) = 383$ thousand frostfree units.

$(.757) (1575) = 1192$ thousand nonfrostfree units.

$(.469)/(.417+.469) = .529 \times 1192 = 631$ thousand chest manual units.

$(.471) \times (1192) = 561$ thousand upright manual units.

Thus, the stock figures for the three freezer types are:

Chest Manual Defrost	631 thousand
Upright Manual Defrost	561 thousand
Upright Automatic Defrost	383 thousand

Addition Rate

The addition rate for all three freezer types is 1.6%.

This is based on the BPA forecast saturation figures for the period 1980 - 2000. The total number of housing units was multiplied by the projected saturations of freezers to get a total number of freezers in 1980 and 2000. Then the average annual growth rate was calculated to be 1.6%.

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE50003E00 FREEZERS-UPRIGHT MANUAL DEFROST

End-Use Description

The upright manual defrost freezer is an upright cabinet for the storage of food at temperatures of 0 degrees F or below, with consumer action required for defrosting.

UEC

The baseline unit energy consumption for this measure is 1750 kWh/year. (See explanation above under "Freezer-Chest Manual Defrost.")

Initial Stock

See explanation above under "Freezers-Chest Manual Defrost."

Addition Rate

The addition rate for freezers is 1.6 %. (See explanation above under "Freezers-Chest Manual Defrost").

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE50002E00 FREEZERS-UPRIGHT AUTOMATIC DEFROST

End-Use Description

The upright automatic defrost freezer is an upright cabinet for the storage of food at temperatures of 0 degrees F or below, with no consumer action required for defrosting.

UEC

The baseline unit energy consumption for upright, automatic defrost units is 3100 kWh/year. (See explanation above under "Freezers-Chest Manual Defrost.")

Initial Stock

See explanation above under "Freezers-Chest Manual Defrost." Addition Rate The addition rate for freezers is 1.6 %. (See explanation above under "Freezers-Chest Manual Defrost").

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE60001E00 COOKING-ELECTRIC COOKING TOPS AND OVENS

End-Use Description

This end-use is the electric oven and burners used for cooking. We considered dividing these into two end-uses but since their saturations are virtually identical (Elrick & Lavidge, 1980) and it may be simpler to consider a total "cooking" end-use, including microwave ovens, toaster ovens, etc. in later studies, we left the oven and burners in one end-use.

A total "cooking" end-use may also be more realistic because we suspect there may be conservation potential through switching to more specialized cooking appliances (microwaves, slow cookers, toaster ovens, etc.).

UEC

The baseline unit energy consumption for this end use is based on the 3/82 ADL/CPES report (ADL, March, 1982) The baseline cooking top UEC is given as 360.6 kWh/year. The baseline oven UEC for a standard oven is 395.7 and for a self-cleaning model it is 392.4. Using the 1980 shipping data to weight the two types of ovens gives an average UEC for ovens of 394.4, or a total baseline UEC of 755 kWh/year.

It is possible that the efficiency has been changing over the past lifetime of ranges, so that the 1980 baseline is not a good figure for the average stock. (This is the case for refrigerators for example). However, we have no evidence that this is the case and the data given by the other regional studies do not reflect a much lower baseline stock UEC.

Estimates from other studies for the total cooking end-use range from about 650 to 1200. It should be noted that some of the studies may also include microwave ovens, toaster ovens, and other cooking appliances in their estimates.

Initial Stock

The stock figure of 2752 was obtained by applying the PNW residential survey (Elrick & Lavidge, July 1980) average saturation for ovens and burners of 0.933 (.932 and .934 respectively) to the total occupied housing stock. [$.933 \times 2950 = 2752$].

Addition Rate

According to the BPA forecast data, housing will grow at approximately 2% per year. We have assumed that the growth rate for cooking will be the same as for housing.

Decay Rate

The decay rate is not applicable (see Appendix A).

LIGHTING

We divided the lighting end-use into six end-uses: old single-family, new single-family, old multi-family, new multi-family, old mobile home, and new mobile home. If there is a significant difference in lighting usage between new and existing units, and/ or if conservation measures could be included at a lower cost in new units, (i.e. if installations of efficient lighting were cheaper than retrofitting), this division between new and old is useful. Square footage trends in housing, as well as lighting levels, contribute to a suspected difference in lighting requirements in new homes.

BPA/ORNL forecasts show decreasing lighting usage in "new" units. The lifetime for lighting is only one year, thus the "new" category for lighting is presumably not only new housing stock. (The BPA forecast technical appendix, (BPA, August, 1982) p. A-116, shows "new" single family lighting use in public utilities drops from 961 kWh/year in 1980 to 848 kWh/year in 2000, but by 2000, existing usage is at the almost identical level of 849 kWh/year.) Thus, we cannot be certain exactly how the BPA/ORNL runs are treating "new" versus "existing" lighting, and are not sure what values to use for new housing stock. Since the lifetime is only one year, the lighting end-use of the entire housing stock presumably becomes "new" each year. (Perhaps the reductions in new and existing are based on increased use of fluorescents in both groups, which may not be considered in the usage factor, which does not vary significantly.)

Lacking data on the baseline UECs for lighting in "new" versus "existing" housing stock, we have used the BPA 1979 baseline energy usage value for lighting for both old (existing) and new housing stock. Square footage levels are increasing, which would tend to increase lighting levels in new homes. Use of more efficient lighting would, however, tend to decrease lighting levels in new residences. Thus, it does not seem unreasonable to use the same baseline for both new and existing housing stock.

END USE E074000E00 LIGHTING-SINGLE FAMILY-OLD

End-Use Description

Lighting for old single family homes is the lighting used by all single family units existing in 1979.

UEC

We have used 1000 kWh/year as the UEC for single family homes; 750 kWh/year for multi-family homes; and 600 kWh/year for mobile homes. These are slightly rounded figures based on the BPA and Hittman baseline numbers for 1979, (BPA Appendix, August, 1982, p. A-44; BPA, Dec., 1981, Hittman, Feb., 1982).

We have continued to use the 1979 values, rather than the slightly lower 1980 values given in the latest technical appendix (August, 1982), because we are using 1979 occupied housing stock levels for the

baseline, and implementing conservation measures beginning in 1980.

Initial Stock

The initial stock for single family lighting is just the number of single family occupied housing units in the Pacific Northwest- 2391 thousand units. (See documentation under demographics section for explanation of this number).

Addition Rate

This is not applicable, since the existing housing stock only decays. (See Appendix A).

Decay Rate

The decay rate is 0.018, based on the estimated lifetime of housing, and assuming linear decay. (See the space heating section).

END USE EN74000E00 LIGHTING-SINGLE FAMILY-NEW

End-Use Description

Lighting for new single family homes is the lighting used by new single family units which enter the stock each year after 1979.

UEC

The UEC for this end use is 1000 kWh/year. (See explanation above).

Initial Stock

The initial stock for new single family lighting is 0. (Note however that the value of existing housing must be entered. See model documentation.)

Addition Rate

The addition rate is 0.020, based on the growth of single family housing stock projected in the BPA Forecast.

Replacement Rate

The replacement rate is 0.018, equal to the decay rate of existing single-family housing. (See above).

END USE E075000E00 LIGHTING-MULTI FAMILY-OLD

End-Use Description

Lighting for old multi-family homes is the lighting used by all multi-family units existing in 1979. (See discussion above under "Lighting-Single Family").

UEC

The UEC used for multi-family lighting is 750 kWh/year. See further explanation above under "Lighting-Single Family."

Initial Stock

The initial stock for multi-family lighting is the number of multi family occupied housing units in the Pacific Northwest- 327 thousand units. (See documentation under demographics section for source explanation of this number).

Addition Rate

This is not applicable for the old stock. (See Appendix A).

Decay Rate

The decay rate for old multi-family lighting, is based on the estimated lifetime of multi-family housing, and assuming linear decay.

END USE EN75000E00 LIGHTING-MULTI FAMILY-NEW

End-Use Description

Lighting for new multi-family homes is the lighting used by new multi-family units which enter the stock each year after 1979. (See discussion above under "Lighting-Single Family").

UEC

The UEC used for multi-family lighting is 750 kWh/year. See further explanation above under "Lighting-Single Family."

Initial Stock

The initial stock for new multi-family lighting is 0. (Note however that the value of existing housing- 327 thousand- must be entered. See model documentation.)

Addition Rate

The addition rate is 0.018, based on the growth of multi-family housing stock projected in the BPA Forecast.

Replacement Rate

The replacement rate is 0.018, equal to the decay rate of existing multi-family housing. (See above).

END USE E071000E00 LIGHTING-MOBILE HOME-OLD

End-Use Description

Lighting for old mobile homes is the lighting used by all mobile homes existing in 1979. (See discussion above under "Lighting-Single Family").

UEC

The baseline UEC for mobile homes is 600 kWh/year. See explanation above under "Lighting-Single Family." (Note: mobile home lighting is less than multi-family lighting, although both the occupancy and square footage figures are higher. The reasons for this need to be clarified. Presumably, use of fluorescents is higher than in the other housing types.)

Initial Stock

The initial stock for old mobile home lighting is just the number of mobile home occupied housing units in the Pacific Northwest- 232 thousand units. (See documentation under demographics section for source explanation of this number).

Addition Rate

This is not applicable to the "old" end-use.

Decay Rate

The decay rate for old mobile home lighting, is based on the estimated lifetime of mobile homes, and assuming linear decay.

END USE EN71000E00 LIGHTING-MOBILE HOME-NEW

End-Use Description

Lighting for new mobile homes is the lighting used by new mobile homes which enter the stock each year after 1979. (See discussion above under "Lighting-Single Family").

UEC

The baseline UEC for mobile homes is 600 kWh/year. See explanation above under "Lighting-Single Family."

Initial Stock

The initial stock for new mobile home lighting is 0. (Note however that the value of existing housing- 232 thousand- must be entered. See model documentation.)

Addition Rate

The addition rate is 0.038, based on the growth of multi-family housing stock projected in the BPA Forecast.

Replacement Rate

The replacement rate is 0.042, equal to the decay rate of existing mobile homes. (See above).

END USE EE80001E00 TELEVISIONS-COLOR

End-Use Description

Televisions have been divided into two end uses- color televisions and black & white televisions. The wattage, and thus the unit energy consumption of the appliance, differs significantly between a color television and a black & white television.

The unit energy consumption is based on the wattage of the model, as well as the estimated hours it will be in use.

Regular television viewing may decline but related activities such as home video, and home computers will probably increase so that hours of usage can be assumed to remain constant.

UEC (Unit Energy Consumption)

The UEC of a color television is dependent on the wattage of the television and the number of hours it is in use. We have requested information on these parameters from research that was done for the U.S. Department of Energy for the Consumer Products Efficiency Standards project. In the meantime, we will use 600 kWh/year as a preliminary estimate. This is based on the Scanlon/Hoffard figure of 639 kWh/year (Scanlon, Hoffard, Dec. 1981) which was used by BPA in the Technical Appendix to their forecast (BPA, 1982). We have rounded this figure down to reflect the uncertainty level and because several estimates from other sources are lower.

Initial Stock

The initial stock figure was calculated by using the PNW residential survey (Elrick & Lavidge, July, 1980). Using questions 79 and 80, the total television saturation can be calculated to be 1.45, with the breakdown between color and black & white equal to .95 and .50 respectively. $(.675)(1) + (.117)(2) + (.013)(3) = .95$ $(.393)(1) + (.041)(2) + (.007)(3) = .50$

Thus, the initial stock of color televisions is equal to the saturation, .95, multiplied by the number or occupied housing units.

Addition Rate

The BPA Forecast shows that housing units will grow by about 2% per year. Since we have divided televisions into two types, we decided that although the total addition rate for televisions should be consistent with the 2% growth rate, the saturation of black and white units seems likely to decline relative to the saturation of color units.

To account for this, we have decreased the addition rate for black & white televisions to 1%, while increasing the addition rate for color televisions to 2.5%. This is just an estimate as we have no data on expected increases in saturation of color televisions or black and white televisions.

Decay Rate This is not applicable (see explanation under "Refrigerators-Single Door Manual").

END USE EE80002E00 TELEVISIONS-BLACK & WHITE

UEC

There is a wide range of estimates for usage of black and white televisions. As with color televisions, the unit energy consumption depends on the wattage of the appliance and the hours of usage.

Estimates for black and white range from 129 kWh/year to 500 kWh/year. (See paragraph under "Other Studies" below). We have chosen a preliminary estimate of 200 kWh/year.

Initial Stock

See explanation above under "Televisions-Color."

Addition Rate

The addition rate for black and white televisions is estimated to be 1.0%. See explanation under "Televisions-Color."

Decay Rate

This is not applicable (see explanation under "Refrigerators-Single Door Manual").

Other Studies

Wright et al, LBL, 1981, cite 130 kwh/year (from Berman et al 1976); Parti & Davis, give a conditional demand estimate of 129 kwh/year; and the ADL/SCE conservation study says 500 kwh/year.

END USE EE80003E00 CLOTHES DRYER-ELECTRIC

End-Use Description

An electric dryer uses electricity as the heat source to dry clothes in a tumble-type drum with forced air circulation.

For a more thorough technical description of this type see the DOE/ADL Consumer Products Efficiency Standards Engineering Analysis (ADL, March, 1982) and the DOE Test Procedures (Federal Register 46FR 27324, May 19, 1981).

UEC

The baseline unit energy consumption for electric clothes dryers is estimated to be 1000 kWh/year. This is based on the 3/82 ADL/CPES report (ADL, March, 1982) which shows a baseline UEC of 1015 kWh/year, and rounded down to reflect both the uncertainty of the average stock currently in the Northwest region, (including the possibility that some compact dryers which use lower amounts of energy are included in the stock figures) and the lower estimates in most of the previous studies done in the region.

The AHAM/SAI shipment data shows that the efficiency of dryers did not increase too significantly during the 1972 to 1980 period (in fact the UEC of dryers increased from 1972 to 1978). There was an increase in the efficiency between 1978 and 1980 apparently due to increased shipments of models with temperature settings but this only lowered the UEC a few kWh below the 1972 level. Thus, the stock of dryers can be assumed to have an average UEC of about 1000 kWh/year.

Initial Stock

The stock figure was obtained by applying the PNW residential survey (Elrick & Lavidge, July, 1980) saturation of clothes dryers (.717), multiplied by the saturation of electricity for dryers (.98), to the PNW occupied housing stock. $(.717) (.98) (2950) = 2073$

Addition Rate

We have estimated the addition rate of dryers to be 2.6% per year.

This was estimated by using data from the Pacific Northwest Residential Survey.

Housing units built before 1950 have a clothes dryer saturation of .701, while the saturation for units built between 1950 and 1964 is .842; the saturation for units built between 1965 and 1974 is .788; and the saturation for units built from 1975 to 1979 is .792. (Volume 4, page 137.) The overall saturation is .717 in 1980 but from the above data which show a higher saturation in newer housing units, we have estimated that the saturation in 2000 could be .800. Thus, the average annual growth rate (or addition rate) is calculated to be 2.6% per year.

[0.717 (2950) = 2115 thousand units in 1980; 0.800 (4432) = 3546 thousand units in 2000; growth rate = $\{\ln 3546/2115\}/20$ years = 0.0258].

Decay Rate

The decay rate is not applicable (see Appendix A).

END USE EE80004E00 CLOTHES WASHER

End-Use Description

We are not including the energy used to heat the water in this end-use. It is included as part of the water heating end-use.

UEC

The baseline UEC of 100 kWh/year is based on the 4/81 BPA Technical Appendix and 7/81 Hittman Report which both quote 104 kWh/year for clothes washers.

Initial Stock

The stock figure for clothes washing machines is obtained by applying the PNW residential survey (Elrick & Lavidge, 1980) saturation figure of .779 to the total occupied housing stock. $(.779) (2950) = 2298$

Addition Rate

We have estimated the addition rate for clothes washers to be the same as for new housing, about 2% per year.

The Pacific Northwest Residential Survey (volume 4, page 133) shows that there is no large difference in the saturation of clothes washers among housing units built in different time periods. Thus we see no evidence that the saturation of clothes washers will be increasing over the next 20 years.

Decay Rate

The decay rate is not applicable (see Appendix A).

Availability of Other Studies

Most studies, including conditional demand and utility metering, include hot water consumption in the estimate of clothes washer energy consumption.

END USE EE80005E00 DISHWASHERS

End-Use Description

We are not including the energy used to heat the water in this end-use. It is included as part of the water heating end-use. Thus, the energy consumption for this end use is based just on the motor energy and the heating for drying. The heating element uses 0.3 kWh/cycle (product literature), and can be turned off in many models. Since this requires consumer action each time the appliance is used, we have not included it as a separate measure, but the savings potential should be noted.

At least one model currently on the marketplace has a booster to heat the water in the dishwasher. If more of the market switches to this type of dishwasher, this end-use must be re-evaluated in conjunction with the hot water end-uses. Most European dishwashers currently include a water heating booster.

UEC

The baseline unit energy consumption of 175 kWh/year is based on the 4/81 BPA Technical Appendix and the 7/81 Hittman Report which quote figures of 174 and 173 kWh/year respectively.

Initial Stock

The stock figure was obtained by applying the PNW residential survey (Elrick & Lavidge, 1980) saturation figure of .498 to the total occupied housing stock. $(.498) (2950) = 1469$

Addition Rate

We have estimated the addition rate of dishwashers to be 4.1% per year.

This was estimated by using data from the Pacific Northwest Residential Survey.

Housing units built before 1950 have a dishwasher saturation of .347, while the saturation for units built between 1950 and 1964 is .532; the saturation for units built between 1965 and 1974 is .636; and the saturation for units built from 1975 to 1979 is .748. (Volume 4, page 13*.) The overall saturation is .498 in 1980 but from the above data, which show a higher saturation in newer housing units, we have estimated that the saturation in 2000 could be .75. Thus, the average annual growth rate (or addition rate) is calculated to be 4.1% per year.

$[0.5 (2950) = 1475$ thousand units in 1980; $0.75 (4432) = 3324$ thousand units in 2000; growth rate = $\{\ln 3324/1475\}/20$ years = 0.0406].

Decay Rate

The decay rate is not applicable (see Appendix A).

Availability of Other Studies

Most estimates include hot water consumption.

END USE EE90001E00 WELL WATER PUMPS

End-Use Description

It is difficult to describe the average residential well water pump because the depth of the wells and the efficiencies of motors vary widely, as well as the amount of water being pumped by the residential user.

UEC

We estimate an average yearly unit energy consumption of 300 kWh/year.

This is based on calculations of estimated depths and motor efficiencies and water usage values. A Pacific Gas & Electric employee estimated about 600 kWh/year as a "back of the hand" estimate for residential well water pumps. This figure included some irrigation of arid areas, etc. and we have lowered our preliminary estimate for the Northwest.

There appears to be little data on well depths; this might be a good area for some research.

Initial Stock

The initial stock is estimated by use of the Pacific Northwest Residential Survey (Elrick & Lavidge, July, 1980, Volume 3, p. 82). The saturation given in the survey (.104) was applied to the total 1980 occupied housing stock (2950 thousand) to give an initial stock figure of 307 thousand well pumps.

Addition Rate

The addition rate is assumed to be the same as for housing, 2.0%.

Decay Rate

The decay rate is not applicable (see Appendix A)

Availability of Other Studies

There is not much data on residential well water pumps.

Caveats

Even though the data are minimal, we have pulled well pumps out of miscellaneous "other" usage and made them a separate end-use because they almost certainly use a fair amount of electricity, and there is good potential for saving electricity through pump motor efficiency improvements.

END USE EE90003E00 WATERBEDS

End-Use Description

Waterbeds come in different sizes, with "king-sized" and "queen-sized" being the most common. They are generally heated to temperatures of 80 to 90 degrees F.

UEC

The unit energy consumption for waterbeds varies depending on the size, temperature setting, and bed coverings. We have estimated the baseline consumption to be 1200 kWh/year. This is based on measurements and estimates ranging from 1004 kWh/year to 3285 kWh/year. (See studies below)

Initial Stock

The initial stock figure is 15 % of the total housing stock, or 442 thousand units. This is based on surveys done for California which show 18 to 20 percent, rounded down to reflect uncertainty in the Northwest.

Addition Rate

The addition rate is assumed to be the same as the BPA forecasted growth rate of housing, 2.0%.

Decay Rate

The decay rate is not applicable (see Appendix A).

Availability of Other Studies

Wright et al states that a king sized bed heated to 87 degrees F. uses 115 kWh/ month, resulting in a UEC of 1380 kWh/year. James Weiss metered a queen sized bed heated to 32 degrees C. (in air temperature 19 degrees C.) and got uses ranging from 1004 kWh/year for an unslept, covered bed, to 3285 kWh/year for a totally stripped bed. Southern California Edison (SCE) has been studying waterbeds. The preliminary range of their data was from 1278 kWh/year to 2555 kWh/year for a king-sized bed.

CONSERVATION MEASURES

CONSERVATION MEASURE ME40001E0001

NAME

Refrigerator-Single Door Manual, Buy Efficient Market Model

MEASURE DESCRIPTION

Refrigerator models sold today vary considerably in energy consumption. Even among models of similar type and size, the energy consumption is significantly different. An efficient model purchased at the time of replacement of the appliance may have a higher initial cost, but energy savings result.

This measure assumes that, at the time of replacement of the appliance, the most energy efficient appliance is purchased.

The list of available models (and their sizes and UECs) that we used to select the most efficient model was the April, 1982 California Energy Commission (CEC) Directory of Refrigerators/Freezers Which Comply With November 3, 1979 Standards. (In California there are appliance efficiency standards which appliances must meet in order to be sold in California. Manufacturers must certify their models with the CEC if they are to be sold in the state. Since the standards are for minimum efficiency levels, we have assumed that the most efficient models will appear on the lists of certified California models.)

In choosing the most efficient model for a refrigerator type, we have looked at only those models which are similar in size to the representative baseline model used in the DOE/CPES (ADL, March, 1982) report.

Thus, for single door, manual defrost refrigerators, the baseline model was 13.0 cubic feet, and we looked at the list of models sold in California to find the lowest UEC for a model of approximately 13 cubic feet. There are several models shown in this size range which use 570 kWh/year. (These models are 13.88 cubic feet, and use less energy than any others in the range of 13 cubic feet or greater.)

Note that the "corrected volume" should also be verified to be in the same range as the ADL baseline model.

COST

The estimated cost for this measure is \$22.

The more efficient models generally have a higher first cost, due to increased labor and materials costs for the added insulation, etc. Rather than attempting to compare retail costs for the "efficient"

model and an "average" model, we used the cost data provided by the DOE/ADL CPES report (DOE/ADL, March, 1982). According to the data given in this report, the incremental cost of increasing the efficiency of the 13.0 cubic foot basic model for a single door, manual defrost refrigerator to an energy factor of 11.2, with a UEC of 456 kWh/year, is about \$40. (The cost increases from \$340 to either \$371 or \$389 depending on the type of manufacturer).

We have used the \$40 cost per unit (to increase the efficiency from the baseline 1980 model to an efficient model which uses 456 kWh/year) as the total cost for implementing both this measure and the following measure (ME40001E0002) which is to purchase a model with all of the CPES efficiency improvements.

The improvements in efficiency shown in the ADL analysis were made under the assumptions that design options were based on technologies "available," (i.e. presently implemented in units available in the marketplace) and that the lead times available for implementing the necessary design changes would be long enough so that no significant increase in engineering staff would be required. (DOE/ADL, March, 1982, p. C-1, C-4).

Apparently the models available in 1980 which use 570 kWh/year have already incorporated some, but not all, of the CPES improvements. There is no significant difference in the cost/savings ratios of the efficiency improvement steps shown in the DOE/ADL analysis. Thus, we see no evidence for allocating the costs between this measure of purchasing the best available model and the measure of buying a model with all the CPES improvements differently than on an approximate per kWh basis.

We first looked at the difference between the UEC of the best-on-market and the 1980 baseline unit used in the DOE/ADL CPES analysis (March, 1982). Then we used the ratio of this "savings" to the savings from the second measure -buying a model which has all the efficiency improvements described in the CPES analysis. We used this ratio to allocate the cost between the two measures.

Thus, for single door, manual defrost models, the ratio is $138 \frac{(708 - 570)}{114} \frac{(570 - 456)}{}$, so the cost allocation (rounded) is \$22 to \$18.

We recommend that some Northwest retail cost sampling be done to see how these figures match with the prices consumers are actually faced with.

AVERAGE SAVINGS

The savings for this measure is equal to the difference in UEC between the existing stock average UEC and the UEC of the most efficient model on the market of similar type and size. Since, for single door, manual defrost refrigerators, the existing stock average UEC is 750 kWh/year (see end-use documentation), and the UEC of the best-on-market model is 570 kWh/year (see documentation above under

"technical description"), the average savings for this measure is 180 kWh/year.
 $750 - 570 = 180$

LIFETIME

The lifetime used for all refrigerator measures is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1980, since the measure is to purchase appliances which are already on the market.

ROLL-IN TIME

We will assume that these appliances are purchased at the time of replacement of an old appliance, so assuming linear decay of the old refrigerators, the roll-in time for this measure is the refrigerator lifetime- 19 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of refrigerators can be replaced.

CONSERVATION MEASURE ME40001E0001

NAME

Refrigerator-Single Door Manual, CPES Improvements

MEASURE DESCRIPTION

The March, 1982 Consumer Products Efficiency Standards Engineering Analysis Document, prepared by Arthur D. Little for the Department of Energy (ADL, March, 1982), shows design improvements available on units currently on the marketplace, and gives cost- efficiency data for these.

The design options considered in the ADL analysis are:

- Foam Insulation Substitution in Doors
- Increased Door Insulation Thickness
- High Efficiency Compressor Substitution
- Double Door Gasket
- Anti-Sweat Heater Switch
- Increased Cabinet Insulation Thickness
- Reduced Heat Load Of Through the Door Feature
- Increased Evaporator Surface Area

See the ADL analysis for a more thorough description of these options which, it should be noted, are not all applied to all product types in the analysis. Of course, the best-on-market model already must incorporate some of these options; this measure is just to purchase a model with all of the design improvements that are included in the ADL model with the lowest UEC.

COST

The cost for this measure is estimated to be \$18. See explanation above under "COST" for the measure "Buy Efficient Market Model."

AVERAGE SAVINGS

The savings for this measure are the difference in UEC between the most efficient model on the market and the model which has all the applicable efficiency design improvements described in the DOE/ADL CPES analysis. Thus, for single door refrigerators, the savings are equal to 115 kWh/year (570 - 456 = 115)

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is estimated to be 1985, that is, models with all of the applicable CPES improvements could be on the market by 1985, since these improvements were all available market technologies in 1980 (presumably not all available on one model since the best market model had a higher UEC than the model with all the CPES improvements).

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model.")

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of refrigerators can be replaced.

CONSERVATION MEASURE ME40001E0002

NAME

Refrigerator-Single Door Manual, 1987 Improvements

MEASURE DESCRIPTION

Arthur D. Little and Amana have developed a prototype low-energy top-freezer, frostfree refrigerator. However, since a high efficiency compressor, and increased wall insulation are the main characteristics of the prototype, we believe that higher efficiency models of other refrigerator types could also be developed.

The 16 cubic foot prototype uses 1.8 kWh/day or 657 kWh/year. The most efficient top freezer shown in the ADL analysis has a UEC of 920 kWh/year. This is a 28% reduction. We have applied this same percentage reduction to the most efficient models of other types in the ADL analysis.

Amana has already successfully tested 25 18 cu. ft. prototypes, which used 2.04 kwh/day (745 kwh/year). The electricity consumption of these prototypes was very similar to the DOE test results. (Topping, ADL, Dec., 1982).

Some Japanese models have UECs lower than the Amana prototype, and Goldstein suggests that marrying the new high efficiency compressors to the Amana prototype could further reduce consumption to 420 kwh/year. (Goldstein, 1982). An additional measure should be added as new test results become available.

COST

For single door manual defrost models we have used an estimate of \$50 for this measure. It is difficult to estimate costs for prototype models, so as the start date for this measure approaches, the cost data should be revised if necessary.

The high-efficiency top freezer prototype models mentioned above (see measure description) were offered in a test for \$30 over the price of the current high efficiency models. Goldstein cites \$50 as the extra cost of a top freezer prototype with a UEC of 650, and \$75 - \$125 as the estimated retail price difference between the efficient Japanese models (UEC 540) and American models. (Goldstein, 1982). We have used \$50 to \$100 as the cost for this measure, with the lower cost for the less expensive single door models, and the higher cost for side-by-side models. (Partial Automatic, Top Freezer, and Bottom Freezer types are in the middle of this cost range.)

The above costs estimates are very rough estimates; in any event, the savings for this measure are large enough so that the CCE will remain low even if the costs are doubled.

AVERAGE SAVINGS

The savings for this measure are estimated to be 130 kWh/year (.28 x 456 kWh/year). (see explanation of method above under technical description).

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1987.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model.")

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME40002E0001

NAME

Refrigerator-Partial Automatic Defrost, Buy Efficient Market Model/CPES Improvements

MEASURE DESCRIPTION

This measure is to buy the most efficient partial automatic defrost model of a similar size as the baseline model used in the ADL/CPES engineering analysis.

There is a model listed by the CEC which is 14.2 cubic feet and has a unit energy consumption of 625 kWh/year. (Since this is a model currently on the market with unit energy consumption lower than the model in the ADL/CPES analysis with all the applicable design improvements, there is no further measure to incorporate CPES design changes.)

COST

The estimated cost for this measure is \$35 (see "Refrigerators-Single Door Manual" for explanation of method of allocating costs).

AVERAGE SAVINGS

The savings for this measure are 675 kWh/year, based on the difference between the existing stock average and the most efficient market model.
[1300 - 625 = 675].

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1980 because there are models available on the market (and were in 1980) which have a UEC of 625 kWh/year; thus models being replaced could obtain the full 675 kWh/year savings from the baseline existing stock average beginning in that year.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40002E0002

NAME

Refrigerator-Partial Automatic Defrost, 1987 Improvements

MEASURE DESCRIPTION

See above under "Refrigerators-Single Door Manual."

COST

The cost for this measure is estimated to be \$60. See explanation above under "Refrigerators-Single Door Manual."

AVERAGE SAVINGS

The estimated savings for this measure are 180 kWh/year (.28 x 635). See the explanation for the method under "Refrigerators- Single Door Manual."

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1987.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40003E0001

NAME

Refrigerators-Top Freezer, Automatic- Buy Efficient Market
Model/CPES Improvements

MEASURE DESCRIPTION

This measure is to buy the most efficient top freezer, automatic defrost model of a similar size as the baseline model used in the ADL/CPES engineering analysis (17 cubic feet).

There is a model listed by the CEC which is 17.12 cubic feet and has a unit energy consumption of 914 kWh/year. (Since this is a model currently on the market with unit energy consumption lower than the model in the ADL/CPES analysis with all the applicable design improvements, there is no further measure to incorporate CPES design changes.)

Note that there is also a model that is 18 cu. ft. and has a UEC of only 865 kWh/year. We have not included this model as the "best-on-market" because the freezer volume is less (and the fresh-food compartment volume more) than the other models of similar total cu. ft. size.

COST

The cost for this measure is estimated to be \$22, based on the ADL/CPES analysis (ADL, March, 1982).

AVERAGE SAVINGS

The savings for this measure are estimated to be 910 kWh/year based on the difference between the existing stock average and the most efficient market model.
[1825 - 914 = 911].

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40003E0002

NAME

Refrigerators-Top Freezer, Automatic- 1987 Improvements

MEASURE DESCRIPTION

See explanation above under "Refrigerator-Single Door Manual."

COST

The cost for this measure is estimated to be \$75. See explanation above under "Refrigerators-Single Door Manual."

AVERAGE SAVINGS

The estimated savings for this measure are 257 kWh/year [914 - 657 = 257]. See the explanation for the method under "Refrigerators- Single Door Manual."

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1987.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40005E0001

NAME

Refrigerators-Bottom Freezer, Automatic- Buy Efficient Market Model

MEASURE DESCRIPTION

This measure is to buy the most efficient bottom freezer, automatic defrost model of a similar size as the baseline model used in the ADL/CPES engineering analysis (19.1 cubic feet).

There is a model listed by the CEC which is 19.1 cubic feet and has a unit energy consumption of 1316 kWh/year.

COST

The cost for this measure is estimated to be \$19.

[1870 (ADL 1980 baseline model) - 1316 (efficient market model) = 554. 1316 - 990 = 326. $554 / (554 + 326) = .63$. $.63 \times \$30 = \19 .]

See explanation for methodology of allocating costs under Single Door Refrigerator section above.

AVERAGE SAVINGS

The savings for this measure are estimated to be 1485 kWh/year based on the difference between the existing stock average and the most efficient market model.

[2800 - 1316 = 1484].

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1980, since the model using 1316 kWh/year is available on the marketplace.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40005E0002

NAME

Refrigerator-Bottom Freezer, Automatic, CPES Improvements

MEASURE DESCRIPTION

The March, 1982 Consumer Products Efficiency Standards Engineering Analysis Document, prepared by Arthur D. Little for the Department of Energy (ADL, March, 1982), shows design improvements available on units currently on the marketplace, and gives cost-efficiency data for these. (See above under Single Door Manual Refrigerator.)

See the ADL analysis for a more thorough description of these options which, it should be noted, are not all applied to all product types in the analysis. Of course, the best-on-market model already must incorporate some of these options; this measure is just to purchase a model with all of the design improvements which are included in the ADL model with the lowest UEC.

COST

The cost for this measure is estimated to be \$11. See explanation above under "COST" for the measure "Buy Efficient Market Model."

AVERAGE SAVINGS

The savings for this measure are the difference in UEC between the most efficient model on the market and the model which has all the applicable efficiency design improvements described in the DOE/ADL CPES analysis. Thus, for bottom freezer, automatic defrost, refrigerator-freezers the savings are equal to 325 kWh/year

[1316 - 990 = 326].

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is estimated to be 1985. It is assumed that models with all of the applicable CPES improvements could be on the market by 1985, since these improvements were all available market technologies in 1980 (presumably not all available on one model since the best market model had a higher UEC than the model with all the CPES improvements).

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of refrigerators can be replaced.

CONSERVATION MEASURE ME40005E0003

NAME

Refrigerators-Bottom Freezer, Automatic- 1987 Improvements

MEASURE DESCRIPTION

See explanation above under "Refrigerator-Single Door Manual."

COST

The cost for this measure is estimated to be \$75. See explanation above under "Refrigerators-Single Door Manual."

AVERAGE SAVINGS

The estimated savings for this measure are 275 kWh/year. ($.28 \times 990 = 277$). See the explanation for the method under "Refrigerators-Single Door Manual."

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1987.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40004E0001

NAME

Refrigerators, Side by Side- Buy Efficient Market Model

MEASURE DESCRIPTION

See explanation under "Refrigerators-Single Door Manual."

COST

The cost for this measure is estimated to be \$16.
[1773 (ADL 1980 baseline unit) - 1358 (efficient market model) =
415. 415/415 +110 = .79. .79 (\$20) = \$16.] See explanation for
method of allocating costs under "Refrigerators-Single Door Manual".

AVERAGE SAVINGS

The savings for this measure are the difference between the baseline
consumption and the model on the market of similar size and type
which has the lowest unit energy consumption. Since there are 22
cubic feet models with UECs of 1358 kWh/year, the savings are 1290
kWh/year (2650 - 1358 = 1292).

LIFETIME

The lifetime used for all refrigerator measures is the lifetime
given by the latest DOE/ADL-CPES report (March, 1982), which is 19
years.

START YEAR

The start year for this measure is 1980, since the measure is to
purchase models which are already on the market.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation
above under the measure "Buy Efficient Market Model," in the Single
Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME40004E0002

NAME

Refrigerators, Side by Side- CPES Improvements

MEASURE DESCRIPTION

See explanation above under "Refrigerators-Single Door, Manual."

COST

The cost for this measure is estimated to be \$4. [\$20 - \$16]. (See COST above under "Buy Efficient Market Model" and see method for allocating CPES costs above under "Refrigerators-Single Door Manual").

AVERAGE SAVINGS

The savings for this measure are estimated to be 110 kWh/year.

[1358 - 1249 = 109].

This is the difference between the best-on-market model and the ADL most efficient model of this type.

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is estimated to be 1985. It is assumed that models with all of the applicable CPES improvements could be on the market by 1985, since these improvements were all available market technologies in 1980 (presumably not all available on one model since the best market model had a higher UEC than the model with all the CPES improvements).

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME40004E0003

NAME

Refrigerators, Side by Side- 1987 Improvements

MEASURE DESCRIPTION

See explanation under "Refrigerators-Single Door Manual."

COST

The cost for this measure is estimated to be \$100. See explanation above under "Refrigerators-Single Door Manual."

AVERAGE SAVINGS

The savings for this measure are estimated to be 350 kWh/year (.28 x 1249; see explanation above under "Refrigerators- Single Door Manual").

LIFETIME

The lifetime used for all refrigerator measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 19 years.

START YEAR

The start year for this measure is 1987.

ROLL-IN TIME

The roll-in time for this measure is 19 years. (See explanation above under the measure "Buy Efficient Market Model," in the Single Door Manual end-use.)

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME50001E0001

NAME

Freezer, Chest Manual Defrost- Buy Efficient Market Model

MEASURE DESCRIPTION

The energy consumption of freezer models sold today varies considerably. Among models of similar type and size, the energy consumption is significantly different. If an efficient model is purchased at the time of replacement of the appliance, the initial cost is apt to be higher, but energy savings result.

This measure assumes that, at the time of replacement of the appliance, the most energy efficient appliance, available on the market in 1980 is purchased.

The list of available models and their sizes and UECs which we used to select the most efficient model was the April, 1982 list of California Energy Commission (CEC) certified models sold in California. (In California there are appliance efficiency standards which appliances must meet in order to be sold in California. Manufacturers must certify their models with the CEC if they are to be sold in the state. Since the standards are for minimum efficiency levels, we have assumed that the most efficient models will appear on the lists of certified California models.)

In choosing the most efficient model for a freezer type, we have looked at only those models which are very similar in size to the representative baseline model used in the DOE/CPES (ADL, March, 1982) report.

Thus, for chest freezer, manual defrost, the baseline model was 15.0 cubic feet, and we looked at the list of models sold in California to find the lowest UEC for a model of approximately 15 cubic feet. There are models shown in this size range which use 704 kWh/year.

COST

The cost for this measure is estimated to be \$12.

The more efficient models sold generally have a higher first cost, due to increased labor and materials costs for the added insulation, etc. Rather than attempting to compare retail costs for the "efficient" model and an "average" model, we used the cost data provided by the DOE/ADL CPES report (DOE/ADL, March, 1982). According to the data given in this report, the incremental cost of increasing the efficiency of the 15.0 cubic foot baseline model for a manual defrost chest freezer to an energy factor of 17.7, with a UEC of 536 kWh/year, is about \$25. (The price increases from \$340 to either \$361 or \$367 depending on the type of manufacturer).

We have used the \$25 cost per unit (to increase the efficiency from the baseline 1980 model to an efficient model which uses 536 kWh/year) as the total cost for implementing both this measure and the following measure (ME50001E0002) which is to purchase a model with all of the CPES efficiency improvements.

The improvements in efficiency shown in the ADL analysis were made under the assumptions that design options were based on technologies "available," (i.e. presently implemented in units available in the marketplace) and that the lead times available for implementing the necessary design changes would be long enough so that no significant increase in engineering staff would be required. (DOE/ADL, March, 1982, p. C-1, C-4).

Apparently the models available in 1980 which use 704 kWh/year have already incorporated some, but not all, of the CPES improvements. There is no significant difference in the cost/savings ratios of the efficiency improvement steps shown in the DOE/ADL analysis. Thus, we see no evidence for allocating the costs between this measure of purchasing the best available model and the measure of buying a model with all the CPES improvements much differently than on a per kWh basis. We first looked at the difference between the UEC of the best-on-market and the 1980 baseline unit used in the DOE/ADL CPES analysis (March, 1982). Then we used the ratio of this "savings" to the savings from the second measure -buying a model which has all the efficiency improvements described in the CPES analysis. We used this ratio to allocate the cost between the two measures. (See example under "Refrigerators-Single Door Manual").

We recommend that some Northwest retail cost sampling be done to see how these figures match with the prices consumers are actually faced with.

AVERAGE SAVINGS

The savings for this measure is equal to the difference in UEC between the existing stock average UEC and the UEC of the most efficient model on the market of similar type and size. For chest freezers the existing stock average UEC is 1475 kWh/year (see end-use documentation), and the UEC of the best-on-market model is 704 kWh/year (see documentation above under "technical description"), so the average savings for this measure is about 770 kWh/year.
 $1475 - 704 = 771$

LIFETIME

The lifetime used for all freezer measures is the freezer appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is 1980, since the measure is to purchase appliances which are already on the market.

ROLL-IN TIME

We will assume that these appliances are purchased at the time of replacement of an old appliance, so assuming linear decay of the old freezers, the roll-in time for this measure is the freezer lifetime-21 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of chest freezers can be replaced.

CONSERVATION MEASURE ME50001E0002

NAME

Freezer, Chest Manual Defrost- CPES Improvements

MEASURE DESCRIPTION

The March, 1982 Consumer Products Efficiency Standards Engineering Analysis Document, prepared by Arthur D. Little for the Department of Energy (ADL, March, 1982), shows design improvements available on units currently on the marketplace, and gives cost- efficiency data for these.

The design improvements are:

- Foam Insulation Substitution in Cabinet
- Foam Insulation Substitution in Door
- Increase Cabinet Insulation Thickness
- Increase Door Insulation Thickness
- High Efficiency Compressor Substitution

(See the ADL analysis for a more complete description of the options.)

Of course, the best-on-market model already must incorporate some of these options; this measure is just to purchase a model with all of the design improvements which are included in the ADL model with the lowest UEC.

COST

The cost for this measure is estimated to be \$13. See explanation above under "COST" for the measure "Buy Efficient Market Model."

AVERAGE SAVINGS

The savings for this measure are the difference in UEC between the most efficient model on the market and the model which has all the applicable efficiency design improvements described in the DOE/ADL CPES analysis. Thus, for chest freezers, the savings are equal to about 170 kWh/year (704 - 536 = 168)

LIFETIME

The lifetime used for all freezer measures is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is estimated to be 1985. It is assumed that models with all of the applicable CPES improvements could be on the market by 1985, since these improvements were all

available market technologies in 1980 (presumably not all available on one model since the best market model had a higher UEC than the model with all the CPES improvements).

ROLL-IN TIME

The roll-in time for this measure is 21 years. (See explanation above under the measure "Buy Efficient Market Model," in the Chest Freezer, Manual Defrost end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of chest freezers can be replaced.

CONSERVATION MEASURE ME50003E0001

NAME

Freezer, Upright Manual Defrost- Buy Efficient Market Model

MEASURE DESCRIPTION

See general description of this measure under "Freezers- Chest Manual Defrost."

For upright freezer, manual defrost, the baseline model was 16.0 cubic feet, and we looked at the list of models sold in California to find the lowest UEC for a model of approximately 16 cubic feet. There is a model shown in this size range which uses 774 kWh/year.

COST

See general explanation above under "Freezers-Chest, Manual Defrost." The cost for this measure is estimated to be \$33.

AVERAGE SAVINGS

The savings for this measure is equal to the difference in UEC between the existing stock average UEC and the UEC of the most efficient model on the market of similar type and size. For upright freezers, manual defrost, the existing stock average UEC is 1750 kWh/year (see end-use documentation), and the UEC of the best-on-market is 774 kWh/year, thus the savings is about 975 kWh/year.

LIFETIME

The lifetime used for all freezer measures is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is 1980, since the measure is to purchase appliances which are already on the market.

ROLL-IN TIME

The roll-in time for this measure is 21 years. (See explanation above under the measure "Buy Efficient Market Model," in the Chest Freezer, Manual Defrost end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since the entire stock of upright freezers can be replaced.

CONSERVATION MEASURE ME50003E0002

NAME

Freezer, Upright Manual Defrost- CPES Improvements

MEASURE DESCRIPTION

See explanation under "Freezers-Chest, Manual Defrost."

COST

The cost for this measure is estimated to be \$12. See explanation above under "COST" for the measure "Buy Efficient Market Model."

AVERAGE SAVINGS

The savings for this measure are the difference in UEC between the most efficient model on the market and the model which has all the applicable efficiency design improvements described in the DOE/ADL CPES analysis. The model with all the ADL design improvements uses 656 kWh/year. Thus, for upright freezers, manual defrost, the savings are equal to about 118 kWh/year

[774 - 656 = 118].

LIFETIME

The lifetime used for all freezer measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is estimated to be 1985. (See explanation above under "Freezer-Chest, Manual Defrost.")

ROLL-IN TIME

The roll-in time for this measure is 21 years. (See explanation above under the measure "Buy Efficient Market Model," in the Chest Freezer, Manual Defrost end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is estimated to be 1.0.

CONSERVATION MEASURE ME50002E0001

NAME

Freezer, Upright Automatic Defrost- Buy Efficient Market Model

MEASURE DESCRIPTION

This measure is to buy the most efficient upright freezer with automatic defrost of a similar size as the baseline model used in the ADL/CPES engineering analysis.

There is a model listed by the CEC which is 16.1 cubic feet and has a unit energy consumption of 1240 kWh/year.

COST

The estimated cost for this measure is \$25. Instead of attempting to compare retail costs for the "efficient" model and an "average" model, we used the cost data provided by the DOE/ADL CPES report (DOE/ADL, March, 1982). According to the data given in this report, the incremental cost of increasing the efficiency of the 16.0 cubic foot baseline model for an upright automatic defrost freezer to an energy factor of 10.3, with a UEC of 982 kWh/year, is about \$45. (The cost increases from \$450 to either \$486 or \$505 depending on the type of manufacturer). See above under "chest freezer" for an explanation of the method of allocating the costs between this measure and the measure below.

AVERAGE SAVINGS

The savings for this measure are the difference between the average existing stock (3100 kWh/year) and the most efficient model (1240 kWh/year). Thus the savings are 1860 kWh/year.

LIFETIME

The lifetime used for all freezers measures is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is 1980, since the measure is to purchase appliances which are currently on the market.

ROLL-IN TIME

The roll-in time for this measure is 21 years. (See explanation above under the measure "Buy Efficient Market Model," in the Chest Freezer, Manual Defrost end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0 since the entire stock of baseline units is eligible for replacement.

CONSERVATION MEASURE ME50002E0002

NAME

Freezer, Upright Automatic Defrost- CPES Improvements

MEASURE DESCRIPTION

See explanation under "Freezers-Chest, Manual Defrost."

COST

The cost for this measure is estimated to be \$20. See explanation above under "COST" for the measure "Buy Efficient Market Model."

AVERAGE SAVINGS

The savings for this measure are the difference in UEC between the most efficient model on the market and the model which has all the applicable efficiency design improvements described in the DOE/ADL CPES analysis. The model with all the ADL design improvements uses 982 kWh/year. Thus, for upright automatic freezers, manual defrost, the savings are equal to 258 kWh/year [1240 - 982 = 258].

LIFETIME

The lifetime used for all freezer measures is the lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 21 years.

START YEAR

The start year for this measure is estimated to be 1985. (See explanation above under "Freezer-Chest, Manual Defrost.")

ROLL-IN TIME

The roll-in time for this measure is 21 years. (See explanation above under the measure "Buy Efficient Market Model," in the Chest Freezer, Manual Defrost end-use.)

ELIGIBLE FRACTION

The eligible fraction for this measure is estimated to be 1.0.

CONSERVATION MEASURE ME60001E0001

NAME

Cooking-Electric Ranges (Burners & Ovens)-CPES Improvements

MEASURE DESCRIPTION

The March, 1982 Consumer Products Efficiency Standards Engineering Analysis Document, prepared by Arthur D. Little for the Department of Energy (ADL, March, 1982), shows design improvements available on units currently on the marketplace, and gives cost-efficiency data for these.

The design improvements for electric ovens and burners are

- improved insulation
- reduced vent size
- reduced conduction losses
- improved contact conductance

COST

The cost for this measure is \$22., based on the cost/efficiency relationship given in the ADL/CPES analysis (ADL, March, 1982).

[\$2.7 for burners + (.62) \$25.8 for std. ovens + (.38) \$8.6 for self-cleaning ovens = \$22 total.]

AVERAGE SAVINGS

The savings for this measure are 45 kWh/year, based on the ADL/CPES analysis.

[9.1 for burners + (.62) 50.5 for std. ovens + (.38) 8.3 for self cleaning ovens = 43.6].

LIFETIME

The lifetime used is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 18 years

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

We will assume that the efficient ranges are purchased at the time of replacement of an old range, so assuming linear decay of the old appliances, the roll-in time for this measure is the lifetime- 18 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME60001E0002

NAME

Cooking-Electric Ranges (Burners & Ovens): Bi-Radiant Oven

MEASURE DESCRIPTION

A bi-radiant oven would be purchased to replace a conventional electric oven, at the time of replacement. A bi-radiant oven has three major features which improve the energy performance for baking food, while retaining acceptable food quality. These features are: (1) there are two heating elements operating at relatively low temperatures which provide the radiant flux, so no pre-heat cycle is necessary; (2) the wall surfaces of the oven are highly reflective, reflecting the radiant flux from the heating elements; and (3) the utensil surfaces are highly absorptive of the radiant flux from the heating elements. For a more thorough technical description of the bi-radiant oven concept, see Dewitt and Peart, ORNL/Sub-80/0082/1, April, 1980.

COST

The cost for this measure is estimated to be \$25. This technology is not fully commercialized, therefore the cost is uncertain. There may be less insulating material used in this oven than in conventional ovens, which could offset any increased costs for the reflective materials used. Purchase of cooking utensils appropriate for use in the bi-radiant oven might also be considered as an expense, although a difficult one to account for.

AVERAGE SAVINGS

The ORNL report on the bi-radiant oven found savings from 57 to 73 percent compared to conventional ovens for baking a range of goods. (See Table 4.6, p. 83 in Dewitt and Peart, ORNL/Sub-80/0082/1, April, 1980.

Based on this data, savings will be (conservatively) assumed to be 50 % of the conventional oven usage (pre-CPES improvements), or about 200 kWh/year.

LIFETIME

The lifetime used is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 18 years

START YEAR

The start year for this measure is 1985, since these ovens are still in the design stage.

ROLL-IN TIME

The roll-in time for this measure is 18 years. (See explanation under measure above).

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.5, since this measure is not assumed to be a viable option for all consumers. It requires use of special baking utensils, etc.

LIGHTING-SINGLE FAMILY OLD

CONSERVATION MEASURE MO74000E0001

NAME

Lighting, Single Family Old- Fluorescent in Kitchen (with renovation)

MEASURE DESCRIPTION

Many kitchens, especially in older homes, have incandescent lighting in the kitchen--either a 150 watt "kitchen light" or a triple 60 watt unit. These can be replaced with a fluorescent unit that will provide the same illumination with significant wattage savings.

There is a significant difference in the cost of replacing the kitchen bulb with a fluorescent, depending on whether or not contractor costs are involved. Thus, we have divided the kitchen fluorescent replacement into two measures: (1) replacement at the time of renovation of the kitchen so that additional contractor labor is not involved; and (2) replacement done at other times, involving contractor labor.

COST

The cost for this measure includes the added costs of the fluorescent fixture and bulb minus the cost of the incandescent bulbs which would have been used.

It could be argued that this is a zero cost measure since the avoided replacement costs of incandescent bulbs may more than offset the costs of the fluorescents over the lifetime of the lighting fixture. (See 1981 Fall/Winter Sears Catalog, p. 1178.)

However, we will conservatively assume the lifetime is equal to the lifetime of one fluorescent bulb, and only credit avoided incandescent replacement costs for that period.

For this measure there is no contractor cost because installation is done in conjunction with renovation work or by the resident.

The cost is then estimated to be \$17. This is the initial cost of a fixture with 54 watts--and presumably about an 11 watt ballast--minus the avoided incandescent replacement costs.

The initial cost of the fixture and bulb is \$27 and the rated lifetime is 7500 hours (1981 Fall/Winter Sears Catalog). The lifetime of equivalent incandescent lighting (160 watts) is 1000 hours. Thus, over the five year lifetime (at 1500 hours usage per year) of the fluorescent, seven and one-half incandescent replacements are avoided.

Three 60 watt bulbs cost \$1.32 (at \$0.44 each, Sears Catalog). $7.5 \times \$1.32 = \9.90 , so about \$10 in avoided incandescent replacement costs is subtracted from the \$27 initial fixture and bulb cost, giving a total cost of \$17 for this measure.

AVERAGE SAVINGS

The savings for this measure are based on the LBL California analysis (Wright et al, Jan., 1981, p.92), except that less hours of usage for a kitchen light were assumed. If a 65 watt fluorescent unit is used to replace 180 watts of kitchen light, which is assumed to be used 1500 hours per year the savings is $115 \text{ watts} \times 1500 \text{ hours}$, or 172 kWh/year.

LIFETIME

The rated lifetime of this fluorescent is 7500 hours. Assuming 1500 hours of usage per year, the bulb will have a lifetime of 5 years.

START YEAR

Since fluorescent bulbs are available on the market, the start year for this measure is 1980.

ROLL-IN TIME

We will assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years.

ELIGIBLE FRACTION

Some newer homes already have fluorescent bulbs in the kitchen, and thus would not be eligible for this measure. We have chosen 0.30 as the eligible fraction for this measure.

INTERACTIVE EFFECTS

The fluorescent bulb will give off less heat than the incandescent it is replacing, since it is lower wattage. Thus, there will be some interaction with heating and air conditioning. Interaction effects with space heating are dealt with as a reduction in internal gains in the space heating analysis. (See program documentation.)

CONSERVATION MEASURE MO74000E0002

NAME

Lighting, Single Family Old- Fluorescent in Kitchen (with labor)

MEASURE DESCRIPTION

Many kitchens, especially in older homes, have incandescent lighting in the kitchen—either a 150 watt "kitchen light" or a triple 60 watt unit. These can be replaced with a fluorescent unit that will provide the same illumination with significant wattage savings.

There is a significant difference in the cost of replacing the kitchen bulb with a fluorescent, depending on whether or not contractor costs are involved. Thus, we have divided the kitchen fluorescent replacement into two measures: (1) replacement at the time of renovation of the kitchen so that additional contractor labor is not involved; and (2) replacement done at other times, involving contractor labor.

COST

The cost for this measure includes the costs of the fluorescent fixture and bulb and the contractor labor costs, minus the cost of the incandescent bulbs which would have been used.

For the cost of the fixture and bulb minus the incandescent replacement costs (\$17), see above under the measure "Fluorescent in Kitchen (with renovation)."

We estimate \$18 of additional contractor cost based on one-half hour of labor at \$35 per hour.

The total cost for this measure is \$35.

AVERAGE SAVINGS

The savings for this measure are 172 kWh/year, which are the same as for the above measure "Fluorescent in Kitchen (with renovation)." See the documentation for the savings above.

LIFETIME

The rated lifetime of this fluorescent is 7500 hours. Assuming 1500 hours of usage per year, the bulb will have a lifetime of 5 years.

START YEAR

Since fluorescent bulbs are available on the market, the start year for this measure is 1980.

ROLL-IN TIME

We will assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years.

ELIGIBLE FRACTION

Some newer homes already have fluorescent bulbs in the kitchen, and thus would not be eligible for this measure. We have chosen 0.30 as the eligible fraction for this measure.

INTERACTIVE EFFECTS

See explanation under this section under the measure above (to replace fluorescent in kitchen-with renovation).

CONSERVATION MEASURE MO74000E0003

NAME

Lighting, Single Family Old- Outside Fluorescent (labor)

MEASURE DESCRIPTION

This measure is to replace an outdoor incandescent bulb with a fluorescent. Many fluorescent bulbs do not start well at low temperatures. The Sears Catalog does list a fluorescent fixture with a low temperature ballast that can be used outdoors. This measure assumes that the replacement is done using a contractor.

COST

The cost for this measure is \$65. The fixture and bulb cost \$45 (Sears), and we have assumed about one-half hour of contractor labor is needed at \$40/hour.

AVERAGE SAVINGS

The 18 watt fluorescent is replacing a 60 watt incandescent bulb. The bulb is assumed to be on for 3000 hours/year. The savings are $42 \text{ watts} \times 3000 \text{ hours/year} = \underline{126 \text{ kwh/year}}$.

LIFETIME

Since a major portion of the cost of this measure is the fixture, the lifetime is assumed to be 10 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

The roll-in time for this measure is 5 years.

ELIGIBLE FRACTION

This measure is assumed to apply only to single family residences that have outdoor lighting that is left on for long periods. We have estimated the total eligible fraction for the outdoor lighting measures to be 0.5. We divided this eligible fraction evenly between this measure and the following measure, which assumes that the outdoor fluorescent is newly installed or installed during renovation, so that there are no labor costs. For this measure, therefore, the eligible fraction is 0.25.

CONSERVATION MEASURE MO74000E0004

NAME

Lighting, Single Family Old- Outside Fluorescent (with renovation)

MEASURE DESCRIPTION

This measure is to replace the outdoor light with a fluorescent bulb during renovation, so there are no labor costs involved.

COST

The cost for this measure is \$45, for the fixture and bulb.

AVERAGE SAVINGS

The estimated savings for this measure are 125 kwh/year. (See the measure above for explanation.)

LIFETIME

The lifetime is 10 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

The roll-in time for this measure is 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.25. (See the measure above for explanation.)

CONSERVATION MEASURE MO74000E0005

NAME

Lighting, Single Family Old- Replace High Use Bulbs With SL Lamps

MEASURE DESCRIPTION

There are new fluorescent lamps which directly replace incandescents. We have chosen to model the energy savings from replacing incandescents by using the NORELCO (North American Philips Lighting Corporation) SL lamp. These lamps replace 75 watt incandescents. For this measure, we are assuming they replace only "high use" incandescents, which we are defining to be bulbs that are on for an average of 1000 hours per year.

For single family homes, we have decided there could be two "high use" bulbs to replace: a living/family room bulb and a bedroom/study bulb.

COST

The cost of each bulb is currently \$25 and is expected to decrease as production of these bulbs increases. We have decided to use (conservatively) \$25 as the initial cost for each bulb, and then subtract the avoided incandescent replacement costs.

Each of the two fluorescents replaces a 75 watt incandescent. The cost of a 75 watt incandescent bulb is \$0.44 and the rated lifetime is 850 hours (Fall/Winter 1981 Sears Catalog). The SL lamp is rated to last 7500 hours, so the avoided incandescent replacement costs are: $[7500/850 \times 2 \times \$.44 = \$7.76]$. Thus, the total cost will be $\$25 \times 2 = \$50 - \$7.76$, or about \$42. for the measure.

AVERAGE SAVINGS

Assuming the 18 watt fluorescent bulb will be replacing a 75 watt incandescent, the savings will be $57 \text{ watts} \times 1000 \text{ hours} \times 2 \text{ bulbs replaced} = \underline{114 \text{ kWh/year}}$.

LIFETIME

The lifetime used is the lifetime of the fluorescent bulb. Thus, for the SL lamp which has a rated average life of 7500 hours (Norelco Specification Sheet), the lifetime would be 7.5 years. Since the model uses integer lifetimes we have rounded this to 7 years.

$[7500 \text{ hours} / 1000 \text{ hours use per year} = 7.5 \text{ years}]$.

START YEAR

The start year for this measure is 1980 since these bulbs are currently available on the market.

ROLL-IN TIME

We will assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.9 because very few, if any, residences used all fluorescent lighting in 1980.

INTERACTIVE EFFECTS

See explanation under this section under the measure to replace fluorescent in kitchen.

CONSERVATION MEASURE MO74000E0006

NAME

Lighting, Single Family Old- Replace Medium Use Bulbs with SL Lamps

MEASURE DESCRIPTION

This measure uses the same SL lamps discussed above in the measure for "High Use Bulb Replacement." For this measure, we are assuming they replace only "medium use" incandescents, which we are defining to be bulbs that are on for an average of 750 hours per year.

For single-family homes, we have decided there would be four "medium use" bulbs to replace.

COST

The initial cost for replacement of medium use bulbs would be the same per bulb as for replacement of high use bulbs- \$25. The avoided incandescent replacement costs would be $\$.44 \times 7500/850 = \3.88 per bulb. Thus, the total cost for this measure would be $4 \text{ bulbs} \times \$25/\text{bulb} - 4(\$3.88) = \$84.48$, rounded to \$84.

AVERAGE SAVINGS

The savings per bulb replaced is 57 watts x the # of hours of usage. (See explanation above under measure to replace high use bulbs). For this measure, the savings are thus: $57 \text{ watts} \times 750 \text{ hours} \times 4 \text{ bulbs} = \underline{171 \text{ kWh/year}}$.

LIFETIME

The lifetime used for this measure is 10 years. [7500 hours/750 hours per year = 10 years.] See explanation above under "lifetime" for "fluorescent in kitchen.")

START YEAR

The start year for this measure is 1980 since these bulbs are currently available on the market.

ROLL-IN TIME

We assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years. 1984.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.9 because very few, if any, residences used all fluorescent lighting in 1980.

INTERACTIVE EFFECTS

See explanation under this section under the measure to replace fluorescent in kitchen.

LIGHTING-SINGLE FAMILY NEW

CONSERVATION MEASURE MN74000E0001

NAME

Lighting, Single Family New- Fluorescent in Kitchen

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Fluorescent in Kitchen (with renovation). All inputs are identical except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the fluorescent in kitchen measure is 0.7. It equals the sum of the "with renovation" and "with labor" measures in "Single Family Old," plus an extra 0.1 to account for the simpler incorporation of fluorescents in new residences. We assume that there is a higher saturation of kitchen fluorescents in new residences than in old residences. However, the 1980 UECs are the same for both "new" and "old" stock types, hence we include this increased saturation as part of the eligible fraction here. These numbers must be revised when the 1980 UECs for "new" and "old" stock are differentiated.

CONSERVATION MEASURE MN74000E0002

NAME

Lighting, Single Family New- Outside Fluorescent

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Outside Fluorescent (with renovation). All inputs are the same except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the outside fluorescent measure is 0.5. This is equal to the sum of the "with renovation" and "with labor" measures in "Single Family Old."

CONSERVATION MEASURE MN74000E0003

NAME

Lighting, Single Family New- SL Lamp For High Use Bulbs

See documentation for this measure in "Lighting-Single Family,Old"
since the measure is the same.

CONSERVATION MEASURE MN74000E0004

NAME

Lighting, Single Family New- SL Lamp For Medium Use Bulbs

See documentation for this measure in "Lighting-Single Family, Old"
since the measure is the same.

LIGHTING-MULTI FAMILY OLD

CONSERVATION MEASURE MO75000E0001

NAME

Lighting, Multi-Family Old- Fluorescent in Kitchen (with renov.)

See documentation for this measure in "Lighting-Single Family," since the measure is the same.

CONSERVATION MEASURE MO75000E0002

NAME

Lighting, Multi-Family Old- Fluorescent in Kitchen (with labor.)

See documentation for this measure in "Lighting-Single Family," since the measure is the same.

CONSERVATION MEASURE MO75000E0003

NAME

Lighting, Multi-Family Old- Outside Fluorescent (with labor)

This measure is the same as the "Outside Fluorescent (with labor)" measure for single family residences, except for the eligible fraction.

ELIGIBLE FRACTION

We include only those residences which have an exterior light which is left on for long periods each night. Some apartments with interior entrances may not have outdoor lighting. Thus, the eligible fraction for the outdoor fluorescent lighting measures is quite low: 0.3 for the outdoor fluorescent measures combined, with 0.15 for the "with labor" measure.

CONSERVATION MEASURE MO75000E0004

NAME

Lighting, Multi-Family Old- Outside Fluorescent (with renovation)

This measure is the same as the "Outside Fluorescent (with renovation)" measure for single family residences, except for the eligible fraction.

ELIGIBLE FRACTION

See measure above. The eligible fraction is 0.15 for the "with renovation" measure.

CONSERVATION MEASURE MO75000E0005

NAME

Lighting, Multi-Family Old- Replace High Use Bulbs With SL Lamps

MEASURE DESCRIPTION

See description under "Lighting-Single Family." For multi family units, we estimate there would be one "high use" bulb to replace:

COST

The cost for replacing one bulb is estimated to be \$21. See explanation under "Lighting-Single Family," for two bulbs; this cost is one-half.

AVERAGE SAVINGS

The savings for one bulb replacement are 57 kWh/year. See explanation under "Lighting-Single Family."

LIFETIME

The lifetime used for this measure is 7.5 years. See explanation under "Lighting-Single Family."

START YEAR

The start year for this measure is 1980. See explanation under "Lighting-Single Family."

ROLL-IN TIME

The roll-in time for this measure is 5 years. See explanation under "Lighting-Single Family."

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.9

INTERACTIVE EFFECTS

See explanation under "Lighting-Single Family."

CONSERVATION MEASURE M075000E0006

NAME

Lighting, Multi-Family Old- Replace Medium Use Bulbs With SL Lamps

MEASURE DESCRIPTION

See description under "Lighting-Single Family." We estimate that there would be 3 bulbs eligible for replacement in multi-family units.

COST

The cost for replacing three bulbs is estimated to be \$63. See explanation under "Lighting-Single Family," for four bulbs; this cost is three-fourths.

AVERAGE SAVINGS

The savings from replacement of three bulbs are 128 kwh/year. See explanation under "Lighting-Single Family," for four bulbs; these savings are three-fourths.

LIFETIME

The lifetime used for this lighting measure is 10 years. See explanation above under "Lighting-Single Family."

START YEAR

The start year for this measure is 1980 since these bulbs are currently available on the market.

ROLL-IN TIME

We assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.9 because very few, if any, residences used all fluorescent lighting in 1980.

INTERACTIVE EFFECTS

See explanation under "Lighting-Single Family."

LIGHTING-MULTI-FAMILY, NEW

CONSERVATION MEASURE MN75000E0001

NAME

Lighting, Multi-Family New- Fluorescent in Kitchen

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Fluorescent in Kitchen (with renovation). All inputs are the same except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the fluorescent in kitchen measure is 0.7. (See explanation under "Lighting, Single Family New").

CONSERVATION MEASURE MN75000E0002

NAME

Lighting, Multi-Family New- Outside Fluorescent

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Outside Fluorescent (with renovation). All inputs are the same except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the outside fluorescent measure is 0.5. This is equal to the sum of the "with renovation" and "with labor" measures in "Multi-Family Old."

CONSERVATION MEASURE MN75000E0003

NAME

Lighting, Multi-Family New- SL Lamp For High Use Bulbs

See documentation for this measure in "Lighting-Multi-Family,Old" since the measure is the same.

CONSERVATION MEASURE MN75000E0004

NAME

Lighting, Multi-Family New- SL Lamp For Medium Use Bulbs

See documentation for this measure in "Lighting-Single Family, Old"
since the measure is the same.

LIGHTING-MOBILE HOME, OLD

CONSERVATION MEASURE MO71000E0001

NAME

Lighting Mobile Homes Old- Fluorescent in Kitchen (with renov.)

See documentation for this measure in "Lighting-Single Family," since the measure is the same, except for the eligible fraction.

ELIGIBLE FRACTION

Many newer units already have fluorescent bulbs in the kitchen, and thus would not be eligible for this measure. We have estimated 0.2 as the eligible fraction for replacement of a kitchen bulb with a fluorescent. This eligible fraction is divided evenly between this measure and the following measure, thus the eligible fraction for this measure is 0.10

CONSERVATION MEASURE MO71000E0002

NAME

Lighting Mobile Homes Old- Fluorescent in Kitchen (with labor)

See documentation for this measure in "Lighting-Single Family," since the measure is the same, except for the eligible fraction. See the measure above ["Lighting Mobile Homes Old-Fluorescent in Kitchen (with labor)"] for explanation of the eligible fraction, which is 0.1 for this measure.

CONSERVATION MEASURE MO71000E0003

NAME

Lighting Mobile Homes Old- Outside Fluorescent (with labor)

This measure is the same as the "Outside Fluorescent (with labor)" measure for single family residences, except for the eligible fraction.

ELIGIBLE FRACTION

We have used an eligible fraction of 0.5 for both the outdoor fluorescent measures, and divided it evenly between the "with renovation" and "with labor" measures. The eligible fraction is therefore 0.25.

CONSERVATION MEASURE MO71000E0004

NAME

Lighting Mobile Homes Old- Outside Fluorescent (with renovation)

This measure is the same as the "Outside Fluorescent (with labor)" measure for single family residences, except for the eligible fraction. See the measure above (outside fluorescent with labor) for explanation of the eligible fraction, 0.25.

CONSERVATION MEASURE MO71000E0005

NAME

Lighting Mobile Homes Old- Replace High Use Bulbs With SL Lamps

MEASURE DESCRIPTION

See description under "Lighting-Single Family." For mobile homes, we estimate there would be one "high use" bulb to replace:

COST

The cost for replacing one bulb is estimated to be \$21. See explanation under "Lighting-Multi Family."

AVERAGE SAVINGS

The savings from one bulb replacement are 57 kWh/year. See explanation under "Lighting-Multi Family."

LIFETIME

The lifetime for this measure is 7.5 years. See explanation under "Lighting-Single Family."

START YEAR

The start year for this measure is 1980. See explanation under "Lighting-Single Family."

ROLL-IN TIME

The roll-in time for this measure is 5 years. See explanation under "Lighting-Single Family."

ELIGIBLE FRACTION

The eligible fraction for this measure is 0.9 See explanation under "Lighting-Single Family."

INTERACTIVE EFFECTS

See explanation under "Lighting-Single Family."

CONSERVATION MEASURE MO71000E0006

NAME

Lighting Mobile Homes Old- Replace Medium Use Bulbs With SL lamps

MEASURE DESCRIPTION

See description under "Lighting-Single Family." We estimate that there would be 2 bulbs eligible for replacement in mobile homes.

COST

The cost for replacing two bulbs is estimated to be \$42. See explanation under "Lighting-Single Family," for four bulbs; this cost is one-half.

AVERAGE SAVINGS

The savings from replacement of two bulbs are 85 kwh/year. See explanation under "Lighting-Single Family," for four bulbs; these savings are one-half.

LIFETIME

The lifetime used for this lighting measure is 10 years. See explanation above under "Lighting-Single Family."

START YEAR

The start year for this measure is 1980 since these bulbs are currently available on the market.

ROLL-IN TIME

We assume that these bulbs are rolled into the eligible fraction of the existing stock in 5 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.9 because very few, if any, residences used all fluorescent lighting in 1980.

INTERACTIVE EFFECTS

See explanation under "Lighting-Single Family."

LIGHTING-MOBILE HOME, NEW

CONSERVATION MEASURE MN71000E0001

NAME

Lighting, Mobile Home, New- Fluorescent in Kitchen

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Fluorescent in Kitchen (with renovation). All inputs are the same except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the fluorescent in kitchen measure is 0.25. This is equal to the sum of the "with renovation" and "with labor" measures in "Mobile Home Old," plus an extra 0.05. (See explanation under "Lighting, Single Family New").

CONSERVATION MEASURE MN71000E0002

NAME

Lighting, Mobile Home, New- Outside Fluorescent

MEASURE DESCRIPTION

This measure is the same as the measure "Lighting, Single Family, Old-Outside Fluorescent (with renovation). All inputs are the same except for the eligible fraction.

ELIGIBLE FRACTION

The eligible fraction for the outside fluorescent measure is 0.5. This is equal to the sum of the "with renovation" and "with labor" measures in "Mobile Home, Old."

CONSERVATION MEASURE MN71000E0003

NAME

Lighting, Mobile Home New- SL Lamp For High Use Bulbs

See documentation for this measure in "Lighting-Mobile Home, Old" since the measure is the same.

CONSERVATION MEASURE MN71000E0004

NAME

Lighting, Mobile Home, New- SL Lamp For Medium Use Bulbs

See documentation for this measure in "Lighting-Mobile Home,Old"
since the measure is the same.

CONSERVATION MEASURE ME80001E0001

NAME

Televisions, Color- Solid State Improvement

MEASURE DESCRIPTION

Solid state televisions consume significantly less energy than their predecessors. This measure is to purchase a solid state model at the time of purchase or replacement of a color television.

COST

Since solid state models are basically all that are available in the marketplace, this is judged to be a no-cost measure.

AVERAGE SAVINGS

The savings for this measure are estimated to be 400 kWh/year.

This is based on the fact that there are numerous color televisions (19 inch) on the market with rated average power consumption of under 100 watts(see 1981 Sears Catalog). Assuming 1700 to 2000 hours per year of usage, this leads to a unit energy consumption of 170 - 200 kWh/year. Using the higher UEC to allow for some purchases of large, higher wattage units gives a savings from the baseline of $600 - 200 = 400$ kWh/year savings.

LIFETIME

The lifetime for this measure is the estimated television lifetime of 10 years.

START YEAR

The start year for this measure is 1980

ROLL-IN TIME

This measure is expected to roll-in as the appliances are replaced, so assuming linear decay, the roll-in time is the same as the television lifetime, 10 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME80001E0002

NAME

Televisions, Color- 1985 Improvements

MEASURE DESCRIPTION

Solid state televisions are continuing to decrease in energy consumption. This measure is to reflect the probability that by 1985, the power consumption will be lower than in 1980.

COST

We have assigned a cost of \$10 for this measure. This may also be a no-cost measure but to be conservative we have assigned a cost to it.

AVERAGE SAVINGS

The savings for this measure are 50 kWh/year.

This is based on the fact that there are currently 19 inch color televisions on the market which use 83 watts (Sears Catalog, 1981), and power consumption is expected to continue to decrease (DOE). Thus, an average UEC of 150 kWh/year for color televisions purchased in 1985 and afterwards does not seem unreasonable, even assuming usage continues to be up to 2000 hours/year.

LIFETIME

10 years.

START YEAR

The start year for this measure is assumed to be 1980.

ROLL-IN TIME

The roll-in time for this measure is the same as the appliance lifetime, 10 years. (See measure above for explanation.)

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 1.0.

CONSERVATION MEASURE ME80002E0001

NAME

Televisions, Black and White- Solid State Improvement

MEASURE DESCRIPTION

Solid state televisions consume significantly less energy than their predecessors. This measure is to purchase a solid state model at the time of purchase or replacement of a black & white television.

COST

Since solid state models are basically all that are available in the marketplace, this is judged to be a no-cost measure.

AVERAGE SAVINGS

The savings for this measure are estimated to be 150 kWh/year.

This is based on the fact that there are currently black and white televisions on the market with average rated power consumption of 28 watts (Sears Catalog, 1981, 12 inch). At usage levels of 1700-2000 hours of yearly usage this leads to a UEC of 47 -56 kWh/year. We have chosen 50 kWh/year, under the assumption that though there may be some purchases of larger, higher consuming models, many purchases of black and white televisions are for portable, second televisions which may have less hours of usage during the year.

The baseline for black and white televisions is 200 kWh/year, thus the savings is $200 - 50 = 150$ kWh/year.

LIFETIME

The lifetime for this measure is the estimated television lifetime of 10 years.

START YEAR

The start year for this measure is 1980

ROLL-IN TIME

The roll-in time for this measure is the same as the appliance lifetime, 10 years. (See "Roll-In Time" under "Televisions, Color-Solid State Improvement" for explanation.)

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME80002E0002

NAME

Televisions, Black and White- 1985 Improvements

MEASURE DESCRIPTION

Solid state televisions are continuing to decrease in energy consumption. This measure is to reflect the probability that by 1985, the power consumption will be lower than in 1980.

COST

We have assigned a preliminary cost of \$10 for this measure. This may also be a no-cost measure but to be conservative we have assigned a cost to it.

AVERAGE SAVINGS

The estimated savings for this measure are 25 kWh/year.

This is based on both the anticipated decline in solid state television power consumption, and the expectation that hours of usage of black and white televisions will decline.

LIFETIME

The lifetime for this measure is the estimated television lifetime of 10 years

START YEAR

The start year for this measure is assumed to be 1980.

ROLL-IN TIME

The roll-in time for this measure is the same as the appliance lifetime, 10 years. (See "Roll-In Time" under "Televisions, Color-Solid State Improvement" for explanation.)

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 1.0.

CONSERVATION MEASURE ME80003E0001

NAME

Clothes Dryers- CPES Improvements

MEASURE DESCRIPTION

The March, 1982 Consumer Products Efficiency Standards Engineering Analysis Document, prepared by Arthur D. Little for the Department of Energy (ADL, March, 1982), shows design improvements available on units currently on the marketplace, and gives cost- efficiency data for these.

The design improvements for electric dryers are

- Moisture Sensor
- Insulation

COST

The cost for this measure is \$35., based on the cost/efficiency relationship given in the ADL/CPES analysis (ADL, March, 1982).

AVERAGE SAVINGS

The savings for this measure are 50 kWh/year, based on the ADL/CPES analysis (ADL, March, 1982)

LIFETIME

The lifetime used is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 18 years. (rounded from 18.5 years.)

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

This measure is expected to roll-in as the appliances are replaced, so assuming linear decay, the roll-in time is the same as the dryer lifetime, 18 years.

ELIGIBLE FRACTION

The eligible fraction is 1.0.

CONSERVATION MEASURE ME80003E0002

NAME

Clothes Dryers- Heat Pump Dryer

MEASURE DESCRIPTION

The heating element in a dryer is replaced by a heat pump which extracts moisture from the air stream by condensation, much as in a dehumidifier, and recirculates the hot air to the dryer. The 5 kw heater in an electric dryer would be replaced by the equivalent of a 13,000 btu/hour input air conditioner drawing 1.5 kw. The dryer could also be used to replace a basement dehumidifier, but savings from this possibility are not considered here.

It should be noted that this measure has not been commercially tested, and some technical problems may occur. These include:

- Improved lint filtration will be needed to keep the heat exchanger from clogging.
- Either a higher temperature refrigeration cycle or a greater air flow rate through the dryer will be needed.
- The condensed water must be drained.

COST

The cost for this measure is estimated to be \$500.

AVERAGE SAVINGS

The savings for this measure are estimated to be 660 kWh/year.

Assuming baseline usage is 1000 kWh, the usage would become $1000 \times (1.5 + 0.3) / (5 + 0.3) = 339$.

LIFETIME

The lifetime used is the appliance lifetime given by the latest DOE/ADL-CPES report (March, 1982), which is 18 years. (rounded from 18.5 years.)

START YEAR

The start year for this measure is estimated to be 1987.

ROLL-IN TIME

The roll-in time for this measure is the same as the appliance lifetime, 18 years. (See above measure for explanation.)

ELIGIBLE FRACTION

The eligible fraction is estimated to be 0.3.

CONSERVATION MEASURE ME80004E0001

NAME

Clothes Washer- Improved Efficiency

MEASURE DESCRIPTION

This measure is for improvements in the efficiency of the clothes washer, other than through the reduction of hot water consumption which is considered under water heating measures. The values used for this measure remain the preliminary ones based on past studies. This is an area where continued research is necessary to the appliance, the costs and savings.

COST

The cost for this measure is estimated to be \$50, based on a BPA technical appendix (BPA, April, 1981) and the Hittman work (Hittman, July, 1981).

AVERAGE SAVINGS

The savings for this measure are estimated to be 30 kWh/year based on the BPA and Hittman works cited under "costs" above, and rounded down to reflect the uncertainty we feel about this measure data.

LIFETIME

The lifetime for this measure is 10 years

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

This measure is expected to roll-in as the appliances are replaced, so assuming linear decay, the roll-in time is the same as the clotheswasher lifetime, 10 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0.

CONSERVATION MEASURE ME80005E0001 NAME

Dishwashers- Improved Motor Efficiency

MEASURE DESCRIPTION

This measure is to increase the efficiency of the dishwasher motor.

COST

The estimated cost for this measure is \$50. (LBL/SERI, 1981-LBL input files to the SERI report).

AVERAGE SAVINGS

The savings from this measure are estimated to be 50 kWh/year. (LBL/SERI, 1981; Hittman, February, 1982).

LIFETIME

The lifetime for used for this measure is 10 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

This measure is expected to roll-in as the appliances are replaced, so assuming linear decay, the roll-in time is the same as the dishwasher lifetime, 10 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is 1.0, since all dishwashers are eligible for replacement with the motor efficiency improvements.

CONSERVATION MEASURE ME90001E0001

NAME

Well Pumps- Improved Motor Efficiency

MEASURE DESCRIPTION

This measure increases the motor efficiency of the well pump. We found no literature on this measure; however, we are certain that standard motor improvements can be applied here. We included this measure to emphasize the importance of well pump electricity use. This is an area which has potential for conservation but needs additional research.

COST

The cost of this measure is estimated to be \$100.

AVERAGE SAVINGS

The savings for this measure are estimated to be 100 kWh/year.

LIFETIME

The lifetime of the well pump is estimated to be 15 years.

START YEAR

The start year for this measure is 1980.

ROLL-IN TIME

Since the lifetime for this measure is estimated to be 15 years, and this measure is assumed to roll-in as the pumps are replaced, the roll-in time for the measure is 15 years.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.8.

CONSERVATION MEASURE ME90003E0002

NAME

Waterbed- Use Comforter Cover

MEASURE DESCRIPTION

If a waterbed is left uncovered, there is significant upward heat loss. This measure is to have a comforter cover on top of the bed during all periods when the bed is not in use. Of course there is variability in the thickness of covers. We are basing the savings of this measure on studies of the consumption of waterbeds under different conditions, including "covered." We are interpreting "covered" to be the use of a comforter cover, although thick blankets would probably result in similar savings.

COST

We are using \$20 as the cost for this measure. This is based on the approximate increase in cost to purchase a comforter rather than a standard blanket.

AVERAGE SAVINGS.

We are estimating the savings from this measure to be 400 kWh/year, or one-third of the initial consumption.

This is based on data from California studies on waterbed energy consumption. (Weiss, 1982; Southern California Edison, unpublished).

LIFETIME

The lifetime of the waterbed and comforter is estimated to be 10 years.

START YEAR

The start year for this measure is 1980, since comforters could be purchased immediately.

ROLL-IN TIME

The roll-in time for this measure is 10 years, the same as the waterbed lifetime. This measure could be retrofitted to existing waterbeds, but we did not accelerate the roll-in time to account for this. Since the cost of the measure is not for the entire comforter, but only the additional cost of purchasing a thick comforter or blanket rather than a standard blanket, we decided the measure would only roll-in at the waterbed purchase time.

ELIGIBLE FRACTION

Since many waterbed owners undoubtedly already have comforter covers, we have estimated the eligible fraction of this measure to be 0.3.

INTERACTIVE EFFECTS

This measure will interact with space heating since the heat loss to the room will be decreased through use of a comforter. We have not included this effect in the analysis at this point but it may be included later if it is judged to be significant.

CONSERVATION MEASURE ME90003E0001

NAME

Waterbed- Insulate Sides/Bottom

MEASURE DESCRIPTION

This measure consists of insulating the sides and bottom of the waterbed with foam. The insulation reduces conduction losses.

COST

The estimated cost of this measure is \$20.

AVERAGE SAVINGS

The estimated savings for this measure are 200 kWh/year. We are not aware of any measurements, so we have estimated the energy consumption decrease.

LIFETIME

The estimated lifetime for this measure is 10 years.

START YEAR

The start year for this measure is 1980, since we assume that insulation could be placed around the sides and bottoms of a heater at any time the bed is not filled.

ROLL-IN TIME

There could be a very short roll-in time for this measure since it could be either retrofitted or included when a bed is purchased or replaced. However, we decided that waterbeds are typically emptied infrequently, and thus it would be difficult to retrofit the insulation. We decided to stay with a 10 year roll-in time, based on the estimated lifetime.

ELIGIBLE FRACTION

The eligible fraction for this measure is assumed to be 0.8, since some waterbed frames may not allow room for insulation.

APPENDIX A
Documentation of CPS 2.0

APPENDIX A: DOCUMENTATION FOR CPS 2.0

1 Introduction

The CPS 2.0 computer model is an updated and revised version of a model developed under the auspices of the California Policy Seminar by the Lawrence Berkeley Laboratory and used to evaluate potential supplies of conserved energy.¹ We describe in this appendix the general logic of CPS 2.0, the data input requirements, the types of output available, and the error messages generated. Appendix B, "Work4 Documentation", details the heat loss subroutine portion of the model. Appendix C is a brief guide to the interpretation of the tabular outputs of the model. Appendix D contains a complete copy of the CPS 2.0 program and a list of the variable names and functions. Note that this program listing is that available on the LBL CDC computer system. Modifications have been made to this version in order to operate on the BPA system.

These appendices are not intended to be a complete description of the structure and function of the model. Rather, they are designed as a guide for the user who already has some familiarity with FORTRAN programs and conservation end-use modeling. Those desiring a more complete understanding of the logic of the model should refer to the program listing in Appendix D. The listing includes detailed commentary.

CPS 2.0 is essentially an accounting and simplified loads program that is used to organize and display detailed data on energy residential-sector end-uses and conservation potential. The model is not a forecasting program. Rather it is a tool that can be used to determine the "maximum technically achievable conservation potential", not the likely penetration of conservation measures. It is designed to be used in conjunction with a forecasting model, not in place of one. Part 2 of the main report describes in more detail the philosophy of conservation supply curves, the approach we used in this analysis, and the relationship between CPS 2.0 and the BPA ORNL residential forecasting model.

¹ Wright, Janice, et al., Supplying Energy Through Greater Efficiency, The Potential for Conservation in California's Residential Sector, LBL-10738, EEB 80-2, January 1981.

Here we describe the structure and function of the model.

2 General Logic of CPS 2.0

The CPS 2.0 model is composed of a main program and 20 subroutines. The basic structure of the model is illustrated in Figure 1. Each of the subroutines is described briefly below.

CPS 2.0 is designed to evaluate the potential impacts of various energy conservation measures on a disaggregated set of energy end-uses. The user can specify a variety of general conditions, such as discount rates or fuel prices, and the model will determine an economically optimal ordering of conservation measures and calculate the energy savings that would result from each measure if applied in that order.² Once this ordering has been established the model will produce, if requested, a series of conservation measure and end use tables and supply curves. CPS 2.0 can also produce technology cost curves (TCCs). Examples of these outputs are given in Figures 2, 3, and 4. The policymaker can then use the outputs to evaluate various conservation implementation strategies.

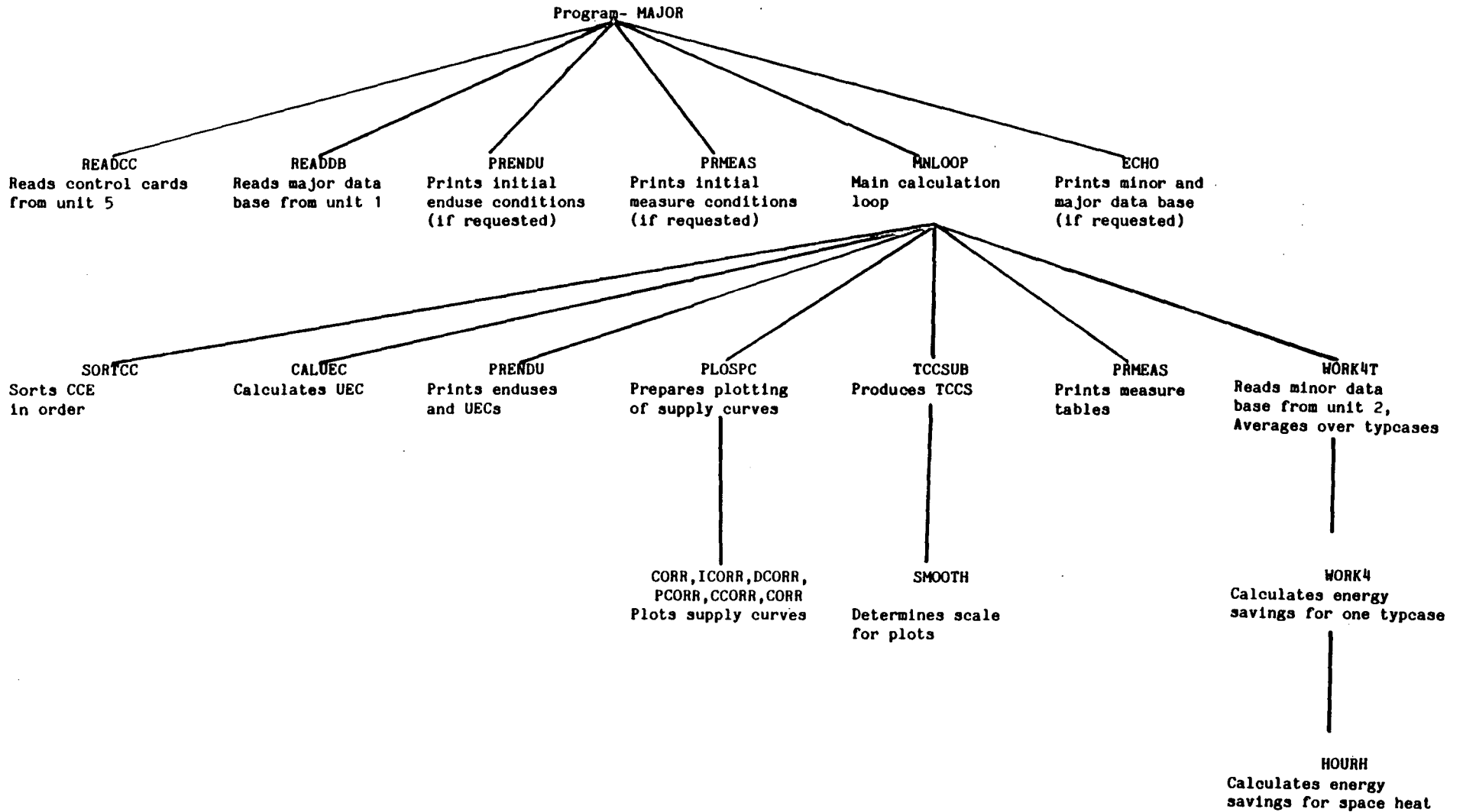
2.1 Types of Inputs Used by CPS 2.0

The model recognizes three enduse "stocktypes": existing (E), old (O), and new (N). The "existing" stock is based on the assumption that the units in the 1980 ("program start year") stock are identical. There is no vintaging of units for this stocktype. "Existing" should be used when the UECs of existing stock and baseline stock are similar. In this case, the entire end use is described as a single stocktype.

² See Part 2 of the main report for a discussion of the ordering strategy. For more information on the terminology used in this section see the "Input Format" section, below.

Figure A-1

SIMPLIFIED STRUCTURE OF CPS 2.0



A-3

Figure A-2. Enduse and Conservation Measure Tables (Example)

1979 ENDUSE TABLE

(A) END USE DESCRIPTION	(B) ID CODE	(C) TOTAL STOCK (1000S)	(D) ADD RATE	(E) DECAY OR REPLACE RATE	(F) BASELINE UEC (KWH/YR)	(G) POTENTIAL UEC (KWH/YR)	(H) WORK4 USED	(I) LAST UPDATE
SPACE HEATING-SPD,OLD (EXAMPLE)	E012100E00	214.	0.	.045	20143.	-INDEP	1	9-82
SUBTOTAL		214.			20143.	0.		
TOTAL		214.			4310.6	0.		

1979 CONSERVATION MEASURE INPUT TABLE

(A) MEASURE DESCRIPTION	(B) ID CODE	(C) MEAS COST (80\$)	(D) PROGH COST (80\$)	(E) MEAS SAV (KWH/YR)	(F) LIFE (YRS)	(G) STAR YEAR	(H) END YEAR	(I) ROLL IN (YRS)	(J) PROG PEN (YRS)	(K) ELIG PRAC	(L) PROG PRAC	(M) LAST UPDAT	(N) SEASON VALUE
SPACE HEAT-SPD,OLD ADD R-19 TO ATTIC	Z1 H012100E00	1	-0.	-0.	-0.	-0	1980	0.	4.000	-0.	-0.	9-82	
SPACE HEAT-SPD,OLD ADD R-11 TO WALLS	Z1 H012100E00	2	-0.	-0.	-0.	-0	1980	0.	4.000	-0.	-0.	9-82	
SPACE HEAT-SPD,OLD REDUCE INFL .2 ACH	Z1 H012100E00	3	-0.	-0.	-0.	-0	1980	0.	4.000	-0.	-0.	9-82	
SPACE HEAT-SPD,OLD ADD SETBACK THERM.	Z1 H012100E00	4	-0.	-0.	-0.	-0	1980	0.	4.000	-0.	-0.	9-82	
SPACE HEAT-SPD,OLD HEAT PUMP	Z1 H012100E00	5	-0.	-0.	-0.	-0	1980	0.	3.000	-0.	-0.	9-82	

1985 ENDUSE TABLE

(A) END USE DESCRIPTION	(B) ID CODE	(C) TOTAL STOCK (1000S)	(D) ADD RATE	(E) DECAY OR REPLACE RATE	(F) BASELINE UEC (KWH/YR)	(G) POTENTIAL UEC (KWH/YR)	(H) WORK4 USED	(I) LAST UPDATE
SPACE HEATING-SPD,OLD (EXAMPLE)	E012100E00	156.	0.	.045	20143.	11624.	1	9-82
SUBTOTAL		156.			20143.	11624.		
TOTAL		156.			3146.7	1815.9		

1985 CONSERVATION MEASURE OUTPUT TABLE

(A) MEASURE DESCRIPTION	(B) ID CODE	(C) TOT COST	(D) SAVINGS (KWH)	(E) LIFE (YRS)	(F) ELIG PRAC	(G) CCE (\$/KWH)	(H) TOTAL SAV (QWH)	(I) CUH. TOTAL SAVINGS (TWH) (AVG HW)
1 SPACE HEAT-SPD,OLD ADD SETBACK THERM.	Z1 H012100E00	4	130.	3898.	10	.300	182.7	.2 20.9
2 SPACE HEAT-SPD,OLD ADD R-19 TO ATTIC	Z1 H012100E00	1	560.	2843.	20	.900	399.7	.6 66.5
3 SPACE HEAT-SPD,OLD HEAT PUMP	Z1 H012100E00	5	1650.	6973.	10	.500	544.6	1.1 128.7
4 SPACE HEAT-SPD,OLD REDUCE INFL .2 ACH	Z1 H012100E00	3	430.	1069.	8	.600	100.2	1.2 140.1
5 SPACE HEAT-SPD,OLD ADD R-11 TO WALLS	Z1 H012100E00	2	1900.	1659.	20	.400	103.7	1.3 151.9

Figure A-3. Supply Curve of Conserved Energy (Example)

SUPPLY CURVE FOR 1985

X-AXIS IS CUMULATIVE ENERGY IN TMI/YEAR

Y-AXIS IS COST OF CONSERVED ENERGY IN \$/KMI

PLOT ENTRIES		105 OUTSIDE		100			
X	MIN Y	MIN		X	MAX Y	MAX	
	0.	0.			.2000E+01	.1000E+00	

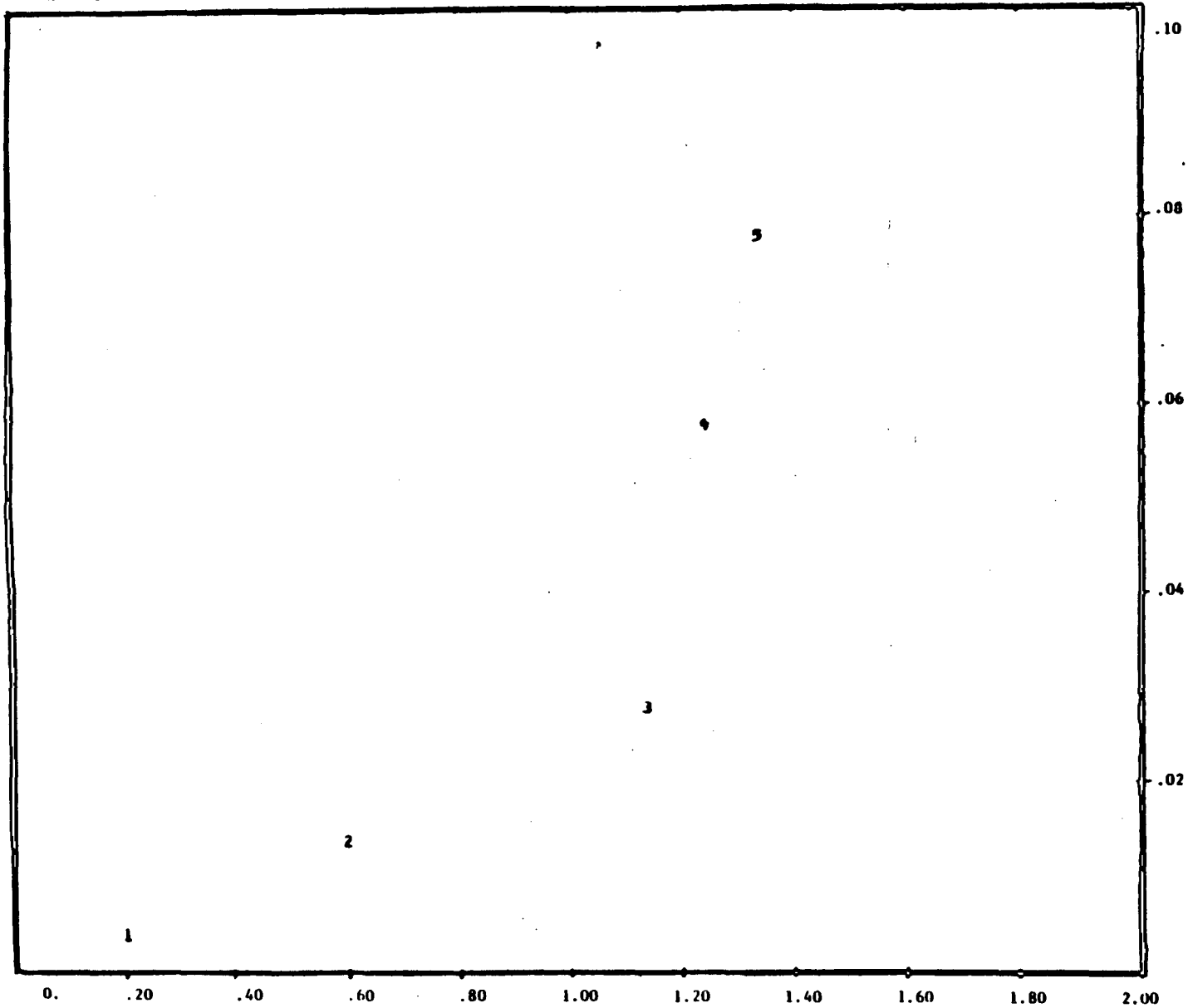


Figure A-4. Technology Cost Tables and Curves (Example)

TECHNOLOGY COST TABLE FOR ENDUSE ED12100000 SORTED BY ROI ORIGINAL UEC 20143. KWH

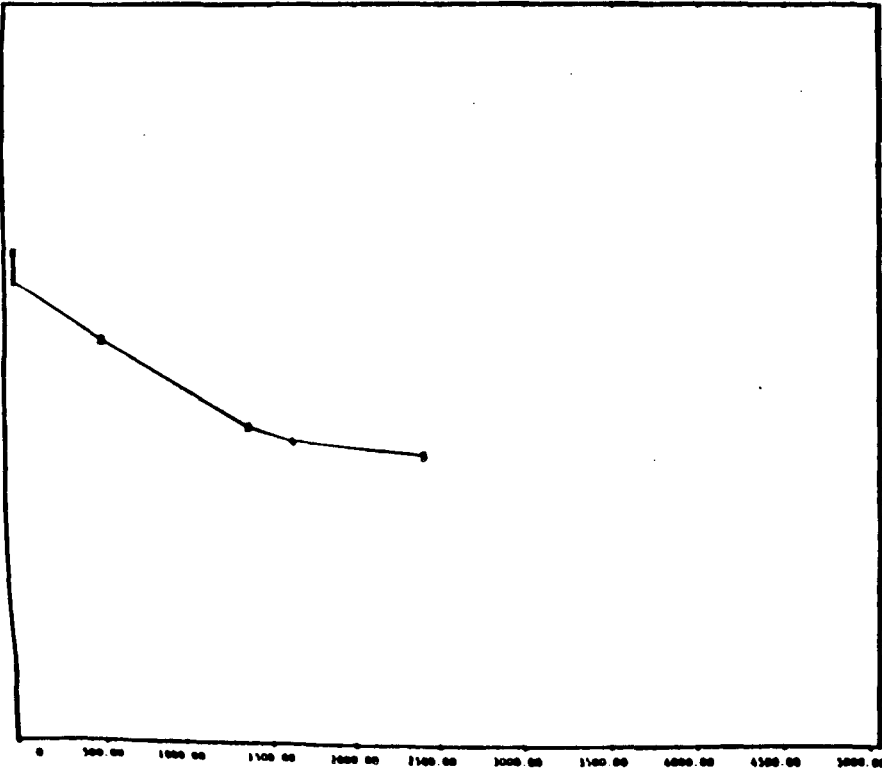
(A) MEASURE	(B) CUMULATIVE INVESTMENT (1980\$)	(C) ENERGY USED (KWH/YR)	(D) ROI OR CCE	(E) ENERGY USED/ORIGINAL UEC
1 SPACE HEAT-SFD.OLD ADD SETBACK THERM. Z1	39.00	18973.82	29.99	.942
2 SPACE HEAT-SFD.OLD ADD R-19 TO ATTIC Z1	543.00	16415.10	6.00	.016
3 SPACE HEAT-SFD.OLD HEAT PUMP Z1	1360.00	12920.01	4.23	.642
4 SPACE HEAT-SFD.OLD REDUCE INFL .2 ACH Z1	1626.00	12207.34	2.49	.610
5 SPACE HEAT-SFD.OLD ADD R-11 TO WALLS Z1	2306.00	11623.74	.07	.877

TECHNOLOGY COST TABLE FOR ENDUSE ED12100000 SORTED BY CCE ORIGINAL UEC 20143. KWH

(A) MEASURE	(B) CUMULATIVE INVESTMENT (1980\$)	(C) ENERGY USED (KWH/YR)	(D) ROI OR CCE	(E) ENERGY USED/ORIGINAL UEC
1 SPACE HEAT-SFD.OLD ADD SETBACK THERM. Z1	39.00	18973.82	.00	.942
2 SPACE HEAT-SFD.OLD ADD R-19 TO ATTIC Z1	543.00	16415.10	.01	.016
3 SPACE HEAT-SFD.OLD HEAT PUMP Z1	1360.00	12920.01	.03	.642
4 SPACE HEAT-SFD.OLD REDUCE INFL .2 ACH Z1	1626.00	12207.34	.06	.610
5 SPACE HEAT-SFD.OLD ADD R-11 TO WALLS Z1	2306.00	11623.74	.00	.877

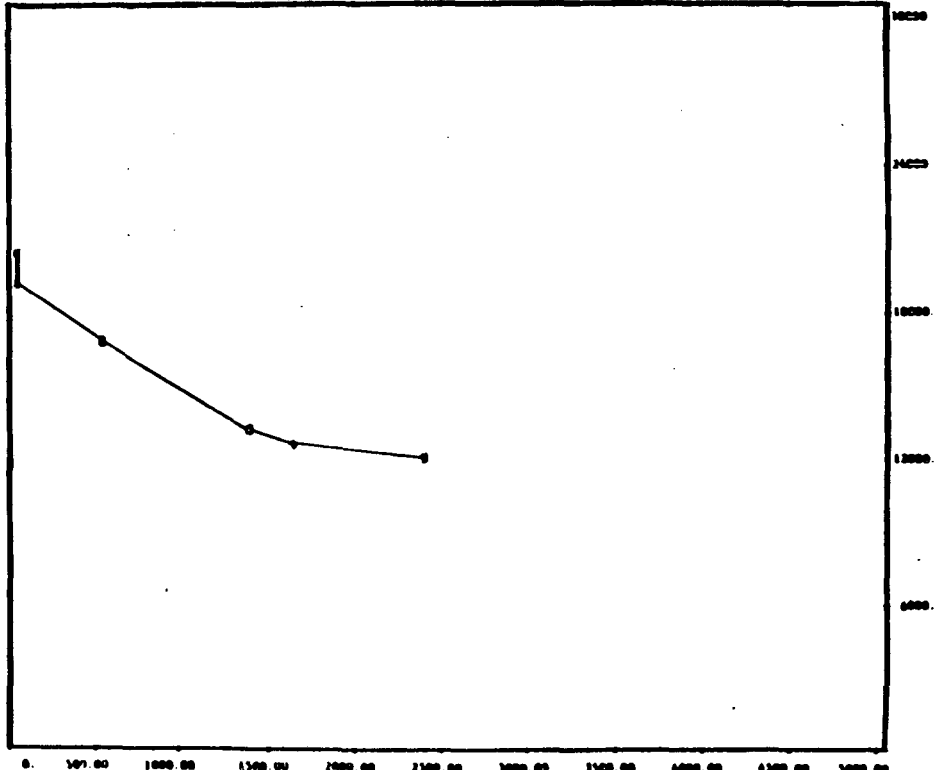
TECHNOLOGY COST CURVE FOR ENDUSE ED12100000 SORTED BY CCE
X AXIS IS CUMULATIVE INVESTMENT IN DOLLAR
Y AXIS IS UEC IN KWH/YEAR

PLOT ENTRIES 6 OUTSIDE 0
XMIN YMIN 0. 0. XMAX YMAX .8000E+04 .3000E+06



TECHNOLOGY COST CURVE FOR ENDUSE ED12100000 SORTED BY ROI
X AXIS IS CUMULATIVE INVESTMENT IN DOLLAR
Y AXIS IS UEC IN KWH/YEAR

PLOT ENTRIES 6 OUTSIDE 0
XMIN YMIN 0. 0. XMAX YMAX .8000E+04 .3000E+06



In general, the division between "new" and "old" stock should be made when there is a significant difference in the UECs of the stock already in place in the base year and new, post-1980 stock, or when the cost of a conservation measure differs for the two stocktypes. For example, in the case of space heating, retrofit insulation may be more expensive than installation of insulation in a new home. In the current data base for BPA, however, we divided the stock into "new" and "old" rather than "existing" only for the latter case, i.e. when the costs of conservation measures differ. This is the case for the space heating and lighting end uses. The "existing" stocktype has been used for appliances such as refrigerators and televisions, even though the UECs of new base-line units differ significantly from the UECs of the stock average. This is because we are evaluating savings as compared to an unvintaged "frozen efficiency" forecast, where the UECs of these appliances are frozen at the existing 1980 stock average. When the BPA version of the ORNL model incorporates vintaging features capable of distinguishing between the UECs of new and existing stock, these end uses should be divided into the "new" and "old" stock categories.

The "existing" stocktype refers to all the units in a given year of the analysis. When there is an old/new stock division, "old" stock represents all units remaining in a given year which are part of the stock that was present in the region in the base year, and the "new" stock represents all new units added after the base year (that is, post-1980). The model uses addition and decay (or replacement) rates to reflect the differences between the "existing" stocktype and the old/new stocktypes.³ Existing stock (E) can either remain constant or grow. Old stock (O) can only decay. New stock (N) can grow both by replacement of old stock and by net additions to the total stock. The MNLOOP subroutine description gives details on how the model treats the stocktypes.

³ Note that the old and new stocktypes are treated as independently entries by CPS 2.0. There is no programmed link between the two stocktypes, even when they refer to the same end use. Consequently, changes to the input values of one stocktype will have no effect on the other stocktype. It is important to check that the old and new stocktype data has been entered correctly, otherwise incorrect outputs will be produced.

Each of the stocktypes has a group of conservation measures associated with it. The measures are implemented (or "rolled in") in an end use at a rate which depends upon the start year, the roll-in time, and the eligible fraction specified with the measure. For example, consider a conservation measure having a start year of 1980, a roll-in time of 5 years and an eligible fraction of 0.85. By 1985, 85% of the total stock of the end use will have installed the conservation measure. CPS 2.0 will then continue to add the measure to 85% of the post 1985 additions (E and N stocktypes) to the stock. If, however, an end year is included with the measure specifications, it will start to roll out of the stock (beginning in the end year) and will be replaced by a new measure. In all case, the model will determine the total energy savings in one year, for all of the installations of a given measure, that are in place that year. This will be referred to as the total energy savings. If the user has included a "cut-off" energy price and requested UECs, the model will generate "potential" UECs for each end use (see below for further explanation of "potential" UEC)

2.2 Subroutines

The CPS 2.0 model is made up of functionally specific subroutines. Below is an sequential listing and description of each of the subroutines.

Program MAJOR

The MAJOR program controls the program operation. It calls the subroutines which read the control cards, the major and the minor data bases. It also calls the main calculation subroutine MNLOOP.

Subroutine READCC

READCC is the first subroutine called by the model. It reads the control cards from unit 5 (which contains the control card file) and makes a number of consistency checks. These checks are used to determine if incorrect control cards have been entered or if default values must be provided for certain variables. The subroutine makes the following checks:

1. The number of snapshot years must be from 1 to 31.
If no snapshot year is specified a default value (the program start year) will be used.
2. The snapshot years must be in ascending order.
3. The number of enduses must be from 1 to 99.
4. A program start year must be specified. If one is not entered a default value (1980) will be used.
5. A discount rate must be specified. If one is not specified a default value (0.03) will be used. If the rate has been entered as zero (0), it will be set to a very small value ($1e-10$).
6. The fuel type of the enduses must be E (electric), G (natural gas) or O (fuel oil).
(Note: this BPA version is designed exclusively for electricity.)
7. The fuel types of all enduses must be the same.
8. If UECs are requested, a cut-off price for the fuel type used must be specified.
9. If technology cost curves (TCCs) are requested, one of the snapshot years must be the same as the program start year.

If an incorrect control card is encountered the program will quit and an appropriate error message will be printed. For explanations of these error messages see the "Error Messages Generated by CPS 2.0" section below. If no fatal errors are detected, a table of control cards settings and default values will be printed at the beginning of the CPS output.

Subroutine READDB

This subroutine performs a function similar to READCC except it reads the major data base inputs contained in unit 1 (the major data base file). READDB checks to see that the major data base has been properly entered or if more than 750 measure have been included. If there are any errors detected appropriate messages will be printed; if not, the major data base is stored in an array where it can be further processed by the program. The subroutine will also print a listing of the enduse codes and the number of measures associated with each code. The user should check the listing carefully to verify that each enduse has the desired number of measures.

Subroutine PRENDU

This subroutine prints an enduse table for each year requested by the control card, SNAPSHOT. Included in this are the end use descriptor, id code, stock, addition rate, decay or replacement rate, baseline uec and usage, potential uec and usage, work4 flag, and the Last update. stock, baseline uec and usage, and potential uec and usage subtotals are calculated for each group (first 5 id code characters the same). Total stock, baseline usage, and potential usage values are calculated and displayed for all end uses. See Figure 2 for a sample of the output.

Subroutine PRMEAS

This subroutine prints a conservation measure table for each year requested by the control card SNAPSHOT. There are two types of conservation tables available, the input table and the output table. The input table (requested by setting the variable "Length" to a positive number) contains the following information: measure description, id code, measure cost, program cost, average savings, lifetime, start year, end year, roll-in, program penetration, eligible fraction, program fraction, last update, and seasonal value. The output table (requested by setting

"Length" to a non-positive value) is the default form for all years beyond the initial year. This shorter form contains: the measure description, ID code, total cost, savings, lifetime, eligible fraction, cce, total savings, cumulative total savings in TWh, and cumulative total savings in average MW. If a cutoff price is specified the a cutoff line will also appear in the table.

Subroutine MNLOOP

Following these checking and formatting procedures the program calls the subroutine MNLOOP. This subroutine contains the major calculation algorithms of the program. Figure 5 illustrates the logic of MNLOOP. The outermost loop (label 80) increments by year, beginning with the program start year and ending with the last snapshot year. Within this loop, first the energy prices for the year are calculated, based on the initial energy price and escalation rates entered in the control card file. Following this the stocks are increased or decreased appropriately. Each of the three stocktypes (E, O, and N) have different algorithms for calculating stock changes. Table 1 summarizes these algorithms.

After all the end use stocks have been updated, the subroutine enters a loop over all enduses (label 35). Inside this loop WORK4 is called to calculate measure costs, savings, lifetime, and eligible fraction, if necessary for this enduse. In order to do this MNLOOP establishes two arrays for use by WORK4, the first, 'jorder' contains the measure id (taken from The second, 'korder', contains the location in the major data base arrays of the information for that measure. (The measure ids must appear in ascending order, within each enduse, in the major data base and in the minor data base.) The subroutine then performs a series of checks to see if WORK4 should be called this year. If WORK4 is used for this enduse it is called in the first year and whenever a new measure starts or a measure stops. If WORK4 is to be called this year MNLOOP calls WORK4T, the subroutine that controls the manipulation of the minor data base. After WORK4 runs, the cost and savings results are stored in the corresponding major database arrays.

Table A-1			
End Use Stock Change by Stock Type			
Stock Type	Add Rate	Decay or Rplcmt. Rate	Formula ¹
Existing (E)	Exp.	N.A.	endsto(j)=endsto(j) * (1+endadd(j)-enddec)
Old (O)	N.A.	Linear	endsto(j)=endsto(j)-enddec(j)*endref(j) if (endsto(j) le. 0) endsto(j)=0
New (N)	Exp.	Linear ²	alif=1./enddec(j) ilif=alif repln=(1-istay)*endref(j)*enddec(j) if (1-istay.lt.ilif)repln=repln+endref(j)*enddec(j) if (1-istay.eq.ilif)repln=repln+endref(j) *(1.-ilif*enddec(j)) if (1-istay.gt.ilif)repln=endref(j) if (1-istay.gt.ilif)repln=repln endsto(j)=(endsto(j)-repln+endref(j))*(1.+endadd(j)) -endref(j)+repln repln=repln

Exp.- rate is exponential

Linear- rate is linear

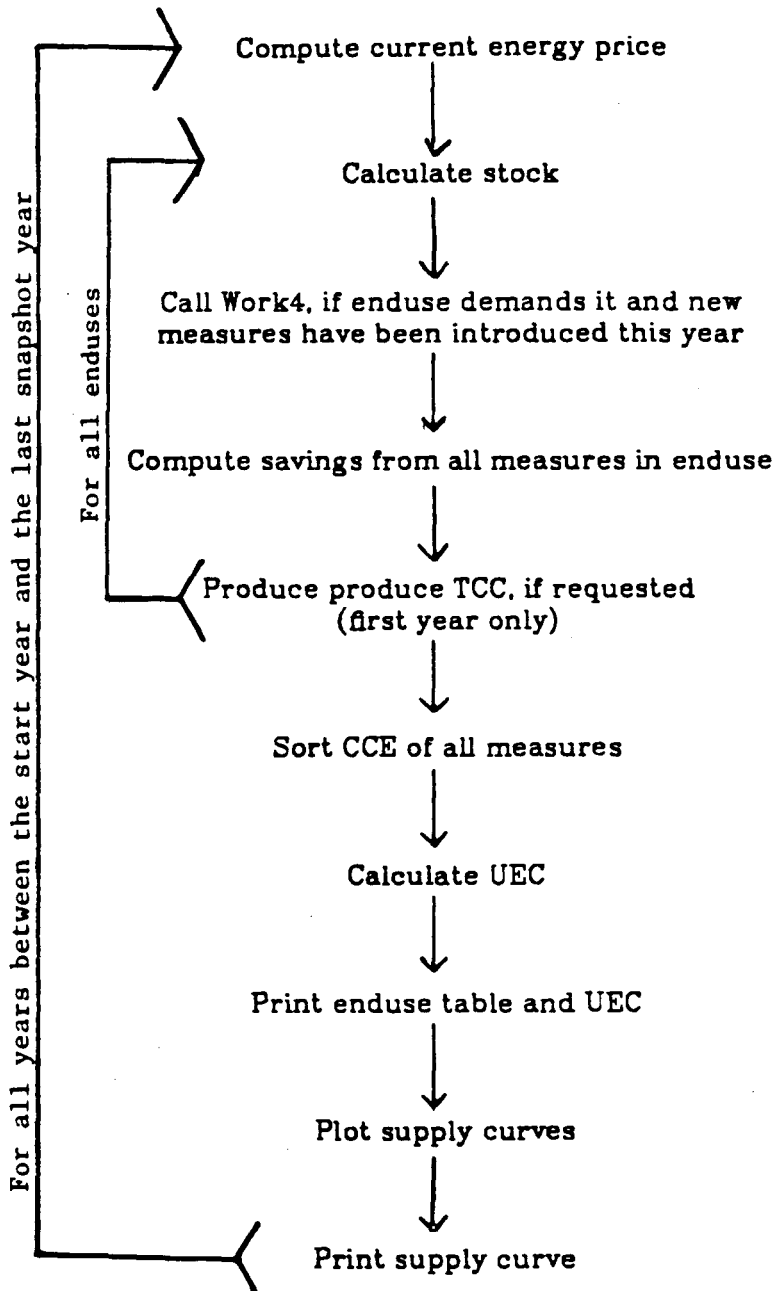
N.A.- not applicable

¹ See the "Variable Names and Functions" in Appendix D for a description of these variables.

² This entry must be the same as type 0 decay. For new stock it is used as a replacement rate.

Figure A-5

SIMPLIFIED MNLOOP FLOW CHART



MNLOOP then enters a loop over all measures in the enduse (label 15). In this loop MNLOOP calculates the savings this year for all measures for which the start year has been reached or passed. (This may include some measures which have rolled out completely and whose savings will be zero.) The savings for each measure are calculated according to the following formula:

$$\begin{array}{ccccccc} \text{Savings in} & = & \text{Stock in} & * & \text{Average} & * & \text{Eligible} & * & \text{FR} \\ \text{this year} & & \text{this year} & & \text{savings} & & \text{fraction} & & \end{array}$$

where "FR" is the part of the eligible fraction that has rolled in so far (up to 1.0 when rollin is complete) or the part of the eligible fraction that is left in place during rollout (0.0 when rollout is complete)

The cost of conserved energy (CCE) for each measures is also calculated within this loop, using the following formula:

$$CCE = \frac{I}{E} * \frac{d}{1 - (1 + d)^{-n}}$$

where:⁴

- I = cost of the measure
- E = annual energy savings
- n = amortization period (or lifetime)
- d = discount rate

After the measure loop a TCC is produced if requested, and control passes to the next enduse.

After the enduse loop is complete, control passes to the next year unless this year is a snapshot year. If this year is a snapshot year the CCEs of all measures are sorted in increasing order (not in the array CCE itself, but the index array, IORDER) and tables and curves are

⁴ Refer to the control card section, below, for information on how to specify these values for the program.

printed.

Subroutine SORTCC

This subroutine sorts the conservation measures contained in the array 'cce', in order of ascending cost of conserved energy. The results are then stored in an index array, 'iorder'.

Subroutine CALUEC

This subroutine calculates the total energy savings and the potential UECs. It first finds the total savings for all measures in an enduse with a CCE less than the cut-off price. The total savings are then divided by the current stock to derive the change in the UEC, by enduse. The current UEC ('ueccur') is then calculated as the difference between initial UEC ('enduec') and the change in UEC. Note that the initial UEC is a "frozen efficiency" value and is remains unchanged from the baseline (program start) year. The "frozen efficiency" baseline is discussed in Part 2 of the main report.

Subroutine ECHO

This subroutine prints the contents of the minor and major data bases and the control card file as they are entered. Printing of the minor data base is requested by control card EMI, the major data base by control card EMA, and the control card file by control card ECC. A line count and row letters are also included to aid in identifying improperly entered fields.

Subroutine PLOSPC

This subroutine prepares the plotting of supply curves. It initializes the plotting subroutine package (ICORR, etc.) with a fixed size of 50 by 100. It then calculates reasonable scales for these axes. After plotting all the points, it adds the price cut-off line.

Function SMOOTH

This function determines a round number for use as a scale factor for plots.

Subroutine TCCSUB

This subroutine produces technology cost curves and tables for the start year. Only measures which are active in the start year are incorporated into the tccs. Different TCCs are produced for each enduse specified on the tcc control card. Two sets of tables and curves are created for each enduse. The first set is sorted by return on investment (ROI), defined as savings divided by cost, the second by cost of conserved energy (CCE). The program prints stars in the ROI table for zero-cost measures. The technology cost curves show the last digit of the measure number as means of identification. The savings and costs reported in the TCC tables are the product of the measure savings and costs, and the eligible fraction, respectively. See Figure 4 for a sample of the output.

Subroutine WORK4T

This subroutine reads the minor data base for one enduse, calls WORK4 for each typical case within it, and averages the results for use by the MNLOOP.

Subroutine WORK4

This subroutine calculates average savings and costs for a group of "typical" cases representing an end use. WORK4 is described, in detail, in Appendix B.

Subroutine HOURH

HOURH calculates the energy consumption for space heating typcases using hourly weather data. Inputs to the subroutine are the UA of the building ($\text{kW}/^\circ\text{F}$), the inside temperature ($^\circ\text{F}$), the standby losses ($\text{kWh}/\text{heating season}$) and the climate number. Currently seven climates can be specified: 1) Portland,OR; 2) Spokane,WA; 3) Missoula,MT; 4) Boise,ID; 5) Seattle,WA; 6) Astoria,OR; and 7) Lewiston, ID.⁵ The number of hours a certain temperature (between -35°F and $+65^\circ\text{F}$ in steps of one $^\circ\text{F}$) occurs in a year is stored for each climate zone. The subroutine then adds up, for each different outside temperature, the amount of furnace output needed (equal to the heat flow through the shell of the house minus the free heat delivered by appliances etc.). This summation stops at the balance temperature (defined as the temperature where the heat flow equals the free heat). The average difference between inside and outside temperature is stored in the output variable 'fac1'. The fraction of free heat used ('fac2') is also passed to the calling program. See Appendix B for further explanation of the subroutine.

Subroutine package CORR, CCORR, CORRC, ICORR, DCORR, AND PCORR.

This package of subroutines is invoked by PLOSPC. It prints a plot with user-defined lengths of abscissa and ordinate. Scaling of the axes is done automatically, if not specified otherwise. Every point has a weight. Display of weights is possible in the range 1 to 35. Available

⁵ The weather data was adapted from, Department of Air Force Manual, Facility Design and Planning: Engineering Weather Data, AFM 88-29, July 1, 1978.

calls are

ICORR(ix,iy) initializes the package and prepares a correlation plot with dimension ix by iy. In the calling program there must be a common/acorr/ with ix*iy+100 words.

DCORR(xmin,ymin,xmax,ymax,40htext) is an optional call defining lower and upper limits and a title. DCORR must be called before any call to CORR.

CORR(x,y,gw) makes one entry; gw is the weight of that entry

PCORR print plot

CCORR/CORRC additional plotting subroutines. See the program code for further details.

3 Input Format

The model, as it currently exists, is written in FORTRAN and is designed to operate on the Lawrence Berkeley Laboratory's CDC 7600 computer. The program was designed for the LBL version of the MNF4 compiler, which has been modified to include the FTN4 I/O library routines. CPS 2.0 requires six input files for operation. These files, in order, are:

- Majorjob** This file contains the system jobcards necessary for the program to run on the LBL CDC 6000/7600 computer system.
- Majorpgm** This file contains the major program and all subroutines to that program except Work4t, Work4, and the Corr subroutines.
- Minorpgm** This file contains the subroutines Work4t, Work4, Corr, Ccorr, Corrc, Icorr, Dcorr, Pcorr.
- Majordat** This file contains all of the major data base entries.
- Minordat** This file contains all of the minor data base entries.
- Majorcc** This file contains all of the CPS 2.0 specific control cards

CPS 2.0 requires three types of input: control cards, major data base entries, and minor data base entries. These inputs are contained in the files majorcc, majordat, and minordat, respectively.

Each of the sections below illustrates the format of the input cards with an example.⁶ After each example the function of the card and the data entry order is explained. Not all the information must be entered to run the program.

⁶ We have used the term "card" throughout as a convenience. It refers to input data entered as if it were punched on a standard 80 column computer card.

3.1 Control Cards

The control cards determine what inputs CPS 2.0 will read and what outputs it will produce. There are three types of control cards: logical variables, fixed input, and variable input. All control cards start in column number one. The name of the control card may take up to 10 characters, but only the first three will be inspected. At least one enduse must be specified for CPS 2.0 to run. All other control cards are optional.

The control card settings are always displayed in the "Program Parameter" section at the beginning of each CPS 2.0 printout. (Default values for the unspecified control cards are also printed.)

3.1.1 Logical Variables Cards

The first type of control cards have no numerical values associated with them. If a specific control card is included in the deck the logical variable is set to "true". Omitting the control card sets the variable to "false". The following cards are in this true/false group.

LOGICAL VARIABLE CONTROL CARDS - EXAMPLE 1

.....1.....2.....3.....4.....5.....6.....7.....8
ADMINCOST
BPAPENET
CURVES
ECC
EMA
EMI
TABLES
UEC
WORK4

ADMINCOST Any Administrative Cost associated with a measure will

be added to Measure Cost. The CCE will then be calculated based on this revised cost. Administrative Cost and Measure cost inputs are described in the Conservation Measure Data Card section, below.

- BPAPENET Program Fraction and Program Penetration will be used in place of Roll-in Time and Eligible Fraction, respectively. Program Fraction, Program Penetration, Roll-in, and Eligible Fraction are discussed in the Conservation Measure Data Card Section, below.
- CURVES Supply curves of conserved energy will be generated.
- ECC All control cards inputs will be printed at the end of the output, after the "end" banner.
- EMA All major data base inputs will be printed at the end of the output, after the "end" banner.
- EMI All minor data base inputs will be printed at the end of the output, after the "end" banner.
- TABLES CPS 2.0 will generate conservation enduse and measure tables.
- UEC Potential UEC and potential usage values will be calculated for each end use. The values will be calculated for all measures up to the cut off energy price. An energy price card (ELEPRICE, GASPRICE, OILPRICE) must be included if UECs are requested.
- WORK4 Only the Work4 subroutine will be run. ADMIN COST, BPAPENET, CURVES, TABLES, TCC and UEC cards are ignored. The ECC, EMA, and EMI cards still function.

3.1.2 Fixed Input Cards

The second type of control card carries a fixed number of input items.

FIXED INPUT CONTROL CARDS - EXAMPLE 2

.....1.....2.....3.....4.....5.....6.....7.....8
DIAGNOSTIC 0
DISCOUNT 0.03
STARTYEAR 1980
ELECPRICE 0.04 0.05

DIAGNOSTIC This variable sets the output to be printed by
CPS 2.0. Level 0 will yield minimum output. Level 2 will
provide maximum output. See Table 2 for more details.
Input should be one integer (I10).

DISCOUNT This variable sets the discount rate, in percent.
If the DISCOUNT is set to zero (0) the program will use 1.e-10.
in order to avoid infinities. If the card is omitted a default
of 0.03 will be used.
The input should be one real number (F10.1).

STARTYEAR This variable sets the start year. The start year is the first year
that CPS 2.0 will begin to calculate savings potential.
If no start year is specified the default year, 1980, will be used.
The input should be one integer (I10).

Only one of the following three cards can be included in the control
card file. These entries will be used to calculate energy cut-off
prices.

ELECPRICE This variable sets electricity price and annual escalation rate.
Electricity price is in \$/kWh and escalation rate is
percentage per year.
The input should be two real numbers (F10.1).

GASPRICE This variable sets gas price and annual escalation rate.
The input should be two real numbers (F10.1).

OILPRICE This variable sets oil price and annual escalation rate.

The input should be two real numbers (F10.1).

3.1.3 Variable Input Cards

The third type of control cards carries a variable number of input items. The items must be stored sequentially on cards. The end of inputs for one command is recognized by an incompletely filled card. If the last card happens to be completely filled, a blank card is required to terminate the input.

VARIABLE INPUT CARDS - EXAMPLE 3

```
.....1.....2.....3.....4.....5.....6.....7.....8
ENDUSES
ee12100E00ee13400E00ee18800E00ee11100E00
NOTYPCASE
ee12100E00
TCC
ee13400E00ee11100E00
SNAPSHOT
  1980 1995 1998
```

ENDUSES This card lists the enduses to be used by CPS 2.0. There is a maximum of 99 enduses in any single CPS run. The enduses are entered 8 per card (8A10) with no blank spaces separating them. In order to obtain a correct calculation of enduse subtotals enter all E-type enduses first, followed by alternate groupings of O- and N-type enduses.

NOTYPCASE This card lists the enduses which have a Work4 flag, but should not use the the minor data base. There is a maximum of 99 excluded enduses in any single CPS run. The enduses are entered 8 per card (8A10) with

Table A-2
Output from Control Card Diagnostic Levels

Subroutine	Level 0	Level 1	Level 2
MAJOR	All	All	All
READCC	All	All	All
READDB	Nothing	End of Input Enduse Measures	All
PRENDU	All	All	All
PREMEAS	All	All	All
MNLOOP	Nothing	"Anno Domini"	"Handling Measure" "Measures Skipped" No Savings ¹
CALUEC	Nothing		Current Energy Price
WORK4T	Nothing	Id of Enduses and Typcases Initial UEC	All
WORK4	Nothing	Nothing	Table with Typcase, Energy Use Total, UAl, etc. Final Energy Use Initial Energy Use
TCCSUB	All	All	All

¹ These outputs will only appear at diagnostic level three

no blank spaces separating them.

TCC This card lists the enduses for which technology cost tables and curves are to be generated. The enduses are entered 8 per card (8A10) with no blank spaces separating them. In order for the program to generate TCCs the start year and one of the snapshot years must be the same.

SNAPSHOT This card indicates what years are to be considered snapshot years, i.e., years for which supply curves and tables are to be generated.

There is a maximum of 31 snapshot years in any single CPS run. The snapshot years are entered 16 items per card (16I5) with a space between each entry. Note that the first entry begins in column 2 not column 1, and that the years must be listed in ascending order. If no year is specified the default year, 1980, is used.

3.2 Major Data Base Inputs

The major data base contains two types of input: end use data cards and conservation data cards. The end use cards contain the basic data on the energy end-use sectors to which conservation measures are applied. They contain basic data on UECs, stock characteristics, growth and decay (replacement) rates, and an indicator to call the WORK4 subroutine. The conservation measure cards must be placed immediately after their respective end use. They include cost, savings, and lifetime data for the measure along with program parameters, and measure implementation information. All inputs that are marked with an asterisk "*" are required for all program runs.

3.2.1 End Use Data Cards

END USE CARD EXAMPLE

END USE CARD - EXAMPLE 4
.....1.....2.....3.....4.....5.....6.....7.....8
Refrigerators-Single Door Manual EE40001E00750. 460..010 01-83

columns

1-40 End Use Description (A40)*

The first 40 columns may contain any description of the end use desired. The description will be printed on all end use tables generated.

41-50 ID Code (A10)*

This code uniquely identifies an end use and includes specific alphanumeric descriptors of that end use's characteristics. Similar id codes are included with each conservation measure (see below). This ID is used on the ENDUSE control card and as a reference to minor data base entries and the documentation. The number should be entered carefully, as misidentification can cause the program to fail.

Example: Existing Enduse, Mobile Home-Refrigerator, Type 01, Electric

columns a b c d e f g h i j
sample entry E E 4 1 0 0 1 E 0 0

- a) Indicates that this entry is an end-use (E) or a conservation measure (M).

- b) Indicates whether this entry is for existing (E) stock, old (O) stock, or (N) new stock. All type-0 stock must have a corresponding type-N stock.
- c) This digit refers to the major end use category of the end use or conservation measure.

0-Space conditioning (1 and 2)	4-Refrigeration
1-Space heating	5-Freezing
2-Space cooling	6-Cooking
3-Water heating	7-Lighting
8,9-other appliances (tv,dryer,washing machine, dishwasher, well pump, pool, water bed heater,etc)	

- d) This digit indicates the type of housing unit

0-All housing types	4-All single family (2 and 3)
1-Mobile homes	5-Multi-family (5 or more units)
2-Single family-detached	6 through 9-Not used
3-Single family-attached	

- e) This digit indicates the climate zone or state

0-All zones	6-Washington
1-Climate zone 1	7-Oregon
2-Climate zone 2	8-Idaho
3-Climate zone 3	9-Western Montana
4 and 5- reserved for other climate zones or sub zones	

- f and g) These two values are reserved for further disaggregation of the end-use into sub-categories. The numbers (01 to 99) do not refer to specific descriptors.

- h) The letter designates the type of fuel used.

E-electricity

G-natural gas

0-fuel oil

i and j) These number refer to prototype (typical) case in the minor data base that make up a major data base entry. In the major data base, the value shown must be 00.

columns

51-56 Base UEC in kWh/yr (F6.0)*

The Base Unit Energy Consumption (UEC) is the average annual usage (in 1980) of an individual appliance or household. Electric end uses are in kWh per year. Natural gas end uses are in therms per year. Fuel oil end uses are in hundreds gallons per year at 5.8 million BTU/gallon. For space conditioning and water heating this base UEC is compared to the UEC calculated by Work4 and an error message is printed if the values differ by more than 5%. If this message appears the minor data base inputs should be adjusted. In all cases, however, the UEC entered here is used for all program calculations, not the Work4 generated UEC.

57-61 Initial Stock in thousands (F5.0).*

The initial stock is the total number of units, in thousands, of a given end-use in the base year. Occupied households are used as the stock number for space conditioning and water heating. Occupied households times saturation values determine the values entered for appliances. For end uses disaggregated by climate zone, the initial value is for the climate zone, e.g. the number of single-family residences with electric heat in climate zone 3. For all end use types (O,N,E) the total number of units in the base year should be entered. The program will use this value as an base value and calculate stock for each snapshot year (see MNLOOP description, above). The value which will appear for new stock (N) in the base year will be only the net new additions to stock, not the value originally entered.

62-65 Addition Rate (F4.0)

The growth rate, in decimal percent per year, is determined exogenously, and entered into the data base. For existing stock (E) and new stock (N) the value entered will be used in an exponential growth equation. E-type end uses use this number as a net growth rate. N-type end uses take this number as a growth rate over and above the replacement of old stock. Do not enter an addition rate for old stock (O).

66-69 Decay Rate or Replacement Rate (F4.0)

The decay rate is only used to calculate the old (O) and new (N) stock. In both instances the value entered is treated as a linear function (not exponential). Consequently, the value entered should be the inverse of the the mean lifetime of the end use. O-type stock treats the decay rate as an actual decay rate, while N-type stock uses the decay rate as a replacement rate. In all cases O-type and N-type decay rates, for the same end use should be identical. Note that the Old and New stocktypes are not linked within the program: they are entirely independent of one another. Consequently, it is possible to obtain incorrect stock values if the decay and replacement are not correctly specified. Do not enter a decay rate for existing stock.

70 Minor Data Base Indicator (I1) *

A "1" indicates that the CPS 2.0 will use WORK4 to calculate: 1) Average Cost, 2) Average Savings, and 3) Eligible Fraction for each conservation measure applied to that end use. The NOTYPCASE control card will override this indicator.

71-75 Last Update (A5)*

This entry indicates the month and year of the most recent modification to any part of the end use entry. It should be entered in the format "MM-YY".

3.2.2 Conservation Measure Data Cards

CONSERVATION MEASURE DATA CARD EXAMPLE

Each conservation measure is contained on two consecutive cards. These measures must follow directly after the appropriate end use and must be in ascending order.

CONSERVATION MEASURE DATA CARD - EXAMPLE 5

.....1.....2.....3.....4.....5.....6.....7.....8
Refrig.-Single Door,Buy Eff. Mkt. Model ME40001E000122. 180. 1919801998
11. 0.53 15. 0.21 2-84 [second card]

First Card

columns

1-40 Conservation Measure Description (A40)

This is a 40 character description of the conservation measures. Any alphanumeric characters can be entered.

41-52 ID Code (A12)*

The measure ID Code corresponds to the end use ID code with the exception of the leading "M" to indicate measure, and two additional digits at the end to uniquely identify the conservation measure order. There is a limitation of 99 conservation measures for any single end use.

53-58 Measure Cost in \$ 1980 (F6.0)

The average cost is expressed in 1980 dollars per installation of a measure. For simple conservation strategies, i.e. those that do not refer to the minor data base, this value is entered directly. For items that are composites of several prototype cases contained in the minor

data base, the average cost is initially entered as a zero. The value is then calculated by Work4.

59-63 Program Cost in \$ 1980 (F5.0)

This is the value added to the per-unit cost of the measure to represent the estimated program implementation costs per measure. The program costs are divided between transfer payments, which reduce the customer's out-of-pocket expense, and administrative expenses incurred by BPA, a utility, etc. to run the program.

64-69 Measure Savings in kWh/yr (F6.0)

These average savings are per measure (either per unit or per household depending on the measure), in kWh/year. Enter zero in the major data base for measures that derive their savings from Work4.

70-72 Lifetime in Years (I3)

This is the average physical lifetime of the measure in years and is entered directly into the data base.

73-76 Start Year (I4)*

This is the year that the measure will first be considered in the supply curve analysis. In most cases the start year will be the initial year of the analysis (1980).

77-80 End Year (I4)*

This is the year that the measure will begin to be rolled out of the program. If no rollout is desired a zero should be entered. For example, if one entered a start year of 1985 and an end year of 1990 the conservation measure would begin to take effect in 1985. After 1990 the measure would start to roll out of the applicable stock with the number of installations and the savings eventually reaching zero. The rolling out procedure would be used when the original measure has been replaced by a new, more energy efficient second measure. If the second measure

simply has an incremental savings over the original measure the roll-out procedure is not used.

Second Card

columns

1-5 Roll-in Years (F5.0)*

The roll-in time is the number of years it will take for the measure to be implemented in all of the eligible portion of the stock. It represents a best estimate of the maximum rate of penetration without market disruption, i.e. without increasing the cost of the measure. The total number of installations at the end of each year is the number of years the measure has been rolling in (the current year minus measure start year + 1) divided by the roll-in time, and multiplied by the eligible fraction and the total stock that year. Thus a measure with a five year roll-in will have been installed in 20% of the eligible stock at the end of the first year, 40% of the eligible stock by the second year, etc. If the stock each year is changing, by growth or decay, then the number of units installed each year will not be a constant, but the fraction of the stock into which the measure has rolled in by the end of the year will be as expressed above.

11-15 Program Penetration in years (F5.0)

This is analogous to the roll-in rate but here represents an estimate of BPA's conservation program penetration. Either the roll-in rate or the estimated program penetration is used, depending on whether the BPAPENET control card has been included in the run (see above).

16-20 Program Fraction (F5.0)

This is analogous to the eligible fraction. It is used to assign a lower level of penetration total if certain portions of the stock are excluded for non-physical reasons. Either the roll-in rate or the estimated program penetration is used, depending on whether the BPAPENET control card has been included in the run (see above)

21-24 Seasonal Value (A4)

This entry is available if one wants to assign a seasonal value to a given conservation measure. An example of this might be a measure which conserves electricity chiefly in the winter when demand is highest and consequently electricity has a value greater than the year-round average. We have not included any seasonal values for conservation measures.

25-29 Last Update of Information (A5)*

This is the month and year of the most recent modification to any part of the conservation measure entry. The data should be entered in the form MM-YY.

3.3 Minor Data Base Inputs

The minor data base is designed as input to the Work4 subroutine. If Work4 is not called by any of the enduses in the major data base, CPS 2.0 will function with an empty minor data base file. In the cases where Work4 is called this data base must be included. A detailed description of the Work4 and its data input formats are contained in Appendix B.

4 Error Messages Generated by CPS 2.0

CPS 2.0 has a variety of error messages included in its output. These are designed to aid the user in understanding why the program failed to run, what default values were used for unspecified inputs, or what cautions should be exercised in interpreting the output. The error messages are listed, in alphabetical order, below.

***** CAUTION POLICYMAKER *****

**UECS ASSUMED IN THE MAJOR DATA BASE AND
CALCULATED IN WORK4 DIFFER BY MORE THAN 5%**

This warning is probably due to changes in the minor data base inputs. The baseline consumption in the major and minor data bases do not agree. Because CPS 2.0 uses the UEC entered in the major data base and the conservation measure savings calculated by Work4, the error should be corrected. Otherwise, savings for a particular end use could exceed the initial UEC value. Consult the Work4 documentation (Appendix B) for information on how to modify the minor data base inputs.

Program location of error message: mnloop 207

DISCOUNT RATE READ IN AS ZERO. CHANGED TO 1.e-10.

The discount rate has been specified as zero. In order to avoid infinities in the calculation of CCE, the rate is set to a very small number. To change the discount rate use the control card, DISCOUNT.

Program location of error message: readcc 216

ENDUSE [ENDUSE ID] HAS WRONG FUELTYPE

All enduses must have the same fueltype (set by the first enduse). Check the control card entry for the enduse ID indicated.

Program location of error message: readcc 219

ENDUSE [ENDUSE ID] STOCK TYPE NEW, HAS NO REPLACEMENT RATE

Enduses with stocktype N must have a replacement rate greater than zero. A positive replacement rate is required for the new stock because it is used to calculate replacement stock for old stock (O) retirements (decay). This error message sometimes will also appear for E-stocktype enduses even though they do not require a replacement or decay rate in order to run. The E-stocktype problem can be corrected by listing all E-type enduses at the beginning of the ENDUSE control card, before any O- or N-types. For N-type enduses check the major data base enduse indicated by the ID code.

Program location of error message: readdb 206

ERROR CHECK VALUES OF NM NUE NETA NS

The values, in the minor data base, of NM-number of measures per enduse, NUA- number of primary UA values, NETA-number of efficiencies, or NS-number of fixed consumptions, exceed their limits. Currently each of these variables is limited to 20 per typcase. Check the typcases in each minor data base enduse.

Program location of error message: work4 202

ERROR IC IS ZERO

This is an error message that occurs when the sorting of measures has not been correctly done. It is caused by faulty data input. Check the minor data base entries for format errors.

Program location of error message: work4 203

ERROR NEGATIVE CONSUMPTION CALCULATED CHECK FIXED LOSS INPUT IN TYP-CASE

This is an error generated when the total energy use in a typical case is negative. The error is probably a result of having a negative fixed loss entry that is too large. Negative fixed losses are interpreted as internal energy gains. Verify also that HOURH is being used if space heating enduses are being made.

Program location of error message: work4 204

INVALID FUELTYPE

The fueltype must be specified as either electric (E), natural gas (G), or fuel oil (O). Check the control card entries for enduses. Program location of error message: readcc 218

INVALID INPUT CARD

Cards in major data base must start with E (enduse) or M (measure) . Check the IDs of each enduse in the major data base. Program location of error message: readdb 201

INVALID NUMBER OF ENDUSES

This message indicates that either no enduses were specified or the number of enduses exceeded the limit of 99. Check the control card entries for enduses. Program location of error message: readcc 211

INVALID NUMBER OF SNAPSHOT YEARS

More than 31 snapshot years have been requested. Check the SNAPSHOT control card in the control card file. Program location of error message: readcc 209

INVALID VALUES FOR IX AND IY STOP

Invalid values for ix (X-dimension) and iy (Y-dimension) have been specified in the plot routine. Their limits are 130 and 60, respectively. Program location of error message: icorr 101

JOB TERMINATED, TYPCASE FRACTIONS DONT SUM TO 1.000

The typcase fraction in the minor database are required to sum to 1.000 (within a range of 1.e-6) or the program will not run. Check the typical case fraction cards in the minor data base. Program location of error message: work4t 217

NO ENDUSE DATA FOR ENDUSE

No enduse card was found in the major data base for an enduse specified in the control cards. Check the major data base IDs to verify that they correspond with the entries on the control card ENDUSE.

Program location of error messages readdb 203

SNAPSHOT YEARS HAVE TO BE ORDERED

The snapshot years given on the control card must be in ascending order. Check the control card entry SNAPSHOT.

Program location of error message: readcc 222

TOO MANY MEASURES

CPS 2.0 handles a maximum of 750 conservation measures in any single run. Either measures will have to be removed from the databases or the input data must be split into two separate runs. Check the major data base for the total number of conservation measures included in the run.

Program location of error message: readdb 205

UECS REQUESTED BUT ENERGY PRICE IS NOT SET

This message indicates that a UEC card has been included in the control card file. However, no energy price has been set by the energy price control card. In order for CPS 2.0 to calculate potential UECS in any future year it is necessary to have a energy price so that a cutoff price can be calculated. (For more information consult the documentation on the MNLOOP subroutine.) Add the control card ELECPRICE, GASPRICE, or OILPRICE to the control card file. A starting energy price must be specified with this card, but an escalation rate is optional.

Program location of error message: readcc 220

WARNING CHECK VALUES OF NM NUA NETA NS

The values, in the minor data base, for NM-number of measures, NUA-number of primary UA values, NETA-number of efficiencies, and NS-number of fixed consumptions are less than or equal to zero. Check that there are no negative or zero entries for any of these values in the the minor data base tycases.

Program location of error message: work4 201

WARNING NO INPUT FOR DISCOUNTRATE. DEFAULT TAKEN

No discount rate has been specified in the control card file. 0.03 is used as the default value. To specify a different discount rate include the control card DISCOUNT.

Program location of error message: readcc 215

WARNING NO INPUT FOR SNAPSHOT YEAR. DEFAULT TAKEN

No snapshot year has been specified in the control card file. In this case 1980 will be used as the only snapshot year. To specify other snapshot years include the control card SNAPSHOT.

Program location of error message: readcc 230

WARNING NO INPUT FOR PROGRAM START YEAR. DEFAULT TAKEN

No start year has been specified in the control card file. In this case 1980 will be used as the start year. To specify an alternate start year include the control card STARTYEAR.

Program location of error message: readcc 214

WARNING TCCS WONT PRINT, SNAPSHOT MUST EQUAL START YEAR

The technology cost curves requested by a TCC card will only print if one of the snapshot years requested corresponds to the start year.

Program location of error message readcc 224

WORK4 — ENDUSE [ENDUSE ID] HAS NO ENDUSE CARD

The enduse, whose ID is indicated, has been requested by a control card but has no corresponding enduse in the minor data base. Check to see that the enduse IDs are correctly specified in the control card and minor data base inputs.

Program location of error message: work4t 204

WORK4 — ENDUSE [ENDUSE ID] HAS NO TYPCASE CARD

The enduse, whose ID is indicated, has been requested by a control card but has no typical cases in the minor data base. Check to see that the enduse IDs are correctly specified in the control card and minor data base inputs. Also check to see that the typcases have been included in the minor database.

Program location of error message: work4t 207

APPENDIX B
Documentation of WORK4

1 Introduction

Work4 is a simple heat loads computer program that determines the economically optimum sequence of conservation measures using a series of prototype or typical cases.. Work4 is flexible; the same program can calculate the energy savings for a series of measures to conserve space heating, water heating, refrigeration, or air conditioning energy.² The measures are ranked by their "cost of conserved energy", an indicator of cost-effectiveness.

Work4 serves three major roles:

1. It determines the optimal sequence of conservation measures for a prototype.
2. It averages the energy savings of similar measures from several prototype cases. This permits calculation of Unit Energy Consumptions (UECs) and development of Technology-Cost Curves.
3. It operates as a subroutine of CPS 2.0 to calculate energy savings of sequence-dependent conservation measures.

¹ This section discusses the WORK4, WORK4T, HOURH subroutines. WORK4 is the calculation subroutine for each individual typical case, while WORK4T is responsible for calling WORK4 for each subroutine and averaging the results of the typical case calculations. For simplicity, however, the function of both subroutines is described using only the WORK4 designation. Refer to the program listing in Appendix D for more information on the division of function between WORK4 and WORK4T.

² Note that in the current conservation supply curve analysis for BPA we have not used Work4 to calculate either refrigerator or space cooling loads.

As with any loads program, the user must supply Work4 with detailed information regarding initial conditions of the prototype and details of the conservation measures. The unusual generality of Work4, that is, its applicability to space heating, water heating, refrigeration, etc., slightly complicate input requirements and may require "creative" structuring of inputs. Therefore, some knowledge of heat transfer terminology and concepts is needed to operate the program. Nevertheless, we find users can make independent runs and obtain relevant output after one day's instruction. Once the user masters the logic of Work4, he or she will find that it can model an extraordinarily diverse collection of heat loss and gain problems.

1.1 Work4 as a Loads Program

Work4 relies on simple algorithms to calculate heat loads and energy savings from conservation measures. It assumes that energy requirements are the sum of several parallel heat loss paths (UA values in space heating calculations) driven by a temperature difference, and divided by the product of several efficiencies. In addition, a fixed consumption, such as a pilot light, may be included. (See the logic section for details.)

Conservation measures are entered as changes to the initial conditions. To enter a measure increasing the attic insulation by R-19, the user (after specifying some economic data for the measure) would indicate that the measure entailed an increase in the insulation value by R-19. Work4 would calculate the energy savings based on average temperature data included in the initial specification.

The data required to use Work4 for water heating is somewhat different but still fits the original formats. For example, instead of entering U values and areas, the user now enters daily consumptions for each activity (i.e. showers, dishwashing, etc.) and a factor to convert gallons/day to Btu/hr-F. The product of these two numbers yields a number whose dimensions are the same as a UA.

Work4 can use results of other, more sophisticated programs (such as DOE-2 or CIRA), and use these results to calculate energy savings for a measure. Measured results can be stored in a similar fashion, too. The savings must in both cases be characterized in terms of the variables Work4 already uses, namely, inside and outside temperatures, U values and areas, fixed consumptions, and efficiencies.

1.2 Work4 as an Averaging Program

Many forecasting models rely on Unit Energy Consumptions (UECs) to characterize demand in end uses. The UEC is the average energy consumption for one unit, be it space heating in one house or of a refrigerator. In principle, the UEC should represent a composite of several prototypes, where the prototypes represent different elements of the stock. Work4 will calculate the average energy consumption for several prototypes. The user can specify a number of prototypes and the fraction of the stock which each represents. Work4 calculates the initial, weighted energy consumption, that is, the UEC. The user can then compare it to the UEC assumed in the forecasting model. If the two estimates are not equal, then the user adjusts the initial conditions or the stock assumptions until they do. The reconciliation process provides insight as to the physical requirements for the UEC assumption to be valid.

Work4 will compute the average energy savings for a conservation measure applied to several prototypes. For example, we might seek to determine the average energy savings for double-glazed windows. Several prototypes would be required to represent the wide range of climates in which the windows are to be installed. Not every situation can be modelled, but a collection of "reasonable" cases can certainly be constructed. The average energy savings should reflect these cases. Work4 provides a realistic basis for an average energy savings value by assuming that it is a composite of several realistic prototypes.

Work4 output can also be used to construct Technology-Cost Curves. Work4 provides the stock weighted energy savings for a series of conservation measures with plots. CPS 2.0 prints two rankings of the

measures, with respect to Return on Investment (ROI) and CCE. (The two sequences are slightly different when the lifetimes of the measures vary.)

1.3 Work4 as a Subroutine for CPS 2.0

As a subroutine in CPS 2.0, Work4 serves two principal roles. First, Work4 examines a number of prototypes or "typical" cases. These typical case are then used to generate suitable average values each measure's energy savings. In the BPA data base, CPS 2.0 calls on Work4 to provide average values in the space and water heating end uses. Second, Work4 calculates loads and energy savings for measures in end uses having sequence-dependent energy savings (i.e., where the savings attributed to one conservation measure depends on measures already implemented.) Revised economic assumptions (especially the discount rate) will change the optimal order of conservation measures and lead to different energy savings being attributed to measures. Work4 calculates the optimal order and energy savings using the particular economic assumptions specified by the CPS 2.0 control cards. In this way, CPS 2.0 avoids double-counting energy savings or incorrect attribution of energy savings.

2 General Logic of Work4

The logic of Work4 is presented as a flow chart in Figure 1. The fundamental equations are presented in Table 1. Work4 assumes that a series of typical (or prototype or representative) cases will be contained within an end use. In the first step, Work4 reads in the initial conditions for a typical case. Work4 requires a set of data establishing the initial conditions for each typical case. These define the thermal parameters and levels of use. For space heating, the initial U-values and areas of all major surfaces must be specified (each associated with one heat loss "path"), in addition to exterior and interior temperatures.¹ For water heating, the volumes of hot water consumed by each "activity" must be specified, in addition to U-values and surface areas of the tank.² The "inside" temperature is the temperature of the hot water, the "outside" temperature is the cold water inlet temperature. In addition, a "mid temperature" is needed to specify the ambient air temperature around the water heater tank. All fixed uses must also be specified. Finally, the user must specify the fraction of stock which he believes is represented by this typical case. Work4 will not run unless the sum of the end use typical case fractions equal 1.000.

Work4 assumes that energy consumption will be the sum of three factors:

1. a set of primary UA-values, driven by an inside-outside temperature difference,
2. a set of secondary UA-values, driven by an inside-midtemperature difference, and
3. a set of fixed consumptions.

The precise relationship is shown in Equation 1 in Table 1. Efficiency terms can be applied to the first two factors. Work4 will accept other inputs in place of UA-values as long as the dimensions are the same. For water heating, the 'A' would correspond to the volume of hot water used daily for a particular activity. The 'U' would correspond to the

Figure B-1

SIMPLIFIED WORK4 FLOW CHART

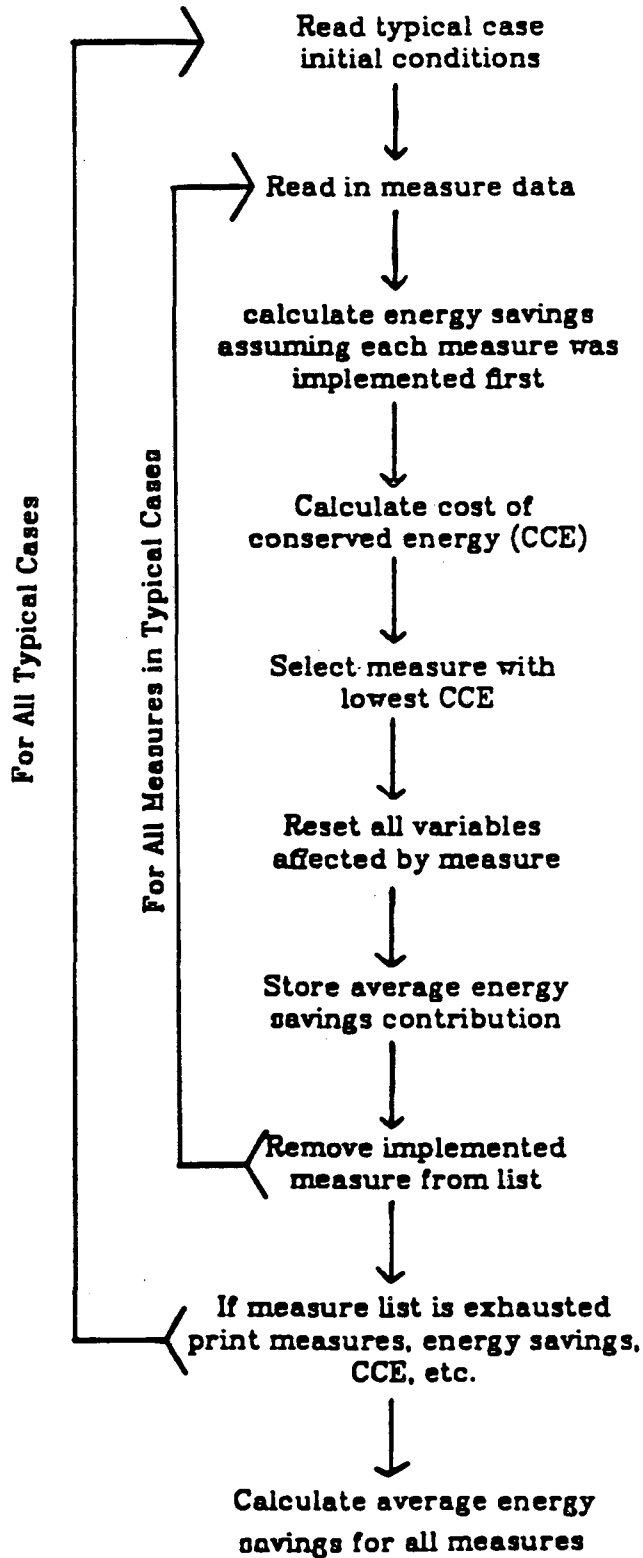


Table B-1

Eqn. 1. Fundamental energy consumption formula:

$$\text{energy consumed per year} = \frac{\sum U_i A_i (T_{in} - T_{out})}{\prod \eta_j} + \frac{\sum U_k A_k (T_{in} - T_{mid})}{\eta_1} + \sum F_m$$

U_i = primary U-values

A_i = primary areas

η_j = efficiencies

U_k = secondary U-values

A_k = secondary areas

T_{in} = inside temperature

T_{out} = outside temperature

T_{mid} = mid-temperature

η_1 = first efficiency entered

F_m = fixed consumption

Eqn. 2 Resetting algorithms:

$$U_{final} = \frac{1}{\frac{1}{U_{initial}} + \frac{1}{U_{measure}}} \quad \text{or} \quad \frac{1}{\frac{1}{U_{initial}} + R_{measure}}$$

$A_{final} = A_{initial} - A_{measure}$ [$A_{final} = A_{initial} (1 - A_{measure})$]; for percentage savings]

$T_{final} = T_{initial} - T_{measure}$

$\eta_{final} = \eta_{initial} + \eta_{measure}$

$F_{final} = F_{initial} - F_{measure}$ [F=energy consumed per year]

The value with the "measure" subscript is the actual value entered in the Work4 inputs. R = resistance

Eqn. 3. Cost of conserved energy (CCE) formula:

$$\text{cost of conserved energy} = \frac{I}{\Delta E} \cdot \frac{d}{1 - (1 + d)^{-n}}$$

I = measure cost
 ΔE = energy savings
d = discount rate
n = lifetime

Eqn. 4. UEC formula:

$$\text{UEC} = \frac{\text{all typical cases}}{\Sigma} (\text{typical Energy Cons.})_i (\text{typcase fraction})_i$$

Eqn. 5. Averaging formulas for eligible fraction, energy savings, cost, and lifetime:

$$\text{eligible fraction} = \frac{\text{all typical cases}}{\Sigma} (\text{typcase fraction})_i (\text{measure fraction})_i$$

$$\text{average energy savings} = \frac{\frac{\text{all typical cases}}{\Sigma} (\text{typical } \Delta E)_i (\text{typcase fraction})_i (\text{measure fraction})_i}{(\text{eligible fraction})}$$

$$\text{average cost} = \frac{\frac{\text{all typical cases}}{\Sigma} (\text{typical cost})_i (\text{measure fraction})_i (\text{typcase fraction})_i}{(\text{eligible fraction})}$$

$$\text{average lifetime} = \frac{\frac{\text{all typical cases}}{\Sigma} (\text{typical life})_i (\text{measure fraction})_i (\text{typcase fraction})_i}{(\text{eligible fraction})}$$

Eqn. 6 Special heat loss formula:

$$\text{Furnace Output} = \frac{UA}{\eta} \sum_{T_{out}=-35}^{T_{out}=65} (T_{in} - T_{out}) \alpha_{T_{out}} - \frac{\alpha_{T_{out}} F}{A}$$

where

UA = the total UA for the house,

T_{out} = outside temperature,

T_{in} = thermostat setting (inside temperature),

$\alpha_{T_{out}}$ = number of hours, per year, for which a temperature, T_{out} , occurred,

F = total annual internal gains (or free heat),

65

A = total number of heating hours, $A = \sum \alpha_T$.

$T=-35$

η = efficiency

This summation continues with increasing T_{out} until the (furnace output) entire expression becomes negative.

heat capacity of water. Thus, the product of the two terms would still have the dimensions energy x 1/time x 1/degrees temperature. (The present BPA version of Work4 assumes that the input will have the dimensions Btu/hr-F.)

Work4 treats conservation measures as changes in these parameters, that is, changes in U,A, temperatures, efficiencies, and fixed consumptions. For example, addition of attic insulation would be entered as a reduction of the attic U-value. A single measure can involve alteration of several (or even all) parameters. Installation of storm windows might be entered as a reduced U-value for the windows and a reduced infiltration value. Work4 calculates the energy consumption for these revised conditions and subtracts it from the initial energy consumption to determine the energy savings.

The cost and estimated lifetime of each measure must also be specified. Work4 combines this information with the energy savings and the discount rate (taken from CPS 2.0) to calculate the cost of conserved energy. The cost of conserved energy formula is shown in Table 1, Equation 3. This procedure is repeated for all the measures. For each iteration, Work4 assumes that each measure is implemented first, that is it calculates energy savings for each measure relative to the initial conditions.

Next, the conservation measures are ranked by their costs of conserved energy (CCE). A measure with a low CCE is more cost-effective than one with a higher CCE. Work4 selects the measure with the lowest CCE and "implements" it. Implementation simply involves adjustment of the initial conditions to reflect the alterations specified by that measure. Work4 treats this revision as the initial conditions and repeats the procedure outlined above to determine the next most cost-effective measure. It continues until the list of measures is exhausted. A summary of the results are printed, including the optimal order of implementation, plus the energy savings and CCE attributed to each measure. Work4 also stores the contribution of that typical case to to the initial UEC, the average savings for each measure, and the final UEC.

Work4 will then move on to the next typical case (if there is more than one). When the computation for all of the typical cases has been completed, Work4 calculates the initial UEC for that end use. This is the weighted average of the initial energy consumptions for all typical cases. The formula is shown in Table 1, Equation 2. Work4 also calculates the final UEC, that is, the UEC after all the measures have been implemented. (The same formula is used.) Work4 calculates the weighted average energy savings. The weighted average reflects the representation of each typical case, the fraction of units eligible for that measure within that typical case, and the measure's energy savings in that typical case. The formula is shown in Table 1., Equation 4. The average energy savings shown in the output are also returned to CPS 2.0 where they are placed in the major data base.

3 The HOURH Subroutine

The simple, base 65°F degree-day technique for estimating heating loads and energy savings from conservation measures yields inaccurate results for homes in the BPA region. Three factors undermine this technique's accuracy. First, the proposed sequence of retrofit measures leads to a dramatically reduced balance temperature, that is, the outside temperature at which the furnace must turn on (because the internal gains are no longer sufficient to offset the heat loss). After all the possible measures have been implemented, the balance temperature is typically below 50°F. Second, homes in the BPA region have unusually high internal gains. These high internal gains further depress the balance temperature. Finally, a large proportion of the homes are located in relatively mild coastal climates. Heating requirements are especially sensitive to the balance temperature in such climates. We developed the HOURH subroutine to circumvent these drawbacks.

The subroutine HOURH relies on tables of hourly occurrences of outside temperatures, such as that published in ASHRAE Systems, for each climate region. The logic of HOURH is shown in Equation 6. HOURH calculates the heat loss for each outside temperature, based on the number of hours that this temperature occurred (taken from the table for the

climate region). For example, in Seattle, there, on average, 1258 hours in the temperature range from 40 and 44 °F. It then subtracts the internal gains that occurred during the same number of hours. The remaining heat loss must be met by the furnace. The program begins at -35 °F (for which there are usually zero hours) and increases in 1 degree increments, and sums the contributions for each temperature bin. The sum continues until the balance temperature is reached. This happens when the heat loss is entirely offset by the contribution of internal gains.

Improvements in the shell thermal integrity will lower a house's UA-value. As a result, each temperature bin the contribution internal gains will offset the heat loss at a lower temperature bin.

4 Input Format

Virtually all of the inputs for Work4 are in fixed field format. Work4 will incorrectly interpret numbers spanning fields or lacking decimal points. Use care!

Words shown entirely in capital letters must be entered as shown. All numbers are entered in either floating point ("F-format") or integer ("I-format"). The floating point format implies a decimal point if none is provided. For example, Work4 often requires F8.3 format; if no decimal point is inserted, the compiler will insert one between the fifth and sixth digit. An I2 format reserves a field of two spaces. Note that a 1 placed in the first position will be interpreted as 10.

Each of the sections below illustrates the format of the input cards with an example. The column numbering line and the material in brackets "{}" are not part of the input data. Column numbers followed by a letter, e.g. [3b], are optional input lines, all number are required inputs. After each example the function of the card and the data entry order is explained.

4.1 End Use Data Cards

1. End Use Card

```
-----  
                          END USE CARD - EXAMPLE 1  
.....1.....2.....3.....4.....5.....6.....7.....8  
ENDUSE ee34000e00  Water Heating SF                [End Use]  
conversion is 8.3/24 from gal/day to btu/h-F = .346 [Comment]  
shower laundry dishes other                        [Comment]  
-----
```

Columns

- 1-7 ENDUSE.
- 8-17 ID number (A10).
- 18-80 end use description.
- 2 - N. Comment Cards, no limit on number (optional).

4.2 Typical Case Cards

 TYPCASE CARD - EXAMPLE 2

1.....2.....3.....4.....5.....6.....7.....8	
typcase	20	SF- w/ clothes, dish;heated area,R11,52 gal.,pipesins.							[1]
04	number of conversions and volumes (I2)							[2]	
.346	.346	.346	.346	.346				[2b]	
15.	12.	5.	5.					[2c]	
03	num. of mid temp-dep u-val.and areas (I2) walls,caps.pipes							[3]	
.08	.15	.08						[3b]	
25.	4.4	1.0						[3c]	
01	number of efficiencies (I2)							[4]	
1.0								[4b]	
0	number of pilot losses (I2)							[5]	
	[this line can be omitted since there are 0 pilot losses]							[5b]	
140.	hot water temperature (F)							[6]	
68.	ambient air temperature outside tank (F)							[7]	
55.	incoming cold water temperature (F)							[8]	
	[climate card is not needed for the water heating]							[10]	

1. Typical Case Card

- 1-7 TYPCASE.
- 8-10 Typical case number (I3).
- 11-80 Typical case description.

2. Primary UA specification card. These UA values are driven by the inside-outside temperature difference and divided by the product of all the efficiencies entered in card 4b.

- 1-2 number of primary U-values and areas entered.
- 11-80 comments.

2b. Primary U-value card. If column 1-2 in previous card is non zero, cards 2b and 2c must follow. The number of U-values must correspond to the number in column 1-2 of previous card. A maximum of 10 U-values will be accepted.

For the BPA version of Work4, the UA product must have the dimensions Btu/hr-F because the conversion factor to kWh/year (2.565) is hard-wired into the program. For conduction heat loss calculations, the U-value will have dimensions Btu/hr-ft²-F. and areas will be expressed in ft². For infiltration heat loss, the "U-value" will be a measure of the heat capacity of the air within the structure, that is, the product of the building's volume and the heat capacity of air (0.018 Btu/ft³-F). The "area" term will now represent the infiltration rate, expressed in the familiar air changes/hour. Water heating "U-values" will be an expression of heat capacity, Btuh/day-gal-F. The corresponding "areas" will be daily water consumption, in gallons/day. For all cases, the product of the "U-value" and "area" will have the dimensions Btu/hr-F.

Columns

- 1-8 U-value for first path (F8.2).
- 9-16 U-value for second path (F8.2).

- 17-24 U-value for third path (F8.2).
- 25-32 U-value for fourth path (F8.2).
- etc. Note number of path must equal number listed in card 2.
Maximum number of U-values is 10.

2c. Primary Area-value card. These inputs are the areas for U-values listed in card 2b. For water heating, these values would correspond to water consumption rates for various activities expressed in gallons/day.

- 1-8 Area for first path or volume for first activity (F8.2).
- 9-16 Area for second path or volume for second activity (F8.2).
- 17-24 Area for third path or volume for third activity (F8.2).
- etc. Note number of path must equal number listed in card 2.
Maximum number of areas is 10.

3. Secondary (or mid-temperature) UA-value specification card. These UA-values will be driven by the inside - mid temperature difference. They will be divided by only the first efficiency entered in card #4. A 100% efficiency is assumed if no efficiency is entered.

- 1-2 Number of mid-temperature dependent UA-values (I2). If this value is non-zero, then cards 3b and 3c must follow. This set of inputs is most frequently used to describe the thermal characteristics of the water heater. It is rarely necessary for space heating typical cases.

11-80 Comments

3b. Midtemperature U-value input card.

- 1-8 U-value for first path (F8.2).
- 9-16 U-value for second path (F8.2).

- 17-24 U-value for third path (F8.2).
25-32 U-value for fourth path (F8.2).
31...etc. U-values for additional paths, all in F8.2 format.

3c. Midtemperature area input card. The areas entered on this card should be placed in the same columns as their corresponding U-values.

- 1-8 Area for first path (F8.2).
9-16 Area for second path (F8.2).
17-24 Area for third path (F8.2).
25-32 Area for fourth path (F8.2).
33...etc. Areas for additional paths, all in F8.2 format.

4. Efficiency specification card. All UA losses are divided by an efficiency factor. The primary UA's, driven by an inside-outside temperature, are divided by the product of all the efficiencies. The mid-temperature dependent UA's, which depend on the inside-midtemperature difference, are divided only by the first efficiency entered (or 1.0 if no efficiency is provided).

- 1-2 Number of efficiencies to be entered (I2). Maximum of 5 efficiencies is permitted. If a zero is inserted, then Work4 assumes that the efficiency is 1.0. If this number is non-zero, then card 4b must be inserted.
11-80 Comments.

4b. Efficiency data card.

- 1-8 First efficiency (F8.2). This value will be applied to both UA series.

- 9-16 Second efficiency (F8.2). The product of all the efficiencies will be applied to the primary UA series.
- 17-24 Third efficiency (F8.2).
- 25-32 Third efficiency (F8.2).
- 33-40 Fourth efficiency (F8.2).
- 41-48 Fifth efficiency (F8.2). A maximum of 5 efficiencies are accepted.

5. Fixed loss specification card. Fixed losses (or gains) are independent of efficiencies or temperature differences. A common fixed loss is a pilot light. Work4 will accept either positive or negative values. Negative values correspond to free heat (such as solar gain) contributions in space heating.

- 1-2 Number of fixed losses to be entered (I2). If this value is non-zero, you must insert card 5b.
- 11-80 Comments.

5b. Fixed Consumption data card. This card is required if column 1-2 in card 5 is non-zero. The BPA version of Work4 expects these losses to be expressed in kWh/year. Internal gains or free heat should be entered as negative numbers.

- 1-8 First fixed loss (F8.2).
- 9-16 Second fixed loss (F8.2).
- 17-24 Third fixed loss (F8.2).
- 25-32 Third fixed loss (F8.2).
- 33-40 Fourth fixed loss (F8.2).

41-48 Fifth fixed loss (F8.2).

6. Inside temperature card. This is the highest temperature. For the BPA version, this is in degrees F.

1-10 Inside (or higher) temperature (F10.2). For water heating, this is the hot water temperature.

11-80 Comments.

7. Midtemperature card. This is the middle temperature. For water heating, this is the air temperature surrounding the water heater tank. Work4 ignores this for space heating measures (unless secondary UA values are entered) but it is nevertheless best to enter 0.0. For the BPA version, this is in degrees F.

1-10 Midtemperature (F10.2).

11-80 Comments.

8. Outside temperature card. This the lowest temperature. This is the cold water inlet temperature for water heating. In the BPA version, this is entered in degrees F.

1-10 Outside temperature (F10.2).

11-80 Comments.

9. Typcase fraction card. The typcase fraction indicates the proportion of the total stock represented by this typical case.

1-10 Typcase fraction (F10.2).

11-80 Comments.

10. Climate card. The climate card is only used for space heating typcases. For all other typcases a blank card should be supplied.

- 1-10 Climate number, right justified (I10).
- 11-11 Space heating identifier, which must to be S for space heating enduses.
- 12-80 Comments.

4.3 Conservation Measure Data Cards

Each conservation measure consists of 12 lines of data. There are no optional cards although cards can be blank. The first four lines are economic information; the remainder are changes in the initial conditions reflecting the type of measure. For example, the measure "add R-19 insulation to attic" would include a change in the attic U-value.

Every typical case within an end use must have the same number of measures. If the average energy savings are to be used (or passed to CPS 2.0), the measures must appear in the same order. For example, the measure, "insulate water heater tank" should be listed first in all the typical cases. (If a measure is not appropriate for one typical case, the measure fraction entry should be set to 0.0; Work4 will ignore the measure.) In addition, the inputs for the same measure may vary with the typical case. Adding R-19 to one typical case may be much more expensive than in another. It is permissible for typical cases to have different costs or energy savings. Thus, even typical cases with only one applicable conservation measure may have a long list of measures listed below the initial conditions because the other typical cases have many more applicable measures. (This procedure preserves the sequence of measures and avoids a complex identification number for each measure.)

TYPCASE MEASURE - EXAMPLE 3

.....1.....2.....3.....4.....5.....6.....7.....8		
measure 04	low flow showerheads	[1]
40.		[2]
13.		[3]
1.0		[4]
		[5]
7.0		[6]
		[7]
		[8]
		[9]
		[10]
		[11]
		[12]

1. Measure description card.

Columns

- 1-7 MEASURE.

- 9-10 Measure number (I2). The first should be listed as number one, the second as number two, and so on. The measure number serves only as an index to clarify input; Work4 does not use this number.

- 11 A "P" in this column indicates that the changes in area should be read as percentage rather than absolute savings.

- 13-77 Measure name (7A10). This description is printed in the output for the typical case summary.

2. Measure cost card.

1-10 Cost of measure in dollars (F10.2). The cost must have a decimal point.

11-80 Comments.

3. Lifetime card.

1-10 Lifetime of measure in years (F10.2). The lifetime must have a decimal point.

11-80 Comments.

4. Measure Fraction card.

1-10 Fraction of homes within typical case eligible for this measure (F10.2). This fraction is used to calculate the eligible fraction, and does not affect the energy savings.

11-80 Comments.

5. Primary U-value adjustment card. Changes in U-values for the primary (inside-outside) series are inserted in this line. A value inserted in the columns 1-8 implies that the change should be applied to the path listed in the corresponding location in the typical case inputs. Many people prefer to think in terms of adding R-values rather than U-values, so Work4 will also accept R-values. Work4 will interpret negative values as R-values. Thus, to add R-19 to the second heat flow path, a -19. would be entered in columns 9-16. (It would also accept .05) Note that Work4 expects changes in U-values, not the final, total U-values.

1-8 First path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.

9-16 Second path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.

17-24 Third path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.

25-32 Fourth path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.

33... Note that changes cannot be entered for non-existent paths. Hence, the maximum number of changes is limited by the number of U-values defined in the typical case.

6. Primary area adjustment card. Reductions in area of paths are entered here. For space heating, this corresponds to zone heating, or a reduction in infiltration rates. For water heating conservation measures, reductions in water use are entered. Again, the reductions must be entered in the columns corresponding to the original path or activity for that typcase. Work4 interprets a positive value as a reduction, a negative value as an increase. If the "P" specification is included with the measure card (see above) the input value will be read as a percentage rather than an absolute reduction.

1-8 First area adjustment (F8.2).

9-16 Second area adjustment (F8.2).

17-24 Third area adjustment (F8.2).

25-32 Fourth area adjustment (F8.2).

33... Note that changes cannot be entered for non-existent areas. Hence, the maximum number of changes is limited by the number of areas defined in the typical case.

7. Secondary (midtemp) U-value series adjustment card. The procedure to input changes is identical to that described in card 5; however, these changes will apply to U-values listed in card 3b of typical case inputs. Work4 interprets negative numbers as R-values.

1-8 First path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.

- 9-16 Second path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.
- 17-24 Third path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.
- 25-32 Fourth path adjustment (F8.2). A positive number will be interpreted as a U-value, a negative number as an R-value.
- 33... Note that changes cannot be entered for non-existent paths. Hence, the maximum number of changes is limited by the number of U-values defined in the typical case.

8. Secondary (midtemp) area adjustment card. the procedure to input changes in areas for the secondary (or midtemp) paths is identical to that described for the primary series in card 6; however, these changes will apply to card 7 in the typical case inputs.

- 1-8 First area adjustment (F8.2).
- 9-16 Second area adjustment (F8.2).
- 17-24 Third area adjustment (F8.2).
- 25-32 Fourth area adjustment (F8.2).
- 33... Note that changes cannot be entered for non-existent areas. Hence, the maximum number of changes is limited by the number of areas defined in the typical case.

9. Efficiency adjustment card. Improvements in efficiency are entered here. Work4 interprets a .05 in columns 1-8 as an improvement in efficiency from X to $(X + .05)$ of the first efficiency listed in the typical case data. An efficiency cannot be changed unless a corresponding efficiency exists in the typical case initial conditions.

- 1-8 First efficiency adjustment (F8.2). Note that changes in the first efficiency will affect both primary and secondary UA calculations.

- 9-16 Second efficiency adjustment (F8.2). Changes in the second through fifth efficiencies adjustments will only affect the primary UA calculations.
- 17-24 Third efficiency adjustment (F8.2).
- 25-32 Fourth efficiency adjustment (F8.2).
- 33-40 Fifth efficiency adjustment (F8.2).

10. Fixed consumption adjustment card. Changes in fixed consumptions, such as extinguishing a pilot light or reduced internal gains, are entered on this card. Work4 interprets a positive number as a reduction in fixed gains, a negative number as an increase. The BPA version of Work4 assumes that all changes will be in kWh/year. A fixed consumption cannot be changed unless a corresponding fixed consumption exists in the typical case initial conditions. Negative values (corresponding to a increase in internal gains) are acceptable. A measure with a negative fixed consumption and a negative cost will appear with a positive CCE. (This feature allows the effects of, say, improved refrigerators to be incorporated in the heat loss calculations.)

- 1-8 First fixed consumption adjustment (F8.2).
- 9-16 Second fixed consumption adjustment (F8.2).
- 17-24 Third fixed consumption adjustment (F8.2).
- 25-32 Fourth fixed consumption adjustment (F8.2).
- 33-40 Fifth fixed consumption adjustment (F8.2).

11. Inside temperature adjustment card. The inside temperature is generally the highest temperature; a change normally corresponds to a thermostat change. Work4 interprets a positive number as a reduction in temperature setting.

1-8 Inside temperature adjustment (F8.2).

12. Midtemperature adjustment card. The midtemperature usually refers to the temperature of the air around the water heater tank. Work4 interprets a positive number as a reduction in temperature setting.

1-8 Midtemperature adjustment (F8.2).

5 Work4 Outputs

Work4 treats each typical case separately. It calculates the initial energy consumption and the optimal sequence of conservation measures (based on the cost of conserved energy). Once all the typical cases within an end use have been examined, Work4 calculates the UECs and average values to be passed to CPS 2.0. The amount of output that will be generated is controlled by the DIAGNOSTIC control card described in Appendix A. The level necessary to generate a given type of output is indicated in parentheses (Refer to Appendix C for brief descriptions of the column labels.)

1. Formatted Echo of Typical Case Input Data Initial Conditions (Level 2)

All of the inputs are echoed in a formatted form. Note that the comments are also reflected. This section is useful for debugging the typical case initial conditions.

2. Measure Effects Table (Level 2)

Work4 prints the decay of the typical case energy consumption as the measures are implemented. The energy use, primary UA-value, secondary UA-value, the T-in/ T-out difference, T-in/T-mid difference, fixed gains (or losses), total efficiency, and first efficiency are also printed at each stage. Total consumption and fixed consumptions are expressed in kWh/year, the UA-values are expressed in Btu/°F, and the temperature differences are in degrees Fahrenheit. When the space hourly-data space heating option is used the T-bal/T-out difference, and the free heat used will be printed in place of the T-in/T-mid difference, and the fixed values. These outputs are usually sufficient to understand the Work4 calculations and assist in debugging inputs. Note that measures with blank inputs will nevertheless appear in the stepwise decay (with zero energy savings).

3. Measure Ranking Table (Level 2)

Work4 prints the cost, lifetime, energy savings (kWh/year), cost of conserved energy (\$/kWh), and rank for each measure. The measures are printed in the order of entry. The "order" column indicates the most cost-effective sequence. The measure with the lowest CCE will be assigned number 1 in the "order" column. Measure that are not used will be indicated as "NOT APPLICABLE".

4. Sum of Fractions for Typical Cases (Level 2)

The typcase fraction listed in each typical case (card 9) must sum to one before Work4 will calculate the average energy savings. If the sum does not equal 1.0 (within a range of $1.e-6$), Work4 prints an error and refuses to continue.

5. Average Savings To Be Passed to Major Data Base (Level 1)

Work4 calculates the average cost, lifetime, eligible fraction, and energy savings for each measure. The left hand number under the "measure" column indicates the order of entry in the typical case lists, not the cost effectiveness order. (Recall that the order of measures within each typical case must be the same.) Work4 averages the values for first conservation measure entered in all the typical cases, then the second, and so on. At diagnostic level one the Typcase titles and numbers will also be printed.

Work4 also calculates an eligible fraction for each measure. This number represents the fraction of the total stock (all houses, or all water heaters) to which the measure applies. The formula is shown in Equation 5.

6. Initial and Final UECs (Level 0)

These UECs are the stock-weighted energy consumptions in kWh/year, based on the typical case energy consumptions and their respective typcase fractions. See Table 1, Equation 4 for the precise calculation. To calculate the final UEC, Work4 assumes that all the applicable measures

listed have been implemented. At diagnostic level 0 only the Work4-calculated Initial UEC and the major data base UEC are printed and compared. If the two UECS differ by more than five (5) percent an error message is printed and the Work4 inputs should be modified.

Figures 2 and 3 contain sample inputs and outputs from the WORK4 portion of CPS 2.0. Note that the entries are merely examples and do not necessarily correspond to actual building characteristics in the Pacific Northwest.

Figure B-2. Work 4 Input (Example)

```
enduse eol2100e00    electric space heating SFD-Old (EXAMPLE)
      ***** THIS IS AN EXAMPLE CASE *****
insert useful introductory information here, such as
order of input numbers for heat loss paths.
note infil is expressed in air changes/hr
ceiling  walls  floor  wndows  infil
123456781234567812345678123456781234567812345678
1        2        3        4        5        6

typcase 1          first typical case, baseboard heated
05          number of u-values & areas
1350.      1014.    1350.    146.    .9
00          number of mid temp-dependent u-values and areas
01          number of efficiencies (furnace and ducts)
1.
02          number of fixed sources (internal/solar gains are negative)
-3500.    -4000.
67.        inside temperature (F)
00.        mid temperature (F) (NOT USED IN SPACE HEATING)
51.9       mean outside temperature (F) (NOT USED IN SPACE HEATING)
ls         test of the climate zone (Portland, Oregon)
```

The measure data will appear in the following order
(each as a row), but the column number will determine
to which heat loss path the measure applies.

- A cost (always first column)
- B life (always first column)
- C fraction of eligibility (always first column, and a 0 means that the measure is not applicable)
- D improvements in u value (If number has negative sign, then work4 treats it as an r-value.)
- E improvements in area
- F improvements in u-value for mid-tem dependent measures
- G area or volume for above
- H improvements efficiencies
- I improvements in pilot losses
- J changes in inside temperature
- K change in mid temp.

```
measure 01    add r-19 insulation to attic
560.
20.
-19.
```

```
measure 02    add r-11 insulation to walls
1900.
20.
-11.
```


Figure 2. Work 4 Input (Example)

work4 treats it as an r-value.)

- E improvements in area
- F improvements in u-value for mid-tem dependent measures
- G area or volume for above
- H improvements efficiencies
- I improvements in pilot losses
- J changes in inside temperature
- K change in mid temp.

measure 01 add r-19 insulation to attic
560.
20.
-19.

measure 02 add r-11 insulation to walls
1900.
20.
 -11.

measure 03 reduce infiltration .2 ach
430.
8.

.2

measure 04 install setback thermostat for setback
130.
10.

3.

measure 05 heat pump , cop 1.8, or .8 imprvment in effic. from 1.
1650.
10.
1.0

Figure B-3. Work 4 Output (Example)

***** ENDUSE E012100E00 ELECTRIC SPACE HEATING SPD-OLD (EXAMPLE)

***** TYPCASE 1 FIRST TYPICAL CASE, BASEBOARD HEATED

INITIAL CONDITIONS
 NUMBER OF U-VALUES & AREAS 5
 INITIAL PRIMARY U-VALUES OR HEAT CAPACITIES
 1.....2.....3.....4.....5.....6.....7
 .090 .110 .050 .910 194.400
 INITIAL PRIMARY AREAS OR VOLUMES
 1350.00 1014.00 1350.00 146.00 .90
 NUMBER OF MID TEMP-DEPENDENT U-VALUES AND AREAS 0
 NUMBER OF EFFICIENCIES (FURNACE AND DUCTS) 1
 INITIAL EFFICIENCIES
 1.00
 NUMBER OF FIXED SOURCES (INTERNAL/SOLAR GAINS ARE NEGATIVE) 2
 INITIAL FIXED CONSUMPTIONS
 -3500.00-4000.00
 INSIDE TEMPERATURE (F) 67.0000
 MID TEMPERATURE (F) (NOT USED IN SPACE HEATING) 0.
 MEAN OUTSIDE TEMPERATURE (F) (NOT USED IN SPACE HEATING) 51.9000
 FRACTION FOR THIS TYPICAL CASE .5000
 TEST OF THE CLIMATE ZONE (PORTLAND, OREGON) 1

B-34

MEASURE EFFECTS FOR TYPICAL CASE NO. 1 WITH 5 POSSIBLE MEASURES

(A) TYPCASE ENERGY USE	(B) TOTAL	(C) UA1	(D) UA2	(J) TBAL-TOUT	(K) (NA) FREE HEAT USED	(L) FREE HEAT USED	(H) EPPIC	(I) EPPIC(1)
INITIAL =	17070.92	608.23	0.	10.94	67.00	-6908.84	1.00	1.00
AFTER MEASURE =	13613.14	608.23	0.	8.73	64.00	-6251.39	1.00	1.00
AFTER MEASURE =	11114.94	531.09	0.	8.16	64.00	-5988.04	1.00	1.00
AFTER MEASURE =	9864.11	492.21	0.	7.81	64.00	-5724.69	1.00	1.00
AFTER MEASURE =	7930.95	431.14	0.	7.17	64.00	-5461.35	1.00	1.00
FINAL ENERGY USE =	7930.95	431.14	0.	7.17	64.00	-5461.35	1.00	1.00

MEASURE RANKING TABLE

(A) MEASURE NAME	(B) COST (\$)	(C) LIFE (YRS)	(D) PRAC	(E) SAVING (KWH/YR)	(F) CCE (\$/KWH)	(G) ORDER
1 ADD R-19 INSULATION TO ATTIC	560.	20	.900	2498.	.015	2
2 ADD R-11 INSULATION TO WALLS	1900.	20	.400	1933	.066	4
3 REDUCE INFILTRATION .2 AC:I	430.	8	.600	1251.	.049	3
4 INSTALL SETBACK THERMOSTAT FOR SETBACK	130.	10	.300	3458.	.004	1
5 HEAT PUMP	NOT APPLICABLE					

Figure 3. Work 4 Output (Example)

***** TYPCASE 2 SECOND TYPICAL CASE, CENTRAL ELEC. FURNACE

INITIAL CONDITIONS	
NUMBER OF U-VALUES & AREAS	5
INITIAL PRIMARY U-VALUES OR HEAT CAPACITIES	
1.....2.....3.....4.....5.....6.....7	
.090 .110 .050 .910 194.400	
INITIAL PRIMARY AREAS OR VOLUMES	
1350.00 1014.00 1350.00 146.00 .90	
NUMBER OF MID TEMP-DEPENDENT U-VALUES AND AREAS	0
NUMBER OF EFFICIENCIES (FURNACE AND DUCTS)	2
INITIAL EFFICIENCIES	
1.00 .85	
NUMBER OF FIXED SOURCES (INTERNAL AND SOLAR GAINS)	2
INITIAL FIXED CONSUMPTIONS	
-4000.00-2000.00	
INSIDE TEMPERATURE (F)	68.0000
MID TEMPERATURE (F) (NOT USED IN SPACE HEATING)	0.
MEAN OUTSIDE TEMPERATURE (F) (NOT USED IN SPACE HEATING)	51.9000
FRACTION FOR THIS TYPICAL CASE	.5000
TEST OF THE CLIMATE ZONE (PORTLAND, OREGON)	1

B-35 MEASURE EFFECTS FOR TYPICAL CASE NO. 2 WITH 5 POSSIBLE MEASURES

(A) TYPCASE ENERGY USE	(B) TOTAL	(C) UA1	(D) UA2	(J) TBAL-TOUT	(K) (NA)	(L) FREE HEAT USED	(H) EFFIC	(I) EFFIC(1)
INITIAL =	23214.22	608.23	0.	12.65	68.00	-5842.36	.85	1.00
AFTER MEASURE =	18875.47	608.23	0.	10.28	65.00	-5369.43	.85	1.00
AFTER MEASURE =	15688.30	531.09	0.	9.79	65.00	-5211.79	.85	1.00
AFTER MEASURE =	8715.72	531.09	0.	9.79	65.00	-5211.79	1.53	1.80
AFTER MEASURE =	7828.29	492.21	0.	9.49	65.00	-5211.79	1.53	1.80
FINAL ENERGY USE =	6443.47	431.14	0.	8.91	65.00	-5001.11	1.53	1.80

MEASURE RANKING TABLE

(A) MEASURE NAME	(B) COST (\$)	(C) LIFE (YRS)	(D) PRAC	(E) SAVING (KWH/YR)	(F) CCE (\$/KWH)	(G) ORDER
1 ADD R-19 INSULATION TO ATTIC	560.	20	.900	3187.	.012	2
2 ADD R-11 INSULATION TO WALLS	1900.	20	.400	1385.	.092	5
3 REDUCE INFILTRATION .2 ACH	430.	8	.600	887.	.069	4
4 INSTALL SETBACK THERMOSTAT FOR SETBACK	130.	10	.300	4339.	.004	1
5 HEAT PUMP, COP 1.8, OR .8 IMPRVMENT IN EFFIC. FROM 1.	1650.	10	1.000	6973.	.028	3

Figure 3. Work 4 Output (Example)

AVERAGED DATA TO BE PASSED TO MAJOR DATA BASE FOR ENDUSE E012100E00

MEASURE	SAVINGS	COST	LIFE	ELIG.PRAC
1	2843.	560.	20.	.900
2	1659.	1900.	20.	.400
3	1069.	430.	8.	.600
4	3898.	130.	10.	.300
5	6973.	1650.	10.	.500

INITIAL UEC = 20143.

FINAL UEC = 7187.

MAJOR DATA BASE UEC 20143.
MINOR DATA BASE UEC 20143.

(NOTE: Column descriptions are contained in Appendix C)

APPENDIX C
Key to Outputs from CPS 2.0

APPENDIX C: KEY TO OUTPUTS FROM CPS 2.0

The following contains a brief description of the columns of output generated by the CPS 2.0 program. The leftmost letter corresponds to the label appearing at the top of each column of output. For more details refer to the program documentation in appendices A and B.

End Use Table

- (a) **Enduse Description-** Unique description of each enduse.

- (b) **ID Code-** Identifier used for each end use. See Appendix A documentation for details on coding.

- (c) **Total Stock-** Total number of units (in thousands) in the year indicated. Both stock additions and decay are included in this entry. Subtotals for major end use categories (e.g. refrigerator) are also reported.
CAUTION: IF THE SNAPSHOT YEAR IS EARLIER THAN THE PROGRAM START YEAR THE STOCK TOTAL WILL BE TOO LARGE BECAUSE NEW STOCK ARE ENTERED AS TOTAL BASELINE STOCK (SEE APPENDIX A FOR DETAILS).

- (d) **Addition Rate-** Annual percentage growth in stock. Used only for (E) and (N) stock types. See program documentation for details.

- (e) **Decay or Replace Rate-** Annual percentage decay or replacement rate. For type "O" enduses the entry is used to calculate annual stock decay. For type "N" enduses the entry is used to calculate the replacement of "old" units by "new" units. See the program documentation for more details.

- (f) **Baseline UEC and Usage-** The initial Unit Energy Consumption in the start year. **Baseline Usage** is the product of **Total Stock** (c) and the **Baseline UEC**. **Baseline UEC and Usage** subtotals are calculated for each major end use category.

WARNING: IF THE SNAPSHOT YEAR IS EARLIER
THE PROGRAM START YEAR THE TOTAL USAGE WILL BE
TOO LARGE BECAUSE OF NEW STOCK ENTERED AS TOTAL
BASELINE STOCK (SEE APPENDIX A FOR DETAILS).

- (g) **Potential UEC and Usage-** Potential per Unit Energy Consumption assuming all conservation measures (at or below the cut off energy price) have been implemented. **Potential Usage** is the product of **Total Stock** (c) and the **Potential UEC**. "INDEF" will appear in the column for any years requested before the start year. **Potential UEC and Usage** subtotals are calculated for each major end use category.
- (h) **Work4 Used-** A "0" indicates that Work4 will not be used to calculate measure savings, measure costs, lifetime, and eligible fraction. A "1" indicates that Work4 will be used to calculate these values.
- (i) **Last Update-** Last time the end use entry was changed.

Conservation Measure Input Table

(This table is only produced when a snapshot year earlier than the start year is requested)

- (a) **Measure Description-** Unique description of the conservation measure
- (b) **ID Code-** Identifier used for each end use. See program documentation for details on coding.
- (c) **Measure Cost-** Contractor cost for installation of the conservation measure. A "-0" indicates that there is no initial entry in the major data base and the value will be supplied by Work4.

- (d) **Program Cost-** Additional costs to the utility of implementing conservation measures.
A "-0" indicates that no value has been entered.
- (e) **Measure Savings-** Savings attributable to the conservation measure. A "-0" indicates that there is no initial entry in the major data base and the value will be supplied by Work4.
- (f) **Lifetime-** Average lifetime of the conservation measure. A "-0" indicates that there is no initial entry in the major data base and the value will be supplied by Work4.
- (g) **Start Year-** Year that implementation of the conservation measure is to begin.
- (h) **End Year-** Year that the measure will begin to roll-out of the stock. This is used when a measure is to be replaced by a second measure. A zero (0) entry indicates that the measure is never rolled out. All BPA values are zero.
- (i) **Roll-In-** Number of years required to implement the measure. See the appendices A and B for the description of the roll-in.
- (j) **Program Penetration-** Analogous to the **Roll-In**. Used in place of roll-in when the user wants to specify different penetration level
A "-0" indicates that no value has been entered.
- (k) **Eligible Fraction-** Fraction of the stock that is physically able to implement the conservation measure. A "-0" indicates that there is no initial entry in the major data base

and the value will be supplied by Work4.

- (l) **Program Fraction-** Analogous to the **Eligible Fraction**.
Used in place of eligible fraction when the user wants to specify a different eligibility level.
A "-0" indicates that no value has been entered.
- (m) **Last Update-** Date of most recent change to data base inputs.
- (n) **Seasonal Value-** Dummy entry to eventually be used for calculation seasonal values for conservation measures

Conservation Measure Output Table

- (a) **Measure Description-** Unique description of the conservation measure
- (b) **ID Code-** Identifier used for each conservation measure use. See program documentation for details on coding.
- (c) **Total Cost-** Cost of the measure. Program cost will be included if requested by the ADMIN COST control card.
- (d) **Measure Savings-** Savings from the conservation measure.
- (e) **Lifetime-** Average lifetime of the measure.
- (f) **Eligible Fraction-** Fraction of the stock that is physically able to implement the conservation measure.
- (g) **Total Savings-** The entry in this column is the total savings attributable to a conservation measure in the current year. Units are gigawatt hours per year.

- (h) **Cumulative Total Savings-** The entry in this column is the cumulative total of "Total Savings" for all measures in the current year. Savings are reported in terawatt hours and as average megawatts (8760 MWh).

Technology Cost Tables

(Two technology cost tables are produced one ordered by ROI (return on investment) the other by CCE (cost of conserved energy))

- (a) **Measure-** Description of the conservation measure.
- (b) **Cumulative Investment-** Total cost of implementing current and all preceding conservation measures. The value is calculated by multiplying measure cost by eligible fraction.
- (c) **Energy Used -** Total annual energy use assuming implementation of current conservation measure and all preceding conservation measures. The value is calculated by multiplying measure savings by eligible fraction.
- (d) **ROI or CCE-** Return On Investment or Cost Of Conserved Energy for each measure.
- (e) **Energy Used/Original UEC-** ratio of energy used value to the initial end use UEC.

WORK4 Tables

Each of the Work4 typical cases produces three sets of output, initial conditions, measure effects, and measure rankings.

Initial Conditions

This section reflects the U-values, areas, temperatures, gains and losses, efficiencies for each typical case. Refer to the minor data base inputs for more details. Initial primary U-values for space heating are input, from left to right, for ceiling/roof, walls, floor, windows, infiltration, and doors.

Measure Effects Table

The formulas used to compute initial energy use and energy reductions due to conservation measures are described in the technical appendix B. (All measures (both applicable and not applicable) will be printed in the table. Not applicable measure will appear at the end of the listing and will have no changes in values indicated)

- (a) **Typcase Energy Use-** Measure are implemented in the order indicated in the measure ranking table.
- (b) **Total-** Total amount of energy used in kwh/yr after implementation of each measure.
- (c) **UA1- Product of the primary U-values** and primary areas. Units are Btu/hr-°F.
- (d) **UA2- Product of the secondary U-values** and secondary areas. Units are Btu/hr-°F.
- (e) **T_{in} - T_{out}-** Difference between the inside and outside temperature in °F.
- (f) **T_{mid} - T_{out}-** Difference between the mid temperature and the outside temperature in °F.
- (g) **Fixed-** Contribution of fixed energy gains (e.g. solar gains) or fixed losses (e.g. pilot losses) to final energy use. Units are kwh/yr.
- (h) **Efficiency-** Product of all efficiencies, both

primary and secondary.

- (i) **Efficiency (l)**- Primary efficiency.
- (j) **Tbal - Tout (replaces column e)**- Printed only for space heating energy typcases. Represents the temperature difference between the balance temperature of the dwelling and the outside temperature in °F.
- (k) **(NA) (replaces column f)**- Printed only for space heating energy typcases. Value is not applicable, i.e. it is not used in any space heating energy calculations.
- (l) **Free Heat Used (replaces column g)**- Printed only for space heating energy typcases. Represents the amount of free heat (internal and solar gains) that are available during the heating season. Note that the value declines as the UA decreases and the effective heating season is shortened. Units are kwh/yr.

Measure Ranking Table (For measure not used in the typcase "not applicable" will appear after the measure name)

- (a) **Measure Name**- Description of the conservation measure.
- (b) **Cost**- Cost of the measure in 1980 dollars.
- (c) **Lifetime**- Lifetime of the measure in years.
- (d) **Fraction**- Fraction of the units in the typical case where the conservation measure can be applied.

- (e) **Savings-** Savings calculated for each measure.
- (f) **CCE-** Cost of conserved energy calculated for each of the applicable measures.
- (g) **Order-** Order of implementation of conservation measures base on values reported in column f.

APPENDIX D
CPS 2.0 Computer Code

APPENDIX D: CPS 2.0 COMPUTER CODE AND VARIABLE LISTING

This appendix contains the complete FORTRAN version for the CPS 2.0 conservation supply potential model as implemented on the Lawrence Berkeley Laboratory's CDC 7600 computer. The program has been designed for use with the MNF4 compiler written and maintained by the University of Minnesota and modified by the LBL computer center. The modifications permit the use of the FTN4 compiler I/O library.

The model is divided into two parts—the majorpgm and the minorpgm. The majorpgm includes the **major** program and the subroutines **readcc**, **readdb**, **prendu**, **prmeas**, **mnloop**, **sortcc**, **caluec**, **echo**, **tccsub** and **plospc**. The minorpgm contains the subroutines, **work4t**, **work4**, **hourh**, **icorr**, **dcorr**, **ccorr**, **corrc**, **corr**, **smooth**, and **pcorr**.^{*} Each of these subroutines are described in Appendix B.

Listings and brief descriptions of the variables used in the model follow the program listing. Subroutine specific variables begin on page D-51, common block variables on page D-57, and an alphabetical listing of all variables can be found on page D-59.

* The program also contains procedures for producing high-quality conservation supply curves using Lawrence Berkeley Laboratory (LBL) graphics facilities. For those using CPS 2.0 outside of LBL, these procedures will not function and have been excluded from this listing.

MAJOR PROGRAM

```
program major(input,output,mindat,majdat,tape3,tapel=majdat,  
* tape2=mindat,tape5=input,tape6=output)  
c  
c   database control program  
c  
c  
c  
c  
c   declaration of commons  
c  
c   /cntrl/ contains control information  
c  
c   common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,  
*   adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,  
*   elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)  
*   ,tcc(99)  
c   logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc  
c  
c   /majdb/ contains major data base  
c  
c   common/majdb/imenum(99),imepoi(99),  
*   enddes(4,99),endid(99),  
*   enduec(99),endref(99),ueccur(99),  
*   endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),  
*   rmedes(4,750),rmeid(750),meaidn(750),  
*   rmecst(750),rmepcs(750),rmesav(750),  
*   mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),  
*   rmeemp(750),rmeemf(750),rmesea(750),rmeupd(750)  
c  
c   /result/ contains some results  
c  
c   common/result/iorder(750),cce(750),aes(750),cumsav(750)  
c  
c   common/acorr/idata(5100)  
c  
c   write (6,200)  
c   write (6,201)  
c   write (6,202)  
c   write (6,204)  
c  
c   read in data from control cards  
c  
c   call readcc  
c  
c   read in major data base  
c  
c   call readdb  
c  
c   print enduse table  
c  
c   if (.not.rwork4.and.isnap(1).lt.istay) call preнду(isnap(1))
```



```

c
c   print long (input) measure table if requested
c
c   do 10 i=1,750
c     iorder(i)=i
10  continue
c     if (.not.rwork4.and.isnap(1).lt.istay)call prmeas(1,nmea,isnap(1))
c
c   call main loop
c
c   call mnloop
c
c   write (6,201)
c   write (6,203)
c
c   print input if requested
c
c   call echo
c   stop
c
c 200 format(1h1)
c
c   masthead is printed at the end and the
c   beginning of the program output
c
c 201 format(
c   * T47, * -----*,/,
c   * T47, * -   cps 2.0 version winter 1983   -*,/,
c   * T47, * -   building energy data group   -*,/,
c   * T47, * -   energy and environment division -*,/,
c   * T47, * -   lawrence berkeley laboratory  -*,/,
c   * T47, * -   berkeley, california 94720   -*,/,
c   * T47, * -----*)
c 202 format(T47,* ----- start -----*,/)
c 203 format(T47,* ----- end -----*)
c 204 format(t45,* (Refer to Appendix C for column descriptions)*,/)
c   end
c   subroutine readcc
c
c   read in control cards from unit 5
c
c
c   /cntrl/ contains control information
c
c   common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
c   * adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
c   * elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
c   * ,tcc(99)
c   logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c   /result/ contains some results
c
c   common/result/iorder(750),cce(750),aes(750),cumsav(750)
c

```

```

c     some variables
c
c     dimension card(8),temp(2)
c
c     set counters
c
c     isnapn=0
c     iendus=0
c     inotyp=0
c     itcc =0
c
c     set some crucial variables to -1
c
c     discou=-1.
c     do 5 kk=1,2
c     elecpr(kk)=-1.
c     gaspri(kk)=-1.
c     oilpri(kk)=-1.
c 5 continue
c
c     set some default values
c
c     adminc=.false.
c     bpapen=.false.
c     curves=.false.
c     tables=.false.
c     rwork4=.false.
c     priuec=.false.
c     ema=.false.
c     emi=.false.
c     ecc=.false.
c     idiag=0
c
c     next card will be read here
c
c     write (6,240)
c 10 continue
c     read (5,101) card
c     if (eof(5).ne.0) goto 80
c
c     mask out first three letters
c
c     cmd=card(1).and.mask(18)
c
c     if (cmd.eq.3ladm) adminc=.true.
c     if (cmd.eq.3lbpa) bpapen=.true.
c     if (cmd.eq.3lcur) curves=.true.
c     if (cmd.eq.3ltab) tables=.true.
c     if (cmd.eq.3lwor) rwork4=.true.
c     if (cmd.eq.3luec) priuec=.true.
c     if (cmd.eq.3lema) ema=.true.
c     if (cmd.eq.3lemi) emi=.true.
c     if (cmd.eq.3lecc) ecc=.true.
c

```

```

    if (cmd.eq.31dis) goto 20
c
    if (cmd.eq.31dia) goto 25
    if (cmd.eq.31sta) goto 25
c
    if (cmd.eq.31ele) goto 30
    if (cmd.eq.31gas) goto 30
    if (cmd.eq.31oil) goto 30
c
    if (cmd.eq.31sna) goto 35
c
    if (cmd.eq.31end) goto 55
    if (cmd.eq.31not) goto 55
    if (cmd.eq.31tcc) goto 55
c
    goto 10
c
    decode one real number
c
20 continue
    decode (20,301,card) discou
    goto 10
c
    decode one integer number
c
25 continue
    decode (20,302,card) itemp
    if (cmd.eq.31dia) idia=itemp
    if (cmd.eq.31sta) istay=itemp
    goto 10
c
    decode two real numbers
c
30 continue
    decode (30,303,card) temp
    do 32 kk=1,2
    if (cmd.eq.31ele) elecpr(kk)=temp(kk)
    if (cmd.eq.31gas) gaspri(kk)=temp(kk)
    if (cmd.eq.31oil) oilpri(kk)=temp(kk)
32 continue
    goto 10
c
    decode up to 31 integer numbers
c
    numbers start on card following snap-card
c
    end of data is signalled by a not completely filled line
c
    input format is 16i5
c
35 continue
    do 45 jj=1,2
    read (5,102) (isnap(isnap+kk),kk=1,16)
    do 40 kk=1,16
    if (isnap(isnap+1).eq.0) goto 50
    isnap=isnap+1
40 continue

```

```

45 continue
50 continue
   goto 10

c
c   decode up to 99 real numbers
c   numbers start on card following enduse/typcno card
c   end of data is signalled by a not completely filled line
c   input format is 8f10.1
c

55 continue
   itemp=0
   do 65 jj=1,13
   if (cmd.eq.3lend) read (5,103) (enduse(itemp+kk),kk=1,8)
   if (cmd.eq.3lnot) read (5,103) (typcno(itemp+kk),kk=1,8)
   if (cmd.eq.3ltcc) read (5,103) (tcc (itemp+kk),kk=1,8)
   do 60 kk=1,8
   if (cmd.eq.3lend.and.enduse(itemp+1).eq.10h ) goto 70
   if (cmd.eq.3lnot.and.typcno(itemp+1).eq.10h ) goto 70
   if (cmd.eq.3ltcc.and.tcc (itemp+1).eq.10h ) goto 70
   itemp=itemp+1
60 continue
65 continue
70 continue
   if (cmd.eq.3lend) iendus=itemp
   if (cmd.eq.3lnot) inotyp=itemp
   if (cmd.eq.3ltcc) itcc =itemp
   goto 10

c
c   end of input      echo and validate
c

80 continue
   write (6,201) iddiag

c

   write (6,203) adminc
   write (6,204) bpapen
   write (6,205) curves
   write (6,206) tables
   write (6,207) rwork4
   write (6,208) priuec
   if (ema) write (6,241)
   if (emi) write (6,242)
   if (ecc) write (6,243)
   write (6,244)

c

   if (istay.le.0) write (6,214)
   if (istay.le.0) istay=1980
   write (6,202) istay

c

   if (isnapn.gt.31) write (6,209) isnapn
   if (isnapn.gt.31) stop
   if (isnapn.eq.0) write (6,230)
   if (isnapn.eq.0) isnap(1)=istay
   if (isnapn.eq.0) isnapn=1
   write (6,210) isnapn,(isnap(kk),kk=1,isnapn)

```

```

c
  if (iendus.le.0.or.iendus.gt.99) write (6,211) iendus
  if (iendus.le.0.or.iendus.gt.99) stop
  write (6,212) iendus,(enduse(kk),kk=1,iendus)
c
  if (inotyp.gt.0) write (6,213)
  * inotyp,(typcno(kk),kk=1,inotyp)
c
  if (itcc.gt.0) write (6,223)
  * itcc,(tcc(kk),kk=1,itcc)
  if (itcc.gt.0.and.isnap(1).ne.istay.and.isnap(2).ne.istay)
  * write(6,224)

c
c   snapshot years have to be ordered
c
  isncmp=0
  do 82 kk=1,isnapn
  if (isnap(kk).gt.isncmp) goto 81
  write (6,222)
  stop
81 continue
  isncmp=isnap(kk)
82 continue

c
  if (discou.lt.0.) write (6,215)
  if (discou.lt.0.) discou=0.03
  if (discou.eq.0) write (6,216)
  if (discou.eq.0) discou=1.e-10
  write (6,217) discou

c
c   check for fuel-consistency
c
  fuelty=shift(enduse(1),42).and.mask(6)
  if (fuelty.ne.11e.and.fuelty.ne.11g.and.fuelty.ne.11o)
  * write (6,218) fuelty
  if (fuelty.ne.11e.and.fuelty.ne.11g.and.fuelty.ne.11o)
  * stop

c
  if (iendus.eq.1) goto 90
  do 85 kk=2,iendus
  fueltz=shift(enduse(kk),42).and.mask(6)
  if (fuelty.eq.fueltz) goto 85
  write (6,219) kk,enduse(kk),fueltz
  stop
85 continue
90 continue

c
c   check for energy prices if uecs are requested
c
  if (.not.priu.ec) goto 100
  if (fuelty.eq.11e.and.(elecpr(1).eq.-1..or.elecpr(2).eq.-1.))
  * write (6,220)
  if (fuelty.eq.11e.and.(elecpr(1).eq.-1..or.elecpr(2).eq.-1.))

```

```

* stop
  if (fuelty.eq.llg.and.(gaspri(1).eq.-1..or.gaspri(2).eq.-1.))
* write (6,220)
  if (fuelty.eq.llg.and.(gaspri(1).eq.-1..or.gaspri(2).eq.-1.))
* stop
  if (fuelty.eq.llo.and.(oilpri(1).eq.-1..or.oilpri(2).eq.-1.))
* write (6,220)
  if (fuelty.eq.llo.and.(oilpri(1).eq.-1..or.oilpri(2).eq.-1.))
* stop
c
  if (fuelty.eq.lle) write (6,250) (elecpr(kk),kk=1,2)
  if (fuelty.eq.llg) write (6,251) (gaspri(kk),kk=1,2)
  if (fuelty.eq.llo) write (6,252) (oilpri(kk),kk=1,2)
c
100 return
c
101 format(8a10)
102 format(16i5)
103 format(8a10)
c
201 format(* diagnostic level           is *,i5)
202 format(* start year *,/,5x,i5)
203 format(* including administrative cost is *,15)
204 format(* using program pen. and frac. is *,15)
205 format(* printing supply curves     is *,15)
206 format(* printing supply tables     is *,15)
207 format(* calling work4 only         is *,15)
208 format(* printing uecs              is *,15)
209 format(* invalid number of snapshot years *,i5)
210 format(* number of snapshot years *,i5,/,5x,16i5,/,5x,16i5)
211 format(* invalid number of enduses *,i5)
212 format(* number of enduses *,i5,10(/5x,10a11))
213 format(* number of enduses work4 is not called*,i5,10(/,5x,10a11))
214 format(* warning no input for program start year. default taken *)
215 format(* warning no input for discontrate. default taken *)
216 format(* discount rate read in as zero. changed to 1.e-10 *)
217 format(* discount rate *,/,f15.5)
218 format(* invalid fueltyp *,a1)
219 format(* enduse *,i3,a1,* has wrong fueltype *,a1).
220 format(* uecs requested but energy price is not set *)
222 format(* snapshot years have to be ordered *)
223 format(* number of enduses tccs are requested*,i5,10(/,10a11))
224 format(* warning tccs wont print,snapshot must equal start year *)
230 format(* warning no input for snapshot year. default taken *)
240 format(*           program parameters *)
241 format(* printing major data base     is      t*)
242 format(* printing minor data base     is      t*)
243 format(* printing control cards       is      t*)
244 format(//)
250 format(* electricity price($/kwh) and annual escalation rate*,/,
  * 10x,2f15.5,/)
251 format(* gas price($/therm) and annual escalation rate*,
  * /,10x,2f15.5,/)
252 format(* oil price($/gal) and annual escalation rate*,/,10x,

```

```

      * 2f15.5,/)
c
301 format(10x,f10.1)
302 format(10x,i10)
303 format(10x,2f10.1)
c
      end
      subroutine readdb
c
c      reads major data base from unit 1
c
c
c      /cntrl/ contains control information
c
      common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
      logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c      /majdb/ contains major data base
c
      common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmcst(750),rmecs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmesea(750),rmeupd(750)
c
c      /result/ contains some results
c
      common/result/iorder(750),cce(750),aes(750),cumsav(750)
c
      logical enshow
      dimension card(8),card2(8)
      data nmeamx/750/
c
      nmea=0
c
      do 25 i=1,iendus
      if (i.eq.1) imepoi(i)=0
      imepoi(i+1)=imepoi(i)
      imenum(i)=0
c
      rewind 1
      enshow=.false.
c
c      look for enduse and measure cards
c
10 continue
      read (1,101) card
      if (eof(1).ne.0) goto 20

```

```

c
c   measure or enduse
c
c   cardty=card(5).and.mask(6)
c   if (cardty.eq.11m) read(1,101) card2
c   if (cardty.ne.11e.and.cardty.ne.11m) write (6,201) card
c   if (cardty.ne.11e.and.cardty.ne.11m) stop
c
c   compare
c
c   shend=shift(enduse(i),6).and.mask(54)
c   shin =shift(card(5) ,6).and.mask(54)
c   if (shend.ne.shin) goto 10
c   if (cardty.eq.11m) goto 15
c
c   matching enduse found
c
c   decode (80,301,card) (enddes(kk,i),kk=1,4),endid(1),enduec(1),
*   endsto(1),endadd(1),enddec(1),iendmn(1),endupd(1)
c   enshow=.true.
c   goto 10
c
c   matching measure found
c
c   15 nmea=nmea+1
c   if (nmea.gt.nmeamx) write (6,205)
c   if (nmea.gt.nmeamx) stop
c
c   imenum(i)=imenum(i)+1
c   imepoi(i+1)=imepoi(i+1)+1
c
c   decode (80,302,card) (rmedes(kk,nmea),kk=1,4),rmeid(nmea),
*   meaidn(nmea),rmecst(nmea),rmepcs(nmea),rmesav(nmea),
*   mealif(nmea),measta(nmea),measto(nmea)
c   decode (80,303,card2) rmerli(nmea),rmeelf(nmea),rmeemp(nmea),
*   rmeemf(nmea),rmesea(nmea),rmeupd(nmea)
c   goto 10
c
c   end of file found
c
c   20 continue
c   if (idiag.gt.0) write (6,202) i,enduse(i),imenum(i)
c   if (.not.enshow) write (6,203) i,enduse(i)
c   if (.not.enshow) stop
c   25 continue
c
c   if (idiag.gt.0) write (6,204) iendus,nmea
c
c   reset cumsav
c
c   do 30 kk=1,nmea
c   aes(kk)=0.
c   30 continue
c

```



```

c      check for decay (replacement).ne. 0 for new stock enduse
c
      ierst=0
      do 40 i=1,iendus
      if (imenum(i).le.0) goto 40
      stckty=shift(rmeid(i),6).and.mask(6)
      if (stckty.ne.1ln) goto 40
      if (enddec(i).ne.0.) goto 40
      write (6,206) endid(i)
      ierst=ierst+1
40    continue
      if (ierst.gt.0) stop
      return
c
101  format(8a10)
201  format(* invalid input card*,/,* *,8a10)
202  format(* enduse*,i4,all,* with*,i4,* measures*)
203  format(* no enduse data for enduse*,i4,all)
204  format(* total of *,i9,* enduses with*,i4,* measures*)
205  format(* too many measures*)
206  format(* enduse *,a10,* stock type new, has no replacement rate*)
301  format(5a10,f6.0,f5.0,2f4.0,i1,a5)
302  format(5a10,i2,f6.0,f5.0,f6.0,i3,2i4)
303  format(4f5.0,a4,a5)
      end
      subroutine prenu(iyear)
c
c      prints enduse tables
c
c
c      /cntrl/ contains control information
c
      common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
      logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c      /majdb/ contains major data base
c
      common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmcst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmeesa(750),rmeupd(750)
c
c      /result/ contains some results
c
      common/result/iorder(750),cce(750),aes(750),cumsav(750)
      data maxlin/50/
c

```

```

lincnt=maxlin
tsto=0.
ssto=0.
tbase=0.
sbase=0.
tpot=0.
spot=0.
c
do 10 i=1,iendus
lincnt=lincnt+1
if (i.eq.1) oldid=endid(i).and.mask(18)
if (lincnt.lt.maxlin) goto 5
c
c
c print header
c
write (6,201) iyear
write (6,210)
write (6,202)
write (6,203)
write (6,204)
lincnt=0
c
c
c print data
c
c
c 5 continue
c
rnewid=endid(i).and.mask(18)
if (rnewid.eq.oldid) goto 8
if (ssto.eq.0.) sbuec=0.
if (ssto.eq.0.) spuec=0.
c
c
c for stock that have reached zero
c skip past uec calculations to avoid calculation of infinite
c
if (ssto.eq.0.) goto 7
sbuec=sbase*1000./ssto
spuec=spot *1000./ssto
c
c
c print subtotals for groups based on the
c first 3 characters of the enduse id code
c
c
c 7 write (6,221) ssto,sbuec,sbase,spuec,spot
sbuec=0.
spuec=0.
ssto=0.
sbase=0.
spot=0.
c 8 continue
c
endusa=endsto(i)*enduec(i)/1000.
if (iyear.ge.istay) potusa=endsto(i)*ueccur(i)/1000.
c
c
c determine enduse stocktype
c if the stocktype is old and the stock is zero

```

```

c   then go to 9 and set the enduec and the ueccur to zero (0)
c   these are indicated by the variable dummy
c
c   stckty=shift(endid(i),6).and.mask(6)
c   if(stckty.eq.110.and.endsto(i).eq.0) go to 9
c
c   write (6,205) (enddes(kk,i),kk=1,4),endid(i),endsto(i),
*   endadd(i),enddec(i),enduec(i),endusa,ueccur(i),potusa,
*   iendmn(i),endupd(i)
c   goto 311
9   dummy=0.
c   write (6,206) (enddes(kk,i),kk=1,4),endid(i),endsto(i),
*   endadd(i),enddec(i),dummy,endusa,dummy,potusa,
*   iendmn(i),endupd(i)
c
c
c   add up subtotals and totals
c
c   311 oldid=endid(i).and.mask(18)
c       tsto=tsto+endsto(i)
c       ssto=ssto+endsto(i)
c       tbase=tbase+endsto(i)*enduec(i)/1000
c       sbase=sbase+endsto(i)*enduec(i)/1000
c       if (iyear.ge.istay) tpot=tpot+endsto(i)*ueccur(i)/1000
c       if (iyear.ge.istay) spot=spot+endsto(i)*ueccur(i)/1000
10  continue
c
c   if(ssto.eq.0.) goto 11
c   sbuec=sbase*1000./ssto
c   spuec=spot *1000./ssto
c   go to 12
11  sbuec=0.
c   spuec=0.
c   sbase=0.
c   spot=0.
c
c   write out final subtotal before printing total
c
c   12 write (6,221) ssto,sbuec,sbase,spuec,spot
c
c   print totals for the entire end use table
c   totals do not include baseline and potential uecs
c
c   write (6,220) tsto,tbase,tpot
c   if (iyear.lt.istay) write (6,211)
c   return
c
201 format(1h1,i5,* enduse table*,//)
202 format(
* * end use description          id code      total *,
* * add      decay or      baseline    potential    work4 *,
* * last      *)
203 format(
* *
* * stock *,

```

```

    ** rate      replace   uec      usage      uec      usage  used *,
    ** update *)
204 format(
    **
    **                                (1000s) *,
    **          rate (kwh/yr) (gwh) (kwh/yr) (gwh) *,/)
205 format(* *,4a10,1x,a10,1x,f5.0,3x,f7.3,3x,f5.3,3x,
    * f6.0,3x,f7.1,2x,f7.0,3x,f7.1,3x,i1,3x,a5,)
206 format(* *,4a10,1x,a10,1x,f5.0,3x,f7.3,3x,f5.3,3x,
    * f6.0,3x,f7.1,2x,f7.0,3x,f7.1,3x,i1,3x,a5,)
c
210 format(
    **          (a)                                (b)      (c)  *,
    ** (d)      (e)                                (f)      (g)      (h) *,
    ** (i)      *)
211 format(T30,*caution new stock values are entered as total *
    *existing stock.*,/)
220 format(* total *,39x,
    * f7.0,30x,f7.1,10x,f9.1)
221 format(* subtotal*,39x,
    * f7.0,20x,f7.0,3x,f7.1,2x,f7.0,f10.1)
    end
    subroutine prmeas(length,imea,iyear)
c
c prints measure tables length=0 short;length=1 long
c long form is the conservation measure input table
c short form is the conservation measure output table
c
c /cntrl/ contains control information
c
c common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,rmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
    logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c /majdb/ contains major data base
c
c common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmecst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmesea(750),rmeupd(750)
c
c /result/ contains some results
c
c common/result/iorder(750),cce(750),aes(750),cumsav(750)
data maxlin/50/
c
c logical todo
c
c if (imea.le.0) return

```

```

    lincnt=maxlin
    todo=.true.
    if (iyear.lt.istay) goto 1
    if (elecpr(3).lt.0.) todo=.false.
1 continue
c
    do 20 j=1,imea
    i=iorder(j)
    lincnt=lincnt+1
    if (lincnt.lt.maxlin) goto 5
c
c    print header
c
    if (length.le.0) goto 2
    write (6,201) iyear
    write (6,210)
    write (6,202)
    write (6,203)
    write (6,204)
    goto 4
2 continue
    write (6,211) iyear
    write (6,214)
    write (6,212)
    write (6,213)
4 continue
    lincnt=0
c
c    print data
c
5 continue
c
    if (length.le.0) avmw=cumsav(i)*114.16
c
    if (length.gt.0)
* write (6,205) (rmedes(kk,i),kk=1,4),rmeid(i),meaidn(i),
* rmcst(i),rmepcs(i),rmesav(i),mealif(i),measta(i),measto(i),
* rmerli(i),rmeemp(i),rmeelf(i),rmeemf(i),rmeupd(i),rmesea(i)
c
c    print cutoff price line
c
    if (iyear.lt.istay) goto 9
    if (todo.and.elecpr(3).lt.cce(i)) write (6,220) elecpr(3)
    if (todo.and.elecpr(3).lt.cce(i)) todo=.false.
9 continue
    if (length.le.0.and.aes(i).le.0) go to 14
    if (length.le.0)
* write (6,215) j,(rmedes(kk,i),kk=1,4),rmeid(i),meaidn(i),
* rmcst(i),rmesav(i),mealif(i),rmeelf(i),cce(i),aes(i),
* cumsav(i),avmw
    go to 20
14 write (6,216) j,(rmedes(kk,i),kk=1,4),rmeid(i),meaidn(i)
20 continue
c

```

```

        return
c
201 format(1h1,i5,* conservation measure input table*,//)
202 format(
    ** measure description                id code      meas*,
    ** progms meas  life star  end  roll prog  elig prog  last *,
    ** season*)
203 format(
    **
    ** cost sav          year year  in  pen  frac frac  updat*,
    ** value*)
204 format(
    **
    ** (80$) (kwh/yr)(yrs)                (yrs) (yrs)                (80$)*
    ** (80$) (kwh/yr)(yrs)                (yrs) (yrs)                *,/)
205 format(* *,4a10,1x,a10,1x,i2,1x,f6.0,1x,f5.0,1x,f6.0,1x,i4,
    * 2x,i4,1x,i4,1x,4(f5.3,1x),a5,1x,a4)
210 format(
    **      (a)                (b)                (c) *,
    **      (d) (e)      (f) (g)  (h)  (i) (j)  (k) (l)  (m) *,
    **      (n) *)
211 format(1h1,i5,* conservation measure output table*,//)
212 format(
    **      measure description                id code      *,
    ** tot savings life elig  cce  totalsav cum. total *,
    **savings *)
213 format(
    **
    ** cost (kwh)  (yrs) frac ($/kwh) (gwh)  (twh) (avg mw)*,/)
214 format(
    **      (a)                (b)                *,
    ** (c) (d)      (e) (h)  (g)  (h)                (i) *)
215 format(* *,i3,1x,4a10,1x,a10,1x,i2,1x,f6.0,1x,f6.0,2x,
    * i4,1x,f5.3,1x,f5.3,1x,3(f7.1,1x))
216 format(* *,i3,1x,4a10,1x,a10,1x,i2,
    ** stock decayed to zero or measure rolled out, no savings*)
220 format(* ++++++*,
    1 * cut off price is *,f7.3,
    2      * ++++++*)
    end
    subroutine mnloop
c
c    main loop
c
c
c
c
c    /cntrl/ contains control information
    common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
    * adminc,bpopen,curves,tables,rwork4,priuec,emi,ema,ecc,
    * elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
    * ,tcc(99)
    logical adminc,bpopen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c    /majdb/ contains major data base

```

```

c
common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmecst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmesea(750),rmeupd(750)

c
c /result/ contains some results
c
common/result/iorder(750),cce(750),aes(750),cumsav(750)
c
c /minmaj/ contains transfer variables between major and minor db
c
common/minmaj/imtran,jorder(99),eligav(20),avelif(20),cosave(20),
* savave(20)

c
dimension korder(99)

c
statement function for cce
c
ccef(savi,cost,life)=cost/savi*discou/(1.-(1.+discou)**(-life))
c
c loop over years
c
do 80 i=istay,isnap(isnapn)
c
c calculate energy prices
c
if (i.eq.istay) elecpr(3)=elecpr(1)
if (i.eq.istay) gaspri(3)=gaspri(1)
if (i.eq.istay) oilpri(3)=oilpri(1)
c
if (elecpr(1).gt.-1.) elecpr(3)=elecpr(3)*(1.+elecpr(2))
if (gaspri(1).gt.-1.) gaspri(3)=gaspri(3)*(1.+gaspri(2))
if (oilpri(1).gt.-1.) oilpri(3)=oilpri(3)*(1.+oilpri(2))
c
kmea is counter for active measures during this year
c
kmea=0
if (idiag.gt.0) write (6,201) i
c
c loop over enduses
c
do 35 j=1,iendus
if (i.eq.istay) ueccur(j)=enduec(j)
c
c set reference stock
c
stckty=shift(endid(j),6).and.mask(6)
if (i.eq.istay) endref(j)=endsto(j)
if (i.eq.istay.and.stckty.eq.1ln) endsto(j)=0.

```

```

c
c   branch according to different stock types
c
   if (stckty.eq.11e) goto 20
   if (stckty.eq.11o) goto 25
   if (stckty.eq.11n) goto 30
   write (6,203) endid(j)
   stop
c
c   existing stocktype
c
20  endsto(j)=endsto(j)*(1.+endadd(j)-enddec(j))
   goto 33
25  continue
c
c   old stocktype
c
   endsto(j)=endsto(j)-enddec(j)*endref(j)
   if (endsto(j).le.0) endsto(j)=0.
   goto 33
c
c   new stocktype
c
30  continue
   alif=1./enddec(j)
   ilif=alif
   replo=(i-istay)*endref(j)*enddec(j)
   if (i-istay .lt. ilif) repln=replo+endref(j)*enddec(j)
   if (i-istay .eq. ilif) repln=replo+endref(j)*(1.-ilif*enddec(j))
   if (i-istay .gt. ilif) replo=endref(j)
   if (i-istay .gt. ilif) repln=replo
c
   endsto(j)=(endsto(j)-replo+endref(j))*(1.+endadd(j))
   *      -endref(j)+repln
   replo=repln
33  continue
c
   if (imenum(j).le.0) goto 35
c
c   set up list of active measures for work4 for this year
c
   imtran=0
   do 1 k=1,imenum(j)
   imea=imepoi(j)+k
   cce(imea)=1.e10
c
c   add program cost if necessary
c
   if (i.eq.istay.and.adminc) rmcst(imea)=rmcst(imea)+rmepcs(imea)
   if ((i.lt.measta(imea))
*      .or.((measto(imea).ne.0.).and.(i.ge.measto(imea)))) goto 1
   imtran=imtran+1
   jorder(imtran)=meaidn(imea)
   korder(imtran)=imea

```



```

1 continue
  if (imtran.le.0) goto 10
c
c   decide whether or not to call work4
c
  if (iendmn(j).eq.0) goto 10
c
c   check in notypc list
c
  if (inotyp.le.0) goto 4
  do 2 k=1,inotyp
  if (endid(j).eq.typcno(k)) goto 10
2 continue
4 continue
c
c   first year ? then call
c
  if (i.eq.istay) goto 8
c
c   new measures starting this year
c
  do 6 k=1,imenum(j)
  imea=imepoi(j)+k
  if ((measta(imea).eq.i).or.(measto(imea).eq.i)) goto 8
6 continue
  goto 10
c
c   call work4
c
8 continue
  write (6,202) endid(j),i
  call work4t(endid(j),uecbef)
  if (rwork4) goto 35
  if (i.eq.istay) write (6,206) enduec(j),uecbef
  if (enduec(j)/uecbef.lt..95.or.enduec(j)/uecbef.gt.1.05)
* write(6,207)
c
c   write results into major data base
c
  do 9 k=1,imtran
  meatmp=korder(k)
  rmcst(meatmp)=cosave(k)
c
c   add program cost if necessary
c
  if (adminc) rmcst(meatmp)=rmcst(meatmp)+rmepcs(meatmp)
  rmesav(meatmp)=savave(k)
  mealif(meatmp)=avelif(k)
  rmeelf(meatmp)=eligav(k)
9 continue
c
C.... if running only work4 then go to next enduse
C.... else compute savings for each measure and print
C.... appropriate tables etc.

```

```

c
  10 continue
    if (rwork4) goto 35
c
c   compute savings
c
  do 15 k=1,imenum(j)
    imea=imepoi(j)+k
    if (idiag.gt.2) write (6,204) imea,rmeid(imea),meaidn(imea)
c
c   replace rmeelf/rmerli with user penetration rate if requested
c
    if (bpapen.and.i.eq.istay) rmeelf(imea)=rmeemf(imea)
    if (bpapen.and.i.eq.istay) rmerli(imea)=rmeemp(imea)
c
c   measures which are not active (have not started
C.... to roll in) at the moment are flagged with cce = 1.e10
C.... and control passes to the end of the loop (next measure)
C   they will not be printed in measure tables
c
    if (i.ge.measta(imea)) goto 12
    if (idiag.gt.2)
      * write (6,205) imea,i,measta(imea),measto(imea)
      cce(imea)=1.e10
      goto 15
c
  12 continue
c
C.... calculate the savings for all measures for which
C.... the present year is larger than the start year for that
C.... measure. This will include active measures (those rolling
C.... in), measures which have completed their rollin, and
C.... measures which have been active and are rolling
C.... out (or have rolled out).
C.... If the measure is rolling(ed) in the program
C.... calculates "fr" which is
C.... the fraction (of the eligible fraction) that has been
C.... rolled in. Not allowed to be more than 1.
C.... (Note that a test has been performed above skipping all
C.... measures which have not started rolling in.)
C.... If the measure is rolling out then "frin", the fraction
C.... of the eligible fractin that rolled in before the stop
C.... year was reached is calculated. Once again not allowed
C.... to be more than 1. Then fr is calculated which
C.... is now the fraction
C.... (of the elig frac) that is still left in place.
C.... Not allowed to be less than 0.
C.... The denominator in the calculation of "fr" is the number
C.... of years since the measure started to rollin or rollout, plus
C.... 1. (Thus it rolls in (out) one years worth in the year that
C.... it begins.)
C.... kmea is a counter of measures which have had thier savings
C.... calculated for use later.
c

```

```

c
  kmea=kmea+1
  year=float(i)

  if ((measto(imea).ne.0.).and.(year.ge.measto(imea))) goto 22
C.... measure is rolling(ed) in
  fr = (year-measta(imea)+1)/rmerli(imea)
  if (fr.gt.1.) fr=1.
  goto 23

C.... measure in rolling(ed) out
  22 frin = (measto(imea)-measta(imea)+1)/rmerli(imea)
  if (frin.gt.1.) frin=1.

  fr = frin - (year-measto(imea)+1)/rmerli(imea)
  if (fr.lt.0.) fr=0.

  23 continue

C.... savings now calculated using the stock this year,
C.... the eligible fraction, the fr from above, the savings
C.... per instalation, and a unit changing factor.

  aes(imea)=endsto(j)*rmeelf(imea)*fr*rmesav(imea)*1000.
c
C.... write diagnostic if this measure is rolling out.
  if (idiag.gt.2.and.measto(imea).ne.0..and.i.ge.measto(imea))
  * write (6,208) imea,i,measto(imea)
c
C.... calculate CCE, this could be done only first year and
C.... any year where work4 was called for the enduse
C.... (or had been since last cce calc if I change this to
C.... only do savings loop for snapshot yrs.)

  cce(imea)=ccef(rmesav(imea),rmecst(imea),mealif(imea))
  15 continue
c
c   produce tcc if requested
c
  if (i.ne.istay.or.itcc.le.0) goto 35
  do 155 kk=1,itcc
  if (endid(j).eq.tcc(kk)) call tccsub(j)
155 continue
c
  35 continue
  if (rwork4) return
c
c   snapshot year or not
c
  do 40 j=1,isnapn
  if (i.eq.isnap(j)) goto 45
40 continue
  goto 80
c

```

```

c     yes
c
c     45 continue
c
c     order cce
c
c     call sortcc(nmea,iorder,cce)
c     if (priuec) call caluec
c     if (priuec) call prenu(i)
c     if (.not.tables) goto 80
c
c     calculate cumulative energy savings
c
c     if (kmea.lt.0) goto 80
c     cumsav(iorder(1))=aes(iorder(1))
c     if (kmea.le.1) goto 55
c     do 50 j=2,kmea
c     cumsav(iorder(j))=cumsav(iorder(j-1))+aes(iorder(j))
50 continue
55 continue
c
c     change to different units
c
c     aes from kwh to gwh
c
c     cumsav from kwh to twh
c
c     do 60 j=1,kmea
c     aes(iorder(j))=aes(iorder(j))/1000000.
c     cumsav(iorder(j))=cumsav(iorder(j))/1000000000.
60 continue
c
c     if (curves) call plospc(kmea,i)
c     if (tables) call prmeas(0,kmea,i)
c
c     change back
c
c     do 70 j=1,kmea
c     aes(iorder(j))=aes(iorder(j))*1000000.
c     cumsav(iorder(j))=cumsav(iorder(j))*1000000000.
70 continue
c
c     80 continue
c     return
201 format(//,* anno domini *,i5,/)
202 format(* calling work4 for enduse *,a10,* year=*,i5)
203 format(* invalid stock type in enduse *,a10)
204 format(* handling measure *,i3,lx,a10,i3)
205 format(* measure *,i4,* skipped in year*,i5,* start *,i5,
*     * stop *,i5)
206 format(/,15x * major data base uec*,f10.0/,/ ,15x
*     * minor data base uec*,f10.0,/)
207 format(/,20x,7h *****,* caution policymaker*,7h *****,
* /,* uecs assumed in major data base and calculated in work4*,

```

```

* * differ by more than 5 percent*,//)
208 format(* measure *,14,* is rolling(ed) out in year*,i5,
* * it started to rollout in *,i5)
end
subroutine sortcc(n,list,elemen)
c
c sort n elements of array elemen in ascending order
c the order of the elements is not changed, instead
c the elements of an list array are ordered
c
dimension list(n),elemen(n)
c
do 10 j=1,n
10 list(j)=j
c
m=n
30 m=m/2
if (m.eq.0) goto 70
k=n-m
j=0
40 if (j.ge.k) goto 30
j=j+1
l2=j
50 l1=l2+m
i1=list(l1)
i2=list(l2)
if (i1.eq.0) goto 70
if (elemen(i1).lt.elemen(i2)) i2=0
if (i2) 60,60,40
60 list(l1)=list(l2)
list(l2)=i1
l2=l2-m
if (l2) 40,40,50
70 continue
return
end
subroutine caluec
c
c calculates uec for enduses
c
c
c /cntrl/ contains control information
c
common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspr(3),oilpr(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c /majdb/ contains major data base
c
common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endld(99),
* enduec(99),endref(99),ueccur(99),

```

```

* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmcst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmesea(750),rmeupd(750)
c
c /result/ contains some results
c
common/result/iorder(750),cce(750),aes(750),cumsav(750)
c
if (idiag.gt.0.and.elecpr(1).gt.-1.) write (6,201) elecpr(3)
if (idiag.gt.0.and.gaspri(1).gt.-1.) write (6,202) gaspri(3)
if (idiag.gt.0.and.oilpri(1).gt.-1.) write (6,203) oilpri(3)
c
do 20 i=1,iendus
c
if (endsto(i).le.0.) goto 20
fuelt=shift(endid(i),42).and.mask(6)
c
if (imenum(i).le.0) goto 20
sum=0.
c
do 10 j=1,imenum(i)
imea=imepoi(i)+j
c
c add aggregate energy savings for energy price .gt. cce
c
if (fuelt.eq.1le.and.cce(imea).lt.elecpr(3)) sum=sum+aes(imea)
if (fuelt.eq.1lg.and.cce(imea).lt.gaspri(3)) sum=sum+aes(imea)
if (fuelt.eq.1lo.and.cce(imea).lt.oilpri(3)) sum=sum+aes(imea)
10 continue
c
c divide sum by total stock and subtract from original uec
c
sum=sum/endsto(i)/1000.
ueccur(i)=enduec(i)-sum
20 continue
c
return
201 format(* current electricity price is *,f10.5)
202 format(* current gas price is *,f10.5)
203 format(* current oil price is *,f10.5)
end
subroutine echo
c
c echoes input
c
c /cntrl/ contains control information
c
common/cntrl/discou,idiag,istay,iendus,ismapn,inotyp,itcc,nmea,
* adminc,bpape,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),ismap(31),enduse(99),typcno(99)
* ,tcc(99)
logical adminc,bpape,curves,tables,rwork4,priuec,emi,ema,ecc

```

```

c
dimension card(8)
data maxlin/50/

c
give measures in output a numbering

c
real measur
data measur/7hmeasure/
data imtes/20/
data blank/1h /
dimension symbar(11)
data symbar/1ha,1hb,1hc,1hd,1he,1hf,1hg,1hh,1hi,1hj,1hk/
measur=measur.and.mask(42)

c
do 20 i=1,3

c
lincnt=maxlin

c
if (i.eq.1.and..not.ema) goto 20
if (i.eq.2.and..not.emi) goto 20
if (i.eq.3.and..not.ecc) goto 20

c
if (i.eq.1) rewind 1
if (i.eq.2) rewind 2
if (i.eq.3) backspace 5

c
5 continue

c
if (i.eq.1) read (1,101) card
if (i.eq.2) read (2,101) card
if (i.eq.3) read (5,101) card

c
if (i.eq.1.and.eof(1).ne.0) goto 20
if (i.eq.2.and.eof(2).ne.0) goto 20
if (i.eq.3.and.eof(5).ne.0) goto 20

c
count lines after a measure card

c
test=card(1).and.mask(42)
imtes=imtes+1
if (test.eq.measur.and.i.eq.2) imtes=0

c
lincnt=lincnt+1
if (lincnt.lt.maxlin) goto 10

c
if (i.eq.1) write (6,201)
if (i.eq.2) write (6,202)
if (i.eq.3) write (6,203)
lincnt=0

c
10 continue

c
if (lincnt/10*10.eq.lincnt) write (6,205)

c

```

```

c      include symbol in front of measures
c
      symb=blank
      if (imtes.gt.0.and.imtes.lt.12) symb=symbar(imtes)
      write (6,204) symb,card
      goto 5
c
      20 continue
c
      return
101 format(8a10)
201 format(1h1,* listing of major data base*,/)
202 format(1h1,* listing of minor data base*,/)
203 format(1h1,* listing of control cards *,/)
204 format(* *,a1,lx,8a10)
205 format(* *,*.....+.....1.....+.....2.....+.....3.....+.....4.....+.....5*,
      * , *.....+.....6.....+.....7.....+.....8 (not in input)*)
      end
      subroutine plospc(imea,iyear)
c
c      plotting supply curve for year iyear
c
c
c      /cntrl/ contains control information
c
      common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
      logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c      /majdb/ contains major data base
c
      common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmecst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmeesa(750),rmeupd(750)
c
c      /result/ contains some results
c
      common/result/iorder(750),cce(750),aes(750),cumsav(750)
c
      dimension scmax(2),axmax(2)
      dimension blank(4)
      data blank/4*10h /
c
      write (6,201) iyear
c
c      initialize plot system
c

```



```

        call icorr(100,50)
c
c   determine maximum on both scales
c
        scmax(1)=0.
        scmax(2)=0.
        do 1 i=1,imea
            if (cumsav(iorder(i)).gt.scmax(1)) scmax(1)=cumsav(iorder(i))
            if (cce(iorder(i)).gt.scmax(2)) scmax(2)=cce(iorder(i))
1        continue
c
        do 5 j=1,2
            axmax(j)=smooth(scmax(j))
5        continue
c
        call dcorr(0.,0.,axmax(1),axmax(2),blank)
c
c   plot points
c
        do 10 i=1,imea
            j=i-1/10*10
            weight=j+0.1
            call corr(cumsav(iorder(i)),cce(iorder(i)),weight)
10        continue
c
c   plot energy price line
c
c
c   warning      line plotted is always electricity price
c
        if (elecpr(1).le.0) goto 100
        do 20 i=1,100
            call corr(axmax(1)*i/100.,elecpr(3),40.)
20        continue
c
c   plot
c
        call pcorr
c
100 return
201 format(1h1,* supply curve for *,i5,/,
        * * x axis is cumulative energy in twh/year*/,/,
        * * y axis is cost of conserved energy in $/kwh*)
        end
        subroutine tccsub(j)
c
c   produces technology cost curves and tables for one enduse
c
c   j is enduse number
c
c   /cntrl/ contains control information
c
c   common/cntrl/discou,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
        * adminc,bpape,curves,tables,rwork4,priuec,emi,ema,ecc,

```

```

* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
  logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
c /majdb/ contains major data base
c
  common/majdb/imenum(99),imepoi(99),
* enddes(4,99),endid(99),
* enduec(99),endref(99),ueccur(99),
* endsto(99),endadd(99),enddec(99),iendmn(99),endupd(99),
* rmedes(4,750),rmeid(750),meaidn(750),
* rmecst(750),rmepcs(750),rmesav(750),
* mealif(750),measta(750),measto(750),rmerli(750),rmeelf(750),
* rmeemp(750),rmeemf(750),rmeesa(750),rmeupd(750)
c
  dimension meatmp(20),roicce(20),lorder(20)
  dimension blank(4)
  data blank/4*10h /
c
c /result/ contains some results
c
  common/result/iorder(750),cce(750),aes(750),cumsav(750)
c
  first make a list of measures
c
  k=0
  do 10 i=1,imenum(j)
  imea=imepoi(j)+1
c
  measure has to be active
c
  if (istay.lt.measta(imea)) goto 10
  k=k+1
  meatmp(k)=imea
10 continue
c
  at least one measure has to be active
c
  if (k.le.0) return
c
  do 30 i=1,2
c
  i=1 roi i=2 cce
c
  cstsum=0.
  do 15 l=1,k
  roicce(l)=1234567989.+1
  if (i.eq.1.and.rmecst(meatmp(l)).ne.0.)
1 roicce(l)=rmesav(meatmp(l))/rmecst(meatmp(l))
  if (i.eq.2) roicce(l)=cce(meatmp(l))
  cstsum=cstsum+rmecst(meatmp(l))
15 continue
c
  order according to roicce

```

```

c
  call sortcc(k,lorder,roicce)
c
c   print table heading      prepare plot
c
  if (i.eq.1) write (6,101) endid(j),enduec(j)
  if (i.eq.2) write (6,102) endid(j),enduec(j)
  write (6,106)
  write (6,103)
  write (6,105)
  call icorr(100,50)
  dollar=0.
  savsum=enduec(j)
c
  axmax=smooth(cstsum)
  aymax=smooth(savsum)
c
  call dcorr(0.,0.,axmax,aymax,blank)
c
c   print table
c
  do 20 l=1,k
  ltemp=lorder(l)
  if (i.eq.1) ltemp=lorder(k+l-1)
  jtemp=meatmp(ltemp)
c
c   note that the cost and the the savings values
c   are multiplied by the measure eligible fraction
c
  dollar=dollar+rmechst(jtemp)*rmeelf(jtemp)
  savsum=savsum-rmesav(jtemp)*rmeelf(jtemp)
c
  ufrac=savsum/enduec(j)
  write (6,104) l,(rmedes(m,jtemp),m=1,4),dollar,
* savsum,roicce(ltemp),ufrac
  iwei=l-1/10*10
  weight=iwei
  if (iwei.eq.0) weight=24.
  call corr(dollar,savsum,weight)
20 continue
c
  if (i.eq.1) write (6,111) endid(j)
  if (i.eq.2) write (6,112) endid(j)
  write (6,113)
  write (6,114)
c
c   indicate starting uec
c
  call corr(0.01,enduec(j),33.)
c
  call pcorr
c
30 continue
return

```

```

101 format(*ltechnology cost table for enduse *,a10,* sorted by roi*,
1 ,* original uec*,f10.0,* kwh*,//)
102 format(*ltechnology cost table for enduse *,a10,* sorted by cce*,
1 ,* original uec*,f10.0,* kwh*,//)
103 format(* measure*,37x,* cumulative investment      energy used*
* ,*   roi or cce  energy used/original uec*)
104 format(* *,i3,2x,4a10,5x,f10.2,14x,f8.2,4x,f10.2,f14.3)
105 format(*      *,37x,*      (1980$)      (kwh/yr)*,/)
106 format(* (a)   *,37x,*      (b)      (c)   *
* ,*      (d)      (e)      *)
111 format(*ltechnology cost curve for enduse *,a10,* sorted by roi*)
112 format(*ltechnology cost curve for enduse *,a10,* sorted by cce*)
113 format(* x axis is cumulative investment in dollar*)
114 format(* y axis is uec in kwh/year*)
end
function smooth(x)

```

c
c
c
c

function determines a round number which is greater than x
and which can be used as a scale factor for plots

```

alg=log10(x)
ilg=alg
pow=10.**ilg
quo=x/pow
iquo=quo+1.
smooth=iquo*pow
return
end

```

MINOR PROGRAM

```

subroutine work4t(endus,uecbef)
c
c   ordering and weighting of typical cases
c
c   input is enduse id
c
   common/work5/maxua,maxeta,maxs,maxm,
1      tout,discou,nua,neta,ns,nm,
2      heatb,fuelb,heata,fuela,iclim,
3      tin,uvalue(20),area(20),effi(5),sloss(5),slossm(5,20),
8      iproza(2,20),jproza,
4      cost(20),life(20),cce(20),iorder(20),saving(20),
5      tinm(20),uvalm(20,20),effim(5,20),aream(20,20),
6      tmid,tmidm(20),uvalu2(20),area2(20),uvalm2(20,20),
7      aream2(20,20),nua2,heatb2,maxua2,heatm2
c
c   /cntrl/ contains control information
c
   common/cntrl/disc,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
*   adminc,bpapen,curves,tables,rwork4,priuvec,emi,ema,ecc,
*   elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
*   ,tcc(99)
   logical adminc,bpapen,curves,tables,rwork4,priuvec,emi,ema,ecc
c
c   /minmaj/ contains transfer variables between major and minor db
c
   common/minmaj/imtran,jorder(99),eligav(20),avelif(20),cosave(20),
*   savave(20)
c
   dimension card(8),text(7),elig(20)
c
   dimension idesc(31,7)
c
   dimension frac(20)
c
   data blank/10h
   data itypcm/50/
c
c   set some variables that limit amount of inputs
c
   itypc=0
   discou=disc
   maxua=10
   maxua2=10
   maxeta=5
   maxs=5
   maxm=20
   frachk=0.
c
   rewind 2
c
10 read (2,101) card

```

```

    if (eof(2).ne.0) goto 90
    decode (80,102,card) title
    if (title.ne.7henduse ) goto 10
    decode (80,109,card) title,eid,text
    if (eid.ne.endus) goto 10
    if (idiag.gt.0) write (6,208) title,eid,(text(kk),kk=1,6)
15 read (2,101) card
    if (eof(2).ne.0) goto 91
    decode (80,102,card) title
    if (title.ne.7htypcase) goto 15
c
c   reset some variables
c
    uecbef=0.
    uecaft=0.
    do 12 ii=1,maxm
    savave(ii)=0.
    cosave(ii)=0.
    avelif(ii)=0.
    eligav(ii)=0.
12 continue
c
c
c   read variables for typcase
c
20 continue
    decode (80,103,card) title,num,text
    itypc=itypc+1
    nm=0
    if (idiag.gt.0) write (6,216) title,num,text
    if (idiag.gt.0) write (6,230)
    if (itypc.gt.itypcm) stop
c
    read (2,106) nua,text
    if (idiag.gt.1) write (6,201) text,nua
    if (nua.gt.0) read (2,107) (uvalue(ii),ii=1,nua)
    if (nua.gt.0) read (2,107) (area(ii),ii=1,nua)
    if (nua.gt.0.and.idiag.gt.1) write (6,210) (uvalue(ii),ii=1,nua)
    if (nua.gt.0.and.idiag.gt.1) write (6,211) (area(ii),ii=1,nua)
c
    read (2,106) nua2,text
    if (idiag.gt.1) write (6,201) text,nua2
    if (nua2.gt.0) read (2,107) (uvalu2(ii),ii=1,nua2)
    if (nua2.gt.0) read (2,107) (area2(ii),ii=1,nua2)
    if (nua2.gt.0.and.idiag.gt.1) write (6,212) (uvalu2(ii),ii=1,nua2)
    if (nua2.gt.0.and.idiag.gt.1) write (6,213) (area2(ii),ii=1,nua2)
c
    read (2,106) neta,text
    if (idiag.gt.1) write (6,201) text,neta
    if (neta.gt.0) read (2,107) (effi(ii),ii=1,neta)
    if (neta.gt.0.and.idiag.gt.1) write (6,214) (effi(ii),ii=1,neta)
c
    read (2,106) ns,text
    if (idiag.gt.1) write (6,201) text,ns

```

```

if (ns.gt.0) read (2,107) (sloss(ii),ii=1,ns)
if (ns.gt.0.and.idiag.gt.1) write (6,215) (sloss(ii),ii=1,ns)
c
read (2,105) tin,text
if (idiag.gt.1) write (6,202) text,tin
c
read (2,105) tmid,text
if (idiag.gt.1) write (6,202) text,tmid
c
read (2,105) tout,text
if (idiag.gt.1) write (6,202) text,tout
c
read (2,105) frac(itypc),text
if (idiag.gt.1) write (6,202) text,frac(itypc)
frachk=frachk+frac(itypc)
c
read (2,110) iclim,prozl,text
if (idiag.gt.1.and.iclim.gt.0) write (6,226) text,iclim
jproza=0
if (prozl.eq.lhs) jproza=1
c
clear measure arrays
c
do 30 ii=1,maxm
tinm(ii)=0.
tmidm(ii)=0.
do 22 jj=1,maxua
uvalm(jj,ii)=0.
aream(jj,ii)=0.
22 continue
do 23 jj=1,maxua2
uvalm2(jj,ii)=0.
aream2(jj,ii)=0.
23 continue
c
do 24 jj=1,maxeta
effim(jj,ii)=0.
24 continue
c
do 26 jj=1,maxs
slossm(jj,ii)=0.
26 continue
30 continue
c
read in measures
c
35 continue
read (2,101) card
title=blank
if (eof(2).ne.0) goto 40
decode (80,102,card) title
if (title.eq.7henduse ) goto 40
if (title.eq.7htypcase) goto 40
if (title.ne.7hmeasure) goto 35

```

```

c
c   check for measure number
c
c   decode (80,104,card) title,num,proz1,proz2,
1   (idesc(nm+1,ip),ip=1,7)
c   do 37 ii=1,imtran
c   if (num.eq.jorder(ii)) goto 39
37 continue
c   goto 35
39 continue
c   nm=nm+1

c
c   check whether area/volume data have to be interpreted as relative
c
c   iproza(1,nm)=0
c   if (proz1.eq.lhp) iproza(1,nm)=1
c   iproza(2,nm)=0
c   if (proz2.eq.lhp) iproza(2,nm)=1
c   read (2,105) cost(nm)
c   read (2,105) rlif
c   life(nm)=rlif
c   read (2,105) elig(nm)

c
c   dont read measure if eligible fraction equal zero
c
c   if (elig(nm).le.0.) cost(nm)=0.
c   if (elig(nm).le.0.) life(nm)=0
c   if (elig(nm).le.0.) goto 35

c
c   if (nua.gt.0) read (2,107) (uvalm(ii,nm),ii=1,nua)
c   if (nua.le.0) read (2,108)
c   if (nua.gt.0) read (2,107) (aream(ii,nm),ii=1,nua)
c   if (nua.le.0) read (2,108)

c
c   if (nua2.gt.0) read (2,107) (uvalm2(ii,nm),ii=1,nua)
c   if (nua2.le.0) read (2,108)
c   if (nua2.gt.0) read (2,107) (aream2(ii,nm),ii=1,nua)
c   if (nua2.le.0) read (2,108)

c
c   if (neta.gt.0) read(2,107) (effim(ii,nm),ii=1,neta)
c   if (neta.le.0) read (2,108)
c   if (ns.gt.0) read (2,107) (slossm(ii,nm),ii=1,ns)
c   if (ns.le.0) read (2,108)

c
c   read (2,107) tinm(nm)
c   read (2,107) tmidm(nm)
c   goto 35

c
c   all measures read   call work4
c
c
40 if (itypc.eq.1) nmmax=nm
c   if (idiag.gt.1) write (6,203) itypc,nm
c   if (nm.ne.nmmax) stop

```



```

c
  call work4
c
c  print summary of inputs and results here
c
  if (idiag.gt.1) write(6,227)
  if (idiag.gt.1) write(6,220)
  if (idiag.gt.1) write(6,223)
  do 42 ii = 1,nm
    if (idiag.gt.1.and.cce(ii).lt.123456788.)
* write(6,221) ii,(idesc(ii,ip),ip=1,7), cost(ii), life(ii),
* elig(ii),saving(ii), cce(ii), iorder(ii)
    if (idiag.gt.1.and.cce(ii).ge.123456788.)
* write(6,222) ii,(idesc(ii,ip),ip=1,7)
42 continue
c
  do 45 ii=1,nm
    savave(ii)=savave(ii)+saving(ii)*frac(itypc)*elig(ii)
    cosave(ii)=cosave(ii)+cost (ii)*frac(itypc)*elig(ii)
    avelif(ii)=avelif(ii)+life (ii)*frac(itypc)*elig(ii)
    eligav(ii)=eligav(ii)+elig (ii)*frac(itypc)
45 continue
c
  uecaft=uecaft+fuela*frac(itypc)
  uecbef=uecbef+fuelb*frac(itypc)
c
  if (title.eq.7htypcase) goto 20
c
c  here are the results
c
  if (abs(frachk-1.).gt.0.000001) write(6,217)
  if (abs(frachk-1.).gt.0.000001) stop
c
  if (idiag.gt.0) write(6,224) endus
  if (idiag.gt.0) write(6,225)
  do 50 ii=1,nm
    savave(ii)=savave(ii)/eligav(ii)
    cosave(ii)=cosave(ii)/eligav(ii)
    avelif(ii)=avelif(ii)/eligav(ii)
    if (idiag.gt.0) write (6,205)
* ii,(idesc(ii,ip),ip=1,7), savave(ii),
* cosave(ii),avelif(ii),eligav(ii)
50 continue
c
  if (idiag.gt.1) write (6,206) uecbef
  if (idiag.gt.1) write (6,209) uecaft
  return
90 continue
  write (6,204) endus
  stop
91 continue
  write (6,207) endus
  stop
101 format(8a10)

```

```

102 format(a7,7a10,3x)
103 format(a7,i3,7a10)
104 format(a7,i3,2a1,6a10,a7)
105 format(f10.2,7a10)
106 format(i2,8x,7a10)
107 format(10f8.2)
108 format(* *)
109 format(a7,7a10)
110 format(i10,a1,6a10,a9)

```

c

```

201 format(* *,7a10,i3)
202 format(* *,6a10,a9,1x,f10.4)
203 format(///,* measure effects for typical case no. *,i3,* with*
*      ,i3,* possible measures*, //)
204 format(* work4 -- enduse *,a10,* has no enduse card*)
205 format(i3,1x,7a10,f10.0, 2f10.0,f10.3)
206 format(///, * initial uec = *,f10.0)
207 format(* work4 -- enduse *,a10,* has no typcase card*)
208 format(1h1,///,7h ***** ,a7,1x,a10,1x,7a10)
209 format(///, * final uec = *,f10.0)
210 format(* initial primary u-values or heat capacities*,/,
* * 1.....2.....3.....4.....5.....6.....7*,/,
* * *,10F8.3)
211 format(* initial primary areas or volumes*,/,* *,10F8.2)
212 format(* tank characteristics (u-values) *,/,* *,10F8.2)
213 format(* tank and pipe areas *,/,* *,10F8.2)
214 format(* initial efficiencies *,/,* *,5F8.2)
215 format(* initial fixed consumptions *,/,* *,5F8.2)
216 format(///,7h ***** ,a7,i3,7a10)
217 format(* job terminated, typcase fractions dont sum to 1.000*)
220 format(*      measure name      *,54x,* cost*,
* *      life frac saving      cce      order*)
221 format(i3,1x,6a10,a7,f10.0,16,2x,f5.3,f10.0,f10.3,i8)
222 format(i3,1x,6a10,a7,* not applicable *)
223 format(*      *,54x,* ($)*,
* *      (yrs)      (kwh/yr)      ($/kwh)      *,/)
224 format(//,* averaged data to be passed to major *,
* *data base for enduse *,a10,/)
225 format(* measure*,68x,* savings      cost      life*,
* * elig.frac*, /)
226 format(* *,6a10,a9,1x,i10)
227 format(//,*      measure ranking table*,//,
*      *      (a)      *,54x,*      (b)*,
*      *      (c)      (d)      (e)      (f)      (g)*
230 format(/,*      initial conditions*)
end

```

```

subroutine work4
trace subscripts

```

c
c
c
c

```
ordering of measures with increasing cce
```

```

common/work5/maxua,maxeta,maxs,maxm,
1      tout,discou,nua,neta,ns,nm,
2      heatb,fuelb,heata,fuela,iclim,

```

```

3      tin,uvalue(20),area(20),effi(5),sloss(5),slossm(5,20),
8      iproza(2,20),jproza,
4      cost(20),life(20),cce(20),iorder(20),saving(20),
5      tinm(20),uvalm(20,20),effim(5,20),aream(20,20),
6      tmid,tmidm(20),uvalu2(20),area2(20),uvalm2(20,20),
7      aream2(20,20),nua2,heatb2,maxua2,heatm2
c
c      /cntrl/ contains control information
c
common/cntrl/disc,idiag,istay,iendus,isnapn,inotyp,itcc,nmea,
* adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc,
* elecpr(3),gaspri(3),oilpri(3),isnap(31),enduse(99),typcno(99)
* ,tcc(99)
logical adminc,bpapen,curves,tables,rwork4,priuec,emi,ema,ecc
c
dimension iact(20)
c
c      cost of conserved energy statement function
c
ccef(sa,co,li)=co*discou/sa/(1.-(1.+discou)**(-li))
c
c      check input
c
if (nua.gt.maxua) goto 190
if (nua2.gt.maxua2) goto 190
if (neta.gt.maxeta) goto 190
if (ns.gt.maxs) goto 190
if (nm.gt.maxm) goto 190
c
if (nm.le.0) goto 180
if (nua.le.0.and.neta.le.0.and.ns.le.0.and.nua2.le.0) goto 180
c
c      initialize
c
irang=0
do 10 i=1,nm
  iact(i)=1
10 continue
c
c      conversion factor
c
confac=2.565
c
c      outer loop
c
do 120 iloop=1,nm
c
c      calculate heat/fuel consumption before
c
u1 = 0.
u2 = 0.
heat=0.
heat2=0.
c

```

```

    if (nua.le.0) goto 15
    do 14 j=1,nua
    ual = ual + (uvalue(j) * area(j))
    heat=heat+uvalue(j)*area(j)
14 continue
15 if (nua2.le.0) goto 19
    do 18 j=1,nua2
    ua2 = ua2 + (uvalu2(j) * area2(j))
    heat2=heat2 + uvalu2(j)*area2(j)
18 continue
19 continue
c
    eff=1.
    if (neta.le.0) effi(1) = 1.
    if (neta.le.0) goto 30
    do 25 j=1,neta
    eff=eff*effi(j)
25 continue
30 continue
c
    slo=0.
    if (ns.le.0) goto 40
    do 35 j=1,ns
    slo= slo + sloss(j)
35 continue
40 continue
c
    heat=heat*(tin-tout) * confac
    fac1=1.
    fac2=1.
    if (jproza.eq.1) heat=heat/(tin-tout)
    if (jproza.eq.1)
1      call hourh(heat/8760.,tin,slo,iclim,fac1,fac2)
    if (jproza.eq.1) heat=heat*fac1
    heat2 = heat2 * (tin-tmld) * confac
c
c   if first time around, loads are set
c
c   if (iloop.eq.1) heatb = heat
    if (iloop.eq.1) heatb2 = heat2
c
c   note that heat2 is divided only by effi(1) because
c   I assume that remaining efficiencies apply to distribution
c
    fuel= (heat/eff) + (heat2/effi(1)) + slo*fac2
    if (jproza.eq.1) fuel=fuel-slo*fac2
c
    if (idiag.lt.2) goto 42
    tdl=tin-tout
    if (jproza.eq.1) tdl=fac1
    slopr=slo
    if (jproza.eq.1) slopr=slo*fac2
    td2=tin-tmld
    if(iloop.eq.1.and.jproza.eq.0) write(6,232)

```

```

if(iloop.eq.1.and.jproza.eq.0) write(6,231)
if(iloop.eq.1.and.jproza.eq.1) write(6,239)
if(iloop.eq.1.and.jproza.eq.1) write(6,238)
if(iloop.eq.1) write(6,233) fuel,ual,ua2,td1,td2,slopr,eff,effi(1)
if(iloop.gt.1.and.iloop.le.nm) write(6,234) fuel, ual,ua2,td1,td2,
* slopr, eff, effi(1)
c   if (fuel.lt.0.) goto 170
   if (fuel.lt.0.) write (6,236)
42 continue
c
   if (iloop.eq.1) fuelb=fuel
c
c   now roll in measures, where jloop is measure increment
c
do 75 jloop=1,nm
if (iact(jloop).eq.0) goto 75
if (nua.le.0) goto 46
heatm=0.
heatm2 =0.
ual = 0.
do 45 j=1,nua
um= uvalue(j)
areanw = area(j)
rvaluej = 1./ uvalue(j)
c
c   if uvalm is negative then it read an r-value
c   and if its 0 the conductivity wasnt changed.
c   maintain original area if not changed
c
if (uvalm(j,jloop).lt.0.) um=1./(rvaluej-uvalm(j,jloop))
if (uvalm(j,jloop).gt.0.)um=1./(rvaluej+(1./uvalm(j,jloop)))
if (aream(j,jloop).ne.0.) areanw = area(j) - aream(j,jloop)
if (aream(j,jloop).ne.0..and.iproza(1,jloop).eq.1)
1   areanw = area(j)*(1.-aream(j,jloop))
c
   ual = ual + (um * areanw)
   heatm=heatm + (um * areanw)
c
45 continue
46 if (nua2.le.0) goto 50
ua2 = 0.
do 47 j=1,nua2
um2= uvalu2(j)
arean2 = area2(j)
rvalu2j = 1./ uvalu2(j)
c
c   if uvalm2 is negative, its an r-value
c   and if its 0, it wasnt changed
c   maintain original area if not changed
c
if (uvalm2(j,jloop).gt.0.)um2=1./(rvalu2j+(1./uvalm2(j,jloop)))
if (uvalm2(j,jloop).lt.0.) um2=1./(rvalu2j-uvalm2(j,jloop))
if (aream2(j,jloop).ne.0.) arean2 = area2(j) - aream2(j,jloop)
if (aream2(j,jloop).ne.0..and.iproza(1,jloop).eq.1)

```

```

1          arean2 = area2(j)*(1.-aream2(j,jloop))
c
c      ua2 = ua2 + (um2 * arean2)
c      heatm2 = heatm2 + (um2 * arean2)
c
47 continue
50 continue
c
c      effm=1.
c      if (neta.le.0) goto 60
c      do 55 j=1,neta
c      effm = effm * (effi(j) + effim(j,jloop))
55 continue
c      efflm = effi(1) + effim(1,jloop)
60 continue
c
c      calculate total standby loss
c
c      slom=0.
c      if (ns.le.0) goto 70
c      do 65 j=1,ns
c      if (iproza(2,jloop).eq.0) slom=slom+sloss(j) - slossm(j,jloop)
c      if (iproza(2,jloop).eq.1) slom=slom+sloss(j)*
1      (1.- slossm(j,jloop)*abs(slossm(j,jloop))/slossm(j,jloop))
65 continue
70 continue
c
c      tdl=tin - tinm(jloop) - tout - tmidm(jloop)
c      td2=tin - tinm(jloop) - tmid
c
c      heatm=heatm* tdl * confac
c      if (jproza.eq.1) heatm=heatm/tdl
c
c      fac1=1.
c      fac2=1.
c      if (jproza.eq.1)
1 call hourh(heatm/8760.,tin-tinm(jloop),slom,iclim,fac1,fac2)
c      if (jproza.eq.1) heatm=heatm*fac1
c      tpr1=tdl
c      if (jproza.eq.1) tpr1=fac1
c      slopr=slom
c      if (jproza.eq.1) slopr=slom*fac2
c
c      heatm2 = heatm2 * td2 * confac
c
c      if first effic changed, then normal fuel calculation fails
c      the next line is my patch
c
c      fuelm = (heatm / effm) + (heatm2 / efflm) + slom*fac2
c      if (jproza.eq.1) fuelm=fuelm-slom*fac2
c
c      fuela=fuelm
c
c      saving(jloop)=fuel-fuelm

```

```

c
c     cce(jloop)=123456789.
c     if (saving(jloop) .ne. 0.0)
c       * cce(jloop)=ccef(saving(jloop),cost(jloop),life(jloop))
c
c 75 continue
c
c     print fuel, etc. if this is the last measure
c
c     if(iloop.eq.nm.and.idiag.gt.1) write(6,235)
c     * fuelm, ual, ua2, tpr1, td2 ,slopr ,effm, efflm
c     if (fuelm.lt.0.) goto 170
c     if (fuelm.lt.0.) write (6,236)
c
c
c     the measure loop ends here , and jloop should equal nm.
c
c
c     now select cheapest measure
c
c     rc=1.e20
c     ic=0
c
c     do 80 jloop=1,nm
c       if (iact(jloop).eq.0) go to 80
c       if (cce(jloop).gt.rc) go to 80
c       rc=cce(jloop)
c       ic=jloop
c 80 continue
c
c     if (ic.le.0) goto 191
c
c     entry in order array  reset measure
c
c     irang=irang+1
c     iorder(ic)=irang
c
c     iact(ic)=0
c
c     make cheapest measure permanent
c     by resetting all appropriate u-, a- values, losses, etc.
c
c     ual=0.
c     if (nua.le.0) go to 86
c     do 85 j=1,nua
c       um= uvalue(j)
c
c       if uvalm is negative its an r-value, if positive a u-value
c       and if zero it remains the same
c
c     rvaluej = 1./ uvalue(j)
c     if (uvalm(j,ic).gt.0.) um= 1./(rvaluej + (1./uvalm(j,ic)))
c     if (uvalm(j,ic).lt.0.) um=1./(rvaluej -uvalm(j,ic))
c     uvalue(j)=um

```

```

      if (iproza(1,ic).eq.0) area(j)=area(j)-aream(j,ic)
      if (iproza(1,ic).eq.1) area(j)=area(j)*(1.-aream(j,ic))
      ual=ual+um*area(j)
85 continue
86 if (nua2.le.0) go to 90
      do 87 j=1,nua2
      um2= uvalu2(j)
c
c      if uvalm2 is negative its an r-value, if positive a u-value
c      and if zero it remains the same
c
      rvalu2j = 1./ uvalu2(j)
      if (uvalm2(j,ic).gt.0.) um2= 1./((rvalu2j + (1./uvalm2(j,ic))))
      if (uvalm2(j,ic).lt.0.) um2=1./((rvalu2j -uvalm2(j,ic)))
      uvalu2(j)=um2
      if (iproza(1,ic).eq.0) area2(j)=area2(j)-aream2(j,ic)
      if (iproza(1,ic).eq.1) area2(j)=area2(j)*(1.-aream2(j,ic))
87 continue
90 continue
c
      if (neta.le.0) go to 100
      do 95 j=1,neta
      effi(j)=effi(j)+effim(j,ic)
95 continue
100 continue
c
c      resetting standby loss
c
      if (ns.le.0) go to 110
      do 105 j=1,ns
      if (iproza(2,ic).eq.0) sloss(j)=sloss(j) - slossm(j,ic)
      if (iproza(2,ic).eq.1) sloss(j)=sloss(j)*
      1 (1.- slossm(j,ic)*abs(slossm(j,ic))/slossm(j,ic))
105 continue
110 continue
c
c
c old      tin = tin-tinm(ic)
c old      tmid = tmid - tmidm(ic)
      tin = tin-tinm(ic)
      tout = tout + tmidm(ic)
c
c
120 continue
      return
c
180 write (6,201) nm,nua,neta,ns
      return
190 write (6,202)
      goto 195
191 write (6,203)
195 slopr=1.
      rvalu2j=1.
      slopr=1./(slopr-rvalu2j)

```



```

stop
201 format(* warning  check values of nm nua neta ns*,4i7)
202 format(* error    check values of nm nua neta ns*,4i7)
203 format(* error    ic is zero *)
231 format(* typcase energy use      total      ual      ua2*,
* *      tin-tout  tin-tmtd  fixed      effic      effic(1)*)
232 format(*      (a)              (b)      (c)      (d)*,
* *      (e)              (f)      (g)      (h)      (i)      *)
233 format(/,*      initial = *, 8f10.2, /)
234 format(*      after measure = *, 8f10.2)
235 format(/,* final energy use = *, 8f10.2)
236 format(* warning  negative consumption calculated *,
1      * check fixed loss inputs *)
238 format(* typcase energy use      total      ual      ua2*,
* *      tbal-tout  (na) free heat used  effic      effic(1)*)
239 format(*      (a)              (b)      (c)      (d)*,
* *      (j)              (k)      (l)      (h)      (i)      *)
end

```

C

subroutine hourh(zw,tin,slo,iclim,facl,fac2)

c

subroutine calculates heating energy consumption from hourly
weather data

c

data iclmax/7/

c

number of weather files currently existing

c

dimension hours1(100),hours2(100),hours3(100),hours4(100)
dimension hours5(100),hours6(100),hours7(100)

c

dimension hours(100)

c

weather data is taken from U.S. Air Force Manual AFM 88-29
Engineering Weather Data 1 July 1978

c

Portland,Oregon

c

data hours1/40*0.,5*0.4,5*2.,5*4.2,5*8.4,5*22.8,5*66.4,5*147.,
1 5*254.,5*260.4,5*260.,5*259.8,5*194.4/

c

Spokane,Wa

c

data hours2/15*0.,5*0.2,5*1.25,5*1.25,5*2.,5*4.2,5*8.0,5*13.4,
1 5*28.8,5*60.,5*118.2,5*206.6,5*207.6,5*189.6,5*161.6,5*152.2,
1 5*140.,5*124.6/

c

Missoula, MT

c

data hours3/10*0.,5*0.4,5*2.2,5*3.0,5*6.4,5*9.6,5*14.6,5*37.,
1 5*38.4,5*55.2,5*88.8,5*143.2,5*206.,5*190.2,5*165.2,5*157.2,
1 5*152.8,5*131.,5*105.6/

c

Boise, ID

c

```

c
  data hours4/20*0.,5*0.2,5*0.2,5*1.2,5*2.2,5*3.6,5*11.,5*26.6,
1 5*59.8,5*101.2,5*166.,5*180.8,5*175.6,5*159.4,5*147.6,5*134.,
1 5*125.6/

c
c   Seattle, WA
c
  data hours5/45*0.,5*0.6,5*3.,5*5.,5*11.4,5*42.8,5*137.4,5*251.6,
1 5*314.6,5*283.,5*266.4,5*200./

c
c   Astoria, OR
c
  data hours6/50*0.,5*1.0,5*4.0,5*13.0,5*54.,5*122.2,5*231.6,
1 5*344.2,5*354.4,5*339.8,5*189.4/

c
c   Lewiston, ID
c
  data hours7/15*0.,5*0.4,5*1.2,5*3.2,5*5.0,5*9.0,5*13.2,5*17.8,
1 5*24.4,5*36.,5*67.2,5*129.,5*193.8,5*195.2,5*178.4,5*172.4,
1 5*158.2,5*139.8/

c
c   hourly weather data
c
c   if (iclim.le.0.or.iclim.gt.iclmax) goto 90
c
c   copy actual weather data to hours
c
c   hsum=0.
c   do 5 i=1,100
c   if (iclim.eq.1) hours(i)=hours1(i)
c   if (iclim.eq.2) hours(i)=hours2(i)
c   if (iclim.eq.3) hours(i)=hours3(i)
c   if (iclim.eq.4) hours(i)=hours4(i)
c   if (iclim.eq.5) hours(i)=hours5(i)
c   if (iclim.eq.6) hours(i)=hours6(i)
c   if (iclim.eq.7) hours(i)=hours7(i)
5 hsum=hsum+hours(i)

c
c   zx=slo/hsum
c   fac1=0.
c   hz=0.
c   sum=0.

c
c   now loop over temperatures from -35 to 65
c
c   do 10 i=1,100
c   zy=(tin+36-i)*hours(i)
c   step=zw*zy+zx*hours(i)
c   if (step.lt.0) goto 20

c
c   result still positive   add to sum
c
c   hz=hz+hours(i)
c   sum=sum+step

```

```

10 continue
c
20 continue
c
c   result got negative   return to work4
c
   fac1=sum/zw/8760.
   fac2=hv/hsum
   return
c
   error handling
c
90 write (6,101) iclim
   stop
101 format(* error in hourh. climate zone is out of range*,I7)
   end
   SUBROUTINE ICORR(IX,IY)
C
C   INITIALIZES PLOT-SYSTEM FOR A PLOT WITH FORMAT IX IY
C
C   PURPOSE OF THIS PACKAGE IS TO PLOT NUMBERS IN AN ARRAY
C
C   FOLLOWING CALLS ARE AVAILABLE
C
C   ICORR(IX,IY) INITIALIZES THE PLOT-SYSTEM
C                   FOR THE PLOT THERE HAVE TO BE IX*IY+100 WORDS
C                   TO BE RESERVED IN COMMON/ACORR/
C
C   DCORR(XMIN,YMIN,XMAX,YMAX,40HTEXT) IS AN OPTIONAL CALL
C                   DEFINING LOWER AND UPPER LIMITS AND A TITLE.
C                   DCORR HAS TO BE CALLED BEFORE ANY CALL TO CORR
C
C   CORR(X,Y,GW)  MAKES ONE ENTRY
C                   GW IS WEIGHT OF THAT ENTRY
C
C   PCORR          PRINT PLOT
C
C   DATA ORGANIZATION
C                   THE FIRST 100 WORDS CONTAIN STEERING
C                   INFORMATION. IF DCORR
C                   IS NOT CALLED, IT WILL CONTAIN THE DATA OF THE
C                   FIRST IX*IY/3 CALLS TO CORR
C                   AFTER THAT CALL, THE SCALE PARAMETERS WILL BE
C                   CHOSEN AUTOMATICALLY.
C                   THE WORDS 1 TO 100 HAVE FOLLOWING MEANINGS
C
C                   1   =0 NO CALL TO ICORR YET   =1 ICORR WAS CALLED
C                   2   =0 NO CALL TO DCORR       =1 DCORR WAS CALLED
C                   3   NUMBER OF CALLS TO CORR
C                   4   NUMBER OF CALLS OUTSIDE RANGE
C                   5   XMIN
C                   6   YMIN
C                   7   XMAX
C                   8   YMAX
C                   9 ... 12 40 CHARACTER TITLE OF PLOT

```

```

C          3  NUMBER OF BINS FOR X
C          13 NUMBER OF BINS FOR Y
C          15 NUMBER OF ENTRIES BEFORE DCORR IS CALLED
C          16 NUMBER OF LOCATIONS USED
C          17 ... 100 NOT USED
C
COMMON/ACORR/IDATA(5100)
COMMON/TESPRI/IPRINT
DATA IXMAX/130/,IYMAX/60/
C
C  INITIALIZE
C
C  iprint=0
C
C  IF (IX.LT.1) GOTO 90
C  IF (IX.GT.IXMAX) GOTO 90
C  IF (IY.LT.1) GOTO 90
C  IF (IY.GT.IYMAX) GOTO 90
C
C  IDATA(1)=1
C  IT=IX*IY+100
C
C  DO 10 I=2,IT
C  IDATA(I)=0
10 CONTINUE
C
C  IDATA(13)=IX
C  IDATA(14)=IY
C  IDATA(15)=IX*IY/3
C  IDATA(16)=IT
C  GOTO 100
90 CONTINUE
WRITE (6,101) IX,IY
STOP
100 RETURN
101 FORMAT(* INVALID VALUES FOR IX AND IY*,2I7,* STOP*)
END
SUBROUTINE DCORR(XMIN, YMIN, XMAX, YMAX, TEXT)
C
C  SUBROUTINE PUTS IN DEFAULT VALUES
C
COMMON/ACORR/IDATA(5100)
DIMENSION DATA(1)
EQUIVALENCE (IDATA(1),DATA(1))
C
COMMON/TESPRI/IPRINT
DIMENSION TEXT(4)
C
C  IF (IDATA(1).NE.1) GOTO 100
C  IF (IDATA(2).NE.0) GOTO 100
C  IF (IDATA(3).NE.0) GOTO 100
C
DATA(5)=XMIN
DATA(6)=YMIN

```

```

DATA(7)=XMAX
DATA(8)=YMAX
DATA(9)=TEXT(1)
DATA(10)=TEXT(2)
DATA(11)=TEXT(3)
DATA(12)=TEXT(4)
C
  IDATA(2)=1
C
100 RETURN
  END
  SUBROUTINE CORR(X,Y,GW)
C
C  MAKES ENTRY TO PLOT
C
  COMMON/ACORR/IDATA(5100)
  DIMENSION DATA(1)
  EQUIVALENCE (IDATA(1),DATA(1))
  COMMON/TESPRI/IPRINT
C
  IF (IDATA(1).NE.1) GOTO 100
  IF (IDATA(2).EQ.1) GOTO 10
C
C  DCORR WAS NOT CALLED, ENTER FIRST ENTRIES
C
  IC=IDATA(3)
  DATA(100+IC*3+1)=X
  DATA(100+IC*3+2)=Y
  DATA(100+IC*3+3)=GW
C
  IC=IC+1
  IDATA(3)=IC
  IF (IC.GE.IDATA(15)) CALL CCORR
  GOTO 100
C
C  DCORR WAS CALLED MAKE PROPER ENTRY
C
10 CONTINUE
  IDATA(3)=IDATA(3)+1
  IX=IDATA(13)*(X-DATA(5))/(DATA(7)-DATA(5))+1.
  IY=IDATA(14)*(Y-DATA(6))/(DATA(8)-DATA(6))+1.
  IF (IX.LE.0.OR.IX.GT.IDATA(13)) GOTO 20
  IF (IY.LE.0.OR.IY.GT.IDATA(14)) GOTO 20
  DATA(100+(IDATA(14)-IY)*IDATA(13)+IX)=
  IDATA(100+(IDATA(14)-IY)*IDATA(13)+IX)+GW
  GOTO 100
20 CONTINUE
  IDATA(4)=IDATA(4)+1
100 RETURN
  END
  SUBROUTINE CORRC(X,Y,GW)
C
C  MAKES ENTRY TO PLOT

```

```

C
COMMON/ACORR/IDATA(5100)
DIMENSION DATA(1)
EQUIVALENCE (IDATA(1),DATA(1))
COMMON/TESPRI/IPRINT
C
IF (IDATA(1).NE.1) GOTO 100
IDATA(3)=IDATA(3)+1
IX=IDATA(13)*(X-DATA(5))/(DATA(7)-DATA(5))+1.
IY=IDATA(14)*(Y-DATA(6))/(DATA(8)-DATA(6))+1.
IF (IX.LE.0.OR.IX.GT.IDATA(13)) GOTO 20
IF (IY.LE.0.OR.IY.GT.IDATA(14)) GOTO 20
DATA(100+(IDATA(14)-IY)*IDATA(13)+IX)=
100 IDATA(100+(IDATA(14)-IY)*IDATA(13)+IX)+GW
GOTO 100
20 CONTINUE
IDATA(4)=IDATA(4)+1
100 RETURN
END
SUBROUTINE CCORR

```

```

C
C
C
AUTOMATIC DETERMINATION OF SCALEFACTORS
C
COMMON/ACORR/DATA(5100)
DIMENSION IDATA(1)
DIMENSION RDATA(3)
EQUIVALENCE (IDATA(1),DATA(1))
COMMON/TESPRI/IPRINT
C
DIMENSION AMINI(2),AMAXI(2),SCF(2),STP(2)
C
C
C
DETERMINE MINIMA AND MAXIMA
C
K=IDATA(3)
C
DO 20 I=1,2
AMINI(I)=1.E90
AMAXI(I)=-1.E90
DO 10 J=1,K
C
IF (DATA(100+(J-1)*3+I).GT.AMINI(I)) GOTO 5
AMINI(I)=DATA(100+(J-1)*3+I)
5 CONTINUE
C
IF (DATA(100+(J-1)*3+I).LT.AMAXI(I)) GOTO 10
AMAXI(I)=DATA(100+(J-1)*3+I)
10 CONTINUE
C
C
C
DETERMINE SCALE FACTOR
C
ALG=ALOG10(AMAXI(I)-AMINI(I))
LDI=ALG*10
LRE=LDI-LDI/10*10
ISC=2

```

```

IF (LRE.GE.3) ISC=5
IF (LRE.GE.6) ISC=10
KDI=ALG
SC=10.**KDI
SCF(I)=SC*ISC/100.
IF (I.EQ.2) SCF(I)=SCF(I)*2.
C
C DETERMINE STARTING POINT
C
STP(I)=0.
IF (AMINI(I).GT.0..AND.AMINI(I)-10.*SCF(I).LT.0.) GOTO 20
C
C CHECK WHETHER 0 IS CONVENIENT
C
ST=AMINI(I)/SCF(I)
IST=ST
IST=IST/10*10
STP(I)=IST*SCF(I)
20 CONTINUE
DATA(5)=STP(1)
DATA(6)=STP(2)
DATA(7)=STP(1)+100.*SCF(1)
DATA(8)=STP(2)+50.*SCF(2)
C
C NOW TRANSFORM INTO RIGHT FORMAT
C
REWIND 3
DO 25 JJ=1,K
WRITE (3) (DATA(100+(JJ-1)*3+KK),KK=1,3)
25 CONTINUE
REWIND 3
IDATA(2)=1
IDATA(3)=0
C
DO 30 JJ=101, IDATA(16)
DATA(JJ)=0
30 CONTINUE
C
IF (IPRINT.GT.1) WRITE (6,301) K, IDATA(2)
301 FORMAT(* IN CCORR K=*,I7,* IDATA2*,I4)
DO 40 JJ=1,K
READ(3) RDATA
CALL CORRC(RDATA(1),RDATA(2),RDATA(3))
40 CONTINUE
C
RETURN
END
SUBROUTINE PCORR
C
C PRINTS THE PLOT
C
COMMON/ACORR/IDATA(5100)
DIMENSION DATA(1)
DIMENSION IFIELD(135)

```

```

DIMENSION IFOUT(14)
DATA IBLA/10H /
DATA IFM /10H+-----/
DIMENSION IFA(2),IFB(3)
dimension px(14),py(11)
EQUIVALENCE (IDATA(1),DATA(1))

C
C
IF (IDATA(1).NE.1) GOTO 10
IF (IDATA(2).EQ.0) CALL CCORR

C
WRITE (6,101) (IDATA(JJ),JJ=9,12)
WRITE (6,102) IDATA(3),IDATA(4)
WRITE (6,104) (DATA(4+KK),KK=1,4)

C
C
SET UP FIRST AND LAST LINE OF PLOT

C
JX=IDATA(13)+2
LX=JX/10
MX=JX-LX*10

C
DO 40 N=1,14
IFOUT(N)=IBLA
40 CONTINUE

C
IF (LX.LE.0) GOTO 60

DO 50 N=1,LX
IFOUT(N)=IFM
50 CONTINUE
60 CONTINUE

C
IF (MX.EQ.0) GOTO 70
IFOUT(LX+1)=IFM.AND.MASK(MX*6)
70 CONTINUE

C
C
SET UP FORMAT FOR HORIZONTAL LINES

C
ENCODE (20,106,IFA) IDATA(13)
106 FORMAT(6H(* I*, , I3 , 11HR1,*I* ) )
ENCODE (30,107,IFB) IDATA(13)
107 FORMAT(6H(* +*, , I3 , 11HR1,*+*, , 10h,f8.2) )

c
c
prepare y scale

c
is=idata(14)/10
do 2 i=1,is
py(i)=data(6)+(data(8)-data(6))*10.*i/idata(14)
2 continue

C
C
WRITE FIRST LINE

C
WRITE (6,105) IFOUT

C

```



```

DO 5 J=1, IDATA(14)
DO 3 K=1, IDATA(13)
V=DATA(100+(J-1)*IDATA(13)+K)
L=V+0.5
IFIELD(K)=55B
IF (V.GT. 0.0.AND.V.LE. 0.5) IFIELD(K)=57B
IF (V.GT. 0.5.AND.V.LE. 9.5) IFIELD(K)=33B
IF (V.GT. 0.5.AND.V.LE. 9.5) IFIELD(K)=IFIELD(K)+L
IF (V.GT. 9.5.AND.V.LE.35.5) IFIELD(K)=0
IF (V.GT. 9.5.AND.V.LE.35.5) IFIELD(K)=IFIELD(K)+L-9
IF (V.GT.35.5) IFIELD(K)=45B
3 CONTINUE
LL=IDATA(14)+1-J
IF (LL/10*10.EQ.LL) WRITE (6, IFB) (IFIELD(KK), KK=1, IDATA(13))
* ,py(LL/10)
IF (LL/10*10.NE.LL) WRITE (6, IFA) (IFIELD(KK), KK=1, IDATA(13))
5 CONTINUE
C
WRITE (6, 105) IFOUT
c
write x-scale
c
is=idata(13)/10
do 7 i=1, is+1
px(i)=data(5)+(data(7)-data(5))*10.*(i-1)/idata(13)
7 continue
c
write (6, 108) (px(i), i=1, is+1)
c
10 CONTINUE
C
RETURN
101 FORMAT(* *, 4A10)
102 FORMAT(* PLOT ENTRIES*, I8, * OUTSIDE *, I8)
104 FORMAT(* XMIN YMIN*, 2E15.5, * XMAX YMAX*, 2E15.5)
105 FORMAT(* *, 13A10, A5)
108 FORMAT(* *, f5.1, 13(f8.2, 2x))
END

```

1 Variable Names and Functions

The following is a listing and brief description of all of the variables used in the CPS 2.0 program. The list is divided into three parts: subroutine-specific variables, common block variables, and all variables (both subroutine and common) sorted alphabetically.

1.1 Subroutine Specific Variables

Program MAJOR

Name	Type	Main	Use
------	------	------	-----

I I Variable loop index

Subroutine CALUEC

Name Type Main Use

FUELT	R Variable	masked fuel type
I	I Variable	loop index for enduses
IMEA	I Variable	temporary storage for measure number
J	I Variable	loop index for measures
SUM	R Variable	counter for cumulative energy savings

Subroutine ECHO

Name Type Main Use

CARD	R Array	last card read
I	I Variable	loop index for three different files
IMTES	I Variable	counter for labelling of lines on measure cards
LINCNT	I Variable	counter for lines on one page
MAXLIN	I Variable	maximum number of lines on one page
MEASUR	R Variable	variable containing the string 'measure'
SYMB	R Variable	contains label to be printed with measure
SYMBAR	R Array	contains labels to be printed with measure cards
TEST	R Variable	used to compare input card with string 'measure'

Subroutine HOURH

Name Type Main Use

FAC1	R Variable	effective delta T (Tbal-Tout)
FAC2	R Variable	fraction of free heat used
HOURS	R Array	hourly weather data from different cities
HSUM	R Variable	sum of hours for city selected
HZ	R Variable	sum of hours with T less than Tbal
I	I Variable	loop index for degress
ICLIM	I Variable	number of city selected
ICLMAX	I Variable	number of cities for which weather data are supplied
SLO	R Variable	standby losses
STEP	R Variable	degree hours for T less than Tbal
SUM	R Variable	sum of degree hours for T less than Tbal
TIN	R Variable	inside temperature
ZW	R Variable	UA in kW/degree F
ZX	R Variable	slo divided by hsum
ZY	R Variable	product of (Tin-Tout) and hours for Tout

Subroutine MNLOOP

Name Type Main Use

ALIF	R Variable	inverse stock decay rate
ALPHA	R Variable	temporary storage of stock replacement rate
CCEF	R Function	statement function for calculation of CCE
FR	R Variable	temporary storage for eligible frac./roll-in time
I	I Variable	loop index for years
ILIF	I Variable	integer of alif
IMEA	I Variable	number of active measure in measure arrays
J	I Variable	loop index for enduses
K	I Variable	loop index
YEAR	R Variable	index for number of years from measure start year
KK	I Variable	loop index
KMEA	I Variable	counter for active measures
KORDER	I Array	stores numbers of measures sent to work4
MEATMP	I Variable	temporary storage for measure number
REPLN	R Variable	storage for replaced stock
REPLO	R Variable	storage for replaced stock (from last year)
STCKTY	R Variable	masked stock type
UECBEF	R Variable	initial UEC

Subroutine PRENDU

Name Type Main Use

DUMMY	R Variable	zero printed for UECs with Old stock decayed away
ENDUSA	R Variable	baseline usage
I	I Variable	loop index for enduses
IYEAR	I Variable	current year
KK	I Variable	loop index
LINCNT	I Variable	counter for number of lines on one page
MAXLIN	I Variable	maximum number of lines on one page
OLDID	R Variable	storage for last enduse ID (for subtotals)
POTUSA	R Variable	potential usage
RNEWID	R Variable	storage for next enduse ID (for subtotals)
SBASE	R Variable	subtotals for baseload energy use
SBUEC	R Variable	subtotal baseline UEC
SPOT	R Variable	subtotals for potential UEC energy use
SPUEC	R Variable	subtotal potential UEC
SSTO	R Variable	subtotals for stock
STCKTY	R Variable	masked stock type
TBASE	R Variable	totals for baseload
TPOT	R Variable	totals for potential UEC
TSTO	R Variable	totals for stock

Subroutine PRMEAS

Name Type Main Use

AVMW	R Variable	average megawatts
I	I Variable	measure number from CCE ordered array

IMEA	I Variable	number of measures to be printed
IYEAR	I Variable	current year
J	I Variable	loop index for measures
KK	I Variable	loop index
LENGTH	I Variable	marker for short/long form of printout
LINCNT	I Variable	counter for number of lines on one page
MAXLIN	I Variable	maximum number of lines on one page
TODO	L Variable	true, if cut off line is not yet drawn

Subroutine PLOSPC

Name Type Main Use

AXMAX	R Array	maximum axis value as determined by smooth
BLANK	R Array	contains string blanks
I	I Variable	loop index for measures
IMEA	I Variable	number of measures
IYEAR	I Variable	current year
J	I Variable	loop index for x/y
SCMAX	R Array	maximum actual values on both axes
WEIGHT	R Variable	last digit of measure number

Subroutine READCC

Name Type Main Use

CARD	R Array	last data card read
CMD	R Variable	masked three character command code
FUELTY	R Variable	masked fueltype from first enduse card
FUELTZ	R Variable	masked fueltype from subsequent enduse cards
ISNCMP	I Variable	used to ensure increasing order of snapshot years
ITEMP	I Variable	temporary storage of idiag/istay
JJ	I Variable	loop index
KK	I Variable	loop index
TEMP	R Array	temporary storage of elecpr/gaspri/oilpri

Subroutine READDB

Name Type Main Use

CARD	R Array	last card read
CARDTY	R Variable	masked cardtype (E or M)
CARD2	R Array	second card for measure cards
ENSHOW	L Variable	true, if at least one matching enduse card found
I	I Variable	loop index for enduses requested on control card
IERST	I Variable	counter for measures without decay rate (NEW STOCK)
KK	I Variable	loop index
NMEAMX	I Variable	maximum number of measures allowed
SHEND	R Variable	shifted control card ID from enduse card
SHIN	R Variable	shifted control card ID from measure card

STCKTY R Variable masked stock type

Subroutine SMOOTH

Name Type Main Use

ALG	R Variable	logarithm of maximum value
ILG	I Variable	truncated value of alg
IQUO	I Variable	truncated value of quo
POW	R Variable	10 raised to the power of ilg
QUO	R Variable	mantissa of maximum value

Subroutine SORTCC

Name Type Main Use

ELEMEN	R Array	
I1	I Variable	
I2	I Variable	
J	I Variable	
K	I Variable	
LIST	I Array	
L1	I Variable	
L2	I Variable	
M	I Variable	
N	I Variable	

Subroutine TCCSUB

Name Type Main Use

AXMAX	R Variable	smoothed cost value
AYMAX	R Variable	smoothed savings value
CSTSUM	R Variable	cumulative costs
DOLLAR	R Variable	cumulative savings
I	I Variable	loop variable roi/cce
IMEA	I Variable	measure number
IWEI	I Variable	weight=last digit of measure number
J	I Variable	enduse number
JTEMP	I Variable	temporary storage for measure number
K	I Variable	number of measures in enduse J
L	I Variable	loop index for measures
LORDER	I Array	index for sorted measures
LTEMP	I Variable	temporary storage for ordered measure number
M	I Variable	loop index
MEATMP	I Array	array for active measures
ROICCE	R Array	array for roi/cce for active measures
SAVSUM	R Variable	mantissa of maximum value
UFRAC	R Variable	mantissa of maximum value
WEIGHT	R Variable	mantissa of maximum value

Subroutine WORK4

Name Type Main Use

AREANW	R Variable	temporary storage for area
AREAN2	R Variable	temporary storage for area2
CONFAC	R Variable	conversion factor MBtu/h --> kwh/yr
EFF	R Variable	product of efficiencies
EFFM	R Variable	temporary storage for product of efficiencies
EFF1M	R Variable	temporary storage for first efficiency
FAC1	R Variable	actual delta T for space heating
FAC2	R Variable	actual fraction of free heat used in space heating
FUEL	R Variable	total energy used
FUELM	R Variable	temporary storage for fuel consumed
HEAT	R Variable	total heat produced (fuel*eff)
HEATM	R Variable	temporary storage for total heat produced
HEAT2	R Variable	heat produced in secondary UA
I	I Variable	loop index
IACT	I Array	keeps track of measures already applied
IC	I Variable	number of cheapest measure remaining
ILOOP	I Variable	index for outer loop over measures
IRANG	I Variable	counter for installed measures
J	I Variable	loop index
JLOOP	I Variable	loop index
RC	R Variable	comparison value for cheapest CCE
RVALUEJ	R Variable	temporary storage for r-value
RVALU2J	R Variable	temporary storage for r-value
SLO	R Variable	standby losses
SLOM	R Variable	standby losses in measure loop
SLOPR	R Variable	standby losses as printed out
TD1	R Variable	temperature difference tin-tout
TD2	R Variable	temperature difference tmid-tout
TPR1	R Variable	temperature difference tin-tout as printed out
UA1	R Variable	summed ua
UA2	R Variable	summed ua (tmid)
UM	R Variable	summed ua in measure loop
UM2	R Variable	summed ua (tmid) in measure loop

Subroutine WORK4T

Name Type Main Use

BLANK	R Variable	constant, contains 10 alphanumeric blanks
CARD	R Array	holds last card read in from minor data base
EID	R Variable	enduse ID as read from data card
ELIG	R Array	eligible fractions for measures
ENDUS	R Variable	enduse as requested from major data base
FRAC	R Array	fractions for different typical cases
FRACHK	R Variable	checks that sum of typical case fractions is 1
IDESC	I Array	descriptions of measures
II	I Variable	loop index

IP	I Variable	loop index
ITYPC	I Variable	counts typical cases
ITYPCM	I Variable	maximum number of typical cases
JJ	I Variable	loop index
KK	I Variable	loop index
NMMAX	I Variable	number of measures for first typical case
NUM	I Variable	number of typcase/measures as read from card
PROZ1	R Variable	marker for percentage input of ual
PROZ2	R Variable	marker for percentage input of stand-by loss
RLIF	R Variable	measure lifetime as read from card
TEXT	R Array	contains comments on enduse/typcase cards
TITLE	R Variable	contains type of card(enduse/typcase/measure)
UECAFT	R Variable	UEC after calling work4
UECBEF	R Variable	UEC before calling work4

1.2 Common Block Variables

The common block variables are contained in six different common blocks. They are listed below

/cntrl/	Control information read from control cards
/majdb/	Contains major data base
/result/	Contains results
/minmaj/	Data exchange between minor and major data base
/work5/	Data exchange between work4 and work4t
/acorr/	Control information and data for correlation plot

common/cntrl/

adminc	switch for inclusion of administrative cost
bpapen	switch for using estimated market penetration fraction
curves	switch for printing supply curves
discou	discount rate
ecc	switch for printing control cards
ema	switch for printing major data base
emi	switch for printing minor data base
enduse(99)	enduses considered for plots/tables
idiag	diagnostic level
iendus	number of enduses
inotyp	number of enduses for which work4 should not be called
isnap(31)	snapshot years for which tables/curves are printed
isnapn	number of snapshot years
istay	start year
itcc	number of enduses for which TCCs are requested
nmea	total number of measures
priuec	switch for printing of UECs and enduses
rwork4	switch for calling work4 only
tables	switch for printing of supply tables
tcc(99)	enduse IDs for which TCCs are requested
typcno(99)	enduse IDs which should not call work4
elecpr(3)	electricity (1 is original price in \$)
gaspr(3)	gas (2 is escalation rate)

oilpri(3) oil (3 is current price in \$)

common/majdb/

endadd(99) rate of additions to this stock
enddec(99) decay rate for this stock
enddes(4,99) enduse description (40 characters)
endid(99) enduse ID (10 characters)
endref(99) initial stock for this enduse in 1000s
endsto(99) current stock in 1000s
enduec(99) initial UEC in kwh/year
endupd(99) last update
iendmn(99) number of measures for this enduse
imenum(99) number of measures for each enduse
imepoi(99) pointer to measure arrays where first measure
for each enduse starts
meaidn(750) measure ID number (1 - 99)
mealif(750) average lifetime in years
measta(750) start year of measure
measto(750) stop year of measure
rmecst(750) average cost of measure in \$
rmedes(4,750) measure description (40 characters)
rmeelf(750) eligible fraction
rmeemf(750) estimated market fraction
rmeemp(750) estimated market penetration (as fraction)
rmeid(750) measure ID (10 characters)
rmepcs(750) program cost in \$
rmerli(750) roll-in time in years
rmesav(750) average savings in kwh/year
rmesea(750) seasonal value
rmeupd(750) last update
ueccur(99) current UEC in kwh/year

common/result/

aes(750) aggregate energy savings in mwh
cce(750) cost of conserved energy in \$/kwh
cumsav(750) cumulative energy savings in mwh
iorder(750) measure numbers with increasing cce

common/work5/

area(20) primary areas
area2(20) secondary areas
aream(20,20) changes in primary areas of measures
aream2(20,20) changes in secondary areas of measures
cce(20) costs of conserved energy of measures
cost(20) costs of measures
discou discount rate
effi(5) efficiencies
effim(5,20) changes in efficiencies of measures
fuela primary fuel input
fuelb secondary fuel input
heata primary heat load

heatb	secondary heat load
heatb2	heat load due to secondary heat loss paths
heatm2	secondary heat load after measure is implemented
iorder(20)	economic rank of measures
iproza(2,20)	indicator for using percentages for ua(1,..) and slo(2,..) measures
jproza	indicator for using a space heating typcase
life(20)	lifetimes of measures
maxeta	maximum number of efficiencies
maxm	maximum number of measures
maxs	maximum number of fixed consumptions
maxua	maximum number of primary ua values
maxua2	maximum number of secondary u values
neta	number of efficiencies
nm	number of measures
ns	number of fixed consumptions
nua	number of primary ua values
nua2	number of secondary u values
saving(20)	energy savings of measures
sloss(5)	fixed consumptions
slossm(5,20)	changes in fixed consumptions due to measures
tin	inside (highest) temperature
tinm(20)	inside temperature changes of measures
tmid	mid temperature
tmidm(20)	changes in the mid temperature of measures
tout	outside (lowest) temperature
uvalm(20,20)	changes in primary u values of measures
uvalm2(20,20)	changes in secondary u values of measures
uvalu2(20)	secondary u values
uvalue(20)	primary u values

common/minmaj/

avelif(20)	average lifetime of measure
cosave(20)	average cost of measure
eligav(20)	average eligible fraction of measure
imtran	number of measures sent to work4
jorder(99)	order of measures
savave(20)	average energy savings of measure

1.3 Alphabetical Listing of All Variables

adminc	switch for inclusion of administrative cost
aes(750)	aggregate energy savings in mwh
ALG	logarithm of maximum value
ALIF	inverse stock decay rate
ALPHA	temporary storage of stock replacement rate
area(20)	primary areas
area2(20)	secondary areas
aream(20,20)	changes in primary areas of measures
aream2(20,20)	changes in secondary areas of measures
AREAN2	temporary storage for area2
AREANW	temporary storage for area

avelif(20)	average lifetime of measure
AVMW	average megawatts
AXMAX	maximum axis value as determined by smooth
AXMAX	smoothed cost value
AYMAX	smoothed savings value
BLANK	constant, contains 10 alphanumeric blanks
BLANK	contains string blanks
bpapen	switch for using estimated market penetration fraction
CARD	holds last card read in from minor data base
CARD	last card read
CARD	last card read
CARD	last data card read
CARD2	second card for measure cards
CARDTY	masked cardtype (E or M)
cce(20)	costs of conserved energy of measures
cce(750)	cost of conserved energy in \$/kwh
CCEF	statement function for calculation of CCE
CMD	masked three character command code
CONFAC	conversion factor MBtu/h --> kwh/yr
cosave(20)	average cost of measure
cost(20)	costs of measures
CSTSUM	cumulative costs
cumsav(750)	cumulative energy savings in mwh
curves	switch for printing supply curves
discou	discount rate
discou	discount rate
DOLLAR	cumulative savings
DUMMY	zero printed for UECs with Old stock decayed away
ecc	switch for printing control cards
EFF	product of efficiencies
EFF1M	temporary storage for first efficiency
effi(5)	efficiencies
effim(5,20)	changes in efficiencies of measures
EFFM	temporary storage for product of efficiencies
EID	enduse ID as read from data card
elecpr(3)	electricity (1 is original price in \$)
ELEMEN	
ELIG	eligible fractions for measures
eligav(20)	average eligible fraction of measure
ema	switch for printing major data base
emi	switch for printing minor data base
endadd(99)	rate of additions to this stock
enddec(99)	decay rate for this stock
enddes(4,99)	enduse description (40 characters)
endid(99)	enduse ID (10 characters)
endref(99)	initial stock for this enduse in 1000s
endsto(99)	current stock in 1000s
enduec(99)	initial UEC in kwh/year
endupd(99)	last update
ENDUS	enduse as requested from major data base
ENDUSA	baseline usage
enduse(99)	enduses considered for plots/tables
ENSHOW	true, if at least one matching enduse card found
FAC1	actual delta T for space heating

FAC1	effective delta T (Tbal-Tout)
FAC2	actual fraction of free heat used in space heating
FAC2	fraction of free heat used
FR	temporary storage for eligible frac./roll-in time
FRAC	fractions for different typical cases
FRACHK	checks that sum of typical case fractions is 1
FUEL	total energy used
fuela	primary fuel input
fuelb	secondary fuel input
FUELM	temporary storage for fuel consumed
FUELT	masked fuel type
FUELTY	masked fueltype from first enduse card
FUELTZ	masked fueltype from subsequent enduse cards
gaspri(3)	gas (2 is escalation rate)
HEAT	total heat produced (fuel*eff)
HEAT2	heat produced in secondary UA
heata	primary heat load
heatb	secondary heat load
heatb2	heat load due to secondary heat loss paths
HEATM	temporary storage for total heat produced
heatm2	secondary heat load after measure is implemented
HOURS	hourly weather data from different cities
HSUM	sum of hours for city selected
HZ	sum of hours with T less than Tbal
I	loop index
I	loop index
I	loop index for degress
I	loop index for enduses
I	loop index for enduses
I	loop index for enduses requested on control card
I	loop index for measures
I	loop index for three different files
I	loop index for years
I	loop variable roi/cce
I	measure number from CCE ordered array
I1	
I2	
IACT	keeps track of measures already applied
IC	number of cheapest measure remaining
ICLIM	number of city selected
ICLMAX	number of cities for which weather data are supplied
IDESC	descriptions of measures
idiag	diagnostic level
iendmn(99)	number of measures for this enduse
iendus	number of enduses
IERST	counter for measures without decay rate (NEW STOCK)
II	loop index
ILG	truncated value of alg
ILIF	integer of alif
ILOOP	index for outer loop over measures
IMEA	measure number
IMEA	number of active measure in measure arrays
IMEA	number of measures
IMEA	number of measures to be printed

IMEA	temporary storage for measure number
imenum(99)	number of measures for each enduse
imepoi(99)	pointer to measure arrays where first measure
IMTES	counter for labelling of lines on measure cards
imtran	number of measures sent to work4
inotyp	number of enduses for which work4 should not be called
iorder(20)	economic rank of measures
iorder(750)	measure numbers with increasing cce
IP	loop index
iproza(2,20)	indicator for using percentages for ua(1,..) and
IQUO	truncated value of quo
IRANG	counter for installed measures
isnap(31)	snapshot years for which tables/curves are printed
isnapn	number of snapshot years
ISNCMP	used to ensure increasing order of snapshot years
istay	start year
itcc	number of enduses for which TCCs are requested
ITEMP	temporary storage of iddiag/istay
ITYPC	counts typical cases
ITYPCM	maximum number of typical cases
IWEI	weight=last digit of measure number
IYEAR	current year
IYEAR	current year
IYEAR	current year
J	
J	enduse number
J	loop index
J	loop index for enduses
J	loop index for measures
J	loop index for measures
J	loop index for x/y
JJ	loop index
JJ	loop index
JLOOP	loop index
jorder(99)	order of measures
jproza	indicator for using a space heating typcase
JTEMP	temporary storage for measure number
K	
K	loop index
K	number of measures in enduse J
KK	loop index
KK	loop index
KK	loop index
KK	loop index
KK	loop index
KK	loop index
KK	loop index
KMEA	counter for active measures
KORDER	stores numbers of measures sent to work4
L	loop index for measures
L1	
L2	
LENGTH	marker for short/long form of printout
life(20)	lifetimes of measures
LINCNT	counter for lines on one page

LINCNT	counter for number of lines on one page
LINCNT	counter for number of lines on one page
LIST	
LORDER	index for sorted measures
LTEMP	temporary storage for ordered measure number
M	
M	loop index
maxeta	maximum number of efficiencies
MAXLIN	maximum number of lines on one page
MAXLIN	maximum number of lines on one page
MAXLIN	maximum number of lines on one page
maxm	maximum number of measures
maxs	maximum number of fixed consumptions
maxua	maximum number of primary ua values
maxua2	maximum number of secondary u values
meaidn(750)	measure ID number (1 - 99)
mealif(750)	average lifetime in years
measta(750)	start year of measure
measto(750)	stop year of measure
MEASUR	variable containing the string 'measure'
MEATMP	array for active measures
MEATMP	temporary storage for measure number
N	
neta	number of efficiencies
nm	number of measures
nmea	total number of measures
NMEAMX	maximum number of measures allowed
NMMAX	number of measures for first typical case
ns	number of fixed consumptions
nua	number of primary ua values
nua2	number of secondary u values
NUM	number of typcase/measures as read from card
oilpri(3)	oil (3 is current price in \$)
OLDID	storage for last enduse ID (for subtotals)
POTUSA	potential usage
POW	10 raised to the power of ilg
priuec	switch for printing of UECs and enduses
PROZ1	marker for percentage input of ual
PROZ2	marker for percentage input of stand-by loss
QUO	mantissa of maximum value
RC	comparison value for cheapest CCE
REPLN	storage for replaced stock
REPLO	storage for replaced stock (from last year)
RLIF	measure lifetime as read from card
rmeast(750)	average cost of measure in \$
rmedes(4,750)	measure description (40 characters)
rmeelf(750)	eligible fraction
rmeemf(750)	estimated market fraction
rmeemp(750)	estimated market penetration (as fraction)
rmeid(750)	measure ID (10 characters)
rmepcs(750)	program cost in \$
rmerli(750)	roll-in time in years
rmesav(750)	average savings in kwh/year
rmesea(750)	seasonal value

rmeupd(750)	last update
RNEWID	storage for next enduse ID (for subtotals)
ROICCE	array for roi/cce for active measures
RVALU2J	temporary storage for r-value
RVALUEJ	temporary storage for r-value
rwork4	switch for calling work4 only
savave(20)	average energy savings of measure
saving(20)	energy savings of measures
SAVSUM	mantissa of maximum value
SBASE	subtotals for baseload energy use
SBUEC	subtotal baseline UEC
SCMAX	maximum actual values on both axes
SHEND	shifted control card ID from enduse card
SHIN	shifted control card ID from measure card
SLO	standby losses
SLO	standby losses
SLOM	standby losses in measure loop
SLOPR	standby losses as printed out
sloss(5)	fixed consumptions
slossm(5,20)	changes in fixed consumptions due to measures
SPOT	subtotals for potential UEC energy use
SPUEC	subtotal potential UEC
SSTO	subtotals for stock
STCKTY	masked stock type
STCKTY	masked stock type
STCKTY	masked stock type
STEP	degree hours for T less than Tbal
SUM	counter for cumulative energy savings
SUM	sum of degree hours for T less than Tbal
SYMB	contains label to be printed with measure
SYMBAR	contains labels to be printed with measure cards
tables	switch for printing of supply tables
TBASE	totals for baseload
tcc(99)	enduse IDs for which TCCs are requested
TD1	temperature difference tin-tout
TD2	temperature difference tmid-tout
TEMP	temporary storage of elecpr/gaspri/oilpri
TEST	used to compare input card with string 'measure'
TEXT	contains comments on enduse/typcase cards
tin	inside (highest) temperature
TIN	inside temperature
tinm(20)	inside temperature changes of measures
TITLE	contains type of card(enduse/typcase/measure)
tmid	mid temperature
tmidm(20)	changes in the mid temperature of measures
TODO	true, if cut off line is not yet drawn
tout	outside (lowest) temperature
TPOT	totals for potential UEC
TPR1	temperature difference tin-tout as printed out
TSTO	totals for stock
typcno(99)	enduse IDs which should not call work4
UA1	summed ua
UA2	summed ua (tmid)
UECAFT	UEC after calling work4

UECBEF	initial UEC
UECBEF	UEC before calling work4
ueccur(99)	current UEC in kwh/year
UFRAC	mantissa of maximum value
UM	summed ua in measure loop
UM2	summed ua (tmid) in measure loop
uvalm(20,20)	changes in primary u values of measures
uvalm2(20,20)	changes in secondary u values of measures
uvalu2(20)	secondary u values
uvalue(20)	primary u values
WEIGHT	last digit of measure number
WEIGHT	mantissa of maximum value
YEAR	index for number of years from measure start year
ZW	UA in kW/degree F
ZX	slo divided by hsum
ZY	product of (Tin-Tout) and hours for Tout

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