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ENERGY

CONSERVATION

RESEARCH PROGRAM ON THE
ECONOMIC FEASIBILITY AND
COMMERCIALIZATION POTENTIAL
OF ACES

FINAL REPORT
FEBRUARY 1979

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WORK PERFORMED FOR
THE

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

FINAL SUMMARY REPORT

Research Program on the
Economic Feasibility and Commercialization
Potential of the ACES
Contract No. DE-AC05-77C502130

For

U.S. Department of Energy
Washington, D. C.

February 1979

SUMMARY REPORT

I. Introduction and Executive Summary

The contract between the Department of Energy (DOE) and the NAHB Research Foundation, Inc. (NAHBRF) for a "Research Program on the Economic Feasibility and Commercialization Potential of the ACES" was transferred from Headquarters to Oak Ridge Operations on August 17, 1977. The completion date of September 7, 1978, was extended to October 30, 1978, and finally to February 28, 1979.

Based on COPs for heating and cooling supplied by Oak Ridge National Laboratory, NAHBRF analysis of the energy savings and associated utility cost savings showed significant energy savings (64% to 69%) of ACES over conventional installations in the twelve characterized houses. There were substantial reductions in annual energy costs in 9 of the 12 selected houses ($499.71 to $669.93). Three of the selected 12 houses had rather low cost savings (Indianapolis, Indiana, $297.90; Boise, Idaho, $203.88; and Seattle, Washington, $104.80) due to their present low costs of electricity.

Energy savings in nine of the 12 houses would "justify"* substantial first costs for the ACES installation ($5,829 to $7,505). The other three had allowable first costs that were probably too low to justify the ACES installation ($4,590, $3,617 and $2,898).

*See Life Cycle Cost Analysis, page 4-1 and assumptions.

Although pilot model costs are much higher than the above justifiable ACES installation costs, the NAHBRF believes that manufacturers would be able to reduce the cost of ACES equipment when a substantial market exists for such equipment. This market may be developed when builders and new home buyers understand the potential for immediate utility cost reductions in the order of $30 to $50 per month. On the other hand, as discussed in Chapter 8, there are significant barriers to market development that would need to be overcome.

For homes where electricity is the energy selected for space heating and water heating and possibly for some homes using fossil fuels, the NAHBRF believes that there are sufficient ACES energy and cost savings potential for many such homes to interest builders and buyers of single family homes. Assuming ACES installed prices can be reduced to levels at or below those shown in Task 4, Tables 1 through 12, the analysis of applicability of ACES to various homes and climates indicates a potential future market, possibly as high as one-half million units per year. Even when a number of manufacturers are involved, such a market potential appears to offer an opportunity for cost reduction of equipment due to volume production.

The NAHBRF recommends that further demonstrations be arranged in a number of key market areas. Also, that efforts be made to reduce installed cost of the system (in addition to equipment costs); that the on-site installation cost be monitored and evaluated for cost reduction opportunities and that a follow-up program of monitoring actual operating costs, comfort conditions and occupant reaction be undertaken under conditions of normal occupancy. If the results are sufficiently favorable, this information should be widely disseminated and efforts be made to enlist the interest of manufacturers of equipment and home builders to stimulate the commercialization process for ACES. In the meantime, it is recommended that DOE investigate the potential for increasing the use of ACES by tax rebates or other financial incentives.

II SUMMARY OF TASKS

TASK 1- LIAISON WITH ORNL AND RICHMOND ACES

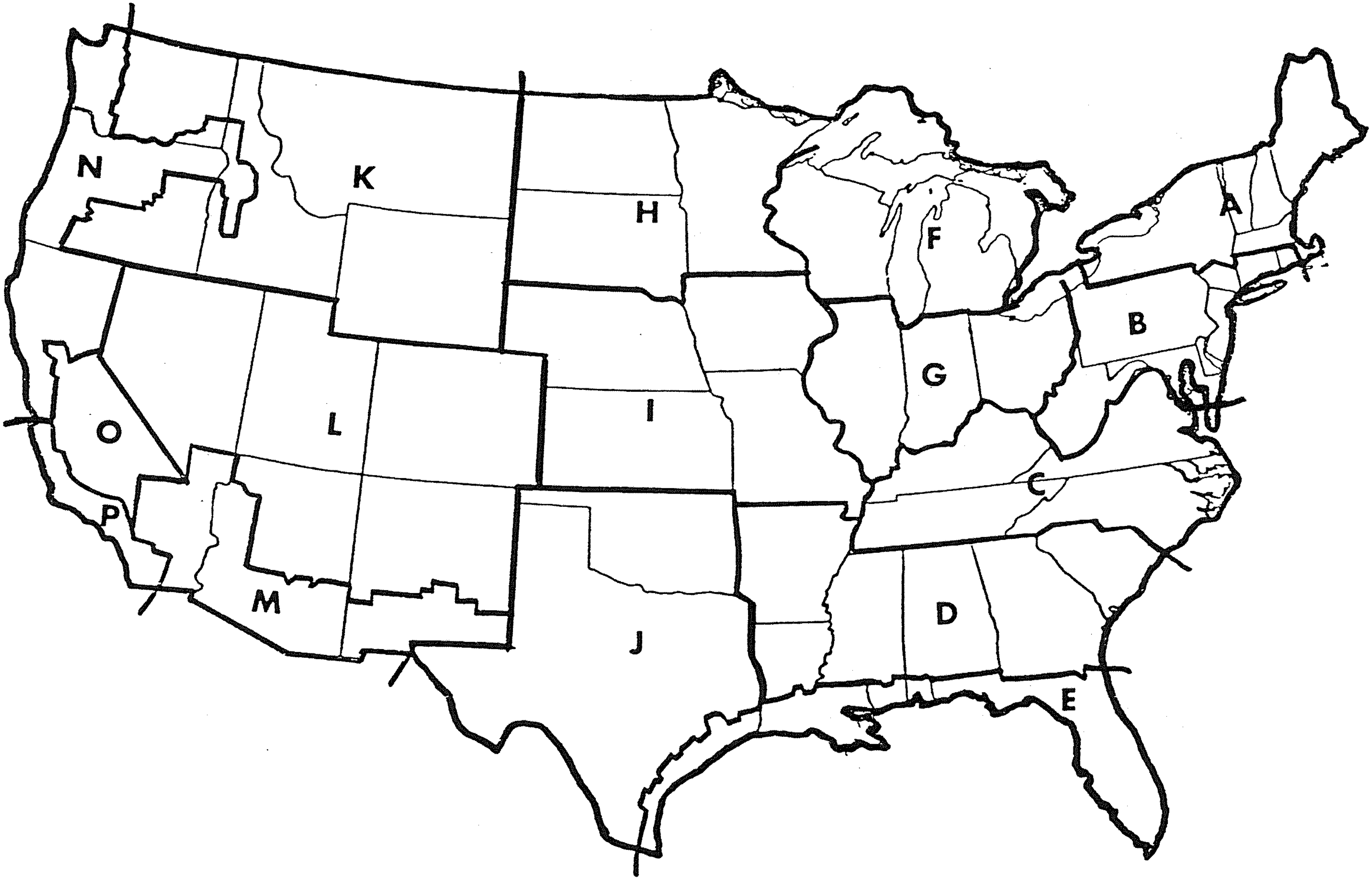
Visits were made to Richmond, Virginia, on October 22, 1976, to ORNL on November 8th and 9th, 1976, and to Philadelphia, Pennsylvania, on November 30, 1976. Several other meetings were held with ORNL and DOE/ERDA personnel to maintain liaison among the necessary participants.

TASK 2 - APPLICABILITY BY CLIMATE

The typical house models selected for analysis were from the NAHB survey from 6000 builders of over 110,000 homes in the NAHB 1976 Home Builder Survey. Sixteen zones were characterized for climatic conditions throughout the country.

The climate zones were based on a combination of factors, including heating degree days, annual cooling hours and other climate characteristics such as summer humidity. Zones are shown on the following map (Task 2 - Table 1) which is followed by the climate descriptions within each zone (Task 2, Table 2).

Twelve zones were selected and the most marketable house type and size was picked from NAHBRF's survey to be analyzed for comparison with conventional and ACES. Analyses were run to determine allowable ACES costs and to show the comparative energy costs in those typical houses.



Task 2, Table 1 CLIMATIC CONDITION ZONES FOR ACES

Task 2, Table 2

RESIDENTIAL CLIMATE ZONE DESCRIPTIONS

Climate Zone	Heating Degree Days	Annual Cooling Hours	ZONE CHARACTERISTICS			
			Winter Intensity	Summer Intensity	Summer Humidity	Other
A.	6000+	600-	Cold to very cold	Mild	Mild to moderate	Little need for A.C.
B.	4500 to 6000	600 to 1000	Moderate to cold	Mild to moderate	Mild to moderate	Moderate need for A.C.
C.	3200 to 4500	1000 to 1400	Moderate	Moderate to warm	Moderate	Moderate to desirable A.C. need
D.	1500 to 3200	1400 to 1750	Mild	Warm to hot	Moderate to humid	A.C. desirable
E.	1500-	1750+	Semi-tropic	Long hot season	Humid	Mandatory A.C. in new homes
F.	6500+	700-	Cold to very cold	Mild	Mild to moderate	Marginal need for A.C.
G.	4500 to 6500	700 to 1000	Moderate to cold	Moderate	Moderate	Moderate A.C. need
H.	7000+	800-	Very cold	Mild	Mild to moderate	Little need for A.C.
I.	4000 to 7000	800 to 1200	Moderate to cold	Moderate to warm	Moderate	Moderate to desirable A.C. need
J.	4000-	1200+	Mild to moderate	Warm to hot	Moderate	Desirable to mandatory A.C. need
K.	6000+	600-	Cold to very cold	Mild	Low	Little need for A.C.
L.	4000 to 6000	600 to 1200	Moderate to cold	Moderate	Low	Marginal to desirable
M.	4000-	1200+	Mild arid	Long dry hot season	Low	Mandatory A.C. in new homes
N.	3000+	600-	Moderate	Mild	Low to moderate	A.C. marginal
O.	3000-	600+	Mild	Moderate to warm	Low	A.C. desirable
P.	3000-	600-	Mild	Mild	Low	A.C. marginal

TASK 3 - EFFECT OF HOUSE TYPES

Analysis of applicability to ACES involves analysis of the heat loss and heat gain to be handled by the system. The major considerations affecting those losses are:

- Area of exposures to the outdoors.
- Resistance to heat transmission by outdoor exposed sections.
- Air leakage (infiltration) through (parts of) outdoor exposed sections.
- Weather (temperature, wind, sun, rain, water vapor).
- Indoor conditions being maintained, and for cooling, internal loads.

Single story houses generally have the following area relationships:

- The exposed outside wall area is about equal to the floor area.
- The top outside exposure is usually the ceiling to attic, also about equal to the floor area.
- The window and door area generally ranged (in the past) between 10 and 25 percent of the total wall area, with 15 percent a satisfactory average.

Foundation types include slab-on-grade, pier construction (open crawl space), vented crawl space, unvented crawl space, partial basement and full basement.

To document some of the conclusions reached earlier in the contract, it had previously been decided to study characteristics of houses built in 1975 and compare them with those predicted to be built in 1982.

Consideration of evolution of insulation practices and the result on load characteristics was part of the reasoning process in past and present analysis. Some discussion of these practices and effects follows.

INSULATION LEVELS: Insulation R-levels in ceilings, walls and floors respectively may be indicated by three values separated by slant lines. As broad generalities, houses built prior to 1950 were insulated 0/0/0 (ceilings/walls/floors). In very cold and very warm climates some insulation was frequently used in ceilings, a little in walls rarely, and floors practically never. In the years that follow, more insulation was used, as estimated below.

Period	Insulation R_t	Section R_t	Glass R_t
From 1950 to 1960	7/0/0	8.5/4/2	.88
1960 to 1970	11/6/0	12.5/9/2	1.06
1970 to 1974	13/11/0	14.5/13/2	1.21
1975	19/11/11	20.5/13/13	1.38

Double glass, as either single pane plus storm windows or manufactured double pane glass lights was used rarely in the 1950's, but is common today except in the southern extremes and along the Pacific Coast. So all single glass is figured for the 50's, one fourth is double for the 60's, and one half is double for the '70-'74, and three fourths double for 1975.

As an exercise in comparatives, let us consider a 1500 sq ft floor area house, 15 percent glass area, with an open crawl space. The components of the load in our over-simplified house, by transmission only, would be (for a 50 degree TD heating), as shown in Table 1.

Granted open crawl foundations are rarely used now, the example illustrates that floors could be disregarded for years under most building codes (and were) and that one such significant area disregarded alters the whole distribution of loss percentages. Infiltration, not included above, is concentrated mainly at door and window openings.

TASK 3, TABLE 1. Heating Loads

	1950-1960		1960-1970		1970-1974		1975	
	MBtuh	%	MBtuh	%	MBtuh	%	MBtuh	%
Ceiling 1500 ft^2 ($75/R_t$)	8.82	11.8	6.00	9.8	5.17	9.1	3.66	16.3
Glass 225 ft^2 ($11.25/R_t$)	12.78	17.0	10.61	17.3	9.30	16.4	8.15	36.2
Opaque Wall 1275 ft^2 ($63.75/R_t$)	15.93	21.2	7.08	11.6	4.90	8.6	4.90	21.8
Floor 1500 ft^2 ($75/R_t$)	37.50	50.0	37.50	61.3	37.50	65.9	5.77	25.7
Total	75.03	100.0	61.19	100.0	56.87	100.0	25.30	100.0

The important conclusions from the exercise in Table 1 are:

- Any insulation added to uninsulated areas dramatically reduced that area's heat loss.
- Glass areas (insulated or not) have higher heat losses than opaque areas (insulated or not).
- Significant reduction of loss through any area alters the loss distribution.
- Increase or decrease (by as much as 20 percent) of insulated ceiling, wall or floor areas would have perceptible but an unimportant effect on total loads.
- Increase or decrease of glass area by as little as 1 percent of floor area value would have a significant effect on losses.
- Because insulation level reduced heat flow in summer and winter, reduction in heat loss by insulation would reduce heat gain in summer (at least) proportionately.

We believe the following are facts in regard to infiltration:

- Infiltration in typical homes built in 1977 averaged under one air change per hour in winter where no storm windows were used.
- Summer infiltration is about half of winter infiltration.
- Where prime windows are not exceptionally tightly sealed, storm windows reduce infiltration by about half.

- Close attention to caulking and otherwise sealing all exterior exposed sections of the building during construction in homes not requiring combustion air may reduce infiltration to a level inadequate to 1) dilute normal odors adequately, and 2) prevent excessive indoor relative humidity in winter.

The above considerations on infiltration contribute to the conclusion that infiltration cut significantly below half the level common in new construction (1977) may require measures to combat odors and excessive indoor humidity in winter when no combustion air is required.

Combining transmission and air exchange load considerations, it was concluded that further improvements in insulation and infiltration prevention would have little effect on the balance between summer and winter loads. The summer and winter loads respectively affect the summer and winter energy consumption for heating and cooling. It is that balance between summer and winter energy consumption which determines the feasibility of ACES residentially.

That is the background against which we concluded that:

- ACES is compatible with all popular house types.

TASK 4 - COSTS OF ALTERNATE DESIGNS

Attached to this report are the ACES Task 4 tables (1-14) which summarize the Task 4 results. Energy costs for the conventional and ACES systems were calculated, and a comparison was made to determine the annual cost savings for each of the twelve selected houses. This cost comparison was based on rates and fuel adjustments in effect from October 1977 through September 1978.

To determine the most logical method of setting the allowable cost for the ACES system to be marketable in each location, the following assumptions were made for the equation:*

$$P = S\left[\frac{a(a^n - 1)}{a - 1}\right]; \text{ where}$$

P = Cost of differential ACES (over conventional installation costs)

S = Operating cost savings in a typical year.

n = Period of years of analysis or time to recoup investment in ACES.

$$a = \frac{1 + f}{1 + i}; \text{ where}$$

f = The estimated annual percentage rate of price increase for energy used, expressed as a decimal.

i = The alternate investment interest rate expressed as a decimal.

For our example, we let:

f = 10% = .1, i = 9% = .09, n = 7 years.*

$$P = S\left[\frac{a(a^n - 1)}{a - 1}\right], \text{ where } a = \frac{1 + f}{1 + i} = \frac{1 + .1}{1 + .09} = 1.009174312$$

*(See Exhibit A - statement by Ralph J. Johnson in 4-19)

$$P = S \frac{1.009174312(1.009174312^7 - 1)}{1.009174312 - 1}$$

$$P = S \frac{1.009174312(1.0066014987 - 1)}{.009174312}$$

$$P = S \ (7.261648535) = S(7.26)$$

Example:

For Syracuse, New York

S = annual cost savings = \$634.52

P = \$634.52 x 7.26 = \$4,607

This means that if an ACES can be built into a house of the type selected for Syracuse, New York (2 story, basement and 2000 sq./ft.), (see Tables A and 1) for less than \$7,239, it would be economically feasible. The conventional installation was priced at \$2,632 and the ACES projected savings at \$4,607, giving a total allowable first cost of \$7,239.

To enhance the ACES marketability, the additional cost should be in the range of 10% to 20% less than the allowable cost based on the 7-year payback period. Most builders may be reluctant to add more than a couple thousand dollars to the selling price because of buyer concern over higher price and higher down payment even though the savings in monthly energy costs would be impressive.

Our calculations show the following allowable capital costs for each of the selected twelve cities with an assumed alternate investment rate of 9%, escalation in energy costs of 10% and a payback period of seven years (see Tables 13 and 14). The annual seasonal COP's used for the ACES were supplied by ORNL. The COP used for the heating portion is 2.7. The COP used for the hot water heating portion is 3.0. The COP used for the cooling portion is 12.0. ORNL also supplied an annual maintenance differential of \$60. This may be low until more experience is gained.

Pressure is being applied by many state and Federal agencies to the utility companies to use demand charges, however, most are just studying the use of demand charges or time of day charges (see Table 2). Lower rates for time of day or demand charges will help ACES in the future.

We did not use demand charge or time of day rates for the three cities presently offering them since they were experimental or optional with a one year trial period.

Further analysis of the energy savings in the twelve selected homes indicates very little variation due to climatic conditions. They vary from a low of 64% energy savings in Zone N, Seattle, WA to a high of 69% in Zone D, Atlanta, GA.

- Significant energy savings using ACES can be shown for all house types in all of the zones analyzed.

TASK 4, TABLE A, DATA ON ZONES & HOUSES SELECTED FOR COSTING

ZONE & CITY ANALYZED		BUILDING TYPE		FOUNDATION TYPE		FLOOR AREA OF RESIDENCE, FT^2	
		% in Zone	Analyzed	% in Zone	Analyzed	Avg in Zone*	Analyzed
A	Syracuse, NY	37.5 2-story	2-story	82 bsmt	bsmt	2016	2000
B*	Philadelphia, PA	40.1 1-story	1-story	72 bsmt	bsmt	1318	1300
C	Richmond, VA	20.8 2-story (57.0 1-story)	2-story	32 bsmt (37 crawl)	bsmt	2188 (1372)	2200
D	Atlanta, GA	72.5 1-story	1-story	47 slab	slab	1481	1500
F	Madison, WI	50.5 1-story	1-story	84 bsmt	bsmt	1311	1300
G	Indianapolis, IN	43.2 bilevel	bilevel	45 bsmt	bsmt	1714	1700
H	Minneapolis, MN	43.2 bilevel	bilevel	86 bsmt	bsmt	1569	1600
I	Kansas City, MO	49.0 1-story	1-story	79 bsmt	bsmt	1345	1300
J	Oklahoma City, OK	94.5 1-story	1-story	97 slab	slab	1655	1700
K	Boise, ID	62.8 1-story	1-story	61 bsmt	bsmt	1243	1200
L	Denver, CO	34.8 1-story	1-story	54 bsmt	bsmt	1409	1400
N	Seattle, WA	54.4 1-story	1-story	55 crawl	crawl	1449	1400

* Average floor area in zone for building type analyzed

** Rev. 7/24/78

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	415	744	1153	1271	1140	1004	570	248	-	-	-	132	6677
MMBtu Heating Conv Eff=1.0	5.55	9.94	15.41	16.98	15.23	13.42	7.62	3.31	-	-	-	1.76	89.22
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	1.00	3.16	3.16	0.67	7.99
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	1.37	1.37	1.37	1.37	16.43
Total MMBtu, Conv	6.92	11.31	16.78	18.35	16.59	14.79	8.99	4.68	2.37	4.53	4.53	3.80	114.34
Total KWH, Conv	2028	3314	4917	5377	4861	4333	2634	1371	694	1327	1327	1113	33296
Cost $ Conv	70.42	109.01	154.93	169.61	163.32	148.15	92.73	50.26	28.24	50.30	50.87	44.23	$1,132.07
MMBtu Heating ACES COP=2.7	2.06	3.68	5.71	6.29	5.64	4.97	2.82	1.23	-	-	-	0.65	33.05
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.15	0.46	0.46	0.10	1.17
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	5.51
Total MMBtu, ACES	2.52	4.14	6.17	6.75	6.09	5.43	3.28	1.69	0.61	0.92	0.92	1.21	39.73
Total KWH, ACES	738	1213	1808	1978	1784	1591	961	495	179	270	270	355	11642
Cost $ ACES	29.17	43.42	60.48	65.90	63.45	57.91	37.36	21.71	11.29	14.50	14.61	17.75	$ 437.55

Conventional Cost less ACES Cost	$ 694.52
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 634.52

Total Projected ACES Savings = Annual Savings $634.52 x 7.26* = $4607

Conventional Installation Cost = $2632

Allowable ACES Installation Cost = $7239

*Present Worth Factor - see Task 4 Calculation

City Syracuse, NY Zone A Degree Days 6760 Degree Days Used 6677 Cooling Hours 630

Task 4, Table 1

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	264	576	924	989	885	753	399	121	-	-	-	57	4968
MMBtu Heating Conv Eff=1.0	3.83	8.36	13.40	14.35	12.84	10.92	5.79	1.75	-	-	-	.83	72.07
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	1.31	5.40	5.40	.90	13.01
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	1.37	1.37	1.37	1.37	16.43
Total MMBtu, Conv	5.20	9.73	14.77	15.72	14.20	12.29	7.16	3.12	2.68	6.77	6.77	3.10	101.51
Total KWH, Conv	1524	2851	4328	4606	4161	3601	2098	914	785	1984	1984	908	29,744
Cost $ Conv	60.98	93.49	139.01	154.98	146.90	134.60	80.88	41.69	34.95	112.38	109.46	42.88	$1,152.20
MMBtu Heating ACES COP=2.7	1.42	3.10	4.96	5.31	4.76	4.04	2.14	0.65	-	-	-	0.31	26.69
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.19	0.79	0.79	0.13	1.90
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.88	3.56	5.42	5.77	5.21	4.50	2.60	1.11	0.65	1.25	1.25	0.90	34.10
Total KWH, ACES	551	1043	1588	1691	1527	1319	762	325	190	366	366	264	9992
Cost $ ACES	30.02	42.12	58.90	64.91	61.93	57.43	37.39	18.52	8.61	15.78	15.24	11.42	$ 422.27

Conventional Cost less ACES Cost	$ 729.93
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 669.93

Total Projected ACES Savings = Annual Savings $ 669.93 x 7.26* = $4864

Conventional Installation Cost = $2121

Allowable ACES Installation Cost = $6985

*Present Worth Factor - see Task 4 Calculation

City Philadelphia, PA Zone B Degree Days 4980 Degree Days Used 4968 Cooling Hours 920

Task 4, Table 2

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	214	495	784	815	703	546	219	38	-	-	-	-	3814
MMBtu Heating Conv Eff=1.0	3.93	9.10	14.41	14.98	12.92	10.03	4.02	0.70	-	-	-	-	70.09
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	1.50	4.80	6.20	6.20	2.05	20.75
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	5.30	10.47	15.78	16.35	14.29	11.40	5.39	3.57	6.16	7.57	7.57	3.42	107.27
Total KWH, Conv	1553	3068	4623	4791	4187	3340	1579	1046	1805	2218	2218	1002	31430
Cost $ Conv	60.67	101.98	138.80	147.07	137.22	117.38	64.17	44.58	92.34	112.70	113.37	52.05	$ 1182.33
MMBtu Heating ACES COP=2.7	1.46	3.37	5.34	5.55	4.79	3.71	1.49	0.26	-	-	-	-	25.97
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	0.22	0.70	0.91	0.91	0.30	3.04
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.92	3.83	5.80	6.01	5.25	4.17	1.95	0.94	1.15	1.37	1.37	0.76	34.52
Total KWH, ACES	563	1122	1699	1761	1538	1222	571	275	337	401	401	223	10113
Cost $ ACES	27.72	47.03	63.34	71.38	67.73	53.37	29.05	16.77	20.29	22.77	22.90	15.81	$ 458.16

Conventional Cost less ACES Cost	$724.17
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$664.17

Total Projected ACES Savings = Annual Savings $ 664.17 x 7.26* = $ 4822

Conventional Installation Cost = $ 2683

Allowable ACES Installation Cost = $ 7505

*Present Worth Factor - see Task 4 Calculation

City Richmond, VA Zone C Degree Days 3860 Degree Days Used 3814 Cooling Hours 1090

Task 4, Table 3

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	127	414	626	639	529	437	168	-	-	-	-	-	2940
MMBtu Heating Conv Eff=1.0	1.97	6.42	9.71	9.91	8.21	6.78	2.61	-	-	-	-	-	45.61
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	2.00	4.14	5.10	5.10	2.05	18.39
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	3.34	7.79	11.08	11.28	9.58	8.15	3.98	3.37	5.50	6.47	6.47	3.42	80.43
Total KWH, Conv	979	2282	3246	3305	2807	2388	1166	987	1612	1896	1896	1002	23566
Cost $ Conv	36.19	76.66	101.38	110.34	99.54	84.18	39.79	34.95	71.09	85.97	86.30	43.80	$ 870.19
MMBtu Heating ACES COP=2.7	0.73	2.38	3.60	3.67	3.04	2.51	0.97	-	-	-	-	-	16.90
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	0.29	0.61	0.75	0.75	0.30	2.70
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.19	2.84	4.06	4.13	3.50	2.97	1.43	0.75	1.06	1.21	1.21	0.76	25.11
Total KWH, ACES	349	832	1190	1210	1026	870	419	220	311	355	355	223	7360
Cost $ ACES	14.75	30.32	40.61	43.90	39.33	33.16	16.13	10.02	13.15	14.81	14.87	10.76	$ 281.81

Conventional Cost less ACES Cost	$ 588.38
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 528.38

Total Projected ACES Savings = Annual Savings $ 528.38 x 7.26* = $3836

Conventional Installation Cost = $2057

Allowable ACES Installation Cost = $5893

*Present Worth Factor - see Task 4 Calculation

City Atlanta, GA Zone D Degree Days 2960 Degree Days Used 2940 Cooling Hours 1320

Task 4, Table 4

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	474	930	1330	1473	1274	1113	618	310	99	-	-	174	7795
MMBtu Heating Conv Eff=1.0	4.21	8.27	11.82	13.10	11.33	9.89	5.49	2.76	0.88	-	-	1.55	69.30
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	0.40	2.70	2.50	0.24	5.84
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	5.58	9.64	13.19	14.47	12.70	11.26	6.86	4.13	2.64	4.07	3.87	3.16	91.57
Total KWH, Conv	1635	2825	3865	4240	3721	3299	2010	1210	774	1193	1134	926	26,832
Cost $ Conv	54.76	87.60	125.75	131.36	118.77	108.49	70.98	45.86	36.91	56.26	52.90	44.58	$ 934.22

MMBtu Heating ACES COP=2.7	1.56	3.06	4.38	4.85	4.20	3.66	2.03	1.02	0.33	-	-	0.57	25.66
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.06	0.40	0.37	0.04	0.87
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	2.02	3.52	4.84	5.31	4.66	4.12	2.49	1.48	0.84	0.86	0.83	1.07	32.04
Total KWH, ACES	592	1031	1418	1556	1365	1207	730	434	246	252	243	314	9388
Cost $ ACES	23.16	37.11	51.27	53.33	48.70	44.83	29.72	18.90	13.09	13.46	12.91	16.44	$ 362.92

Conventional Cost less ACES Cost	$ 571.30
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 511.30

Total Projected ACES Savings = Annual Savings $ 511.30 x 7.26* = $3712

Conventional Installation Cost = $2229

Allowable ACES Installation Cost = $5941

*Present Worth Factor - see Task 4 Calculation

City Madison, WI Zone F Degree Days 7860 Degree Days Used 7795 Cooling Hours 640

Task 4, Table 5

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	316	723	1051	1113	949	809	432	177	-	-	-	90	5660
MMBtu Heating Conv Eff=1.0	3.25	7.43	10.80	11.43	9.75	8.31	4.44	1.83	-	-	-	0.92	58.16
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	2.50	3.50	3.50	1.19	10.69
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	4.62	8.80	12.17	12.80	11.12	9.68	5.81	3.20	3.86	4.87	4.87	3.48	85.28
Total KWH, Conv	1354	2578	3566	3750	3258	2836	1702	938	1131	1427	1427	1020	24,987
Cost $ Conv	40.73	61.35	77.07	83.09	74.35	67.68	47.16	34.69	39.70	46.89	47.37	45.00	$ 665.08
MMBtu Heating ACES COP=2.7	1.20	2.75	4.00	4.23	3.61	3.08	1.64	0.68	-	-	-	0.34	21.53
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.37	0.51	0.51	0.17	1.56
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.66	3.21	4.46	4.69	4.07	3.54	2.10	1.14	0.82	0.97	0.97	0.97	28.60
Total KWH, ACES	486	941	1307	1374	1193	1037	615	334	240	284	284	284	8379
Cost $ ACES	20.78	31.90	38.17	40.35	37.15	34.68	24.20	16.81	13.76	15.44	15.54	18.40	$ 307.18

Conventional Cost less ACES Cost	$ 357.90
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 297.90

Total Projected ACES Savings = Annual Savings $ 297.90 x 7.26* = $ 2163

Conventional Installation Cost = $ 2427

Allowable ACES Installation Cost = $ 4590

*Present Worth Factor - see Task 4 Calculation

City Indianapolis, IN Zone G Degree Days 5700 Degree Days Used 5660 Cooling Hours 870

Task 4, Table 6

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	505	1014	1454	1631	1380	1166	621	288	81	-	-	189	8329
MMBtu Heating Conv Eff=1.0	4.85	9.73	13.96	15.66	13.25	11.19	5.96	2.76	0.78	-	-	1.81	79.95
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	1.50	2.50	2.50	0.20	6.70
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	6.22	11.10	15.33	17.03	14.62	12.56	7.33	4.13	3.64	3.87	3.87	3.38	103.08
Total KWH, Conv	1822	3252	4492	4990	4284	3680	2148	1210	1067	1134	1134	990	30203
Cost $ Conv	63.12	96.45	128.95	142.96	125.03	109.19	70.32	47.84	50.29	53.58	54.08	47.70	$ 989.51
MMBtu Heating ACES COP=2.7	1.80	3.60	5.17	5.80	4.91	4.14	2.21	1.02	0.29	-	-	0.67	29.61
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.22	0.37	0.37	0.03	0.99
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	2.26	4.06	5.63	6.26	5.37	4.60	2.67	1.48	0.96	0.83	0.83	1.16	36.11
Total KWH, ACES	662	1190	1650	1834	1573	1348	782	434	281	243	243	340	10580
Cost $ ACES	29.63	47.58	59.63	64.81	58.18	52.27	34.29	20.14	15.22	13.58	13.69	18.14	$ 427.16

Conventional Cost less ACES Cost	$ 562.35
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 502.35

Total Projected ACES Savings = Annual Savings $ 502.35 x 7.26* = $3647

Conventional Installation Cost = $2491

Allowable ACES Installation Cost = $6138

*Present Worth Factor - see Task 4 Calculation

City Minneapolis, MN Zone H Degree Days 8380 Degree Days Used 8329 Cooling Hours 640

Task 4, Table 7

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	220	612	905	1032	818	682	294	109	-	-	-	-	4672
MMBtu Heating Conv Eff=1.0	3.08	8.55	12.65	14.42	11.43	9.53	4.11	1.52	-	-	-	-	65.29
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	4.16	6.00	6.00	2.50	18.66
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	4.45	9.92	14.02	15.79	12.80	10.90	5.48	2.89	5.52	7.37	7.37	3.87	100.38
Total KWH, Conv	1304	2907	4108	4626	3750	3194	1606	848	1617	2159	2159	1134	29412
Cost $ Conv	48.34	88.06	114.39	126.77	111.71	97.71	63.00	32.77	61.66	83.53	85.42	44.78	$ 958.14
MMBtu Heating ACES COP=2.7	1.14	3.17	4.69	5.34	4.23	3.53	1.52	0.56	-	-	-	-	24.18
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.61	0.88	0.88	0.37	2.74
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.60	3.63	5.15	5.80	4.69	3.99	1.98	1.02	1.06	1.34	1.34	0.83	32.43
Total KWH, ACES	469	1064	1509	1699	1374	1169	580	299	311	393	393	243	9503
Cost $ ACES	18.86	36.81	56.84	63.11	53.19	43.78	23.74	13.01	13.40	16.28	16.62	11.78	$ 367.24

Conventional Cost less ACES Cost	$ 590.90
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 530.90

Total Projected ACES Savings = Annual Savings $ 530.90 x 7.26* = $ 3854

Conventional Installation Cost = $ 2275

Allowable ACES Installation Cost = $ 6129

*Present Worth Factor - see Task 4 Calculation

City Kansas City, MO Zone I Degree Days 4710 Degree Days Used 4672 Cooling Hours 1180

Task 4, Table 8

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	164	498	766	868	664	527	189	-	-	-	-	-	3676
MMBtu Heating Conv Eff=1.0	2.99	9.08	13.97	15.83	12.10	9.60	3.45	-	-	-	-	-	67.02
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	1.50	4.00	6.52	7.50	4.00	23.52
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	4.36	10.45	15.34	17.20	13.47	10.97	4.82	2.87	5.36	7.89	8.87	5.37	106.97
Total KWH, Conv	1277	3062	4495	5040	3947	3214	1412	841	1570	2312	2599	1573	31342
Cost $ Conv	45.43	78.46	115.49	128.76	100.79	84.68	40.61	26.32	57.38	83.32	93.71	57.44	$ 912.39

MMBtu Heating ACES COP=2.7	1.11	3.36	5.17	5.86	4.48	3.56	1.28	-	-	-	-	-	24.82
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	0.22	0.59	0.96	1.10	0.59	3.46
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.57	3.82	5.63	6.32	4.94	4.02	1.74	0.68	1.04	1.42	1.56	1.05	33.79
Total KWH, ACES	460	1119	1650	1852	1447	1178	510	199	305	416	457	308	9901
Cost $ ACES	17.39	32.42	46.14	51.05	40.70	34.79	18.12	9.30	13.00	16.33	17.63	13.09	$ 309.96

Conventional Cost less ACES Cost	$ 602.43
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 542.43

Total Projected ACES Savings = Annual Savings $ 542.43 x 7.26* = $ 3938

Conventional Installation Cost = $ 2491

Allowable ACES Installation Cost = $ 6429

*Present Worth Factor - see Task 4 Calculation

City Oklahoma City, OK Zone J Degree Days 3720 Degree Days Used 3676 Cooling Hours 1240

Task 4, Table 9

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	415	792	1017	1113	854	722	438	245	82	-	-	132	5810
MMBtu Heating Conv Eff=1.0	3.85	7.35	9.44	10.33	7.93	6.70	4.07	2.27	0.77	-	-	1.23	53.94
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	0.39	3.50	3.00	-	6.89
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	5.22	8.72	10.81	11.70	9.30	8.07	5.44	3.64	2.52	4.87	4.37	2.60	77.26
Total KWH, Conv	1529	2555	3167	3428	2725	2365	1594	1360	738	1427	1280	762	22,930
Cost $ Conv	29.67	46.59	58.38	62.82	50.88	46.90	32.75	28.46	17.04	29.69	26.99	17.48	$ 447.65
MMBtu Heating ACES COP=2.7	1.43	2.72	3.50	3.83	2.94	2.48	1.51	0.84	0.29	-	-	0.46	20.00
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.06	0.51	0.44	-	1.01
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.89	3.18	3.96	4.29	3.40	2.94	1.97	1.30	0.80	0.97	0.90	0.92	26.52
Total KWH, ACES	554	932	1160	1257	996	861	577	381	234	284	264	270	7770
Cost $ ACES	15.04	19.82	24.29	25.94	21.51	19.30	14.09	10.49	7.79	8.71	8.34	8.45	$ 183.77

Conventional Cost less ACES Cost	$ 263.88
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 203.88

Total Projected ACES Savings = Annual Savings $ 203.88 x 7.26* = $ 1480

Conventional Installation Cost = $ 2137

Allowable ACES Installation Cost = $ 3617

*Present Worth Factor - see Task 4 Calculation

City Boise, ID Zone N Degree Days 5810 Degree Days Used 5810 Cooling Hours 680

Task 4, Table 10

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	428	819	1035	1132	938	887	558	288	66	-	-	117	6268
MMBtu Heating Conv Eff=1.0	4.63	8.87	11.21	12.26	10.16	9.60	6.04	3.12	0.70	-	-	1.27	67.86
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	0.50	3.40	3.50	0.20	7.60
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	6.00	10.24	12.58	13.63	11.53	10.97	7.41	4.49	2.56	4.77	4.87	2.83	91.89
Total KWH, Conv	1758	3000	3686	3994	3378	3214	2171	1316	750	1398	1427	832	26,924
Cost $ Conv	67.02	104.33	123.23	127.85	108.79	108.58	74.98	51.21	32.16	53.89	55.00	39.72	$ 946.76
MMBtu Heating ACES COP=2.7	1.71	3.29	4.15	4.54	3.76	3.56	2.24	1.16	0.26	-	-	0.47	25.14
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	0.07	0.50	0.51	0.03	1.11
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	2.17	3.75	4.61	5.00	4.22	4.02	2.70	1.62	0.78	0.96	0.97	0.96	31.76
Total KWH, ACES	636	1099	1351	1465	1236	1178	791	475	229	281	284	281	9306
Cost $ ACES	28.56	46.98	53.91	55.45	48.39	48.38	33.40	20.77	10.81	12.95	13.06	14.39	$ 387.05

Conventional Cost less ACES Cost	$ 559.71
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$ 499.71

Total Projected ACES Savings = Annual Savings $ 499.71 x 7.26* = $3628

Conventional Installation Cost = $2201

Allowable ACES Installation Cost = $5829

*Present Worth Factor - see Task 4 Calculation

City Denver, Colorado Zone L Degree Days 6280 Degree Days Used 6268 Cooling Hours 750

Task 4, Table 11

Month	Oct 77	Nov 77	Dec 77	Jan 78	Feb 78	Mar 78	Apr 78	May 78	June 78	July 78	Aug 78	Sept 78	Total
Degree Days	391	633	750	828	678	657	474	295	159	51	62	162	5140
MMBtu Heating Conv Eff=1.0	4.07	6.59	7.81	8.62	7.06	6.84	4.94	3.07	1.66	0.53	0.65	1.69	53.53
MMBtu Cooling EER=6.0	-	-	-	-	-	-	-	-	-	1.19	1.10	-	2.29
MMBtu Water Htg Conv Eff=1.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	16.43
Total MMBtu, Conv	5.44	7.96	9.18	9.99	8.43	8.21	6.31	4.44	3.02	3.09	3.12	3.06	72.25
Total KWH, Conv	1594	2332	2690	2927	2470	2406	1849	1301	885	905	914	897	21170
Cost $ Conv	17.41	26.86	34.58	37.93	31.49	30.59	20.68	13.66	9.25	9.45	9.54	9.37	$ 250.81
MMBtu Heating ACES COP=2.7	1.51	2.44	2.89	3.19	2.61	2.53	1.83	1.14	0.61	0.20	0.24	0.63	19.82
MMBtu Cooling ACES COP=12.0	-	-	-	-	-	-	-	-	-	0.17	0.16	-	0.33
MMBtu Water Htg ACES COP=3.0	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46	0.46	5.51
Total MMBtu, ACES	1.97	2.90	3.35	3.65	3.07	2.99	2.29	1.60	1.06	0.83	0.86	1.09	25.66
Total KWH, ACES	577	850	982	1069	900	876	671	469	311	243	252	319	7519
Cost $ ACES	6.20	8.90	11.23	12.18	10.34	10.08	7.13	5.16	3.93	3.40	3.47	3.99	$ 86.01

Conventional Cost less ACES Cost	$164.80
ACES Additional Maintenance Cost	$ 60.00
Annual Savings ACES vs. Conv	$104.80

Total Projected ACES Savings = Annual Savings $ 104.80 x 7.26* = $ 761

Conventional Installation Cost = $ 2137

Allowable ACES Installation Cost = $ 2898

*Present Worth Factor - see Task 4 Calculation

City Seattle, WA Zone N Degree Days 5140 Degree Days Used 5140 Cooling Hours 200

Task 4, Table 12

	Zone A Syracuse, NY	Zone B Philadelphia, PA	Zone C Richmond, VA
Degree Days/Cooling Hours	6760/630	4980/920	3860/1090
Annual KWH, Conv.Cost $	33,296/$1,132.07	29,744/$1,152.10	31,430/$1,182.33
Annual KWH, ACES/Cost $	11,642/$437.55	9,992/$422.27	10,113/$458.16
Energy Savings*/Annual Savings	65%/$634.52	66%/$669.93	68%/664.17
Projected ACES Savings**	$4,607	$4,864	$4,822
Conventional Installation Costs	$2,632	$2,121	$2,683
Allowable ACES Installation Cost	$7,239	$6,985	$7,505

	Zone D Atlanta, GA	Zone F Madison, WI	Zone G Indianapolis, IN
Degree Days/Cooling Hours	2960/1320	7860/640	5700/870
Annual KWH, Conv./Cost $	23,566/$870.19	26,832/$934.22	24,987/$665.08
Annual KWH, ACES/Cost $	7,360/$281.81	9,388/$362.92	8,379/$307.18
Energy Savings*/Annual Savings	69%/$528.38	65%/$511.30	66%/$297.90
Projected ACES Savings**	$3,836	$3,712	$2,163
Conventional Installation Costs	$2,057	$2,229	$2,427
Allowable ACES Installation Cost	$5,893	$5,941	$4,590

*Energy Savings $= \frac{\text{KWH (Conv)} - \text{KWH (ACES)}}{\text{KWH (Conv)}}$

**Based on: n = 7 yrs. payback; f = 10% annual energy cost increase; i = 9% alternate investment rate.

Projected Savings = 7.26 x Annual Savings

TASK 4, TABLE 13 Summary of allowable ACES costs for Zones A, B, C, D, F and G

	Zone H Minneapolis, MN	Zone I Kansas City, MO	Zone J Oklahoma City, OK
Degree Days/Cooling Hours	8380/640	4710/1180	3720/1240
Annual KWH, Conv.Cost $	30,203/$989.51	29,412/$958.14	31,342/$912.39
Annual KWH, ACES/Cost $	10,580/$427.16	9,503/$367.24	9,901/$309.96
Energy Savings*/Annual Savings	65%/$502.35	68%/$530.90	68%/$542.43
Projected ACES Savings**	$3,647	$3,854	$3,938
Conventional Installation Costs	$2,491	$2,275	$2,491
Allowable ACES Installation Cost	$6,138	$6,129	$6,429

	Zone N Boise, ID	Zone L Denver, CO	Zone N Seattle, WA
Degree Days/Cooling Hours	5810/680	6280/750	5140/200
Annual KWH, Conv./Cost $	22,930/$447.65	26,924/$946.76	21,170/$250.81
Annual KWH, ACES/Cost $	7,770/$183.77	9,306/$387.05	7,519/$86.01
Energy Savings*/Annual Savings	66%/$203.88	65%/$499.71	64%/$104.80
Projected ACES Savings**	$1,480	$3,628	$761
Conventional Installation Costs	$2,137	$2,201	$2,137
Allowable ACES Installation Cost	$3,617	$5,829	$2,898

*Energy Savings = $\frac{\text{KWH (Conv)} - \text{KWH (ACES)}}{\text{KWH (Conv)}}$

**Based on: n = 7 yrs. payback; f = 10% annual energy cost increase; i = 9% alternate investment rate.

Projected Savings = 7.26 x Annual Savings

TASK 4, TABLE 14 Summary of Allowable ACES Costs for Zones H, I, J, L & N

SELECTION OF TIME-TO-RECOUP-INVESTMENT FOR NAHB THERMAL PERFORMANCE GUIDELINES FOR ONE & TWO FAMILY HOUSES

By

Ralph J. Johnson*

The selection of the time-to-recoup-investment, or period of analysis, using the present worth life cycle cost method of determining future net benefits of energy conserving techniques (ECT's), is critical. The selection of the period of analysis greatly effects the extra amount of money available to spend on additional energy conserving techniques and on the annual net cost or benefit to buyers.

A 7-year time-to-recoup-investment was selected for the Guidelines for a number of reasons. First, it is something more than the average period of occupancy for the first owner. Second, it is a commonly used yardstick by which to judge investment of capital. Third, it is reasonably typical of the response of builders and buyers concerning acceptable and marketable payback periods. Fourth, it provides a very substantial sum of money to pay for the first cost of additional ECT's. Fifth, it provides an incentive to buyers, since the monthly energy cost savings will be less than the mortgage amortization and interest costs to pay for the additional first cost of the additional ECT's, see below.

Return periods of 15 or 20 years offhand may sound as though they are meritorious. However, they result in large additional costs to buyers for possibly marginal benefits. For example, assuming an annual rate of price increase for energy of 10% and an alternate investment or mortgage interest rate of 9%, a 20-year time-to-recoup-investment has a present worth factor of $22.04. This means that $11.02 would be available for the added first cost of ECT's to yield $0.50 of saving in the first year.

For a $500 per year saving, at a 9% interest rate on a 25-year mortgage, the increased monthly payment would be $92.46. But the monthly savings would only be $41.67 - a monthly extra cost to the buyer, in the first year, of $50.79 per month. This certainly would be difficult to sell. Also, there would be an increased burden in relation to the income required to qualify buyers.

On the other hand, a 7-year return period would increase the monthly payment for amortization and interest by $30.46 to achieve a $500 per year savings. But the monthly savings would be $41.67, a net operating cost reduction of more than $11 per month. This is an obvious benefit as far as qualifying buyers with lower incomes and produces a significant incentive to the buyer to opt for an energy conserving home. A monthly net benefit in the first year of about $10 per month is considered to be necessary to produce a significant buyer incentive.

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TASK 5 - REGIONAL FOCUS MEETINGS

A minimum effort was expended here per DOE/ERDA instructions.

TASK 6 - POTENTIAL MARKET

The twelve houses selected for the comparison of energy costs with ACES and conventional installation are in areas where significant market activity is expected. Since the ACES cost comparisons in Task 4 have shown substantial savings, the ACES may possibly compete against conventional installations in these markets.

Energy savings proved to be significant regardless of house type, and this will mean there is a much greater market than just these types of houses which were selected as the best markets. Our comparisons against the electric forced air heating, electric cooling and electric hot water heating would lose some, perhaps much, of their advantage if compared to oil or gas, according to current lower prices and taking into account lower seasonal efficiencies of oil and gas heating systems.

The size of equipment that would be needed in future ACES installations would probably be in the size range of 1-1½ ton capacity for the ice-making heat pump, considerably smaller than the 2½ ton unit built by Remcor for the Philadelphia demonstration house.

A NAHB Research Foundation study shows that over a million starts per year for the next five years will be adaptable to ACES equipment (i.e., ducting will be used)

- There is a tremendous market of houses adaptable to ACES installation.

APPENDIX

Thermal Performance
Single Family Homes

This appendix contains basic characteristics of the 110,898 single family detached and 12,660 single family attached data base dwellings that were used to calculate design energy performance data presented in the report. In addition, basic characteristics for 33,012 low-rise multifamily dwelling units are included in this appendix.

Characteristic data include dwelling type (one story, two story, bi-level, split level, townhouse, etc.), living area, foundation type, U-values for building components, window glazing, heating fuel, heating equipment and, in the case of multifamily dwellings, number of buildings and units per building. Characteristics are presented by actual number of units in the sample or by percentage of units with the subject characteristic. In the cases where application of NAHB's Thermal Performance Guidelines (TPG) and HUD's proposed Minimum Property Standards (MPS) resulted in a change in basic characteristics of the data base units, the resultant new characteristics are presented.

SINGLE FAMILY DETACHED

As-Built, TPG, MPS

TABLEA26 Heating Equipment - (% Of Total Homes)

Region	Total No. of Houses	Heat Equipment - (% of Homes with Equip.)				
		Warm Air Furnace	Hot Water	Heat Pump	Radiant Elec.	None
Region 1	6,989	69.5	10.8	4.4	15.3	0
Region 2	25,140	68.4	6.1	11.4	14.1	0
Region 3	20,973	58.3	6.3	20.6	14.8	0
Region 4	15,493	72.7	0.1	20.6	6.6	0
Region 5	5,187	98.8	1.2	0	0	0
Region 6	18,140	83.2	1.1	14.5	0.8	0.2
Region 7	18,976	92.3	0.7	6.9	0.1	0
TOTAL	110,898	75.2*	3.6	13.1*	8.1	0

*Both the 75.2% warm air furnace and the 13.1% heat pump are easily adaptable to the ACES installation.

TASK 7 - MANUFACTURER ATTITUDES

Inquiries were made of over sixty manufacturers of heat pumps or ice-making equipment to determine their interest in ACES-type equipment and to inform them regarding ACES activity.

Very few indicated that ice-making heat pumps were in their product line or that they might be interested. Some indicated a desire to be kept abreast of developments in the ACES program.

A list of the firms contacted is shown in Task 7 Tables 1 and 2.

Appreciable design work would still be necessary to properly size the ACES after an extended period of demonstration.

- A market size of over 500 units would probably be required to get the ice-making heat pump price down to approximately $2,000.
- Studies from Task 6 show a potential market of a million houses suitable for ACES each year for the next five years.

Ice-Maker Manufacturers and Heat Pump Manufacturers (Water-Air)		Negative or Positive Reply to J-J Letter	Cost-Effective Demo Letter Mailed	Negative or Positive Reply to Oct. Letter	Further Correspondence from the Foundation	Further Correcpondence from the Manufacturer
Advance Design Assoc.	1	N-7-77	10/13			
American Air Filter	2		10/12	N-11/8		
Bailey Refrign Co.	3		10/12	P-10/18		
Aug G Barkow Mfg Co	4		10/12			
Beaver Engrng Ltd	5		10/12			
Bryant Air Cond Co	6	N-7/77	10/13			
Budco	7		10/12			
Carrier Air Cond Div	8	?-7/77	10/06			
Chip Ice Corp	9		10/12			
Command-Aire	10	N-6/77	10/13			
Crepace	11		10/12			
Crystal Tips Comml	12	?-7/77	10/13			
Dunham-Bush Inc	13		10/12			
Dillon-Lilly Co	14		10/12			
Dispensing Systems	15		10/12			
Dole Refrigtng Co	16		10/12	N-10/27		
Elmbrook Refrigeration	17		10/12			
Enviro Equip Corp	18		10/12			
Fedders Corp	19		10/12			
FHP Mfg Co	20	P-6/77	10/06			
Flakice Corp	21	P-6/77	10/06	N-10/17		
The Frick Co	22	N-6/77	10/13			
Friederich Group	23	P-7/77	10/06	P-10/21	11/16	
Frigidaire Div	24	N-7/77	10/13			
Frigitemp Corp/CA	25	P-6/77	10/06	?-11/14	12/1	
Heat Controller, Inc	26	N-7/77	10/13			
Heat Exchangers, Inc	27	N-7/77	10/13			
Heil Quaker Corp	28	?-6/77	10/06			
Henry Furnace Co	29	N-6/77	10/13			
Howe Corp	30		10/12			
International Heating &	31		10/12			
Ice Cube Equip Co	32	Rtd by P.O.	10/13			
Ice-O-Matic	33		10/12			

Task 7 Table 1

Ice-Maker Manufacturers and Heat Pump Manufacturers (Water-Air)		Negative or Positive Reply to J-J Letter	Cost-Effective Demo Letter Mailed	Negative or Positive Reply to Oct. Letter	Further Correspondence from the Foundation	Further Correspondence from the Manufacturer
Jordon Comml Refrig	34		10/12			
Keep Rite Prod Ltd	35		10/12			
Lear Siegler, Inc.	36	N-7/77	10/13			
Lern, Inc.	37		10/12			
Liquid Carbonic Corp	38	?-7/77	10/06	P-10/26		
Market Forge Co	39	N-7/77	10/13			
North Star Ice Equip	40		10/12	N-10/27	11/4	
Patco, Inc	41	N-7/77	10/13			
Quick Freeze Ice, Inc	42		10/12			
Refrigeration Research, Inc	43	P-6/77	10/06			
Refrigeration Systems	44	P-7/77	10/06	P-10/31	11/16	12/1
REMCOR Products	45	N-7/77	10/13	P-11/4	11/23	
Scotsman Product Div.	47	P-7/77	10/06	P-10/14	10/19	11/30
Silencer Air Cond	48		10/12	Ret by P.O.		
Climate Control of Singer	49	N-7/77	10/13			
Snowbird Industries	50		10/12			
Star Cooler Corp	51	N-6/77	10/13			
Supreme Aire (Elsters)	52	?-7/77	10/06	P-11/23	12/1	
Turbo Refrigerating	53		10/12			
Tyler Refrigeration	54		10/12	N-10/19		
U-Line Corporation	55		10/12			
Uniflow Mfgr Co	56	N-7/77	10/13			
Vaughn Corp - Wescorp	57		10/12	P-10/27	11/23	
Vogt Machine Co	58	N-6/77	10/13			
Weather King, Inc.	59		10/12			
The Whalen Co	60	N-6/77	10/13			
Whirlpool Corp	61		10/12	P-10/24	10/27	
Wilcox Mfgrng Co	62		10/12			
York Div. Borg-Warner	63	N-6/77	10/13			
John Zink Co	64		10/12			

Task 7 Table 2

TASK 8 - BUILDER POTENTIAL INTEREST

The residential building industry differs from all other major industries in that the majority of the homes are built by medium to small size firms that have very limited management staffs. The predominance of these firms presents a sizable problem to any technology-oriented product. The ACES concept falls directly in this category and therefore will face the following barriers:

- Marketability
- Product and/or System Reliability
- Qualified Suppliers and Installers
- Product Knowledge
- Local Acceptance

Each of these barriers will be discussed in order to show the basic problems that must be removed in order for ACES to be successful in the marketplace.

Marketability

The reference to marketability for an ACES covers a wide range of problems for the builder. The first will be added cost to the home. Presently, few lending institutions will give consideration to the energy savings of an added cost item. This being the case, the addition of $1,000 to $5,000 to the purchase price will mean that the buyer will need to earn about an additional $9.00 a week per thousand dollars of mortgage to qualify. Since qualifying a buyer is not very flexible for most lenders, this will greatly reduce the number of buyers. Second, the builder and the buyer are generally not willing to experiment where base comfort is involved. This will mean a great reluctance for either to want to be an ACES pioneer. Although hard to prove, this may be the biggest barrier of the ACES concept. People will often say that they would be interested in an ACES in a marketing questionnaire, but when ready to buy they will decide against it. This has been shown with far more conventional items, i.e., wood foundations, plastic plumbing fixtures, plastic hardware and a less conventional item: solar devices. Therefore, ACES needs a major, well known company to promote and back the system. One possible approach is to start at the high price end of the industry which would be similar to the way General Motors down sized their cars with the Cadillac Seville being introduced about nine months before the rest of the models. Third, a buyer will be concerned with the loss of basement space. Although many people do not use this space, it's hard to take it away. This has been shown many times when builders have tried to promote slab construction in basement market areas (The only exception has been when prices were far lower than for homes with basements.).

Product and/or System Reliability

Increasing restrictive regulation concerning warranties and builder liability will make the builder very reluctant to add an ACES. Present heating systems with air distribution are extremely simple and easy to maintain. Even replacement when required is not difficult. Since an ACES unit is not presently in production, it will have to meet similar criteria. In addition, maintenance costs, also unknown, will need to be developed before builder confidence can be achieved.

Qualified Suppliers and Installers

This is an area that cannot be overlooked when bringing a new product into the residential industry. The localized nature of the industry keeps subcontractors fairly small and quite frequently technically unable to work with an engineered product. To oversimplify, this can be shown by many contractors oversizing furnace installation sometimes in excess of two times the design requirements. In these cases "more" has always been considered better even after many attempts to educate to the contrary. A further concern in this area will be warranty services, including parts availability. As mentioned before, this is where a large national corporation would be far better able to handle the local concerns than a regional company.

Systems Knowledge

Several of the barriers have referred to "product" problems. This must be further expanded to cover the overall ACES concept. Builders in recent years have become more and more accustomed to buying products that are complete and ready to be hung, plugged in or attached to the frame. This means that the ACES, to be accepted, will need to be handled in a complete package, or at least sold by a contractor who will take responsibility for a turn-key installation. If this is not the case, the builder will not be very receptive to playing purchaser, scheduler, designer, installer and guarantor.

Local Acceptance

This differs from the general marketability barrier noted above in that certain areas of the country have been known to have strong local preferences based purely on preconceived notions and not logic. An example of this was a strong desire for baseboard heating in the northeast (especially Long Island). The desire for air conditioning finally changed this, but it was a slow process. A similar barrier could develop for an ACES-HVAC system, but a national market research survey would be necessary to validate this.

MANUFACTURERS POTENTIAL INTEREST

Experience indicates that there will probably be considerable reluctance on the part of most current major suppliers of residential heating and cooling equipment to convert to ACES production. They would probably tend to see this as competing for their established share of the market.

Companies not presently in this group would be more apt to undertake the production of ACES equipment. One example of this is a firm which could produce approximately a thousand units annually, similar to the ice-making heat pump used in this study for around $2,000. To capture a sizable portion of the market a larger company would have to be interested and capable of producing perhaps a hundred thousand units annually. This would involve a sizable manufacturing plant and facility expenditures.