3211

ECONOMIC ANALYSES OF HOUSE AIRTIGHTENING

Karl R. Stum
Enviro-sun

1643 North 645 West
Orem, Utah 84057
801-224-1274

Energy Efficient Building Association (EEBA)
Sixth Annual International
Energy Efficient Building Conference & Exposition
Portland, Maine
April 1988

ABSTRACT

Since the primary reason for any energy improvement is to save money on utility costs, it is imperative that an accurate total economic picture of the improvement be available to the consumer as well as to designers, builders and lenders.

This study evaluated the economics of making new houses more airtight. The study covered cases where the cost of airtightening was borrowed for by increasing the house mortgage amount. The methodology was one of out-of-pocket cash flow comparison. In the analyses, all of the costs affected by airtightening were evaluated for each house and then compared.

In the study the "Cash Flow" methodology was explained in detail. Then over 400 cases were evaluated and compiled into tables and sensitivity graphs for quick reference. Two levels of airtightening, climates from 6000 to 10,000 DDB.65F, varying occupant loads, house sizes, costs of fuel and mortgage interest rates were all evaluated. Air-to-air heat exchangers and air-to-water heat pump heat recovery ventilators were also compared with the parameters.

It was found that even though the specific economic return varied greatly with the above parameters, house airtightening was very cost effective for the large majority of cases evaluated.

ABBREVIATIONS--GLOSSARY

AAHE	Air-to-air heat exchanger, an HRV ventilation device that brings cold fresh air in from outside and pre-warms it with heat from a stream of out-going warm stale air.
AC/H	Air change per hour (the number of times per hour that the complete interior air volume is exchanged with outside air)
AWHP	Air-to-water heat pump ventilator, See Section 3.3.
BTU	British thermal unit
Cond.	Conditioner (air)
DDB65.F	Degree Days Base 65 degrees Fahrenheit (climate)
EFFIC	Efficiency
Elec.	Electricity
Equip.	Equipment
Extreme	Method of airtightening, See Section 3.2.
FT2	Feet squared (square feet)
FURN	Furnace
HRV	Heat Recovery Ventilator
KWH	Kilowatt hour
l	Liter
M2	Meters squared (square meters)
MECH	Mechanical (the ac/h contribution due to the mechanical ventilation system)
Moderate	Method of airtightening, See Section 3.2.
NAT	Natural air change per hour (also Nat(u)), the air change experienced with no OCCUP or MECH effects, determined from a blower door test.
OCCUP	Occupants' effects ac/h, the contribution the occupants have on the total air change rate due to opening of doors and use of exhaust fans, etc.
Ref.	Reference, See References.
RH	Relative Humidity
STD	Standard, the base reference House being compared to.
THRM	Therm (100,000 BTU's)

1. INTRODUCTION--FORMAT

1.1 INTRODUCTION

In most cases the primary reason for making a house more "airtight" is that by doing so, space heating and cooling costs will be reduced at an acceptable rate when compared to the extra cost of the airtightening system. Therefore, it is important for all those promoting or incorporating airtight housing to be familiar with the economic benefits of the techniques they are recommending.

The purpose of this paper is to aide the designer, builder, homeowner, lender and appraiser to clearly understand the economic impact that house airtightening will have on a homeowner's cash flow. Since most new homes are paid for by mortgaging, most airtightening systems will be paid for by increasing that mortgage. It is under that scenario that the economics of house airtightening have been evaluated in this paper.

1.2 FORMAT

The paper is structured with detailed background information and economic analysis methodology in Sections 2 and 3. This information will offer the reader a thorough understanding of "Cash Flow" analysis, including some special information on analyzing air-to-water heat pump ventilators. In Section 4, Graphs and Tables have been provided that have hundreds of worked out cases comparing various scenarios of airtightening with a base standard (STD) reference case. The Tables and Graphs can be used for quick and accurate reference. Section 5 outlines the differing factors that can affect the "cost effectiveness" of airtightening strategies. Section 6 concludes with an overall summary of the economic ramifications of house airtightening.

2. METHODS TO EVALUATE ENERGY SAVINGS

When economically evaluating energy saving products or techniques, the main procedure common to all methods is to determine the amount of money saved due to the energy saving feature when compared to a base standard case where the feature is not included. Then this dollar savings amount is weighed against the installation cost of the feature.

2.1 SIMPLE PAYBACK METHOD:

This common method gives a "payback" on the investment (the initial cost of the energy saving system). It is calculated by dividing the Initial System Cost by the Annual Utility Savings.

The Simple Payback Method is only good when paying cash for the energy saving system and does not take into account the changing prices in fuel or the time value of money. The results are oversimplified and very misleading.

2.2 SOPHISTICATED METHODS

There are more sophisticated methods which are used by economists which take all the above factors into account and more. However, because the methods are quite complex and results of these methods are in terms that consumers will not generally understand, they are of little worth for use among designers, builders and consumers.

The method that does offer accuracy by taking all important factors into account as well as being easy to understand, is the "Cash Flow" analysis. This method analyzes the out-of-pocket cash flow on a yearly basis and is discussed in detail in Section 3.

3. CASH FLOW ANALYSIS WHEN BORROWING (Ref. 1, 2; 3)

3.1 GENERAL DESCRIPTION

The Cash Flow Analysis, sometimes referred to as a Life Cycle Cost Analysis is extremely valuable if one is borrowing for the airtightening system. Since the borrowing scenario occurs with the large majority of new houses it will be emphasized in this paper. When borrowing to pay for the energy system, one is never at any one time actually spending the total initial system cost, but is paying for it over time. This renders the "simple payback" method of analysis useless.

The Cash Flow Analysis evaluates the areas that are affecting the Homeowner's out-of-pocket cash flow (that is, the monthly or annual expenditures in areas affected by the airtightening system). The Cash Flow Analyses are made for a Standard (STD) base reference house and also for an airtightened house. The annual cash flows (expenditures) for each house are then totaled and compared.

The homeowner's cash flows effected by airtightening are:

1) The space heating cost, which is added to
2) the increased annual mortgage payment to finance the airtightening system installation, which is added to
3) the increased property taxes and insurance due to the value of the airtightening system, minus
4) the value of the interest portion of the mortgage payment as a tax deduction.
5) If using an air-to-water heat pump ventilator (AWHP), water heating and summer space cooling costs are also affected.

In the Analysis the cash flows for each system type are summed for a year and then compared. The affected cash flows change each year as fuel costs change, property taxes increase and the interest portion of the mortgage payment decreases.

3.2 DETAILS OF CASH FLOW ANALYSIS WHEN BORROWING

In order to facilitate the understanding of Cash Flow Analysis, Table 3.1 has been prepared using a typical comparison scenario. Following will be an explanation of each of the terms and areas to be filled out in completing the Cash Flow Analysis using the Table. Each numbered column or term will be explained in sequence. Refer to the Table as needed, as well as Figures 3.1 and 3.2 which graphically display the Cash Flows of each house.

The common features of the sample houses in Table 3.1 are: the size, 2000 FT2 (186M2) one level ranch style, in an 6000 degree day base 65 Fahrenheit (DDB.65F) climate, using an 80% efficient natural gas furnace for space heating, with gas costs at $.75 per therm (100,000 Btu). The insulation levels are the same in both houses and do not affect the airtightening systems.

The STD base case house experiences a total average air change of .5 ac/h. The airtightened house is using a high level of airtightening called the "Extreme Method" and experiences a natural or unoccupied air change of .08 ac/h. Then a 70% efficient air-to-air heat exchanger (AAHE) along with the effects of occupants brings the total air change up to .3 ac/h. The balance of the parameters are found on the Table.

ENERGY IMPROVEMENT INSTALLED COST--The Energy Improvement Installed Cost is the initial cost above the STD base case of installing the energy conserving feature. This should include the cost of airtightening as well as a ventilation system when required. In this case it is the cost of the airtightening system, plus the additional one-time mortgage related costs noted below, less its value in contributing to a smaller less expensive heating system being required because of a smaller heating load.

When the Conservation system is paid for by borrowing, the "up front" costs associated with borrowing must also be included, such as points, loan origination fees and title insurance. It is assumed that these extra one-time costs are borrowed by increasing the mortgaged amount. This paper suggests adding 5% to the initial feature cost to account for these borrowing costs. It is also assumed that the increase in the down payment due to the increased borrowed amount is either 0 or is negligible.

ANNUAL UTILITY BILL OF SYSTEM--The Annual Utility Bill is the cost to replace heat lost due to air change over a winter's period. This applies to both the STD house and to the Airtightened House. These costs increase each year by the given fuel inflation rate, which is variable with time and location.

MAINTENANCE AND REPLACEMENT COSTS--Airtightening systems have virtually no maintenance and replacement costs unless an AAHE is used. But because their life expectancy exceeds, by far, the average time any one homeowner will live in the house, and because for most homeowners, cleaning a filter twice a year is not a big enough inconvenience to attach a dollar value to, the Maintenance and Replacement Costs are assumed to be zero.

ANNUAL MORTGAGE PAYMENT--This value applies to the airtightened house only. It is the increase in the mortgage payment of the house due to borrowing the extra amount (the Net Conservation Feature Cost) for the airtightening system. It is the total of an entire year of increased monthly mortgage payments based on the given fixed interest rate for the given loan period. This value remains constant.

TAXES AND INSURANCE--The airtightening feature increases property values and hence property taxes and insurance costs will increase out-of-pocket expenses as shown. This is assumed to be 1% of the Improvement Cost and increases yearly with the general inflation rate.

MORTGAGE INTEREST TAX DEDUCTION--When borrowing for the airtightening feature, a significant portion of the Annual Mortgage Payment is interest, especially during the earlier years. This interest can generally be deducted from the homeowner's income, subsequently reducing the homeowner's income taxes. The cash value to the homeowner is found by multiplying the interest, by the homeowner's income tax bracket.

ANNUAL EXPENSES FOR THE STANDARD HOUSE--The Total Annual Expenses or out-of-pocket expenditure of the STD house that is affected by the air change rate is simply the Annual Utility Bill. If the comparison is with an AWHP system there will be other costs. See Section 3.3.

ANNUAL EXPENSES FOR AIRTIGHTENED HOUSE--The total of all expenses affected by airtightening in the airtightened house is the sum of the values, for a given year. In houses using an AWHP there are also other costs. See Section 3.3.

NET CASH FLOW SAVINGS (ANNUAL)--This is the difference in Total Annual Costs of the STD House and the Airtightened House. If negative, this means that during that year it is costing more to live in the Airtightened House than the STD House and visa-versa.

PRESENT WORTH FACTOR--This factor is used to multiply the Annual Net Cash Flow by, to obtain the Discounted Net Cash Savings. This factor is used to take inflation into account and to account for the lost opportunity of money spent on the airtightening system which could have been spent on alternative investments. All earning and spending in future years are thus discounted to reflect what those future earnings are worth in today's dollars. If this factor were not used the airtightening features would look even more attractive.

DISCOUNTED NET CASH SAVINGS--This is the Annual Net Cash Savings or flow after it has been multiplied by the Present Worth Factor which then makes it "discounted", reflecting its true current value.

ACCUMULATIVE DISCOUNTED CASH SAVINGS--This is the sum, to that year, of the Discounted Net Cash Flow Savings.

RESALE VALUE OF FEATURE--This is the resale value of the Net Conservation Feature Cost and applies only to the airtightened house. In this case it is assumed to increase yearly at the annual inflation rate, as well as be discounted by the Present Worth Factor. (See Input Data).

PAYBACK OF ALL NEGATIVE CASH FLOWS--This is the years required for the Airtightened House to pay back, in savings, all previous negative cash flows when compared to the STD House. It is found by following the Accumulative Disc. Savings row across until the value is positive.

CASH GAIN ABOVE STD. CASE IF SOLD--This is the cash advantage, when the house is sold, of the Airtightened House above the STD House. It is found by taking the Accumulative Disc. Savings value and adding it to the Resale Value of the feature for a given year.

TOTAL OF ALL NEGATIVE CASH FLOWS--This is the total cash paid out-of-pocket in the Airtightened House above that paid in the STD House up to the year given. It is found by adding up all negative values in the Discounted Net Cash Savings row to the year given.

AVERAGE PERCENT RETURN PER YEAR--This the average return (in net cash savings) on the Total Of All Negative Cash Flows value up to the given year in the airtightened house. It is found by taking the total Accumulative Disc. Savings for the given year, dividing by the Total Of All Negative Cash Flows to the same year, and then multiplying by 100. It is this figure that can be compared to other investments. In such comparing it is noted that these savings are not taxable and thus are worth 20 to 40% more than their nominal value if comparing to taxable investments (depending on the homeowner's tax bracket).

3.3 ANALYZING AIR-TO-WATER HEAT PUMP VENTILATOR (AWHP)

An AWHP is an electric tank water heater that is both a domestic water heater, ventilator for controlling the house total air change, and in summer a water heater, a air conditioner and dehumidifier. It has a refrigerant charged heat pump and an exhaust fan that draws air from the interior of the house and exhausts it outside. Prior to exhausting the stale, warm air outside, it extracts heat out of the air and delivers it to the domestic hot water tank. When the water is heated to the desired temperature the unit then delivers the excess heat from the exhaust air to a remote fan coil which heats the indoor air.

In summer a valve is turned in the unit and the flows are reversed. Hot outside air is drawn into the unit and its heat is extracted by the heat pump and delivered to the domestic hot water tank. The cooled fresh air is then delivered to the house, assisting in the air-conditioning of the house. Thus the water is heated virtually "free".

When comparing an airtightening system that incorporates an AWHP for heat reclaiming ventilation control, the affected areas that must be taken into account in both the STD house and the airtightened house are: 1) The cost for the primary space heating system to replace the heat lost during the heating season due to the total air change experienced by the house; 2) The annual cost to heat the domestic hot water. The house with the AWHP will also require the evaluation of savings in summer space cooling due to the AWHP providing a certain amount of cooling, virtually at no expense. As well, mortgage associated expenses, explained in Section 3.2 will need to be accounted for.

4. SIMPLIFIED ANALYSIS USING TABLES AND GRAPHS

Tables 4.1 through 4.3 have been prepared so that the reader can see some typical cases worked out using the methodology outlined in this paper. The tables provide a comparison of airtightening systems versus STD Base cases and for comparing between airtightening systems. Most of the internal analysis components are visible in order to quickly see what results can be expected for a given scenario and how various factors change the results.

4.1 TABLE 4.1--STD CASE VS NON-HEAT RECOVERY AND AIR-TO-AIR HEAT EXCHANGER (AAHE) CASES

Table 4.1 compares the STD Base case with a Moderate as well as an Extreme Method of airtightening. Both Methods use different degrees of a Modified Airtight Drywall Approach (Ref. 4). The Moderate Method of airtightening results in a house that experiences a natural air change of about .2 to .25 ac/h. When the occupants' effects on the air change are added in, the total air change is about .3 to .4 ac/h. Normally, no added ventilation and thus no heat recovery is needed with the Moderate Method. The STD base case ac/h rates are as given.

The Extreme Method of airtightening realizes a natural air change of about .08 ac/h. Then, in this Table, along with the occupants effects, a 70% efficient AAHE is used (except in the small 1000 FT2 (93M2) house) to bring the total air change rate up to .30 ac/h insuring adequate indoor air quality.

The HOUSE SIZE is given in FT2 and M2. The Table gives the typical air change rates (ac/h): NAT--the natural air change rate, OCCUP-the estimated effect that the occupants' opening of doors and use of bath fans, dryers etc. has on the air change, MECH--the mechanical ventilation rate if any, TOTAL--the sum of the natural, the occupants effects and the mechanical ac/h values.

The occupant number does not play a very significant role in the cost effectiveness of using an AAHE, unlike an AWHP, and so is not parameterized in this Table.

The SYSTEM COST ABOVE STD is the net cost of the airtightening system above the cost of the STD house. Refer to Section 3.2 for details. The cost of the airtightening system is given for a house with an electric heat pump space heating furnace system (E) and and for one with a gas forced air system (G). The gas system requires the expense of air sealing the mechanical room and providing an outside combustion air duct to the room, which is the reason for the cost difference. The seasonal efficiency of the gas furnace is 80% and the electric heat pump has an average COP of 2. Various gas and electric rates are given, as well as the winter seasonal cost to replace the heat lost due to the Total Air Change.

The final results are the First Year Savings in energy costs of the airtightened system compared to the STD house and the Simple Percent Return. The Simple Percent Return is the First Year Savings divided by the Net System Cost above the STD case and is used as a reference when using the the Payback Graph in Section 4.4.

It is noted that these savings are not subject to income tax, unlike most alternative investments. This makes them actually worth 20 to 40% more than their nominal value when comparing to other investments.

4.2 TABLE 4.2--STD CASE COMPARED TO NON-HEAT RECOVERY AND TO AIR-TO-WATER HEAT PUMP (AWHP) CASES

Table 4.2 is based on a large in-depth spread-sheet analysis taking into account all applicable parameters outlined in Section 3.3. The comparisons are to a STD base house that has ac/h rates of .35 to .48 ac/h depending on climate as shown, and is heated with an 80% efficient gas furnace at the given fuel rates. The airtightened houses use the same Moderate and Extreme Methods of airtightening (See Section 4.1) as those in Table 4.1, except that the added ventilation is achieved by an electric AWHP rather than an AAHE (see Section 3.3). Most of the headings in Table 4.2 are the same as those in Table 4.1. Refer to it for explanations. It is noted that the houses using an AWHP have different Natural air change rates depending on the number of occupants. This is, because the optimal air change rate is one that is matched with the amount of air flow needed by the AWHP to meet the domestic hot water needs of the occupants. Other special areas are noted below.

The table is based on an inside RH of 40% at 68F (20C) and average USA outside RH. All space heating is natural gas forced air with efficiencies and gas costs as noted. The AWHP has a remote fan coil to take care of excess heat reclaimed from outgoing air when not needed to heat water.

Cooling loads and hours are as noted. The cooling values used in this Table will generally be high for coastal areas and low for sunny mountain or plains climates. This means that the cooling advantage of the AWHP will be less in coastal areas than in sunny climates. The cooling parameter can also vary considerably from these values, depending on solar orientation. The air conditioning summer cooling savings assumes that total cooling is less than or equal to the AWHP cooling contribution. The primary house cooling system is a refrigerant type. If an evaporative type is used the AWHP savings and returns would be slightly less.

Column 1 gives the house size in FT2 (divided by 1000), the climate in DDB.65F (divided by 1000) and the number of occupants. The number of occupants is critical because their number varies the domestic hot water use (see Figure 5.5).

Nat(u) is the average natural air change rate under unoccupied conditions. Nat(o) is the 24 hr. average natural air change rate during occupied conditions. It accounts for the periods when the AWHP ventilator's exhaust fan is causing a negative interior pressure and subsequently masks part of the natural air change.

To achieve the design 24 hr. average Total Air Change per hour rate, as well as obtain the needed domestic hot water from the AWHP, while allowing the AWHP to operate at an appropriate flow rate (> 65 CFM), the AWHP must cyucle on and off as noted in the INPUT and two of the columns. Rarely, if ever, would there be a situation when the AWHP would run continuously. This sporadic timing of ventilation reduces indoor air quality somewhat, but could be timed to occur during sleeping and other heavily occupied periods.

There are two versions of Table 4.2. One is for All-Electric areas and the other is for Natural Gas or Oil areas.

4.3 TABLE 4.3 AIR-TO-AIR HEAT EXCHANGER VS AIR-TO-WATER HEAT PUMP

Table 4.3 is a compilation of results from Tables 4.1 and 4.2. It compares the first year Simple Return in energy savings of the AWHP and the AAHE over the STD Base case in gas country. Refer to Tables 4.1 and 4.2 and the Table Notes for term explanation.

It should be noted that the AWHP has some advantage in hot water supply convenience as it has an 80 gallon (300l) hot water storage tank and the domestic hot water heater used with the AAHE system has only a 50 gallon (190l) tank. Also, for humid climates the AWHP helps dehumidify the air in the summer.

The Table also is based on using an inexpensive AAHE which does not necessarily mean quality or efficiency have been sacrificed. If for some reason a more expensive AAHE were used the results would subsequently change.

4.3.1 AWHP VS AAHE IN AREAS WHERE NATURAL GAS IS NOT AVAILABLE

In areas where electricity is the prime space and water heating energy source and where there is no natural gas available and fuel oil or propane tank leasing and fuel costs are prohibitively high, the AWHP rather than the AAHE will in almost every case be the better choice for a heat recovering mechanical ventilation system. The savings and returns of an AWHP system over an electrical resistance water heating system are so great that to consider using a resistance water heating system is ludicrous, unless the electrical rates are exceptionally low (< $.04/KWH).

4.4 PAYBACK GRAPH FOR USE WITH THE SIMPLE RATE OF RETURN

The economic end result of the above tables is the first year SIMPLE PERCENT RETURN figure. To **evaluate a case:** find the case on the table that best fits the real one being considered. Then view desired data along the row. Now take the Simple

Return figure and use it directly with the Payback Graph (Fig. 4.1) for in-depth economic results. The Graph is based on a complete Cash Flow Analysis and will give the same Payback as if a complete analysis had been done like Table 3.1, within the given parameters of the graph. It is noted that this Payback graph can be used directly with any energy conserving measure comparison (not just airtightening).

5. FACTORS THAT AFFECT THE COST EFFECTIVENESS OF ENERGY CONSERVING SYSTEMS

Evaluating Tables 4.1 and 4.2 shows that the Simple Rate of Return depends on a number of factors. In addition, there are other parameters besides the Rate of Return which can change the "Cost Effectiveness" in a homeowner's mind.

1. **The method of purchasing or paying for the system:** Under typical parameters, if borrowing for the system installation cost, the payback of all out-pocket-expenses will be significantly less than if the system were paid for with cash. See Figure 5.5. The **income tax bracket** of the homeowner also affects payback in cases where the feature is paid for by borrowing, since when in a higher tax bracket a greater portion of the mortgage interest becomes cash savings.

2. **Coldness of the climate:** The more severe the climate the more energy dollars will be saved while the cost of installing the system remains unchanged. Fig. 5.4 shows how significant the cost effectiveness can be affected by climate change when using an air-to-air heat exchanger (AAHE). Air-to-water heat pump ventilators (AWHP) don't follow the same trend, however. In their case, when the climate gets colder the heat loss energy savings increases, but the summer cooling savings decreases, with the result generally being a net decline in cost effectiveness as the climate gets colder. See Fig. 5.3.

3. **Size of the house:** As the size of the house gets larger the cost of airtightening per unit area becomes less. For instance, virtually the same $900 AAHE system that is used in a 2000 FT2 (186M2) house can be used in a 5000 FT2 (465M2) house, excepting a little more ducting. See Figure 5.6.

4. **Cost of auxiliary fuel:** When fuel costs are high, the cost of replacing the heat loss increases which increases energy savings. See Figure 5.7.

5. **Fuel inflation rate:** The change in the payback period is proportional to the change in the rate at which fuel costs inflate annually. See Figure 5.4.

6. **Efficiency of the space heating equipment:** As the efficiency of the space heating equipment increases the same heat loss costs less to replace and energy savings are likewise lessened.

7. **Desires of the client for economic payback:** Each client will have a different figure for what constitutes an acceptable payback.

8. **Desires of the client for state-of-the-art techniques:** Some clients desire the latest and best in energy technology regardless of whether it pays back in a given time period or not.

9. **Desires of the client for self-sufficiency from Utilities:** Some clients desire more freedom from public or utility companies even if the payback is poor.

10. In addition to the above factors, the cost effectiveness of AWHP systems is also dependent on the **number of occupants** and their **hot water usage** (see Figure 5.5).

11. **The summer cooling system type and load.** Since the AWHP provides some "free" cooling during the summer, the cooling system type and load impact the economic picture when analyzing an AWHP system.

6. ECONOMIC SUMMARY OF HOUSE AIRTIGHTENING--CONCLUSIONS

It has been shown that the Cost Effectiveness of the same airtightening system changes depending on the parameters mentioned in Section 5. It is therefore imperative to take all applicable parameters into account when analyzing any airtightening system for its Cost Effectiveness. The effects of the main parameters are: Any given house airtightening system generally becomes more cost effective as the system cost borrowing rate is lowered, as the size of the house increases, and as the cost of fuel and/or its inflation rate increases. It becomes less cost effective as the heating system efficiency increases. As the climate becomes colder the system using an AAHE becomes more cost effective, but the AWHP system generally becomes less cost effective.

When the Extreme Method of airtightening is used, it is generally cost effective to incorporate heat recovery on the added ventilation, particularly in larger houses and in colder climates. When natural gas is available, the AAHE heat recovery system will currently and in most cases yield a higher economic return than the AWHP system. However, in many cases the AWHP system will be equal to or better economically than the AAHE. This is the case when natural gas is not available and when electricity is the prime fuel.

The analyses in this paper do not account for savings in summer cooling from a load reduction due to less air infiltration. Accounting for this would make the advantage of airtightening even greater.

Airtightening in almost all cases is very cost effective. The **Moderate Method** yields higher rates of return, but gross savings are less than in the **Extreme Method.**
When borrowing for the system, whether the Moderate or Extreme Method, in 6000 to 10,000 DDB.65F climates, using virtually any heating system, almost all cases of those on Table 4.1 (90%) and many on Table 4.2 (40%) show Paybacks or positive cash flows from the very first year. In addition, significant yearly savings are realized along with increased resale value--all without having to spend any cash out-of-pocket!

This occurs because from the first year the energy savings are more than the increased mortgage and related costs to finance the system. In essence the energy savings are more than making the mortgage payment for the energy system. Also, at resale the homeowner receives, in cash, the total original value of the system for which he/she never had to put out any money to get. Even before resale, it is less expensive to own a "more expensive" airtight house. There is no better investment than that: no money down, non-taxable high rates of return, increased real estate value and increased house comfort and structure durability!

It is the hope of the author that these statistics, which overwhelming demonstrate the significant value of house airtightening, will encourage designers, builders and consumers to take advantage of this technology.

REFERENCES

1. Balcomb, Doug. Passive Solar Design Handbook, Vol. 2, p. E2-E44, 1980.

2. Solar Age. August 1982, pp. 59-60; September 1982, pp. 57-58; and December 1984, pp. 24-27.

3. Cowlishaw, R., Builders' Guide to Passive Solar Homes, 1980, pp. 77-80.

4. Stum, Karl, "Modified Airtight Drywall Methods", Proceedings, EEBA International Energy Efficient Building Conference, April, 1987.

TABLE 3.1

ENERGY IMPROVEMENT CASH FLOW ANALYSIS

ENVIRO-SUN / KARL R. STUM
1643 NORTH 645 WEST
OREM, UTAH 84057
801/224-1274

INPUT:

Fuel Inflation Rate:		5 % Per Year
General Inflation Rate:		5 % Per Year
Loan Fees and Points:		3 %
Income Tax Bracket:		15 %
Annual Mortgage Interest Rate (fixed):		10 %
Loan Term:		30 Years
Down Payment:	$	0
Standard Case, Annual Maintenance and Replacement Costs:	$	0
Energy Improved Case, Annual Maintenance and Replacement Costs:	$	0
Standard Case Annual Utility Bill:	$	324
Improved Case Annual Utility Bill:	$	147
Energy Improvement Installed Cost:	$	1490
Real Estate Appreciation Rate:		5 % Per Year

Standard Base Case Description: (System, HVAC Effic.; Etc.)
Total AC/H = .5, 80% Gas Furnace

Energy Improved Case Description: Airtight House Using Modified ADA Method, .08 AC/H Natural + A 70% Effic. AAHE To Bring Total to .3 AC/H, 80% Effic. Gas Furnace.
House Size: 2000 FT2 Climate: 8000 DDB.65F
Utility Costs Taken Into Account: Space Heating Only (due to air leakage)
Cost of Fuel: $.75/Therm

OTHER PARAMETERS

1. Annual Property Taxes and Insurance Are 1% of the Original Improvement Cost and Inflate at the General Rate of Inflation
2. Present Worth Factors = 1/[(1+I)^Y], Where: I = General Rate of Inflation; Y = Year

****

FIRST YEAR UTILITY SAVINGS:	$	177
FIRST YEAR SIMPLE RETURN:		11.9 %
TOTAL BORROWED AMOUNT:	$	1535
ANNUAL MORTGAGE PAYMENT TO FINANCE ENERGY IMPROVEMENT:	$	163

CASH FLOW COMPARISON

[- Values Denote Expenses; + Values Are Savings (in Dollars)]

	CASH FLOWS ($)	YEAR 1	2	3	4	5	6	7	8	9	10
STD HOUSE	Annual Util. Bill	-324	-340	-357	-375	-394	-414	-434	-456	-479	-503
	Maint. & Replac.	0	0	0	0	0	0	0	0	0	0
	Mortgage Payment	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	ANNUAL EXPENSES	-324	-340	-357	-375	-394	-414	-434	-456	-479	-503
ENERGY IMPROVED HOUSE	Annual Util. Bill	-147	-154	-162	-170	-179	-188	-197	-207	-217	-228
	Maint. & Replac.	0	0	0	0	0	0	0	0	0	0
	Mortgage Payment	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163
	Taxes & Insurance	-15	-16	-16	-17	-18	-19	-20	-21	-22	-23
	Mort. Int. Tx. Ded	23	23	23	23	22	22	22	22	21	21
	ANNUAL EXPENSES	-302	-310	-319	-328	-337	-347	-358	-369	-381	-393
Net Cash Flow Savings Of Improved vs STD Case		22	30	39	47	57	66	76	87	98	110
Present Worth Factor		0.952	0.907	0.864	0.823	0.784	0.746	0.711	0.677	0.645	0.614
DISCOUNTED NET CASH SAVINGS		21	27	33	39	44	49	54	59	63	67
ACCUMULATIVE DISC. SAVINGS		21	49	82	121	165	215	269	328	391	459
RESALE VALUE OF FEATURE		1,565	1,643	1,725	1,811	1,902	1,997	2,097	2,201	2,311	2,427

SUMMARIES

(Negative Cash Flow Means the Energy Improved Case Cost More to Live in Than the Standard Base Case and Visa/Versa)

PAYBACK OF ALL NEGATIVE CASH FLOWS: AFTER 0 YEARS

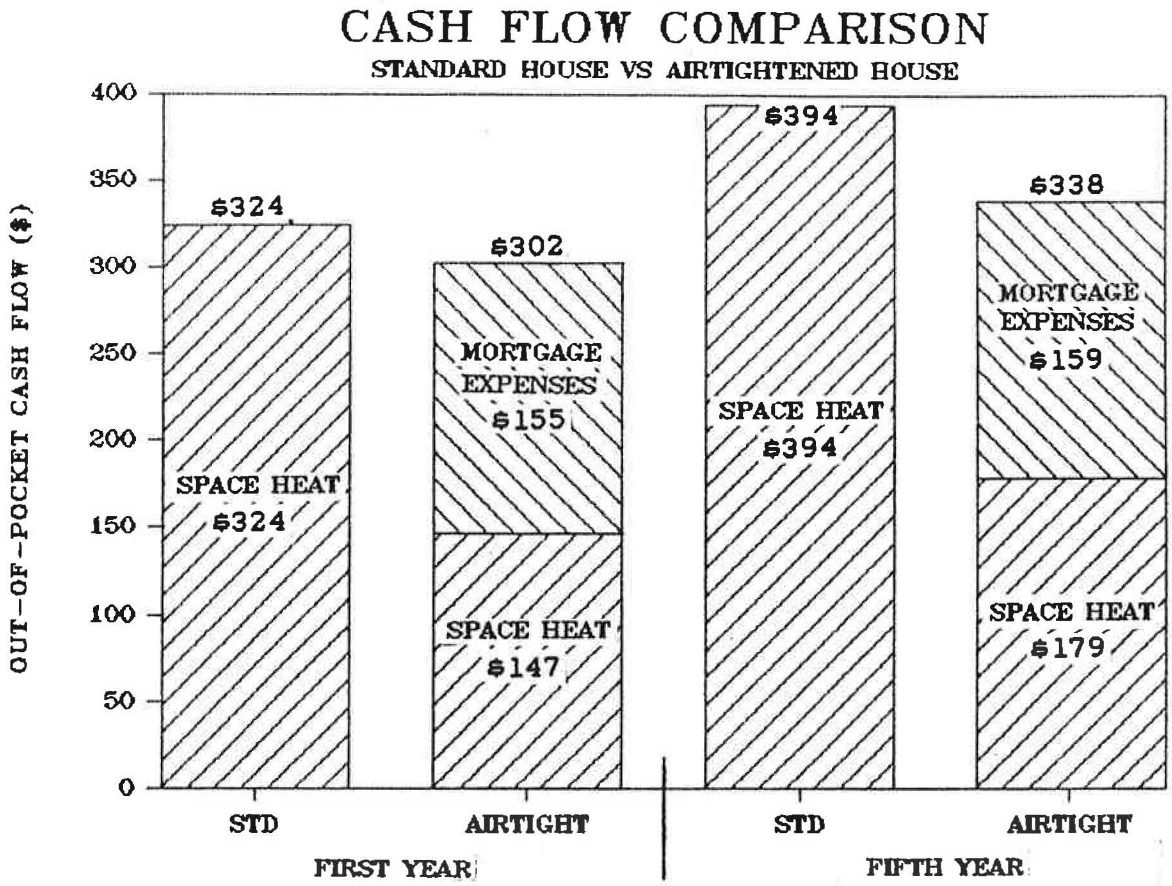
ACCUMULATIVE CASH FLOW SAVINGS AT: 5 YRS $165 10 YRS $459

CASH GAIN ABOVE STD CASE IF SOLD.
ACCUMULATIVE SAVINGS PLUS RESALE VALUE: 5 YRS $2,067 10 YRS $2,886

TOTAL OF ALL NEGATIVE CASH FLOWS AT: 5 YRS $ 10 YRS $

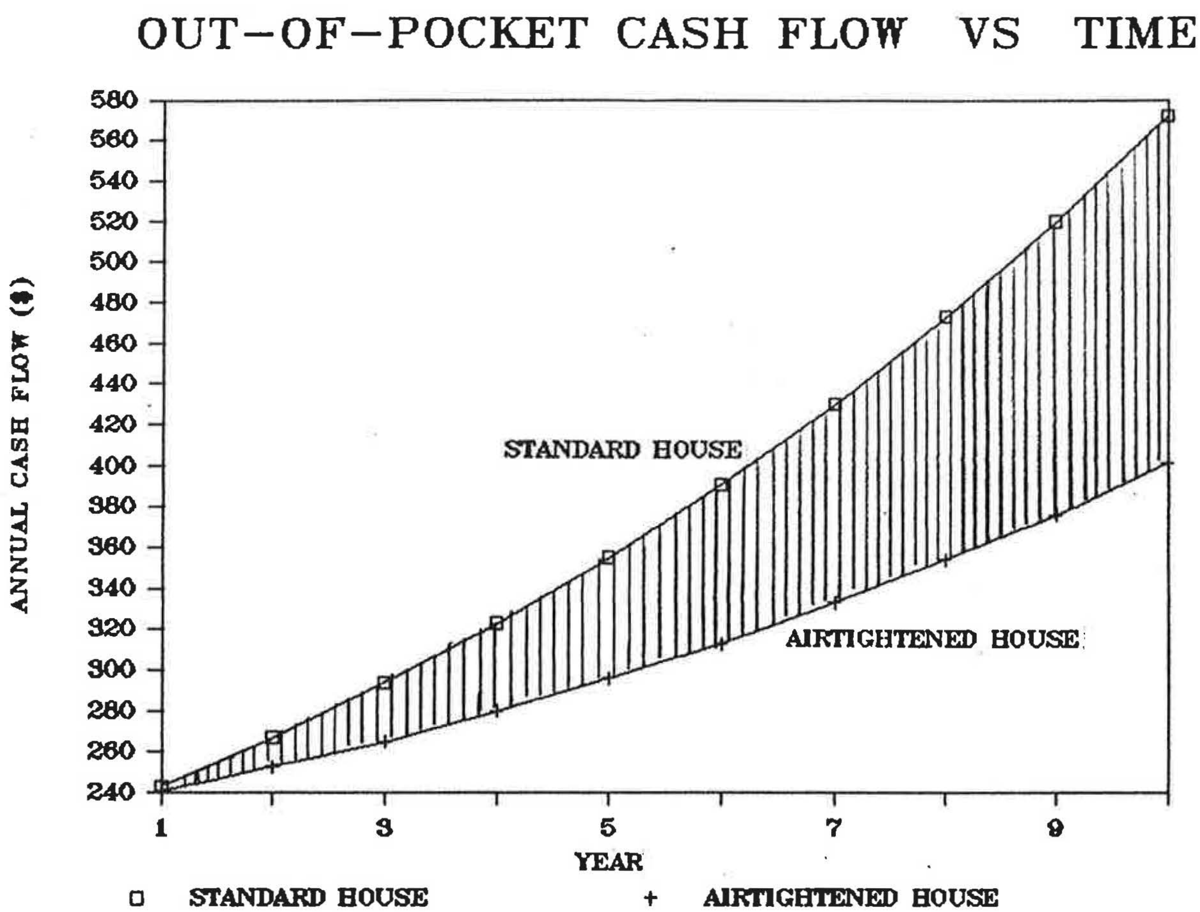
AVERAGE PERCENT RETURN PER YEAR ON TOTAL
NEGATIVE CASH FLOWS AFTER: 5 YRS % 10 YRS

FIGURE 3.1



BASED ON A STD HOUSE WITH .5 TOTAL AC/H, WITH AN 80% EFFIC. GAS FURNACE AND AN AIRTIGHTENED HOUSE WITH A .08 NATURAL AC/H WITH A 70% EFFIC. AAHE AND TOTAL AC/H OF .3, AN 80% EFFIC. GAS FURNA GAS AT $.75/THERM, A 10%, 30 YEAR MORTGAGE INTEREST RATE AND A FUEL INFLATION RATE OF 5%.

FIGURE 3.2



Shaded area represents savings of Airtightened House over the Standard House

TABLE 4.1

PERFORMANCE AND ECONOMIC SAVINGS OF HOUSE AIRTIGHTENING
(USING AN AIR-TO-AIR HEAT EXCHANGER (AAHE) WHEN MECH. VENTILATION IS REQUIRED)

SYSTEM TYPE	HOUSE SIZE: FT2 (M2)	AC/H NAT	AC/H OCCUP	AC/H MECH	AC/H TOT	SYSTEM COST ABOVE STD. (GAS, ELEC)	DEGREE DAYS B65.F	SEASONAL ENERGY COST TO REPLACE AIR CHANGE HEAT LOSS (GAS FURN: 80% EFFIC. ELEC FURN: COP 2) GAS $.50/THRM	GAS $.75/THRM	ELEC $.06/KWH	ELEC $.08/KWH	ELEC $.10/KWH	FIRST YEAR DOLLAR SAVINGS AND SIMPLE PERCENT RETURN OVER STANDARD HOUSE SYSTEM: GAS HEAT $.50/THRM $	%	GAS HEAT $.75/THRM $	%	ELEC HEAT $.06/KWH $	%	ELEC HEAT $.08/KWH $	%	ELEC HEAT $.10/KWH $	%
	1000						6000	$85	$127	$120	$160	$200										
	(93)	.38	.20	0	.58		8000	$113	$169	$160	$213	$266										
							10000	$142	$213	$200	$266	$333										
	2000						6000	$162	$243	$228	$304	$380										
	(186)	.38	.15	0	.53		8000	$216	$324	$304	$406	$507										
STD							10000	$270	$405	$380	$507	$634										
	3000						6000	$212	$318	$298	$396	$495										
	(279)	.38	.10	0	.48		8000	$282	$423	$396	$528	$660										
							10000	$352	$528	$495	$661	$826										
	5000						6000	$329	$493	$463	$617	$771										
	(465)	.38	.05	0	.43		8000	$439	$658	$617	$823	$1,028										
							10000	$548	$822	$771	$1,028	$1,285										
	1000					$475 G	6000	$58	$87	$82	$110	$137	$27	5.7%	$40	8.4%	$38	10.7%	$50	14.1%	$63	17.7%
	(93)	.20	.20	0	.40		8000	$78	$117	$110	$146	$183	$35	7.4%	$52	10.9%	$50	14.1%	$67	18.9%	$83	23.4%
						$355 E	10000	$98	$147	$137	$183	$229	$44	9.3%	$66	13.9%	$63	17.7%	$83	23.4%	$104	29.3%
	2000					$640 G	6000	$107	$160	$150	$200	$251	$55	8.6%	$83	13.0%	$78	15.0%	$104	20.0%	$129	24.8%
	(186)	.22	.13	0	.35		8000	$143	$214	$201	$267	$334	$73	11.4%	$110	17.2%	$103	19.8%	$139	25.7%	$173	33.3%
MODERATE						$520 E	10000	$179	$268	$251	$334	$418	$91	14.2%	$137	21.4%	$129	24.8%	$173	33.3%	$216	41.5%
	3000					$770 G	6000	$132	$198	$185	$247	$309	$80	10.4%	$120	15.6%	$113	17.4%	$149	22.9%	$186	28.6%
	(279)	.22	.07	0	.29		8000	$176	$264	$247	$330	$413	$106	13.8%	$159	20.6%	$149	22.9%	$198	30.5%	$247	38.0%
						$650 E	10000	$220	$330	$309	$413	$516	$132	17.1%	$198	25.7%	$186	28.6%	$248	38.1%	$310	47.7%
	5000					$1065 G	6000	$191	$286	$269	$358	$448	$138	13.0%	$207	19.4%	$194	20.5%	$260	27.5%	$323	34.2%
	(465)	.25	.02	0	.27		8000	$255	$382	$358	$478	$598	$184	17.3%	$276	25.9%	$259	27.4%	$345	36.5%	$430	45.5%
						$ 945 E	10000	$319	$478	$448	$598	$747	$229	21.5%	$344	32.2%	$323	34.2%	$430	45.5%	$538	56.9%
	1000					$1210 G	6000	$41	$61	$57	$77	$96	$44	3.6%	$66	5.5%	$63	5.8%	$83	7.6%	$104	9.5%
	(93)	.08	.20	0	.28		8000	$55	$82	$77	$102	$128	$58	4.8%	$87	7.2%	$83	7.6%	$111	10.2%	$138	12.7%
						$1090 E	10000	$69	$103	$96	$128	$160	$73	6.0%	$110	9.1%	$104	9.5%	$138	12.7%	$173	15.9%
	2000 (AAHE)					$1490 G	6000	$74	$111	$103	$137	$172	$88	5.9%	$132	8.9%	$125	9.1%	$167	12.2%	$208	15.2%
	(186)	.08	.13	.09	.30		8000	$98	$147	$137	$183	$229	$118	7.9%	$177	11.9%	$167	12.2%	$223	16.3%	$278	20.3%
EXTREME						$1370 E	10000	$122	$183	$172	$229	$287	$148	9.9%	$222	14.9%	$208	15.2%	$278	20.3%	$347	25.3%
	3000 (AAHE)					$1720 G	6000	$88	$132	$123	$159	$206	$124	7.2%	$186	10.8%	$175	10.9%	$231	14.4%	$289	18.1%
	(279)	.08	.07	.15	.30		8000	$117	$175	$165	$220	$275	$165	9.6%	$248	14.4%	$231	14.4%	$308	19.3%	$385	24.1%
						$1600 E	10000	$147	$220	$206	$275	$344	$205	11.9%	$308	17.9%	$289	18.1%	$386	24.1%	$482	30.1%
	5000 (AAHE)					$2080 G	6000	$115	$172	$161	$215	$269	$214	10.3%	$321	15.4%	$302	15.4%	$402	20.5%	$502	25.6%
	(465)	.08	.02	.20	.30		8000	$153	$229	$215	$287	$358	$286	13.8%	$429	20.6%	$402	20.5%	$536	27.3%	$670	34.2%
						$1960 E	10000	$191	$286	$269	$358	$448	$357	17.2%	$536	25.8%	$502	25.6%	$670	34.2%	$837	42.7%

TABLE 4.2

PERFORMANCE AND ECONOMIC SAVINGS OF HOUSE AIRTIGHTENING USING AN AWHP FOR MECHANICAL VENTILATION IN AIRTIGHTENED CASES

THIS ANALYSIS IS FOR:

GAS OR OIL COUNTRY:
STD HOUSE: WATER HEATER: GAS <TANK>
SPACE HEATER: GAS FURNACE
AIRTIGHTENED HOUSE: WATER HEATER: ELEC. AWHP
SPACE HEATER: SAME AS STD

FIRST YEAR DOLLAR SAVINGS AND FIRST YEAR SIMPLE PERCENT RETURN OVER STANDARD HOUSE [< > & - ARE NEGATIVE VALUES]

HOUSE SIZE/DD/OCCUP <X1000>	AC/H <24 HR AVERAGE> NAT<U>	MECH	TOTAL	AIRTIGHT & MECH SYSTEM COST ABOVE STD <$>	GAS: @ $ 0.50 /THERM, ELEC. RATE <$> 0.06 /KWH $	%	0.08 /KWH $	%	0.10 /KWH $	%	GAS: @ $ 0.75 /THERM, ELEC. RATE <$> 0.06 /KWH $	%	0.08 /KWH $	%	0.10 /KWH $	%
1FT/600/3	0.17	0.21	0.35	$2,230	$56	2.5%	$25	1.1%	<$7>	-0.3%	$132	5.9%	$100	4.5%	$69	3.1%
1FT/600/5	0.09	0.35	0.45	$2,230	$13	0.6%	<$51>	-2.3%	<$115>	-5.2%	$115	5.1%	$51	2.3%	<$13>	-0.6%
1FT/800/3	0.17	0.21	0.35	$2,230	$27	1.2%	<$13>	-0.6%	<$53>	-2.4%	$101	4.5%	$61	2.7%	$21	0.9%
1FT/800/5	0.09	0.35	0.45	$2,230	<$21>	-0.9%	<$93>	-4.2%	<$166>	-7.4%	$77	3.4%	$5	0.2%	<$68>	-3.0%
1FT/100/3	0.17	0.21	0.35	$2,230	<$24>	-1.1%	<$77>	-3.4%	<$130>	-5.8%	$43	1.9%	<$9>	-0.4%	<$62>	-2.8%
1FT/100/5	0.09	0.35	0.45	$2,230	<$76>	-3.4%	<$161>	-7.2%	<$246>	-11.0%	$13	0.6%	<$72>	-3.2%	<$157>	-7.0%
2FT/600/4	0.26	0.14	0.35	$2,210	$63	2.8%	$15	0.7%	<$33>	-1.5%	$166	7.5%	$118	5.4%	$71	3.2%
2FT/600/6	0.22	0.21	0.35	$2,210	$35	1.6%	<$45>	-2.0%	<$125>	-5.7%	$172	7.8%	$92	4.2%	$12	0.5%
2FT/800/4	0.26	0.14	0.35	$2,210	$28	1.3%	<$28>	-1.3%	<$84>	-3.8%	$127	5.7%	$71	3.2%	$14	0.6%
2FT/800/6	0.22	0.21	0.35	$2,210	$1	.0%	<$87>	-4.0%	<$176>	-8.0%	$134	6.1%	$45	2.1%	<$43>	-1.9%
2FT/100/4	0.26	0.14	0.35	$2,410	<$37>	-1.5%	<$106>	-4.4%	<$175>	-7.3%	$48	2.0%	<$21>	-0.9%	<$90>	-3.7%
2FT/100/6	0.22	0.21	0.35	$2,410	<$64>	-2.6%	<$165>	-6.8%	<$266>	-11.0%	$56	2.3%	<$45>	-1.9%	<$146>	-6.1%
3FT/600/5	0.29	0.12	0.35	$2,390	$70	2.9%	$6	0.2%	<$58>	-2.4%	$200	8.4%	$136	5.7%	$72	3.0%
3FT/600/7	0.27	0.17	0.35	$2,390	$41	1.7%	<$55>	-2.3%	<$151>	-6.3%	$206	8.6%	$110	4.6%	$14	0.6%
3FT/800/5	0.29	0.12	0.35	$2,390	$29	1.2%	<$43>	-1.8%	<$115>	-4.8%	$153	6.4%	$80	3.4%	$8	0.3%
3FT/800/7	0.27	0.17	0.35	$2,390	$2	0.1%	<$102>	-4.3%	<$207>	-8.6%	$160	6.7%	$55	2.3%	<$49>	-2.1%
3FT/100/5	0.29	0.12	0.35	$2,590	<$50>	-1.9%	<$135>	-5.2%	<$220>	-8.5%	$52	2.0%	<$33>	-1.3%	<$118>	-4.6%
3FT/100/7	0.27	0.17	0.35	$2,590	<$77>	-3.0%	<$194>	-7.5%	<$311>	-12.0%	$60	2.3%	<$57>	-2.2%	<$174>	-6.7%
5FT/600/5	0.31	0.07	0.35	$2,750	$111	4.0%	$47	1.7%	<$17>	-0.6%	$262	9.5%	$198	7.2%	$135	4.9%
5FT/600/7	0.31	0.10	0.35	$2,750	$83	3.0%	<$13>	-0.5%	<$109>	-4.0%	$268	9.7%	$172	6.3%	$76	2.8%
5FT/800/5	0.31	0.07	0.35	$2,750	$59	2.2%	<$13>	-0.5%	<$85>	-3.1%	$197	7.2%	$125	4.5%	$53	1.9%
5FT/800/7	0.31	0.10	0.35	$2,750	$32	1.2%	<$73>	-2.6%	<$177>	-6.4%	$204	7.4%	$100	3.6%	<$4>	-0.2%
5FT/100/5	0.31	0.07	0.35	$2,950	<$50>	-1.7%	<$135>	-4.6%	<$220>	-7.5%	$52	1.8%	<$33>	-1.1%	<$118>	-4.0%
5FT/100/7	0.31	0.10	0.35	$2,950	<$77>	-2.6%	<$194>	-6.6%	<$311>	-10.5%	$60	2.0%	<$57>	-1.9%	<$174>	-5.9%

DATA INPUT:

AIRTIGHTENED HOUSE TOTAL DESIGN AC/H: 0.35
STD HOUSE NATURAL<U> AC/H: 6000 DD: 0.48
8000 DD: 0.42
10000 DD: 0.35
AWHP FT3 OF 70F AIR TO HEAT 1 GAL 80F: 550
HOT WATER USE, GAL./OCCUP/DAY: 22
COP FOR ELEC. SPACE HEAT W/A 6000 DD: 2.00
8000 DD: 1.70 10000 DD: 1.40
DESIGN AWHP ON-OFF CYCLES PER DAY: 3

GAS H2O HEATER BURN EFFIC: 0.80
GAS FURNACE EFFIC. <AFUE>: 0.80
ANNUAL COP OF AWHP WATER HEATER: 2.50
AWHP MINIMUM AIRFLOW <CFM>: 70
SUMMER COOLING: NONE [0]
EVAP. [1], REFRIG. [2]: 2

AWHP TONS OF COOLING: 0.60
SUMMER COOLING: HRS >80 | TOT. LOAD IN TONS/1000FT2
FOR 6000 DD: 500 | 1.25
FOR 8000 DD: 300 | 1.00
ELEVATION <FT>: 5000

ABBREVIATIONS / NOTES

AWHP: AIR TO WATER HEAT PUMP WATER HEATER; VENTILATIOR <ELEC>
WATER: ANNUAL DOMESTIC HOT WATER HEATING COST
AC SAVINGS: SAVINGS IN AIR COND. OPERATING COSTS DUE TO AWHP
SPACE: ANNUAL COST TO REPLACE HEAT LOSS DUE TO TOTAL AIR CHANGE
COP OF ELEC. WATER HEATER IN STD. HOUSE ASSUMED TO BE 1.0

NAT<U>: AC/H DURING UNOCCUPIED COND. <NO MECH. VENT>
NAT<O>: AC/H DURING OCCUPIED COND. W/ MECH. VENT.
OCCUP: OCCUPANT EFFECTS AC/H
MECH: MECH. VENTILATION AC/H
<$/GAL OF #2 OIL> / 1.4 = $/THERM

TABLE 4.2

PERFORMANCE AND ECONOMIC SAVINGS OF HOUSE AIRTIGHTENING USING AN AWHP FOR MECHANICAL VENTILATION IN AIRTIGHTENED CASES

THIS ANALYSIS IS FOR

ALL ELECTRIC COUNTRY:
STD HOUSE: WATER HEATER: STD ELEC. (TANK) COP 1
SPACE HEATER: ELECTRIC WITH COP AS NOTED
AIRTIGHTENED HOUSE: WATER HEATER: ELEC. AWHP
SPACE HEATER: SAME AS STD.

FIRST YEAR DOLLAR SAVINGS AND FIRST YEAR SIMPLE PERCENT RETURN OVER STANDARD HOUSE

[( ) & - ARE NEGATIVE VALUES]

HOUSE SIZE/DD/ OCCUP (*1000)	AIRTIGHT & MECH SYSTEM COST ABOVE STD ($)	AC/H (24 HR AVERAGE) NAT(U)	OCCUP	MECH	NAT(O)	TOTAL	AWHP HOURS PER CYCLE	AWHP REQ'D FLOW (CFM)	ELEC. RATE ($) 0.06 /KWH $	0.06 /KWH %	0.08 /KWH $	0.08 /KWH %	0.10 /KWH $	0.10 /KWH %
1FT/6DD/3	$2,230	0.17	0.07	0.21	0.10	0.35	2.9	70	$312	14.0%	$416	18.7%	$520	23.3%
1FT/6DD/5	$2,230	0.09	0.11	0.35	0.04	0.45	4.8	70	$427	19.1%	$569	25.5%	$711	31.9%
1FT/8DD/3	$2,230	0.17	0.07	0.21	0.10	0.35	2.9	70	$287	12.9%	$382	17.1%	$478	21.4%
1FT/8DD/5	$2,230	0.09	0.11	0.35	0.04	0.45	4.8	70	$391	17.5%	$522	23.4%	$652	29.2%
1FT/10D/3	$2,230	0.17	0.07	0.21	0.10	0.35	2.9	70	$231	10.3%	$307	13.8%	$384	17.2%
1FT/10D/5	$2,230	0.09	0.11	0.35	0.04	0.45	4.8	70	$321	14.4%	$427	19.2%	$534	24.0%
2FT/6DD/4	$2,210	0.26	0.04	0.14	0.19	0.35	3.9	70	$410	18.5%	$546	24.7%	$683	30.9%
2FT/6DD/6	$2,210	0.22	0.06	0.21	0.11	0.35	5.8	70	$546	24.7%	$728	33.0%	$910	41.2%
2FT/8DD/4	$2,210	0.26	0.04	0.14	0.19	0.35	3.9	70	$381	17.2%	$508	23.0%	$635	28.7%
2FT/8DD/6	$2,210	0.22	0.06	0.21	0.11	0.35	5.8	70	$520	23.5%	$693	31.4%	$866	39.2%
2FT/10D/4	$2,410	0.26	0.04	0.14	0.19	0.35	3.9	70	$302	12.5%	$402	16.7%	$503	20.9%
2FT/10D/6	$2,410	0.22	0.06	0.21	0.11	0.35	5.8	70	$444	18.4%	$591	24.5%	$739	30.7%
3FT/6DD/5	$2,390	0.29	0.04	0.12	0.21	0.35	4.8	70	$507	21.2%	$676	28.3%	$845	35.4%
3FT/6DD/7	$2,390	0.27	0.05	0.17	0.16	0.35	6.7	70	$644	26.9%	$859	35.9%	$1,073	44.9%
3FT/8DD/5	$2,390	0.29	0.04	0.12	0.21	0.35	4.8	70	$475	19.9%	$633	26.5%	$792	33.1%
3FT/8DD/7	$2,390	0.27	0.05	0.17	0.16	0.35	6.7	70	$614	25.7%	$819	34.2%	$1,023	42.8%
3FT/10D/5	$2,590	0.29	0.04	0.12	0.21	0.35	4.8	70	$373	14.4%	$497	19.2%	$621	24.0%
3FT/10D/7	$2,590	0.27	0.05	0.17	0.16	0.35	6.7	70	$515	19.9%	$686	26.5%	$858	33.1%
5FT/6DD/5	$2,750	0.31	0.02	0.07	0.27	0.35	4.8	70	$566	20.6%	$754	27.4%	$943	34.3%
5FT/6DD/7	$2,750	0.31	0.03	0.10	0.24	0.35	6.7	70	$702	25.5%	$937	34.1%	$1,171	42.6%
5FT/8DD/5	$2,750	0.31	0.02	0.07	0.27	0.35	4.8	70	$524	19.1%	$699	25.4%	$874	31.8%
5FT/8DD/7	$2,750	0.31	0.03	0.10	0.24	0.35	6.7	70	$663	24.1%	$884	32.2%	$1,106	40.2%
5FT/10D/5	$2,950	0.31	0.02	0.07	0.27	0.35	4.8	70	$373	12.6%	$497	16.8%	$621	21.0%
5FT/10D/7	$2,950	0.31	0.03	0.10	0.24	0.35	6.7	70	$515	17.4%	$686	23.3%	$858	29.1%

DATA INPUT:

AIRTIGHTENED HOUSE TOTAL DESIGN AC/H: 0.35
STD HOUSE NATURAL(U) AC/H: 6000 DD: 0.48
8000 DD: 0.42
10000 DD: 0.35
AWHP FT3 OF 70F AIR TO HEAT 1 GAL 80F: 550
HOT WATER USE, GAL./OCCUP/DAY: 22
COP FOR ELEC. SPACE HEAT. 6000 DD: 2.00
8000 DD: 1.70 10000 DD: 1.40
DESIGN AWHP ON-OFF CYCLES PER DAY: 3

GAS WATER HEATER BURN EFFIC: 0.00
GAS FURNACE EFFIC. (AFUE): 0.00
ANNUAL COP OF AWHP WATER HEATER: 2.50
AWHP MINIMUM AIRFLOW (CFM): 70
SUMMER COOLING: NONE [0]
EVAP. [1], REFRIG. [2]: 2

AWHP TONS OF COOLING: 0.60
SUMMER COOLING:

	HRS >80	TOT. LOAD IN TONS/1000FT2
FOR 6000 DD:	500	1.25
FOR 8000 DD:	300	1.00

ELEVATION (FT): 5000

ABBREVIATIONS / NOTES

AWHP: AIR TO WATER HEAT PUMP WATER HEATER; VENTILATIOR (ELEC)
WATER: ANNUAL DOMESTIC HOT WATER HEATING COST
AC SAVINGS: SAVINGS IN AIR COND. OPERATING COSTS DUE TO AWHP
SPACE: ANNUAL COST TO REPLACE HEAT LOSS DUE TO TOTAL AIR CHANGE
COP OF ELEC. WATER HEATER IN STD. HOUSE ASSUMED TO BE 1.0

NAT(U): AC/H DURING UNOCCUPIED COND. (NO MECH. VENT)
NAT(O): AC/H DURING OCCUPIED COND. W/ MECH. VENT.
OCCUP: OCCUPANT EFFECTS AC/H
MECH: MECH. VENTILATION AC/H
($/GAL OF #2 OIL) / 1.4 = $/THERM

TABLE 4.3

AIR TO AIR HEAT EXCHANGER (AAHE) VS AIR TO WATER HEAT PUMP VENTILATOR (AWHP)

(ECONOMIC FIRST YEAR RETURN COMPARISON)

FIRST YEAR SIMPLE RETURN OVER STANDARD HOUSE
(ENERGY SAVINGS / NET ADDED COST)

HOUSE SIZE/DD (x1000)/ OCCUP'S	NET SYSTEM COST ABOVE STD (INCL. SEALING)		GAS SPACE HEAT @ $ 0.50/ THERM						GAS SPACE HEAT @ $ 0.75/ THERM					
			ELEC. RATE ($) 0.06/KWH		ELEC. RATE ($) 0.08 /KWH		ELEC. RATE ($) 0.10 /KWH		ELEC. RATE ($) 0.06/KWH		ELEC. RATE ($) 0.08 /KWH		ELEC. RATE ($) 0.10 /KWH	
	AWHP	AAHE	AWHP	AAHE	AWHP	AAHE	AWHP	AAHE	AWHP	AAHE	AWHP	AAHE	AWHP	AAHE
1FT/6DD/3	$2110	$1210+	*5.1%	3.6%+	*3.9%	3.6%+	2.6%	3.6%+	*9.5%	5.5%+	*8.3%	5.5%+	7.1%	5.5%+
1FT/8DD/3	$1510	$1210+	*6.3%	4.8%+	4.1%	4.8%+	1.8%	4.8%+	*12.9%	7.2%+	*10.7%	7.2%+	*8.4%	7.2%+
1FT/10DD/3	$2110	$1210+	3.4%	6.0%+	1.1%	6.0%+	-1.1%	6.0%+	8.4%	9.1%+	6.2%	9.1%+	3.9%	9.1%+
2FT/6DD/4	$2290	$1490	5.7%	5.9%	3.9%	5.9%	2.2%	5.9%	*11.2%	8.9%	*9.5%	8.9%	7.7%	8.9%
2FT/8DD/4	$2290	$1490	5.9%	7.9%	2.2%	7.9%	0.9%	7.9%	*13.9%	11.9%	10.5%	11.9%	7.1%	11.9%
2FT/10DD/4	$2290	$1490	4.9%	9.9%	2.2%	9.9%	-0.5%	9.9%	11.3%	14.9%	8.7%	14.9%	6.0%	14.9%
3FT/6DD/5	$2270	$1720	6.7%	7.2%	4.3%	7.2%	1.8%	7.2%	*13.6%	10.8%	*11.2%	10.8%	8.8%	10.8%
3FT/8DD/5	$2270	$1720	6.9%	9.6%	4.1%	9.6%	-0.9%	9.6%	14.5%	14.4%	11.7%	14.4%	9.0%	14.4%
3FT/10DD/5	$2470	$1720	6.0%	11.9%	3.0%	11.9%	-0.1%	11.9%	13.7%	17.9%	10.6%	17.9%	7.5%	17.9%
5FT/6DD/7	$2630	$2080	7.2%	10.3%	4.1%	10.3%	0.9%	10.3%	*15.6%	15.4%	12.5%	15.4%	9.3%	15.4%
5FT/8DD/7	$2630	$2080	8.1%	13.8%	4.6%	13.8%	1.1%	13.8%	17.3%	20.6%	13.8%	20.6%	10.3%	20.6%
5FT/10DD/7	$2830	$2080	7.8%	17.2%	4.1%	17.2%	0.4%	17.2%	17.2%	25.8%	13.5%	25.8%	9.9%	25.8%

NOTES:

1. DATA COMPILED FROM TABLE 4.1 AND TABLE 4.2

2. ALL CASES ARE USING THE EXTREME METHOD OF AIRTIGHTENING. WITH THE NATURAL AIR CHANGE (NAT(U)) = .08 AC/H

3. IN ALL CASES THE AAHE YIELDS HIGHER RATES OF RETURN THAN THE AWHP EXCEPT FOR THOSE TAGGED WITH AN * .

4. ALL SYSTEMS ARE USING NATURAL GAS FOR SPACE HEATING

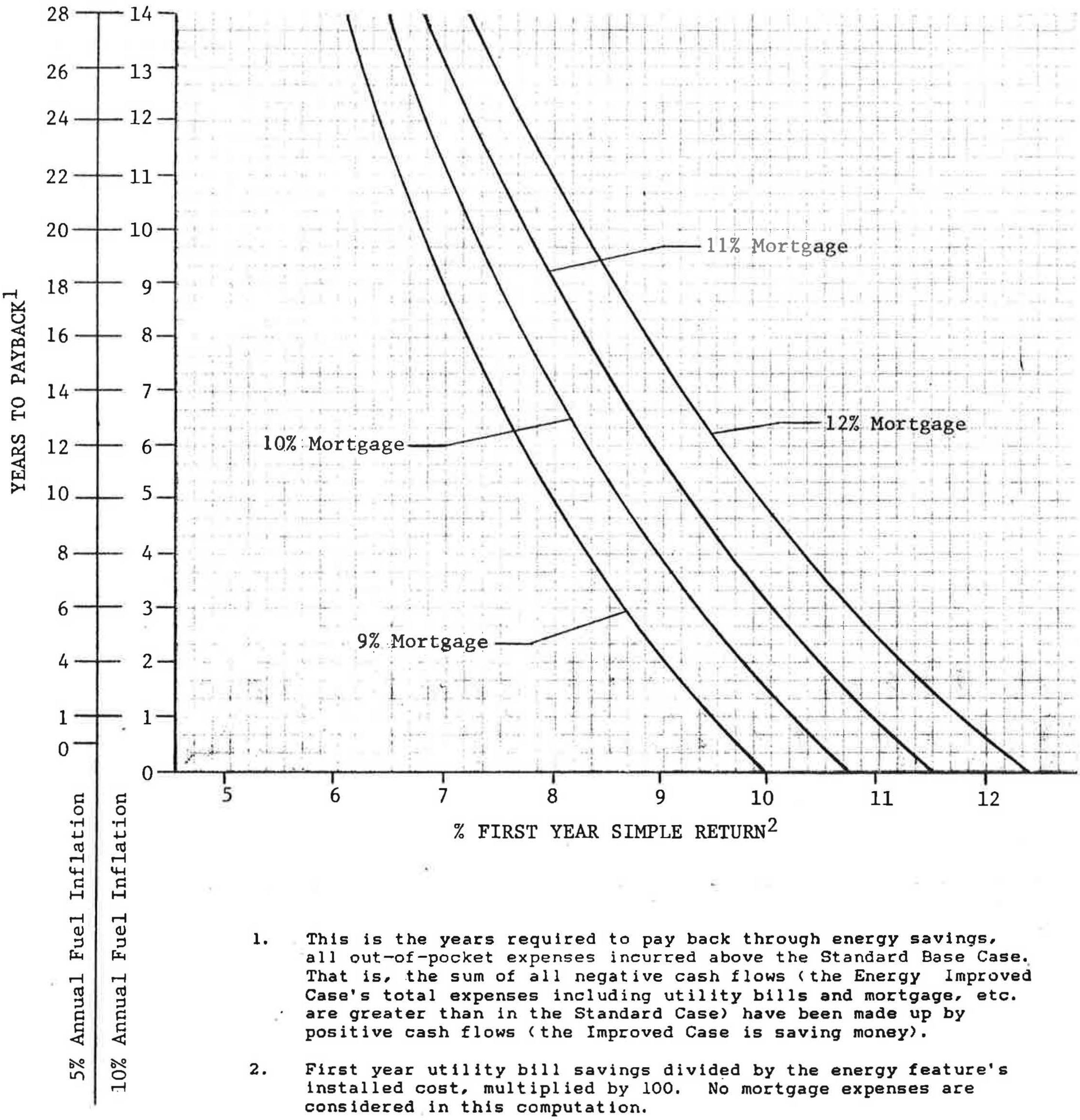
5. COLUMN 1 KEY: 1FT/6DD/3 = 1000 FT2 HOUSE, 6000 DDB.65F; 3 OCCUPANTS

6. NET SYSTEM COST ABOVE STD INCLUDES CREDITS FOR THE AWHP AS THEY ARE ACTING ALSO AS THE WATER HEATER AND PARTIAL AIR CONDITIONER.

\+ HOUSES OF 1000 FT2 DO NOT HAVE AN AAHE. AS THEY GENERALLY NEED NO ADDITIONAL VENTILATION, SEE TABLE 4.1 .

FIGURE 4.1

PAYBACK[1]



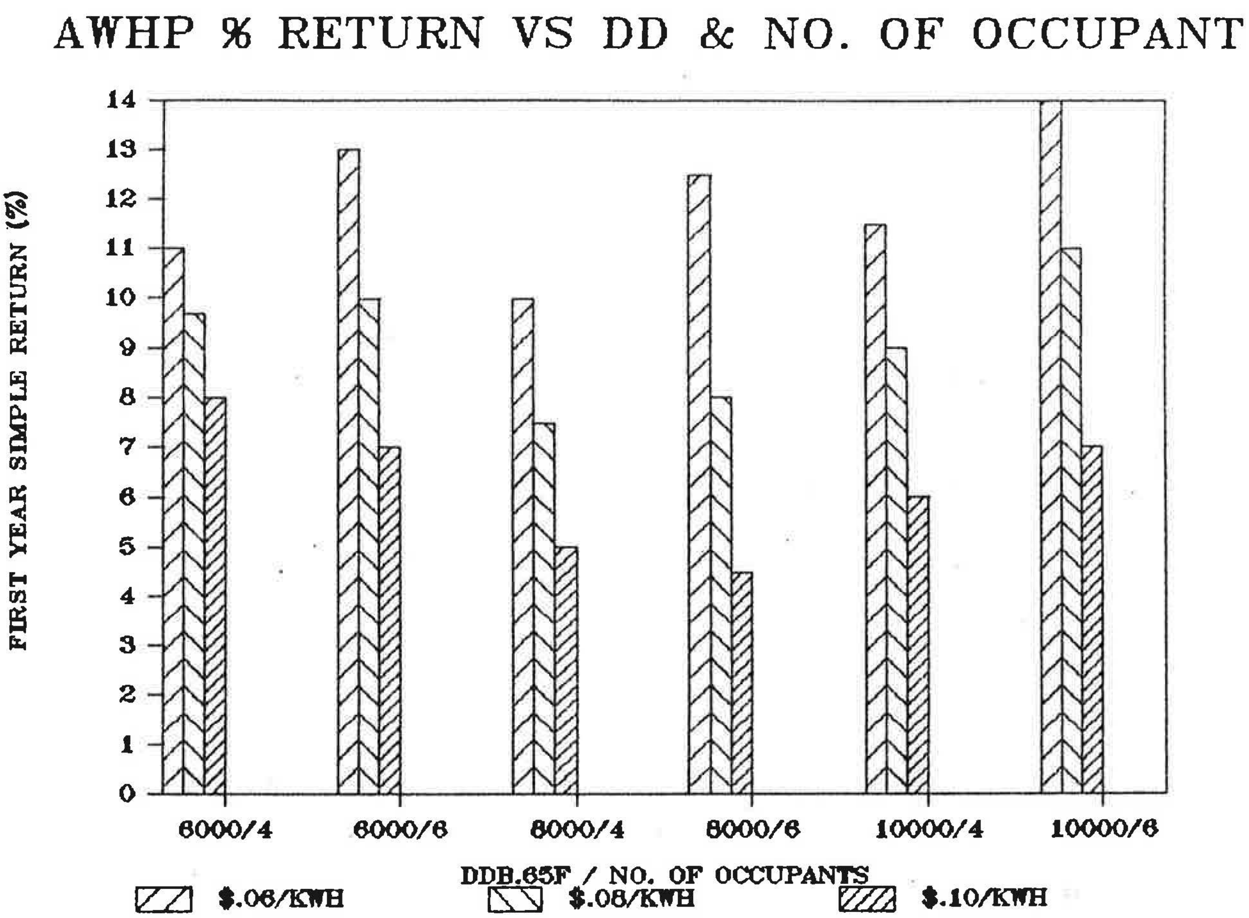
1. This is the years required to pay back through energy savings, all out-of-pocket expenses incurred above the Standard Base Case. That is, the sum of all negative cash flows (the Energy Improved Case's total expenses including utility bills and mortgage, etc. are greater than in the Standard Case) have been made up by positive cash flows (the Improved Case is saving money).

2. First year utility bill savings divided by the energy feature's installed cost, multiplied by 100. No mortgage expenses are considered in this computation.

USE: To use graph: Find the First Year Simple Return, go up to graph representing Mortgage Interest Rate, and then go horizontally to the left to the Years to Payback for the given Inflation Rate.

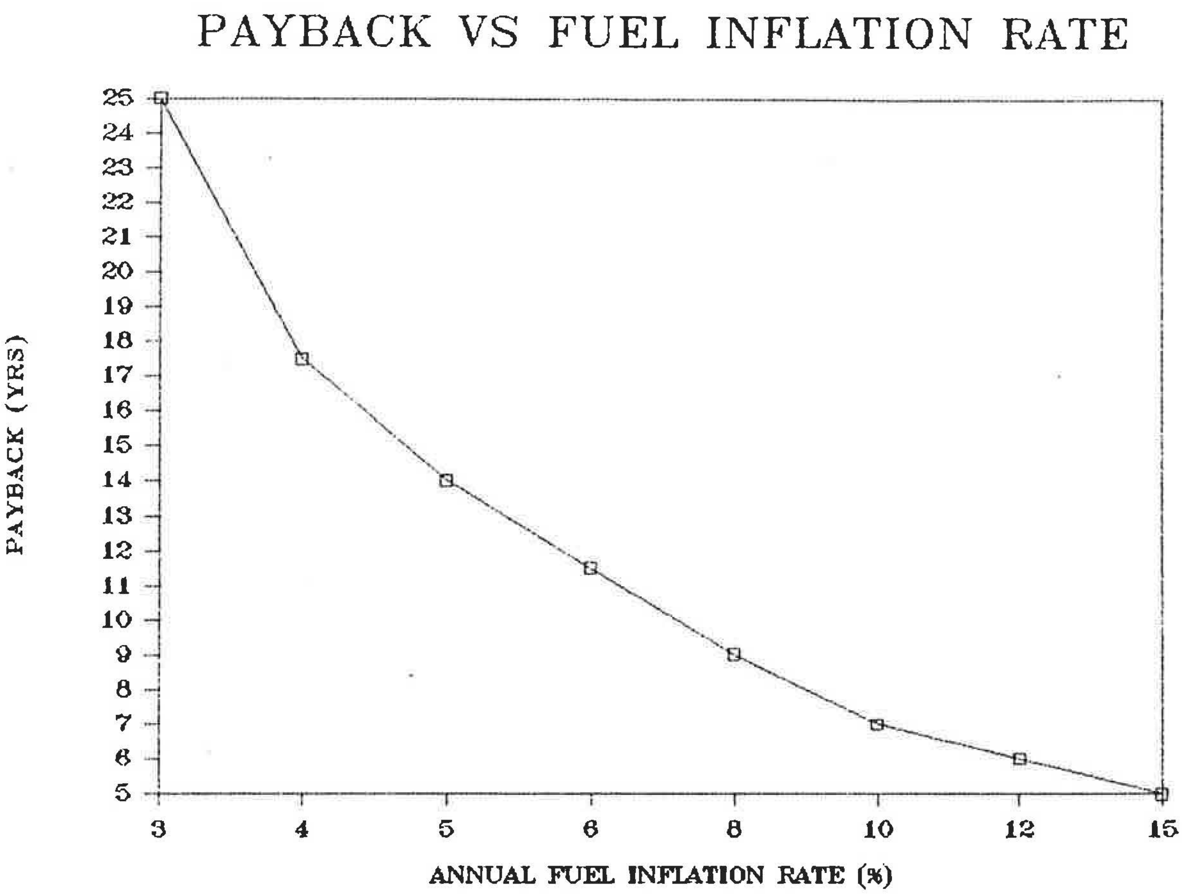
BASIS: Fixed 30 year interest rate, 3% loan fees and points, property taxes and insurance are 1% of feature cost, 15% income tax bracket, no down payment and no maintenance or replacement costs.

FIGURE 5.3



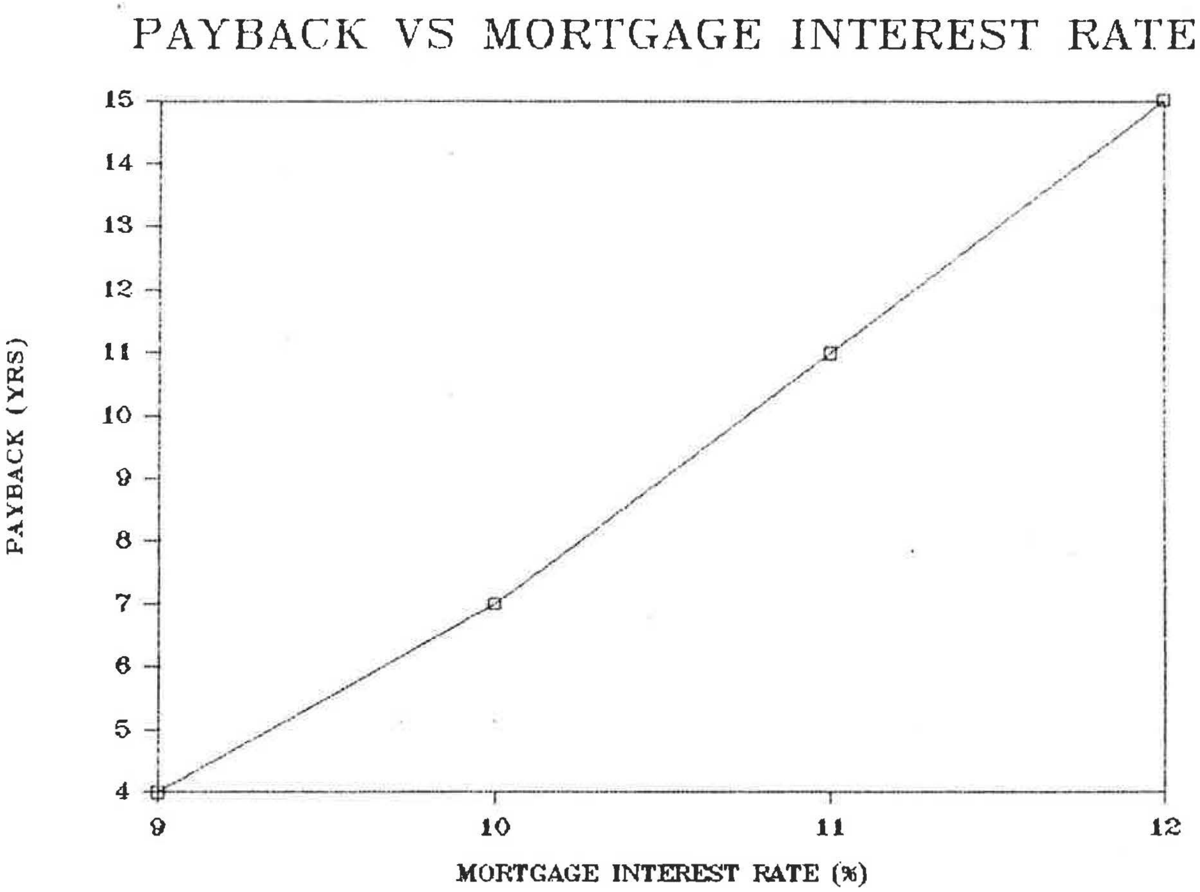
BASED ON A 2000 FT2 (186M2) HOUSE, USING THE EXTREME METHOD, AN AWHP, ELEC. RATES AS NOTED AND NAT. GAS AT $.75/THERM

FIGURE 5.4



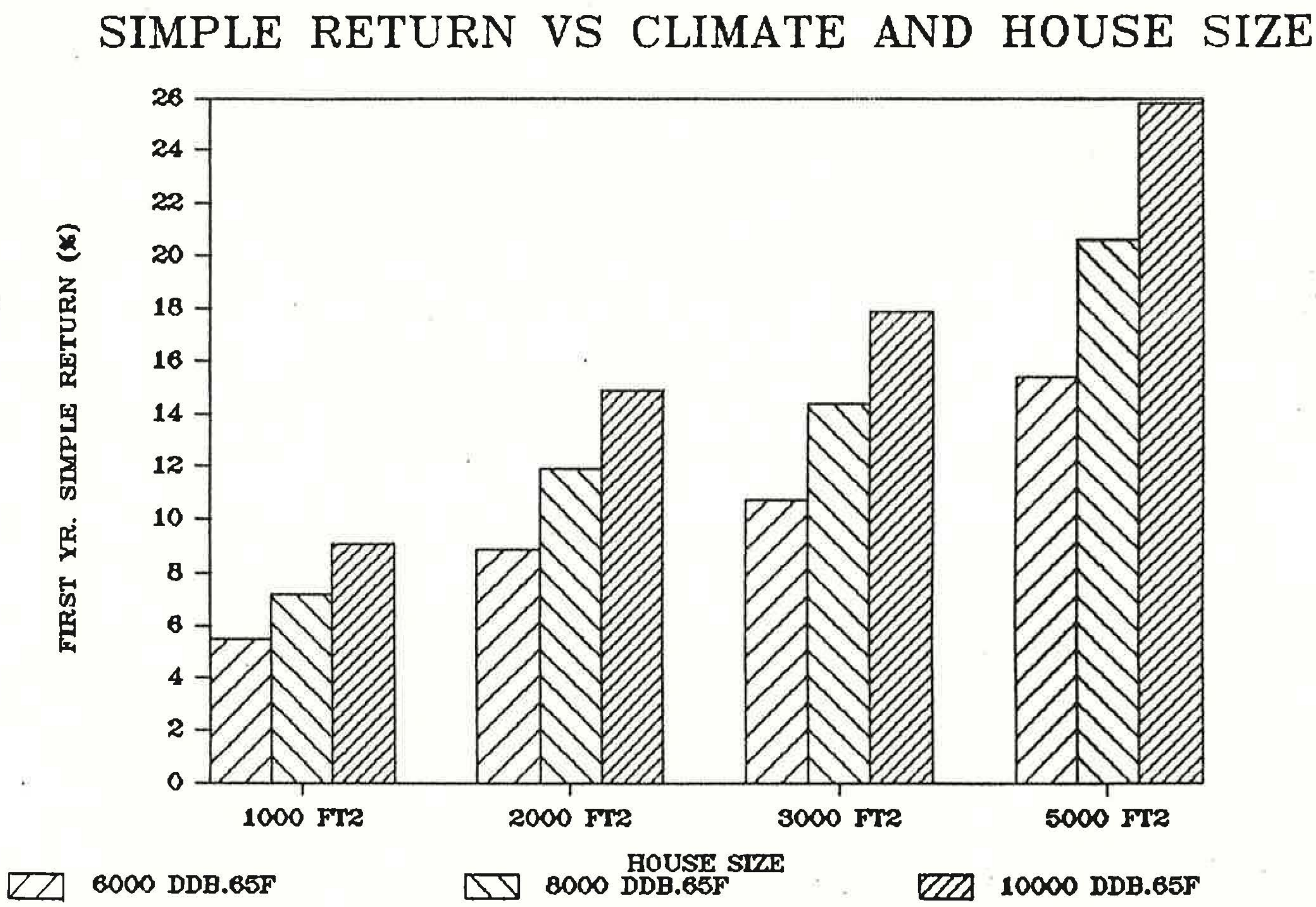
BASED ON AN 8% FIRST YEAR SIMPLE RETURN
AND A 10%, 30 YEAR MORTGAGE RATE

FIGURE 5.5



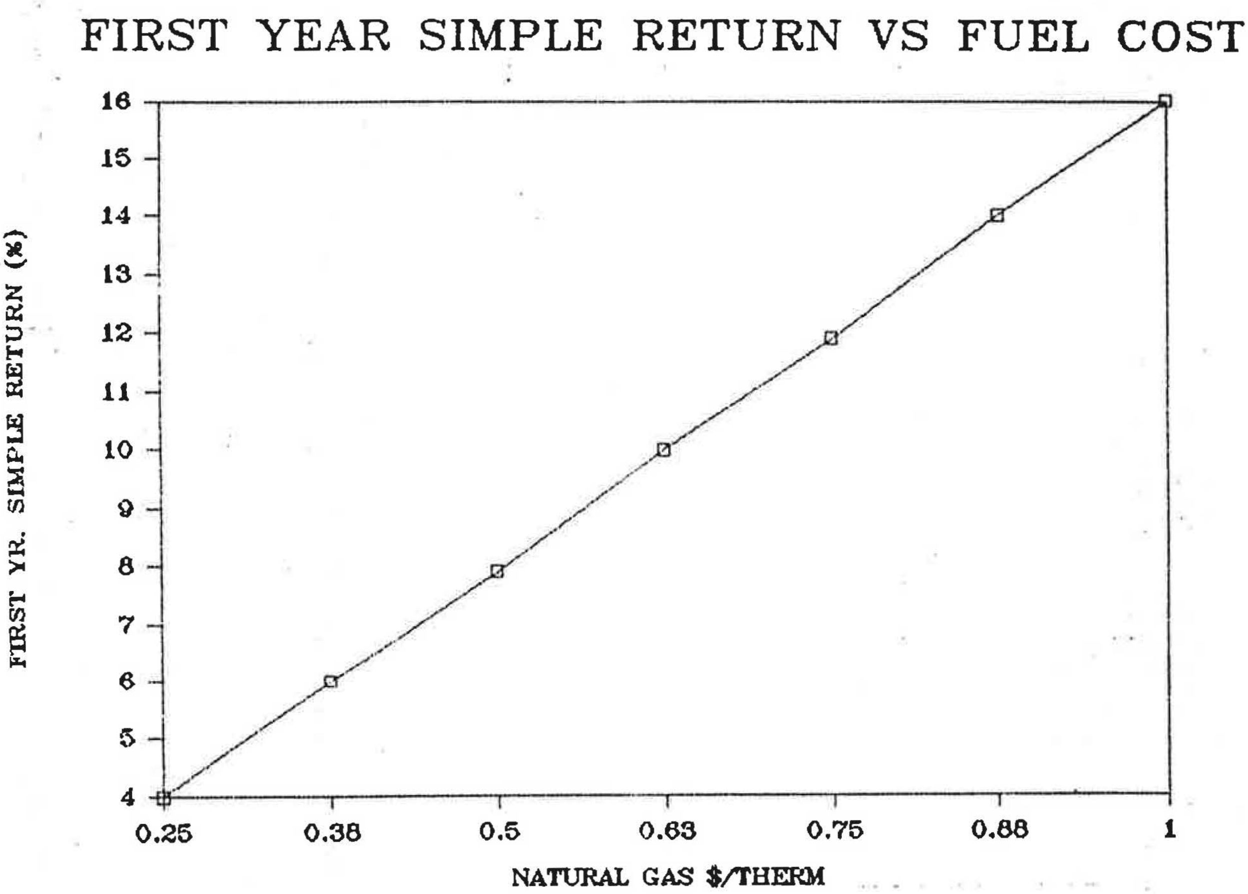
BASED ON A 9% FIRST YEAR SIMPLE RETURN
AND A 5% FUEL INFLATION RATE

FIGURE 5.6



BASED ON EXTREME METHOD, NATURAL GAS AT $.75/THERM AND USING AN AAHE FOR MECHANICAL VENTILATION

FIGURE 5.7



BASED ON A 2000 FT2 (186M2) HOUSE IN AN 8000 DDB.65F CLIMATE USING THE EXTREME METHOD OF AIRTIGHTENING