"Which is the best HVAC system? Which is the most efficient air conditioner, furnace or heat pump?

presented by

Energy Marketing Service

This report is intended to take the mystery out of energy efficient HVAC systems (SEER, HSPF and AFUE ratings) so that you can make an intelligent and competent decision. We do not represent any particular brand, energy source or industry. I promise, if you're contemplating upgrading your HVAC system you will learn more right here than anywhere else on the internet. Please do not allow the length of this page to discourage you from reading it all, as this information will pay you over and over.

Let me introduce myself. My name is John White, In 1969 I went to work for Virginia Electric and Power Co. as an electric heat conversion specialist. My job was to advise, yet convince customers using fossil fuels (gas or oil) to convert to electric heat. Although VEPCO wanted to promote the use of electric heat, the company was much aware that if electric heat was installed in the wrong home it could be financially disastrous to the owner. Therefore, before we would recommend a customer to convert to electric heat I would survey the home and perform a ***load calculation***; the results would indicate the correct size heating and air conditioning system and estimate the operating cost.

More importantly it told us that if the homes heat loss was greater than 35 BTU's/Sq. Ft., we would recommend insulation upgrades or tell the customer to stay with the fossil fuel. We did not want electric heat to get a bad name. The estimated operating cost was given to the customer so they would know what they were getting into before they got their electric bill.

The purpose of this site is to allow you the opportunity to know what you're getting into before upgrading an HVAC system.

Since 1969 I have performed thousands of energy surveys, headed up a large utility companies' energy conservation department, been in the insulation business, been in the HVAC and Plumbing business, and am presently teaching and writing books relating to energy technology, indoor air quality and the

HVAC industry. The information offered below is not just my observation, it is factual; it is base on accepted engineering principles and if you use it, you will benefit for years to come with lower heating and cooling costs and greater comfort.

For those of you planning on installing a system yourself, we are offering HVAC system design software at the end of this report. The software will size the air conditioning and heating equipment, size the ductwork and allow you to compare operating cost.

LET'S GET STARTED

We need to talk about thermodynamics and heat flow in general before discussing HVAC systems

Energy can neither be created nor destroyed, so states the First Law of Thermodynamics, but it can be converted from one form to another. Because of this law there is no system that can be more than 100% efficient. In other words, if an HVAC guy tells you his system will give you $2.00 worth of heat for every $1.00 worth of fuel put in, he is either lying or defying the laws of physics. Heat pumps will provide 3-4 times the energy input, but they *transfer* heat instead of produce heat. Fossil fuel furnaces are 60%-97% efficient while electric heat is for all practical purposes 100% efficient. Most people are familiar with a typical portable electric heater. Well, every year some entrepreneur produces a small electric heater with elements crammed into a case the size of a Rubik's cube and advertises it as "The tiny ceramic heater that will heat the whole room", leaving the consumer to believe they will save energy dollars using their heater. The fact is, the element crammed into the box is rated at 1500 watts, just as the element in the typical heater If each is rated at 1500 watts, that all you will get; no more, no less; the operating cost will be the same no matter which heater you choose, each is 100% efficient If a building needs 60,000 BTU's* to heat it, it will take 60,000 BTUH to heat it whether you are using gas, oil, electricity or buffalo chips. Ultimately, when you pay for fuel to heat or cool your home, you are actually paying buying BTU's. If your fuel dealer offers to sell ether oil or LP gas for $3.00 per gallon which product is the better deal? You can only answer this question intelligently if you know how many BTU's each product contains. I'll tell you oil contains 140,000 BTU's per gallon, LP gas contains 94,000 BTU's per gallon. Now, can you make a decision? What if the oil furnace is only 65% efficient while the LP gas furnace is 94% efficient?

According to the Second Law of Thermodynamics heat goes from a warm place to a cold place and never returns. Thus when heating, heat is lost to the outside (heat loss), when cooling heat is gained from the outside (heat gain). There are three ways heat is transferred, radiation, conduction and convection

Radiation occurs when a source heats an object but not the median in between. When the sun (source) heats an object in your house it is being heated by radiation, as the air in between is not heated. The way to stop radiation heat gain is by shading. Outside shading is much more effective than inside shading. Curtains may keep the sun from beating on your inside walls and floors but since the curtains are inside that means the heat is inside; let's stop it before it gets inside.

Conduction occurs when heat travels through a panel such as walls or ceilings. In the summertime the molecules on the outside wall become warm, then transfer the heat to adjacent molecules until the heat has traveled through the wall. Like placing a teaspoon in a hot cup of coffee, sooner or later the handle will get hot.

Heat is transferred by convection when warm fluids (air is a fluid) are mixed with cool fluids. Convection can be forced or natural. Forced convection occurs when mechanical means such as a fan are used to mix the air. Natural convection occurs when natural forces such as air pressure or temperature differences are present. Warm air rises because it is lighter, thus causing convection currents.

When we insulate a building we are attempting to slow the three forms of heat transfer. Notice I said slow, not stop; heat loss/gain cannot be stopped. If that were the case, we would simply turn the air conditioner on, bring the temperature down to 72 degrees on June 1, and never need to turn the unit on again. Another important point is "heat does not just rise, it goes from a warm place to a cold place, **hot air rises**." Because many people are under the impression that heat rises they are reluctant to waste money on floor insulation. Fact is, most homes would benefit more by insulating the floors then by adding insulation to the ceiling. If you should elect to use our load calculator offered at the end of this paper you will be able to instantly tell where you will get the most bang for your insulation dollar by playing "what if?".

Most homes built in the past 15 years will not produce significant benefits by adding insulation, as the building codes have required optimum insulation levels.

Another mistake made by energy conscientious individuals is buying too much insulation. Insulation abides by the Law of Diminishing Returns; the more you add the less you'll benefit. For example, a 1000 Sq, Ft. ceiling with R-11 may lose 4500 BTU's per hour, add R-19 and the new loss is 1562 BTU's per hour, saving 2938 BTU's. But go hog wild and add another R-19 the new heat loss would be 943 BTU's for an additional savings of only 619 BTU's. This person would have realized a much better return if he'd put the extra insulation in his floors.

Should you insulate your walls? Ten years ago this was an iffy question. Insulating existing walls produced a 10 - 15 year payback. Today, fuel cost have made it a no-brainer. In most climates, paybacks can be as low as four years. Contrary to general belief, brick veneer walls can be insulated. 5/8" holes can be drilled in the mortar joints and through the sheathing, blow in cellulose, patch the mortar joint. and you're good to go. In case you're wondering, 3.5" of insulation (R11) is equivalent to over 14 inches of brick.

Floor insulation is perhaps the most overlooked yet unbelievably best energy saving investments to be made. An uninsulated 1500 Sq. Ft. floor over a crawl space located in an average climate (3500 degree days) will return about $300 per year savings when insulated to R-19. If the job costs $1200, that's a 25% return on investment. Plus your feet will be warm. The first part of your body to get cold is your feet, causing you to turn up your thermostat. Warm floors allow you to lower the thermostat, saving 2-4% per degree. PS: floor insulation does not help much on cooling costs or cooling load.

Another, component in the home that's constantly being advertised are window replacements. If your windows are falling apart, rotting away, lose and rattling it probably will pay to replace them. If they are in relatively good shape with double glass or storm windows you may be looking at a 10- 30 year payback. Much of the infiltration of air at windows comes from around the casing which is not replaced. Load calculations indicate an average 3' X 4' replacement window will save $5-10$ per year in energy cost. You figure out the payback. Another point, in colder climates do no install low-e glass as the sun's radiant heat helps warm the home.

HVAC systems

This discussion is addressed to homeowners who plan to stay in their home and wish to realize the benefits of an efficient and comfortable HVAC system.

The most common question asked of me as an HVAC contractor is "What is the best brand?". My reply is "The only difference is the package and in many cases only the name plate!" Air conditioning and heating equipment has become a commodity. In the old days, central HVAC equipment was a luxury, In 1970 It was not unusual for a central heat and air system to cost $5000; that's equivalent to about $25,000 today. The big manufactures, Lennox, York, Carrier, GE, etc built equipment like a Sherman tank because buyers were willing to pay the price for the luxury. In addition, there were no government regulations demanding minimum efficiencies, therefore, parts and controls were kept to a minimum. As a result, a Sherman tank with few parts would last forever. A number of things happened in the 1980's: (1) Central HVAC became a necessary component in a modern home, (2) the government mandated minimum energy standards, (3) a new kid on the block (Goodman Mfg.) saw HVAC equipment as a commodity and produced and sold units 30% below the going market price and (4) law suites have caused an overkill in safety standards.

Let's look at each event to see how it led to manufacturers making junk.

(1) The 70'sand 80's saw central heating and air conditioning become a staple item in new homes. The few manufactures at the time were geared up to produce mostly commercial equipment. Demand for residential equipment was strong, but the supply was short enough to keep the prices **and the quality** up. Some dealers got so large they were able to control competition by telling their distributors who they could sell to. As a result many dealers were forced to buy from smaller lesser known or new start-up manufactures. Westinghouse, Tappan and Fedders were among some big names that got into the game thinking they would clean up on this highly demanded product.. To differentiate their products they came up with some strange or unorthodox designs that did not work so well and ultimately led to their demise.

(2) In the mid 80's the government mandated minimum energy standards for gas furnaces. Before the standards an average gas furnace was about 60% efficient. The furnace was simple; it consisted of a fan, burner, heat exchanger, pilot light, gas valve, transformer, thermocouple and fan/limit switch. After a 78% minimum efficiency standard was mandated the guts of a furnace more resembled that of a space shuttle. Combustion blowers, pressure switches, electronic ignition, flame sensors and printed circuit boards were added and to make things worse, every manufacturer did his own thing; nothing is interchangeable between brands. With all the extra controls and the problems

associated with getting the exact parts, furnace reliability went south exponentially.

(3) In the mid 80's a large contractor named Harry Goodman thought; "I can make HVAC equipment that will work just as well as the rest of the stuff out here". His marketing plan revolved around one key benefit to the dealer, a 30% lower price. In order for Harry to sell at 30% less. certain concession needed to be made; his equipment was bare bones (no bells and whistles), he would do absolutely no advertising, he would not pay contractors allowances to perform warranty work, he set limits on his distributor's margins and he would sell to any Tom, Dick and Harry including big box retailers. Well, the big boys, who were making halfway decent equipment, had to compete to save market share, the metal got thinner, coil guards disappeared, copper coils became paper thin, parts got crumbier, heat exchangers got a lot thinner, even the paint is thinner. Today most equipment is built to standards set by Goodman. By the way Harry's company is now the largest residential HVAC equipment manufacturer in the world. (I am not speaking for or against Goodman products only telling it like it is).

(4) Due to product liability suites, today's HVAC equipment has so many safety controls that it is liable to quit when a cloud goes by or the atmospheric pressure changes. These controls are responsible for nuisance service calls that were unheard of 25 years ago.

In addition to the above, most manufacturers will label the same piece of equipment with three or more different brand names. I have seen consumer publications rank Rheem as number 3 and Ruud as number 9, while the only difference in the too products are the labels. You can not rely on Consumer Reports.

To answer your question, "Which brand is the best?" I can only say they are all basically the same. In fact most people couldn't tell you what brand they have now . If you decide to pay more for a particularly well advertised brand you are probably paying Madison Avenue. Some of the more expensive brands look nicer esthetically, but once they're opened up, they're all the same. Of more importance, is the contractor you choose. Does he have a reputation of showing up when you need him? Does he do quality work? Remember one thing; "A good contractor who plans on staying in business will not knowingly sell you an air conditioner that he has a history of problems. No one wants the equipment to work well more than he; he's the one who has to get up in the middle of the night or run back and forth 10 times to do warranty work.", and if he has 100 of those units out there???

Some products offer features such as dual compressors, variable speed blowers, zone controls and exotic means to control humidity. You must ask your contractor, "Do I really need that?" A home with an exorbitant amount of west facing windows may benefit from a dual compressor A/C because the load might be extremely low in the AM hours but extremely high in the after noon. You may think you need a variable speed blower until you find out it cost $800 to replace.

Install the correct size equipment

OK, I hope I've convinced you to place more confidence in the contractor than the equipment manufacturer. The next hurdle is sizing. If you've been reading up on other sites you probably know that sizing the equipment is important to assure comfort, humidity control and low operating cost. (See Bigger is not Better) The most common mistake HVAC contractors make is replacing the old unit with the same size unit without performing a load calculation First, the old unit was probably oversized and second, even if the old unit was sized right, it may be oversized today, because insulation, new windows or weather stripping has been added. A load calculation must be performed on your home to determine the correct size. A contractor can usually get by over sizing a heating unit, but not so with the air conditioner. One can oversize a heating unit by 100% and not experience adverse effects but air conditioning should be sized within 10% of the load calculation. An under sized air conditioner normally will not cause problems other than the obvious that it will not cool on the hotter days. Over sizing an air conditioner can cause many problems as listed below:

Poor comfort - An oversized air conditioner will not run long enough to distribute the air evenly, leaving hot and cold spots

High humidity - An air conditioner dehumidifies as it cools (the water running out of the condensate pipe is moisture removed from the air in your home). If the unit is too large it will cool the home down very quickly but not run long enough to remove the humidity. Ideally, 50%-55% indoor relative humidity (RH) would be the desired target. Mold tends to grow when the humidity exceeds 60%.

High operating cost - As size affects the RH in your home, RH affect the operating cost. Temperature and humidity come hand-in-hand. The human body can feel just as comfortable at either 78 degrees @ 55% RH or 73 degrees @ 65% RH. The difference is that it cost less to keep the thermostat set on 78 than on 73 degrees. For each degree the thermostat is turned up a 5%-7%

energy savings is realized, therefore a properly sized air conditioner that removes the humidity will save 25%-35% on operating cost.

Over sizing an air conditioner to keep cool is a fallacy!

So, after reading the above you say, "All this mumbo jumbo is dandy, but I want to make sure I'm cool, so I'm over sizing." Let's suppose the load calculation indicates a 36,000 BTU (3 tons) air conditioner is needed when it is 95 degrees outdoors. You say "I'm putting in 42,000 BTU's (3.5 tons) because it might reach 100 degrees a couple times. The sad fact is, your house will require 45,000 BTU @ 100 degrees, but the 3.5 ton A/C will only produce 37,800 BTU's because the outdoor temperature is so hot. YOU WILL STILL BE UNCOMFORTABLE

Don't pay to much for equipment efficiency.

By now I hope you are convinced insulation and correct equipment sizing saves energy dollars, makes you comfortable and prevents indoor air quality problems. Another important item to discuss is equipment efficiency. Today all residential HVAC equipment must display an energy efficiency card. Let's talk about what these efficiency terms are and then we'll discuss their merit.

Furnace efficiency- If your buying a furnace, whether gas or oil, it will have an AFUE rating (Annual Fuel Utilization Efficiency). The AFUE tells you what percentage of your energy dollar spent for fuel goes into your house, the rest goes up the stack. If you buy a furnace with an AFUE of 80, it means 20 cents out of every dollar in fuel goes up the stack. Likewise, a furnace with an AFUE of 94 will only waste 6 cents. The decision you have to make is, "is the 94% efficient furnace worth the extra money?". If you know how much fuel was used last year you may be able to approximate the savings using the following formula: (If you need an estimated operating cost our load calculation will do it for you)

NEW AMOUNT OF FUEL = (OLD AFUE / NEW AFUE) X LAST YEARS FUEL

Using the same equation, if you assume an 80% furnace will use 600 therms, then a 90% efficient furnace should use 533, for a savings of 67 therms. Convert this to monetary savings by multiplying 67 therms by the cost per therm. If gas is selling for $1.70 per therm then the new furnace will save $113.90 per year, excluding inflation (67 x $1.70). If the 90 % furnace costs $800 more than the 80% furnace, then you will realize a seven year

payback. Sometimes the payback is not so good, but because your purchasing a premium product the warranty may be better or longer on the 90% furnace. You must take all things into consideration.

Air conditioning efficiency- An air conditioner has a SEER rating (Seasonal Energy Efficiency Ratio). If you put 1 watt of energy into an air conditioner and it produces an average of 13 BTU's of cooling, then it's SEER rating is 13. The minimum SEER rating that can be manufactured today is 13. To compare the operating cost of one SEER rating with another use the following formula:

NEW AMOUNT OF KWHR'S = (OLD SEER / NEW SEER) X OLD AMOUNT OF KWHR'S

If you have an 8 seer air conditioner which uses 7500 KWHR's per year, a new 13 seer unit would use 4615 KWHR's. The savings would be 2885 KWHR's or $288.50 per year if electricity costs $.10/KWHR. Not a bad return, but think real hard before you move up to a 15 SEER unit for $700 more

Operating cost of 13 SEER = $750.00 - $288.50

= $461.50

NEW OPERATING COST = (LESS EFFICIENT SEER/MORE EFFICIENT SEER) X LESS OPERATING COST

= (13 SEER/15 SEER) X $461.50

= $399.96

= $61.54 savings per year (This is an eleven year payback, is it worth it?)

IMPORTANT IF YOU'RE CONSIDERING A HEAT PUMP

Electric utilities traditionally have had problems keeping up with high summer peak demand. Since air conditioners with high SEER's use less electricity to produce BTU's the utility has highly promoted high SEER equipment. On the other hand the electric company has plenty of capacity in the winter time and would like to sell as many KWHR's as the meter can handle, therefore they do not promote HSPF's (heating efficiency), so you've probably never heard of the term. The fact is, most heat pumps may have the same cooling efficiency (SEER) but widely vary with the heating efficiency (HSPF) You must look at

both efficiencies when purchasing a heat pump. If the price is the same, would you rather purchase a heat pump with a 13 SEER and 8.5 HSPF or one with a 13.5 SEER and a 7.8 HSPF?

Heat pumps (air to air)- Heat pumps cool and heat. Therefore, they have two efficiencies, a SEER rating while air conditioning and an HSPF rating (Heating Seasonal Performance Factor) while heating. The SEER calculations are made just as they are above for an air conditioner. Like the SEER rating the HSPF is the average amount of BTUH's of heat the heat pump puts out when 1 watt of energy is put in. To compare operating costs the equation is similar to the SEER equation,

NEW OPERATING COST = (LESS EFFICIENT HSPF/MORE EFFICIENT HSPF) X LESS EFFICIENT OPERATING COST

Heat pumps (water source) - Water to air or geothermal heat pumps have gained popularity in recent years due to there inherently low operating cost and government rebate programs. The *cooling* efficiency of water source equipment is stated as EER (energy efficiency ratio). Like an SEER the EER is determined by the ratio of Watts input versus BTU's output. For example, a typical water source heat pump may have an EER of 17 (1 watt in 17 BTU's out). SEER and EER cannot be compared, however, as an EER is determined by the ground water temperature. If the EER of our example is 17 at 60F entering water temperature, the EER will drop to about 13 with an 80F entering water temperature, where as an air to air system is rated at approximately 86F constant air temperature.

As for heating efficiency, water to air heat pumps are rated by their COP (coefficient of performance), BTU's input vs BTU's output. A high performance water source heat pump will have a COP of approximately 5.0 at 60F entering water temperature, but drop to 4.5 at 5-F entering water temperature. Nevertheless, a water source heat pump can have about a tremendous advantage over an air to air heat pump in the heating mode. An air to air heat pump with an HSPF of 9.2 would have an average COP of 2.7.

The downside of installing water source heat pumps is initial cost. A typical water source installation will cost about three times more than a most high efficiency HVAC systems. To combat this initial cost and promote energy efficiency the federal government is offering a 30% tax credit to individuals who install the systems. This has enabled the average homeowner to recover the additional cost in about 10 years. With a system life expectancy of 30 years,

the homeowner will enjoy 20 years of real savings, if he stays in the house that long.

Mini Splits or wall hung units

Mini split systems for the most part are ductless, although some manufacturers offer a small air handler that is capable of handling duct work. Most offer units with *inverter* technology that allows SEER's as high as 27 and HSPF as high as 13, although, 16-18 SEER and 9-10 HSPF is more typical for whole house systems. Some manufactures allow as many as 8 wall hung air handlers (8 zones) to be served by one outdoor unit. The great thing about these units is there is no duct loss and each room or zone may be individually controlled without the need of troublesome dampers and other controls necessary when using a ducted system. A house full of mini splits could prove to be the most economical of all systems when the ability to completely shut off rooms is considered.

Ductwork

A HVAC system consists of two elements. the equipment and the air distribution system. Thus far we have only talked about the equipment, but what good does it do to select the most efficient equipment and place it on antiquated, leaky, poorly insulated or poorly designed ductwork? Up until the past four or five years it was rare to find duct work that was sealed, now codes require it. Today most codes require ductwork to be sealed and insulated to at least R-6 or R-8. In the past, R-2 or R-4 insulation had been the norm and the system was not sealed for leakage. If your ductwork looks in bad shape, it is in bad shape, and if it is over 5 years old it could be costing you 15%-20% more in energy usage. Also, many new high efficiency units require greater airflow, which means the ducts may not be large enough to allow proper operation. The bottom line is, have you contractor make sure the ductwork is adequate.

A duct system must be designed based on the heating or cooling load of each room. A room-by-room **load calculation** must be performed in order to determine the correct amount of cubic feet per minute (CFM) air to go into each room. Otherwise, the room to room temperature may vary significantly. Furthermore, undersized ductwork will result in high operating cost and shorten the life of compressors and heat exchangers due to inadequate air flow.

If possible, locate the ductwork inside the conditioned area (inside the house). Thus, eliminating any chance of heating or cooling the outdoors.

I hope this paper gives you a better understanding of your HVAC system so you can you make an intelligent purchasing decision. I have mentioned a number of times the importance of properly sizing the equipment. Now I'm going to let you in on an embarrassing industry secret. Perhaps **90% of the HVAC contractors cannot and will not perform a load calculation.** If you don't believe me. ask for one when getting estimates. They will hem and haw and tell you how long and drawn out it will be and hope you say never mind. They are good mechanics, not mathematical engineers. Many had to perform a load calculation to get a license, but after that they went back to Rules-of-Thumb. Most customers do not know a load calculation should be performed, so they never ask for one. This problem is about to be turned around as more and more jurisdictions are requiring evidence of a load calculation when a permit is applied for. The International Mechanical Code states in section 312, "heating and cooling equipment shall be sized based on building loads calculated in accordance with ACCA Manual J", and "ductwork shall be sized according to ACCA's Manual D or other approved methodologies." You may go to the Air Conditioning Contractor's of America site and purchase Manuals J and D to perform your own load calculation or continue reading below.

Time out for a commercial break

Now you can be assured your HVAC system is sized right by performing your own load calculation, using our "Worlds Easiest Load Calculator" program. It only costs $39 for a 60 day license. It will tell you what size furnace, air conditioner or heat pump you need. It will tell you how much they will cost to operate. It will compare operating cost of one system vs. another. It will give you paybacks and return on investment. You may play "what if" buy changing efficiencies or insulation values. Finally, it will tell you how much air (cfm) to put in each room and size the ductwork to assure an even temperature throughout your home. If you can measure your house and calculate square footage you can use this calculator. **CLICK ON THE INSTRUCTIONS TO SEE HOW EASY IT IS.**

I hope this information helps you make a sound HVAC decision.

John White