Selecting a Home Cooling System

January 2000

Introduction

Selection of a cooling system for a new or existing home requires an understanding of how various systems operate, their initial cost, and their operating costs. This fact sheet provides background on common residential cooling systems, explains how they work and are rated for energy performance, and provides a method of estimating operating costs.

Cooling systems covered in this fact sheet include central systems; air- and water-source heat pumps; and unitary air conditioners including window units, through-the-wall units, and ductless-split systems.

Cooling system sizing

Accurate sizing of cooling systems is important if the unit is to both cool and properly dehumidify. If the unit is oversized, it cannot control humidity properly. Oversizing also increases the cost paid for equipment, money better spent on purchasing more efficient equipment.

Determining proper size for the cooling system requires estimating heat gain through the roof, walls, windows, and basement, and heat contributed by home appliances under maximum summer weather conditions. The sum of all heat gains is the design cooling load for the home. Equipment size is then selected based on this load. Select the unit size that is the next larger size available for your design cooling load. If the design cooling load is only slightly over the capacity for the next smaller size of equipment, no more than about 10%, select that unit size. A slightly undersized unit will provide better humidity control and higher overall performance than an oversized unit.

The contractor bidding the cooling system should determine the correct size using techniques that evaluate the insulating value and area of each home component. Using “rule-of-thumb” for sizing equipment often results in a unit that is over or undersized.

If you plan to use a window air conditioner, you will probably select and install the unit yourself. To estimate the correct size, use the procedure, Sizing Window AC, at the end of this fact sheet.

Selecting the most cost-effective cooling system

Selection of the most cost-effective system will depend on price of the equipment and electricity. Higher initial investments are often justified by reduced utility costs over the lifetime of the unit. Methods for estimating annual operating costs for central units are provided at the end of this fact sheet. To determine the most cost-effective system, it will be necessary to obtain bids from several contractors. The additional cost for a more efficient system must be compared to the energy savings.

If the equipment is for a new home, cost of the cooling system will be part of the mortgage. If the annual total cost of cooling energy plus the mortgage payment for one system is less than for

Engineering Extension

another, then the system is cost effective. If you are installing the air conditioner in an existing home, you must decide if the savings from a more efficient system are enough to justify the additional cost. It is important to remember that cooling systems are only replaced about every 15 years so you will have to live with your decision for some time.

Central cooling systems

Central cooling systems include traditional air conditioners and both air- and water-source heat pumps. Distribution of cooling is almost always by way of cooled air through ducts. Ducts must be well sealed. Studies throughout the country indicate duct leakage significantly reduces delivered efficiency of heating and cooling systems. Sealing with duct tape is not satisfactory because most duct tapes fail soon after installation. The duct installer must use a mastic-type sealant or at a minimum, foil-backed tape at all joints.

Return ducts must also be sealed. Return air ducts are often constructed by encasing a standard building cavity with sheet metal or gypsum board. The space between floor joists is often panned off with sheet metal or sections of interior partitions are covered with gypsum board. Building cavity return air ducts must be sealed, just like supply ducts.

It is common to find up to one-inch gaps between the sheet metal and floor joists. A powerful furnace fan creates a strong negative pressure in the return ducts, drawing air from unheated sections of the home. Because these defects are covered with wallboard, they must be corrected during construction. New techniques in duct sealing allow special airborne mastic to be injected into the ducts where it seeks out and seals most holes. However, it is easier to seal ducts correctly during construction rather than attempt to seal them after the home is finished.

In addition to sealing, supply and return ducts running in the attic or crawl space should be insulated to a minimum R-5. If they are located outdoors, then they should be insulated to at least R-8.

Central air conditioners

One of the most common cooling appliances used in the Plains states is the central air conditioner. The seasonal performance rating of a central air conditioner is its Seasonal Energy Efficiency Ratio (SEER). It is the ratio of the cooling delivered from the unit in Btus divided by the power input to the unit in watts. The minimum available SEER is 10. New standards are being considered that raise the minimum rating available for sale from an SEER of 10 to 12. Ratings of 12 are almost always cost effective and ratings of up to 18 are available. Your supplier can provide ratings for the units under consideration. Ratings for all air conditioners and heat pumps are available from the Air-Conditioning and Refrigeration Institute's *Directory of Unitary Equipment* [1] or on-line at *www.ari.org/*.

Two types of compressors are commonly used in central air conditioners and heat pumps. For years, all compressors were of the reciprocating type. Improvements in manufacturing technologies have allowed the inexpensive manufacture of scroll compressors. Scroll compressors are more rugged, tolerant of liquid refrigerant slugs, and quieter than typical reciprocating compressors. Most manufacturers now offer scroll compressors on mid- to high-performance central cooling equipment.

Annual cooling costs for a home equipped with a conventional air conditioner, an air-source heat pump, or a ground-source heat pump are dependent on the heat gain of the home, the cost of electricity, and performance of the unit. A simple method for estimating annual cooling costs is provided at the end of this fact sheet. A more accurate approach is provided in the Air-Conditioning and Refrigeration Institute's *Directory of Unitary Equipment*.

When purchasing cooling equipment, in addition to energy performance, it is important to examine warranties. Warranties generally range from five years to ten years on the compressor and from one to two years on the remainder of the unit.

Air conditioners with two stages of capacity are available. These units operate at low capacity when the weather is mild and at full capacity when it is hot outside. This two-stage operation offers distinct advantages. The overall energy performance is high and humidity control is excellent because the unit operates more hours.

Air-source heat pumps

Air-source heat pumps deliver cooling as efficiently as traditional central air conditioners. An air-source heat pump works like a standard air conditioner in the summer delivering cool air to the home, but is capable of reversing the flow of heat in the winter so it delivers heat to the home. During the summer, heat is gathered from the house and rejected to the outside air. During the winter, heat is gathered from outside air and rejected (delivered) to the home.

Air-source heat pump performance is measured as Seasonal Energy Efficiency Ratio (SEER) for the cooling mode and as Heating Seasonal Performance Factor (HSPF) in the heating mode. Higher SEERs and HSPFs mean higher energy efficiency. SEERs range from 10 to over 17.

Multi-speed air-source heat pumps are available and becoming more commonplace. They operate at low speed when heating or cooling conditions are low and at high speed when needed. In addition to higher HSPF and SEER ratings, indoor temperatures remain more constant, there is better humidity control, and the units are quieter.

Ground-source heat pumps

Ground-source heat pumps work in a fashion similar to air-source heat pumps except they transfer heat from or to the ground rather than the air. Two general approaches are used for coupling the heat pump to the ground. The oldest method, referred to as a ground-water heat pump (GWHP), pumps water from a well or other water source, and transfers heat from the water in the winter and to the water during the summer. The water is discharged back to the ground. The second and newer approach, referred to as a ground-loop heat pump (GLHP), buries a long loop of plastic pipe through which a water and glycol mixture is circulated. The heat pump transfers heat to or from the water. The water is circulated in the buried loop of piping where it transfers heat to the ground.

Performance and operating cost of a ground-source heat pump are dependent on performance of the heat pump and the ground loop or water source.

Water temperatures in the piping loop of a ground-loop heat pump will increase in the summer and fall in the winter as heat is added or removed. If the loop is undersized, it will not be able to transfer enough heat to meet the home's needs. The water temperature in the loop will exceed design values and equipment performance and life will suffer as a result. Similar results can occur if the soil condi-

Table 1. Efficiencies of ground-source heat pumps

Heat Pump Systems	Heating COP	Heating* HSPF-Equivalent	Cooling EER	Cooling* SEER-Equivalent
GWHP				
Average	3.2	10.0	14.0	13.5
Above Average	3.5	11.0	15.5	15.0
Top-of-the-Line	3.9	13.0	19.0	18.0
GLHP				
Average	2.8	8.5	13.0	12.5
Above Average	3.1	9.5	14.5	14.0
Top-of-the-Line	3.6	11.0	18.0	17.0

* HSPF-Equivalent and SEER-Equivalent are estimates. More accurate methods for determining system performance and cost are provided in the *Ground-Source Heat Pumps, An Efficient Choice for Residential and Commercial Use* manual prepared for the Kansas Electric Utilities Program.

tions do not allow adequate heat transfer between the ground and the ground loop. Sandy or dry soil reduces heat transfer rates.

Oversizing the loop will improve system performance but the increased cost of an oversized ground loop will not be cost effective. For cost-effective performance, the loop must be properly sized and installed to meet the home's cooling and heating requirements, and for the soil conditions on site. Proper backfilling during installation of the loop is also critical for satisfactory operation.

With GWHPs, amount and quality of water available will impact performance. If water flow rates are inadequate to remove or supply the needed heat, or if the water tends to rapidly scale the heat exchanger, performance and equipment life will degrade. If water quantities and qualities meet design requirements, performance of GWHPs will generally exceed those of GLHPs because the water is at a constant temperature.

Ground-source heat pumps are not rated with a seasonal performance rating. Instead, they are rated with an energy efficiency ratio (EER) for cooling of between 14 and 19, and a coefficient of performance (COP) between 3.2 and 3.9 for heating. The ratings are determined at one or two operating conditions and do not reflect seasonal performance. A listing for current products is available from the Air-Conditioning and Refrigeration Institute. Table 1 provides a range of reasonable values for seasonal COP (HSPF-equivalent) and seasonal EER (SEER-equivalent) values for properly designed and installed GWHPs and GLHPs.

To help assure adequate humidity control in the summer, the GSHP is often sized to match the home cooling requirements with the cooling capacity of the equipment. As a result, single-speed units often need supplemental resistance heating to meet peak heating requirements. Multi-speed and multi-staged GSHPs are available that provide a better match between the heating and cooling needs of a home and the capacities of the equipment.

Typically, dual-capacity units will operate on low speed or single-stage during the summer or when heating needs are moderate. High-speed or two-stage operation will commence during peak heating requirements.

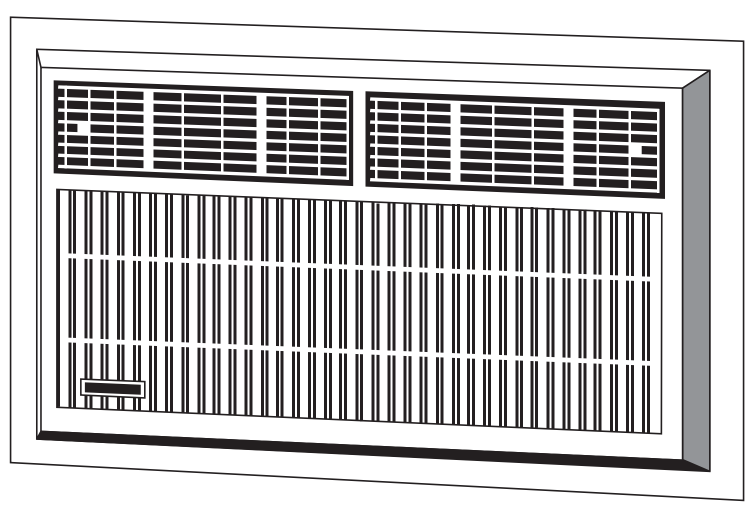
Refrigerants

Most central cooling equipment is charged with R-22. The ozone depletion index of R-22 is .05, one twentieth of R-12. However, production of R-22 is scheduled for phase out in 2020. Some alternative refrigerants are available at a premium price but there is no improvement in system performance as a result of the refrigerant. Decisions on the type of refrigerant used should be based on anticipated life of the equipment and the cost premium required. Average life of an air conditioner is around 15 years.

Unitary systems

Some cooling systems provide cooling to only a portion of a home. These include window, through-the-wall, and ductless split-system air conditioners and heat pumps. Through-the-wall air conditioners and heat pumps are often called packaged terminal air conditioners. Unitary systems are frequently used where ductwork is not present, installation difficulties exist, or where cooling is desired in only a portion of the home.

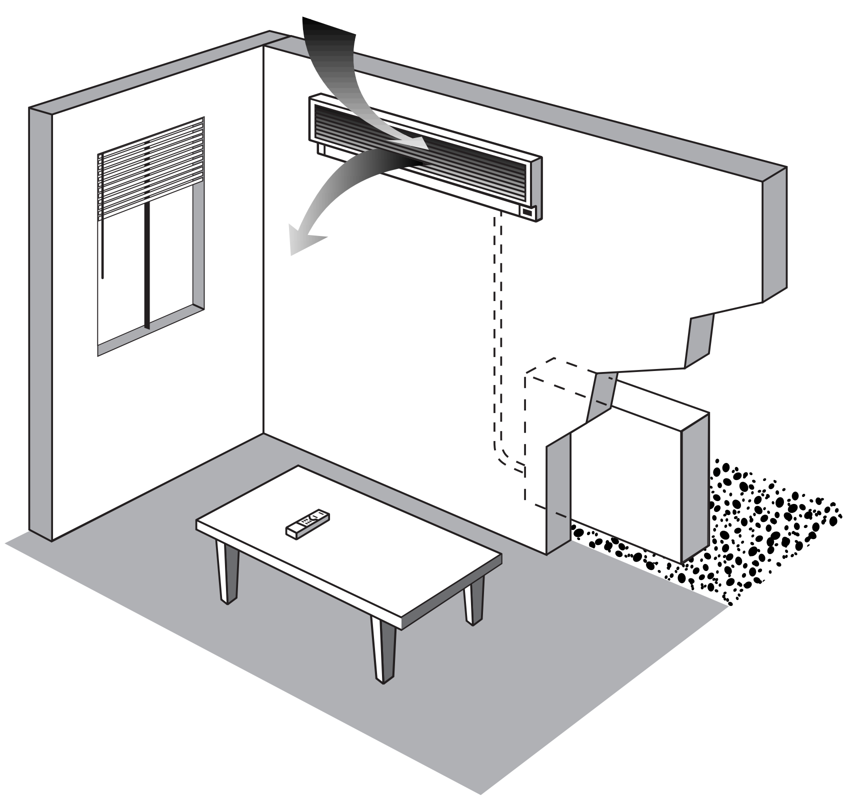
The performance rating for window and through-the-wall units is the Energy Efficiency Rating (EER). It is the ratio of the cooling capacity in Btus divided by the energy input in watts. It is not a



seasonal performance rating but rather is determined at a single outside condition. Room air conditioners generally range from 5,500 Btu per hour to 14,000 Btu per hour. National appliance standards require room air conditioners built after January 1, 1990, to have an EER of 8.0 or greater. Select a room air conditioner with an EER of at least 9.0 if you live in a mild climate. If you live in a hot climate, select one with an EER over 10. An Energy Guide label will provide you with the rating for the unit being considered and the range for that class of product.

Through-the-wall air conditioners and heat pumps are also rated in EER. Minimum EERs will range from 7.6 to 8.9 depending on size. With both window and through-the-wall units, higher EERs are available and should be considered.

One disadvantage of window and through-the-wall units is noise. The compressor and circulating fan are housed in the unit. Compressor noise is difficult to dampen. Some manufactures offer units with a low profile such that the compressor is located outside and below the window opening. This helps reduce but not eliminate noise.



Ductless split-system air conditioners and heat pumps are relatively new on the market. They use a remote condensing unit located outside, usually mounted at ground level. Inside the building is a small fan unit with the cooling coil. Only refrigerant lines connect the condensing unit with the fan and cooling coil. A small condensate line is required for draining condensate from the unit. If a direct path to the outside is not available for condensate drainage, a small condensate pump is used to discharge the water to a remote location. Because the compressor is located outside and not in contact with the building, the units tend to be very quiet. The inside fan and coil can be wall or ceiling mounted. Often, they are equipped with a wireless remote for control. These units can be used to cool a single room or many manufacturers offer a dual-zone unit that will cool two rooms, each with independent control. SEER, as with conventional central air conditioners, is the rating for ductless split-systems.

Estimating cooling costs

Annual cost of cooling is affected by cost of electricity, efficiency of the cooling system, cooling requirements of the home, and the lifestyle of the occupants. The simple method described below will provide a rough estimate of annual cooling costs that can be used to compare the performance of different cooling systems. Because this is a simplified procedure based on average conditions and use, your actual cooling costs will vary from these estimates.

First, determine from Figure 1 which climate zone you are in.

If you have had a detailed cooling load done on your home, use the cooling load and Formula 1 to estimate your Seasonal Cooling Load.

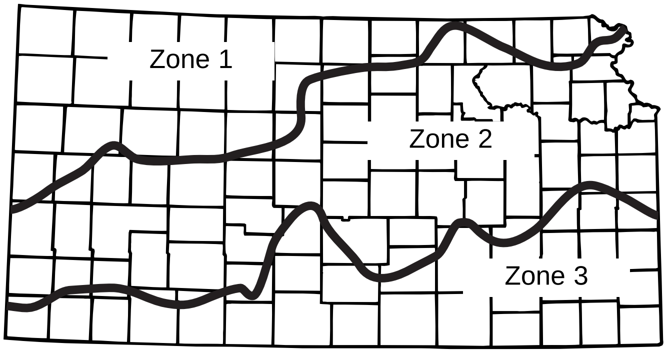


Figure 1. Kansas climate zones

Formula 1.

Seasonal Cooling Load = Cooling Load x Full Load Hours
Where: Cooling Load = Design Cooling Load in Btu/Hour
Full Load Hours = 800 for Zone 1; 1,000 for Zone 2; and 1,200 for Zone 3

If you haven't had a cooling load done, estimate the Design Load using Table 2 and adjust for your home size. Compare insulation levels and other energy features of your home to those listed in Table 2 to determine if your home resembles a current practice, Model Energy Code-compliant, energy-efficient, or super-insulated home.

Formula 2.

Seasonal Cooling Load = Design Load x Area of House x Full Load Hours
Where: Design Load = Design Load from Table 2
Home Area = Conditioned area of home in square feet
Full Load Hours = 800 for Zone 1; 1,000 for Zone 2; and 1,200 for Zone 3

Using the average summer cost of electricity, estimate the annual cost of cooling using Formula 3.

Table 2. Seasonal cooling loads for housing in Kansas

Efficiency Level	Ceiling R-value	Wall R-value	Glass[1] U-value	Foundation[2] R-value	Infiltration[3] ACH	Design Cooling Load Btuh/ft²
Current Practice	R-30	R-13	U-0.60	R-0	0.6	
Zone 1						16.5
Zone 2						17.5
Zone 3						18.5
MEC Compliant	R-38	R-19	U-0.60	R-5	0.4	
Zone 1						14.0
Zone 2						15.0
Zone 3						16.0
Energy Efficient	R-38	R-19	U-0.35	R-10	0.4	
Zone 1						13.0
Zone 2						13.5
Zone 3						14.0
Super Insulated	R-45	R-24	U-0.25	R-10	0.2	
Zone 1						10.5
Zone 2						11.0
Zone 3						11.5

[1] Glass U-value is center of window.

[2] Foundation R-value for basements. Insulation is to bottom of wall.

[3] Infiltration is expressed in air changes per hour (ACH). The rate for a super-insulated home of .2 ACH is below the minimum recommendation of .35 ACH and would require mechanical ventilation with heat recovery.

Formula 3.

$$\text{Annual Cost} = \frac{\text{Seasonal Cooling Load x Fuel Price}}{\text{SEER} \times 1{,}000}$$

Example 1.
Estimate the cooling cost for a 2,500-square-foot, MEC-compliant home in Baxter Springs using a central air conditioner with a SEER of 12. From Table 2, the Design Cooling Load for an MEC-compliant home in Zone 3 is 16.0 Btuh/Ft^2.

Seasonal Cooling Load =
$16.0 \times 2{,}500 \text{ x } 1{,}200 = 48{,}000{,}000.$

Using Formula 3.

$$\text{Annual Cost} = \frac{48{,}000{,}000 \text{ x } .08}{10 \text{ x } 1{,}000} = \$384$$

Example 2.
How much would be saved if an air conditioner with a SEER of 14 was used? The Seasonal Cooling Load would be the same; only the SEER would change in Formula 3.

$$\text{Annual Cost} = \frac{48{,}000{,}000 \times .08}{14 \times 1{,}000} = \$275$$

The annual cost would go from $384 to $275 for a savings of $109 per year.

Sizing window AC

Multiply the room height, room width, room length, exposure factor, and insulation factor together, and divide the results by 60. This gives the required capacity of the room air conditioner in British Thermal Units per hour (Btuh).

Exposure factor depends on orientation of the wall containing the most window area. If two or more walls have roughly the same area of glass, use the factor for the longest outside wall. The exposure factor for walls facing north is 16; east, 17; south, 18; and west, 20.

Insulation factor is a subjective judgment of the amount and quality of the room insulation. Good insulation equals 10 while poor insulation equals 18. Use a factor of 10 if the roof or attic is well insulated, or if there is another room above the one being cooled. Use a factor of 18 if the room has many windows or an uninsulated ceiling or roof. Values within this range can be used.

For example, the cooling load of a room 14 feet by 16 feet with an 8-foot ceiling, on the first floor of a two-story house (insulation factor 10), with the longest outside wall facing east (exposure factor 17), is computed as follows:

$$\frac{14 \times 16 \times 8 \times 10 \times 17}{60} = 5{,}077 \text{ Btuh.}$$

Further information

For questions regarding this fact sheet or further information on home cooling systems, please contact Engineering Extension Programs at 785-532-6026. This fact sheet is posted on the Kansas State University Engineering Extension Web page at *www.oznet.ksu.edu/dp_nrgy/ees*. Other KSU Engineering Extension Fact Sheets posted at this site include the following:

- Tips for Purchasing an Energy-Efficient Home
- Foundation Insulation
- Selecting a Home Heating System
- Energy-Efficient Mortgages
- Energy-Efficient Windows
- Residential Insulation
- Air Sealing Your Home

References

[1] Directory of Certified Unitary Equipment Standards 210/240/270, Air-Conditioning and Refrigeration Institute, 4301 North Fairfax Drive, Arlington, VA 22203

[2] Directory of Certified Applied Air-Conditioning Products, Air-Conditioning and Refrigeration Institute, 4301 North Fairfax Drive, Arlington, VA 22203

[3] Kansas Electric Utilities Research Program's Ground-Source Heat Pumps, An Efficient Choice for Residential and Commercial Use, 700 S.W. Harrison, Suite 1430, P.O. Box 1007, Topeka, KS 66603 (also available from Engineering Extension, 785-532-6026)

Printed on recycled paper

"This material was prepared with the support of the U. S. Department of Energy (DOE) Grant No. DE-FG48-97R802102. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE."