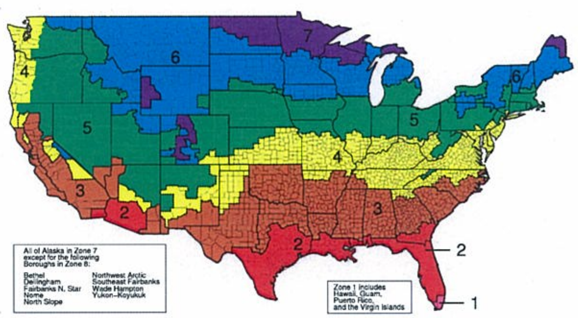
Radiant Barrier Fact Sheet

Overview

Radiant barriers and interior radiation control coatings are designed to work in your attic to keep some of the heat from the sun away from your living space. For *homes with air-conditioning ductwork in the attic* in the deep south (such as in Miami in Zone 1 or Austin in Zone 2 in the map below), radiant barriers could reduce your utility bills by as much as $150 per year using average residential electricity prices. If you're able to participate in one of the Time of Day rate plans, your savings can be even greater (almost $200 per year under the current Miami Time of Day rate plan). For milder climates, like those in Atlanta and Baltimore, annual energy savings will be about half those of their southern neighbors. In the northern climate zones, the savings drops further, going from about $40 to $10 per year as you go from Chicago to Fairbanks.

Contents:



If *there are no ducts or air handlers in the attic*, the savings are much less, going from about $20 per year in Miami to $5 per year in Baltimore, but a radiant barrier may still help to improve comfort and to reduce the peak air-conditioning load.

What is a radiant barrier?

Radiant barriers consist of a thin layer of a highly reflective material, usually aluminum, applied to one or both sides of another material that provides strength and durability. These other materials include kraft paper, plastic films, cardboard, plywood or oriented strand board (OSB) sheathing, and air infiltration barrier material. *Be sure that the label indicates that the product emittance is less than 0.1, as measured by ASTM C1371.* (Please see the Glossary for definitions of many terms used in this fact sheet.)

Photos courtesy of the Reflective Insulation Manufacturers Association International (www.rimainternational.org)

What is an interior radiation control coating?

An interior radiation control coating is a liquid that is spray-applied to the underside of a roof system. The coating must be applied at a certain thickness, perhaps over a primer coating, to provide the desired performance. *Be sure that the label indicates that the product emittance is less than 0.25 as measured by ASTM C1371.* Many interior coating products have names that sound like a radiation control coating, but unless the label shows the emittance is between 0 and 0.25, they won't perform as intended. *The rest of this article will refer to radiant barriers, but interior radiation control coatings may apply in many cases. Savings for these coatings may be a little less due to higher emissivity, but that may be counter-balanced if the coatings cover more of the exposed surface than a radiant barrier.*

Many interior coating products have names that sound like a radiation control coating, but unless the label shows the emittance is between 0 and 0.25, they won't perform as intended.

If you are a homeowner considering radiant barriers, please read:

- How do radiation barriers save energy?
  - Why does it matter whether there is air-conditioning ductwork in the attic?
- Radiant barriers are one component in the attic system
- If you've decided to install a radiant barrier product
  - Installation options
  - Important non-energy considerations

If you want to learn more about radiant barriers, please read:

- More about heat transfer in attics
  - Have energy savings been measured?
  - How did we estimate the savings shown in this fact sheet?

Radiant barriers can be used in residential, commercial, and industrial buildings. However, this fact sheet was developed only for radiant barriers in *ventilated attics of residential buildings*. For information on other applications, see Where to go for more information.

How do radiation barriers save energy?

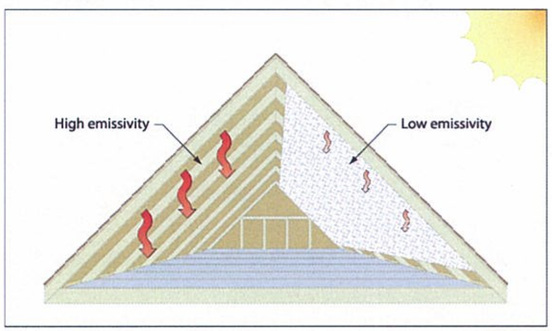
On a sunny summer day, solar energy is absorbed by the roof, heating the roof sheathing and causing the underside of the sheathing and the roof framing to become hot. These surfaces then radiate heat downward toward the attic floor. Radiant barriers reduce that energy flow. Since the amount of heat radiation striking the top of the insulation is less than it would have been, the insulation surface temperature is lower and the heat flow through the insulation is reduced. By reducing the energy reaching the attic floor, radiant barriers also reduce the attic air temperature.

The amount of energy exchanged between the roof deck and the attic floor depends on two factors.

- The temperatures of each surface
- The properties of the attic surface materials, called the "emittance" and "reflectivity."

Energy exchange is greatest when the temperature difference is high, when the emittance is high, and when the reflectivity is low. The underside of a roof deck made of wood will typically have a high emittance. When a radiant barrier with a much lower emittance covers that wooden surface, the thermal radiation is reduced. When a radiant barrier with a high reflectivity is placed on top of the attic floor insulation, much of the heat radiated from the hot roof is reflected back toward the roof.

In the winter, radiant barriers can reduce indoor heat losses through the ceiling, especially during winter nights when the roof surface is coldest. However, they also reduce beneficial daytime heat gains due to solar heating of the roof. Depending on your climate, level of attic insulation, and other factors, the net winter effect can be positive or negative.



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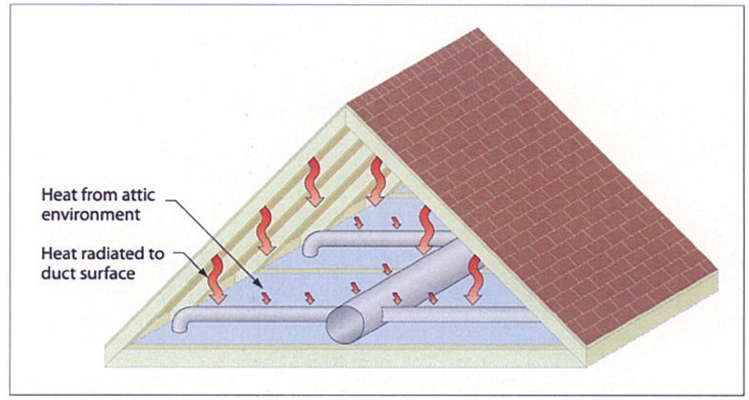
Why does it matter whether there is air-conditioning ductwork in the attic?

Radiant barriers reduce energy losses from air conditioning ductwork in the attic in three ways. First, the outside surface of any ductwork located in the attic exchanges thermal radiation energy with the roof deck in the same way as the attic floor. Because the temperature difference between the roof deck and the duct surface is even greater than that between the roof deck and attic floor, this thermal radiation is significant. Second, the outside surface of the ductwork exchanges energy with the air in the attic space, and that energy loss is reduced when the attic temperature is moderated by the radiant barrier. Third, ducts leak. When return ducts leak, the air that is sucked into the ducts through the leaks feeds into your HVAC air handler, which then has to use extra energy to cool this warmer air. When the capacity of the HVAC system is nearing its limit, as on very hot summer days, this can make



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a noticeable difference in the comfort within the house. (When supply ducts leak, the air you've paid to condition goes into your attic and out with the attic ventilation. Furthermore, this diversion of the supply air can reduce the pressure inside your home, so that more outside air is pulled into any existing openings, such as cracks around windows and doors and openings between the attic and the conditioned space.) So in both cases, sealing up duct leaks can improve comfort and save energy.

Radiant barriers are one component in the attic system

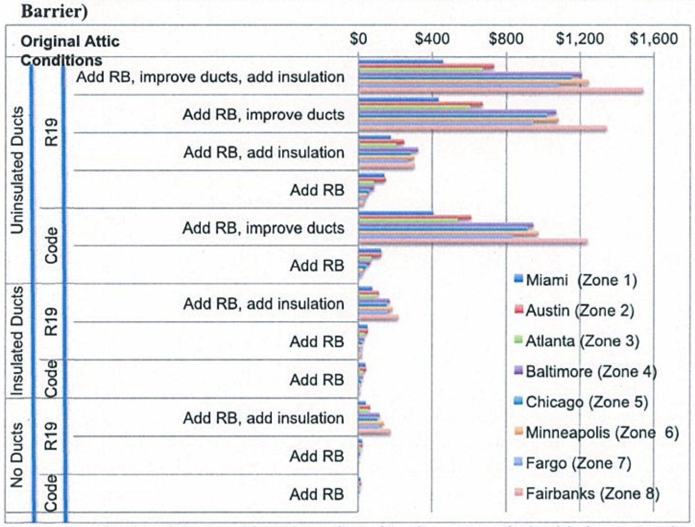
Your attic is a complex system where many components work together to maintain comfortable (and dry!) indoor conditions, so you can increase your savings by considering the whole attic system. The radiant barriers reduce radiant energy transfer. Insulation on the attic floor reduces conductive and convective heat transfer. The duct insulation reduces conductive and convective heat transfer at the duct surface. Duct sealing reduces the energy losses caused by increased air exchange between the inside and outside of your home. Special shingles or ventilation arrangements can reduce the amount of energy that enters the attic from the outside.

So, when you consider a radiant barrier, look at the whole attic system. We calculated the first year savings for a 1,540 square foot attic for several combinations of attic improvements: adding a radiant barrier, reducing duct energy losses, and upgrading insulation from R19 to code levels. The results shown here were based on a number of assumptions and won't represent your house exactly. (The assumptions and methodology are discussed later in this fact sheet.) For example, if your home heating and cooling system has a lower efficiency than the efficiency used in these calculations, then your savings will be greater (until you replace the air conditioner).

Reducing any air leaks between your house and the attic, that is, through the ceiling or inside any wall cavities, is also important and should be the first step in any attic improvement effort. (see http://www.engext.ksu.edu/henergy/envelope/airsealing.pdf)

Comparing the different system improvement options is easier if you look at this bar chart. The greatest savings are available to homes with uninsulated, or poorly insulated, ducts in the attic (the values are also given below in tables for folks who don't like graphs). Research has shown that any duct system that hasn't been subjected to a formal testing process leaks, it's just a question of how much. These homes with the greatest savings potential are also likely to be homes with higher energy bills. If your ducts are already well sealed, or – even better, not located in the attic at all, your savings potential is less because you're starting with an attic that is already more efficient.

Calculated annual savings for a 1,540 ft² house in eight climate zones (RB = Radiant Barrier)



Calculated annual savings for a 1,540-ft2 house *with uninsulated ducts in the attic*

Original attic condition	R19 Attic Insulation				Code-level Attic Insulation	
Attic system modification	*Add RB, improve ducts, add insulation*	*Add RB, improve ducts*	*Add RB, add insulation*	*Add RB*	*Add RB, improve ducts*	*Add RB*
Miami (1)	$460	$430	$180	$140	$410	$120
Austin (2)	$730	$670	$240	$150	$610	$120
Atlanta (3)	$670	$600	$200	$80	$540	$70
Baltimore (4)	$1,210	$1,070	$320	$80	$950	$60
Chicago (5)	$1,150	$1,020	$280	$60	$910	$40
Minneapolis (6)	$1,250	$1,080	$300	$45	$970	$25
Fargo (7)	$1,080	$940	$260	$35	$830	$15
Fairbanks (8)	$1,540	$1,340	$300	$25	$1,240	$0

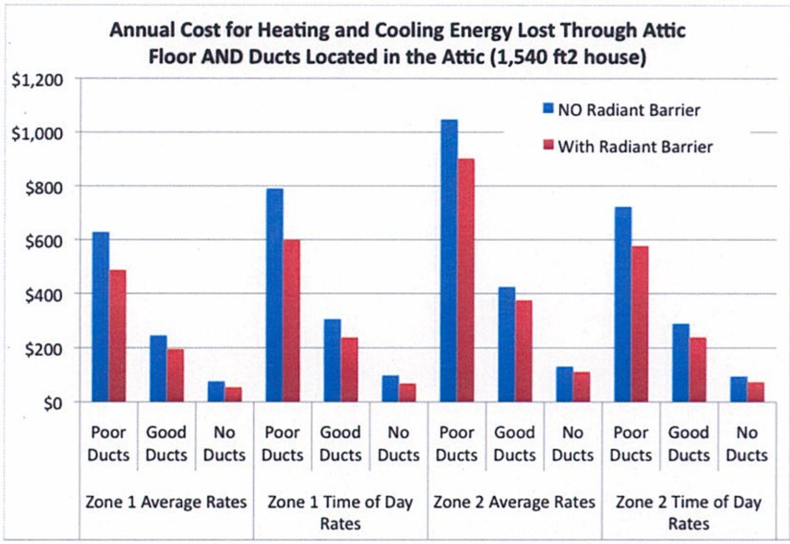
Calculated annual savings for a 1,540 ft² house *with well-insulated and sealed ducts, or no ducts, in the attic*

Original attic condition	Insulated and well-sealed ducts			No ducts		
	R19 Attic Insulation		Code-level Attic Insulation	R19 Attic Insulation		Code-level Attic Insulation
Attic system modification	*Add RB, add insulation*	*Add RB*	*Add RB*	*Add RB, add insulation*	*Add RB*	*Add RB*
Miami (1)	$75	$50	$40	$40	$20	$15
Austin (2)	$110	$50	$40	$60	$20	$15
Atlanta (3)	$100	$30	$25	$55	$15	$10
Baltimore (4)	$170	$30	$20	$120	$10	$5
Chicago (5)	$150	$20	$15	$110	$5	$5
Minneapolis (6)	$180	$20	$10	$140	$5	$0
Fargo (7)	$150	$15	$10	$120	$0	$0
Fairbanks (8)	$210	$15	$10	$180	$5	$0

Selecting your best approach will depend on your house's configuration, including physical attic constraints, and your budget. For a shallow attic, it may not be possible to add conventional insulation, so a radiant barrier alone may be the best choice. If you already have a higher level of insulation in your attic (R-30 or more in the south, R-38 or more in the middle and northern climates), then adding attic insulation would not be your first choice. If your ducts are not in the attic, or if they are already well-sealed and insulated, then improving the ductwork will not be an effective choice. But in any case, addressing and improving the whole attic as a system will give you the greatest savings. (See http://www.energysavers.gov/tips/ducts.cfm)

The annual savings are calculated by comparing the hourly energy consumption of attics with two different configurations. Another way to look at the issue is to look at the calculated annual cost for the total heating and cooling energy lost through the attic floor AND ducts located in the attic. Because we calculate the energy exchange for every hour during a year, we can also show the impact of Time-of-Day rates that are available to some homes in Miami and Austin. The figure below shows the cost we calculated for that energy for a 1,540-ft² house for both time-of-day (from October 2010) and 2008 state average energy prices. In Miami, the savings due to installing a radiant barrier were about 35% greater with time of day pricing than with average pricing; in Austin they were only about 5% greater. (Also, if you're considering participation in a time-of-day rate plan, remember that this only represents a portion of your total utility bill, and the effect of your appliance use schedule will also play an important role.)

Calculated annual cost for energy lost through the attic floor PLUS the energy lost due to ducts located in the attic.



Looking at this figure, the most important message is for anyone building a new home – even if it costs more — don't put the ducts in the attic!

Conventional insulations are usually rated by their R-value. Since the performance of radiant barriers depends on many variables, simple R-value ratings do not apply.

For all the attic system elements, you need to compare the potential savings over many years to the installed cost. The next two tables give you the annual savings per square foot, one for homes with uninsulated ducts in the attic, and one for homes with well-insulated and sealed ducts, or no ducts at all, in the attic. You can estimate a reasonable purchase price by multiplying the values in the table by the size of your attic floor

and then multiplying that by ~15. (This simple 15-year payback is approximately the same as the present value of your energy savings over the next 20 years, for a reasonable rate-of-return value of 2 to 3%, and assuming that energy prices don't go up faster than inflation. You could multiply the annual savings by ~20 if you want to consider the present value of savings over the next 30 years.) We don't know what will happen to energy prices in the future, but if you think your energy prices will increase above the general inflation rate, then your savings in future years will be even greater than the first-year savings shown here.

Calculated annual savings per ft² with *uninsulated ducts in the attic* (Values with Time-of-Day pricing shown for zones 1 and 2)

	R19 Attic Insulation				Code-level Attic Insulation	
Zone	**Add RB, improve ducts, add insulation**	**Add RB, improve ducts**	**Add RB, add insulation**	**Add RB**	**Add RB, improve ducts**	**Add RB**
Miami (1)	$0.30 ($0.38)	$0.28($0.36)	$0.11($0.15)	$0.09($0.12)	$0.26($0.34)	$0.08($0.11)
Austin (2)	$0.47($0.34)	$0.44($0.31)	$0.16($0.13)	$0.09($0.10)	$0.39($0.29)	$0.08($0.08)
Atlanta (3)	$0.43	$0.39	$0.13	$0.05	$0.35	$0.05
Baltimore (4)	$0.78	$0.69	$0.21	$0.05	$0.61	$0.04
Chicago (5)	$0.75	$0.66	$0.18	$0.04	$0.59	$0.03
Minneapolis (6)	$0.81	$0.70	$0.19	$0.03	$0.63	$0.02
Fargo (7)	$0.70	$0.61	$0.17	$0.02	$0.54	$0.01
Fairbanks (8)	$1.00	$0.87	$0.20	$0.02	$0.80	$0.00

Calculated annual savings per ft² with *well-insulated and sealed ducts, or no ducts, in the attic* (Values with Time-of-Day pricing shown for zones 1 and 2)

	Insulated and well-sealed ducts			No ducts		
	R19 Attic Insulation		Code insulation,	R19 Attic Insulation		Code-level Attic Insulation
Zone	**Add RB, add insulation**	**Add RB**	**Add RB**	**Add RB, add insulation**	**Add RB**	**Add RB**
Miami (1)	$0.05($0.06)	$0.03($0.04)	$0.03($0.04)	$0.03($0.04)	$0.01($0.02)	$0.01($0.01)
Austin (2)	$0.07($0.05)	$0.03($0.03)	$0.03($0.03)	$0.04($0.03)	$0.01($0.01)	$0.01($0.01)
Atlanta (3)	$0.06	$0.02	$0.02	$0.04	$0.01	$0.01
Baltimore (4)	$0.11	$0.02	$0.01	$0.07	$0.01	$0.00
Chicago (5)	$0.10	$0.01	$0.01	$0.07	$0.00	$0.00
Minneapolis (6)	$0.12	$0.01	$0.01	$0.09	$0.00	$0.00
Fargo (7)	$0.10	$0.01	$0.01	$0.07	$0.00	$0.00
Fairbanks (8)	$0.14	$0.01	$0.01	$0.11	$0.00	$0.00

For example, if you lived in a 2000 ft² house in Miami, had R19 attic insulation, and the ductwork in your attic was poorly insulated, then you could save ~$0.28/ft², or $560 per year by adding a radiant barrier and sealing and insulating the ducts. The present value of those savings over a 20-year period would then be about $8,400. If the price to make these modifications were less than that value, then this would be an economical choice.

Radiant barrier, coatings, and insulation costs vary widely. As with most purchases, some comparison shopping can save you money. Get prices from multiple contractors, or multiple stores if you're going to do the installation yourself. You should always check with your local or state energy office or building code department for current insulation recommendations or see the Insulation Fact Sheet or the ZipCode Calculator (www.ornl.gov/sci/roofs+walls/insulation/ins_01.html or www.ornl.gov/~roofs/Zip/ZipHome.html) Costs will depend on several factors, including:

- Homeowner- or contractor-installation.
- New home or existing home.
- What extra "features" are desired; e.g., a radiant barrier with perforations and reinforcements may be more expensive than a "basic" radiant barrier.
- Any necessary retrofit measures such as adding venting (soffit, ridge, etc.)
- Type of radiant barrier selected, or type of insulation selected (loose-fill insulation is usually lower in price than "batt" insulation or blown foam insulation)
- Installation location and coverage
- Region of the country

After you've decided to install a radiant barrier product

> ***If a radiant barrier is reflective on only one side, the reflective side must face toward the main attic space, regardless of whether the radiant barrier is at the rafters or the attic floor.***

After considering the options and deciding to use a radiant barrier in your attic, there are several things you should do to optimize the performance. Most important, you must insure that the installation follows all the guidelines and recommendations provided by the manufacturer. Other guidance is provided in two ASTM Standard Practices for the installation of radiant barriers. Find out if your contractor follows these practices. (ASTM C1321 and C1158)

To obtain the best performance with both radiant barriers, the gable ends of the attic should also be covered, but do not cover the gable vent area. For attics that are open to the space over garages or carports, the radiant barrier should extend eight feet or more into the garage or carport to achieve the same effect. It is not necessary to cover the gable ends if a radiant barrier is placed on top the attic floor insulation.

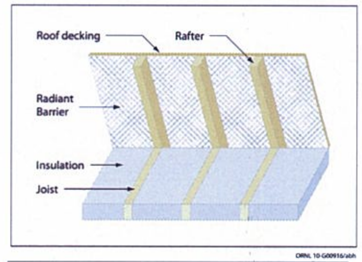
If a radiant barrier is reflective on only one side, the reflective side must face toward the main attic space, regardless of whether the radiant barrier is at the rafters or the attic floor.

While working in the attic to install a radiant barrier, care should be taken not to compress existing insulation present in the attic. The effectiveness of the existing insulation is dependent upon its thickness, so if it is compressed, its R-value is decreased.

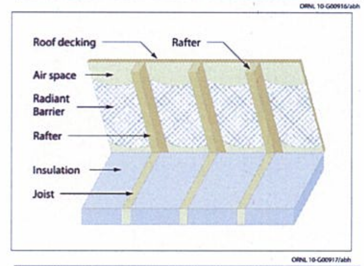
If you select a radiant barrier product, you have several installation location options described in the next section. If you select an interior radiation control coating, you should be sure that the application covers ALL the roof support structure connected to the roof deck.

Installation options

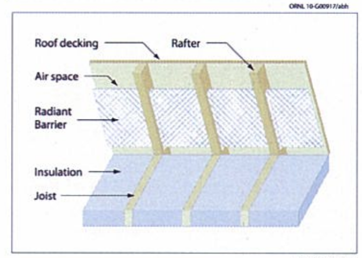
Most residential roofs provide some type of attic or airspace that can accommodate an effective radiant barrier system. In new residential construction, it is fairly easy to install a radiant barrier system. The following images show five possible locations for the installation of an attic radiant barrier system.



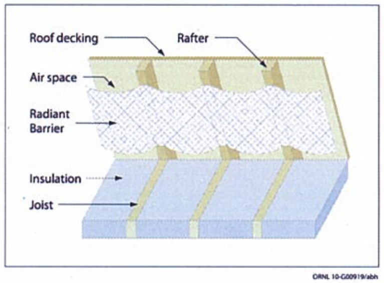
Location 1, where the radiant barrier material is pre-applied to the roof decking (you can purchase radiant barrier decking), is appropriate if you are building a new house or if you are replacing your roof decking for other reasons.



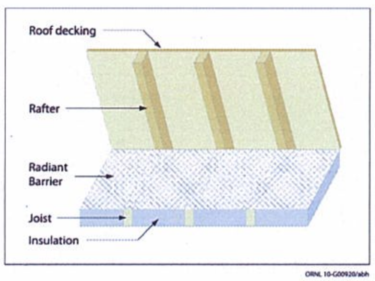
Location 2 may offer advantages to the builder during construction of a new house. Before the roof sheathing is applied, the radiant barrier is draped over the rafters or trusses in a way that allows the product to droop 1-1/2 to 3 inches between each rafter.



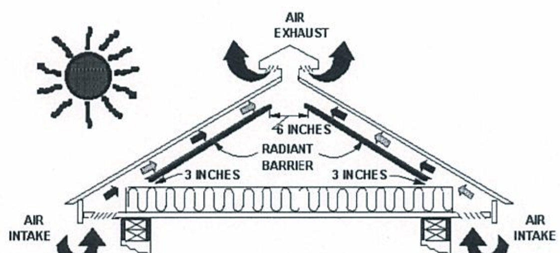
In Locations 3 and 4, the radiant barrier is attached to either the faces or bottoms of the rafters or top chords of the roof trusses. Locations 3 and 4 may be used with either new construction, or with retrofit of an existing house.



Location 4



In Location 5, the radiant barrier is laid out on the attic floor over the top of existing attic insulation. (See the discussion for important information about performance problems associated with dust for this option.)



With either Location 2, 3 or 4, the space between the roof sheathing and the radiant barrier provides a channel through which warm air can move freely. For any of the radiant barrier locations (and for attics without radiant barriers), ideal venting would provide equal areas on intake (soffit) and exhaust (gable or ridge) vents. For proper air flow, with a roof-mounted radiant barrier, a gap of approximately 3 inches should be left between the radiant barrier and the insulation, and a gap of at least 6 inches should be left near the ridge. Both of these gaps should be left for attics with either ridge or gable venting.

Even though some testing shows that a brand new application in location 5, the attic floor, will work better than the roof applications, there are several drawbacks to this location. The attic floor application is most susceptible to accumulation of dust, while downward facing reflective surfaces used with many roof applications are not likely to become dusty. After a long enough period of time, a dusty attic floor application will lose much of its effectiveness. Predictive modeling results, based on testing, suggest that a dusty attic floor application will lose about half of its effectiveness after about one to ten years. For this location, moisture (see below) issues must also be considered. The floor location is not appropriate when a large part of the attic is used for storage, since the radiant barrier surface must be exposed to the attic space. Also, kitchen and bathroom vents and recessed lights should not be covered with the radiant barrier. If a one-sided radiant barrier is laid on top of the insulation with the reflective side facing down and touching the insulation, the radiant barrier will lose most of its effectiveness in reducing heating and cooling loads.

Important Non-Energy Considerations

Potential for moisture condensation

Condensation can be a concern when a radiant barrier is installed on the attic floor directly on top of conventional insulation. During cold weather, water vapor from the interior of a house may move into the attic. In most cases, this water vapor will not cause any problem because attic ventilation will carry excess vapor away. But, during cold weather, a radiant barrier on top of the insulation could cause water vapor to condense and even freeze on the barrier's underside. A radiant barrier used in the attic floor application must therefore allow water vapor to pass through it. Some allow water vapor passage through holes or perforations, while others are naturally permeable. Some testing has been performed to determine the potential for moisture condensation with perforated radiant barriers laid on top of the insulation. A test was conducted during the winter in Climate Zone 4, using houses that were operated at much higher-than-normal indoor relative humidities. Since this testing did not reveal any significant moisture condensation problems, it is expected that moisture condensation will not be a problem in warmer climates.

Attic ventilation

Attic ventilation helps to cool your attic in the summer and to remove excess water vapor in winter. Unfortunately, specific recommendations for the best type and amount of attic ventilation for use with radiant barriers are not available. Where no ridge or gable vents exist, it is recommended that one or the other be installed. Always check existing ridge vent systems to ensure that roofing paper is not blocking the vent opening, and check the soffit vents to ensure that they have not been covered with insulation.

Effect of radiant barriers on roof temperatures

Field tests have shown that radiant barriers can cause a small increase in roof temperatures. Roof mounted radiant barriers may increase shingle temperatures by 2 to 10°F, while radiant barriers on the attic floor may cause smaller increases of 2°F or less. The effects of these increased temperatures on roof life, if any, are not known. Some shingle manufacturers will not warrant their shingle with a radiant barrier whereas others will. Check with the manufacturer before selecting a shingle for a new roof.

Fire ratings

The fire ratings of radiant barriers are important because flame and smoke characteristics of materials exposed to ambient air are critical. To obtain these ratings, a material must have an ASTM E-84 Flame Spread Index test and the resulting rating must be printed on the product. Rating requirements vary depending upon whether or not the attic is accessible and may also vary from one code jurisdiction to another. You should check to see what rating your local building code requires.

Other safety considerations

- The installer should wear proper clothing and equipment as recommended by the radiant barrier manufacturer. Handling conventional insulation may cause skin, eye, and respiratory system irritation. If in doubt about the effects of the insulation, protective clothing, gloves, eye protection, and breathing protection should be worn.
- Be especially careful with electrical wiring, particularly around junction boxes and old wiring. Never staple through, near, or over electrical wiring. Repair any obvious frayed or defective wiring in advance of radiant barrier installation.
- Work in the attic only when temperatures are reasonable.
- Work with a partner. Not only does it make the job go faster, it also means that you'll have assistance should a problem occur.
- If the attic is unfinished, watch where you walk. If you step in the wrong place, you could fall through the ceiling. Step and stand only on the attic joists or trusses or the center of a strong moveable working surface.
- Watch your head. In most attics, roofing nails penetrate through the underside of the roof. A hard hat may be of some use.
- Make sure that the attic space is well ventilated and lighted.

Do not cover any recessed lights or vents with radiant barrier material (attic floor application).

More about heat transfer in attics

Radiant barriers and conventional insulation both reduce cooling bills by reducing the amount of heat that is transferred from the attic into the house. They differ in the way they reduce the heat flow. Conventional insulation traps air within the insulation, reducing heat transfer by air movement (convection). The insulation fibers or particles also partially block radiation heat transfer through the space occupied by the insulation. A radiant barrier reduces the amount of heat radiated across an open air space next to the radiant barrier. The performance of a radiant barrier depends on two material properties, the emittance and the reflectivity.

Radiant barrier materials must have high reflectivity (usually 0.9, or 90%, or more) and low emittance (usually 0.1 or less), and must face an open air space to perform properly.

Interior radiation control coatings must have a low emittance (usually 0.25 or less), and must face an open air space to perform properly.

The emittance (also called the emissivity) is the property that determines how well a radiant barrier will perform. This property is a number between 0 and 1, with lower numbers indicating better potential for performance

The effective emittance and reflectivity of a radiant barrier in an attic environment may change if the surface gets dirty or is torn. If the surface is dirty, the performance and energy savings may be cut in half.

because the lower the emittance, the lesser the emitted radiation. It is not always possible to judge the emittance by visual appearance, as the heat transfer is longwave radiation and not visible radiation. There are materials than can appear to be shiny and aluminum colored, but may be coated such that they actually have high emissivity. Measured emittance values should be part of the information provided by the manufacturer.

A closely related material property is the "reflectance" (also called the "reflectivity"). This is a measure of how much radiant heat is reflected by a material. The reflectivity is also a number between 0 and 1 (sometimes, it is given as a percentage, and then it is between 0 and 100%). For a material that is opaque (that is, it does not allow radiation to pass directly through it), the emittance and reflectivity add up to one. Hence, a material with a high reflectivity has a low emittance, and vice versa. Again, the reflectivity of concern is in the longwave spectrum and thus how reflective it appears based upon the part of the light spectrum that humans can see is not applicable.

Where to go for more information

Web Sites

ASTM	http://www.astmpubs.com/
DOE program	http://www1.eere.energy.gov/buildings/envelope_rd.html
FSEC	*www.fsec.ucf.edu*
Insulation Fact Sheet	www.ornl.gov/sci/roofs+walls/insulation/ins_01.html
ORNL	www.ornl.gov/sci/ees/etsd/btric
RIMA	*www.**rima**international.org*

Glossary

ASTM	American Society for Testing and Materials
ASTM C1158	Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Building Construction
ASTM C1313	Standard Specification for Sheet Radiant Barriers for Building Construction Applications
ASTM C1321	Standard Practice for Installation and Use of Interior Radiation Control Coating Systems (IRCCS) in Building Construction
DOE	U.S. Department of Energy
Emittance and emissivity	The emittance (sometimes called the emissivity) is the ability of a material to release heat by radiation. Emittance is expressed as a number between 0 and 1, with lower numbers indicating less heat radiation and numbers close to one greater heat radiation. Dull black materials will usually have an emittance close to 1 and shiny materials will usually have a low emittance, but it is not always possible to judge the emittance just by visual appearance.
FSEC	Florida Solar Energy Center

gal.	gallon
KWH	Kilowatt-hour(of electricity)
ORNL	Oak Ridge National Laboratory
Present Value	The amount of money it would take today to generate a future series of payments. The present value is determined by the rate-of-return, the number of payments in the series, and the size of each payment. The rate-of-return represents the interest you could earn on an alternative investment over an above the general inflation rate.
Reflectance and reflectivity	The reflectance (sometimes called the reflectivity) is a measure of how much radiant heat that hits a material is reflected. The reflectance is a number between 0 and 1, with lower numbers indicating less heat reflection and numbers close to one greater heat reflection. Sometimes the reflectance is given as a percentage, and then it is between 0 and 100%.
RIMA	Reflective Insulation Manufacturers Association

About this Fact Sheet

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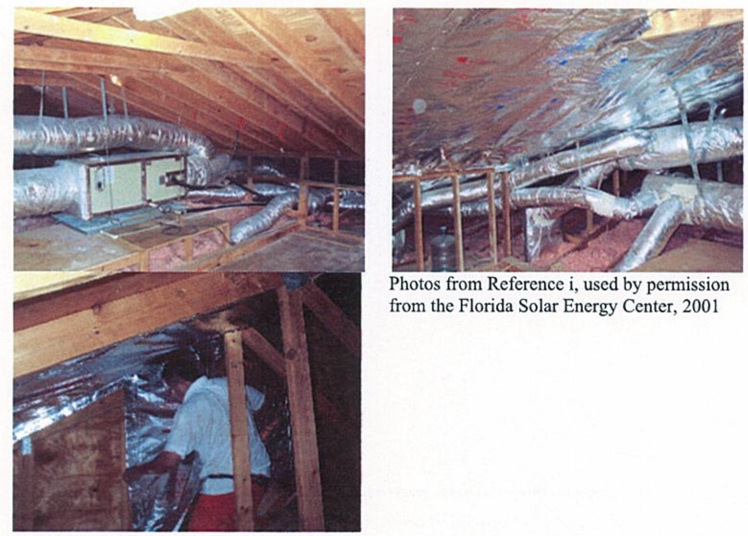
Appendix: Background information about radiant barriers and the analysis used to prepare this Fact Sheet

We know that radiant barriers save energy under certain conditions because there have been extensive tests and analysis.

Have energy savings been measured?[1]

Extensive experimental work has identified the energy savings and peak-load reduction benefits of radiant barriers in attics in the southern climates of the U.S. Eight homes, all with air-handling equipment located in the attic, were retrofit with radiant barrier systems in 2000 in central Florida. Subsequent monitoring and data analysis showed cooling energy savings of 9%, peak load reduction of 16%, and an improvement in indoor comfort.[i]

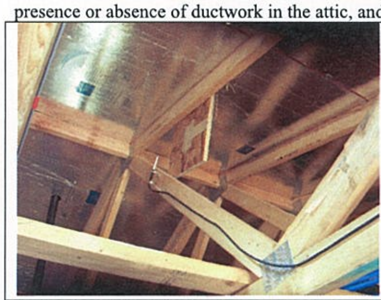


Photos from Reference i, used by permission from the Florida Solar Energy Center, 2001

Previous experimental work in Tennessee on uninhabited homes with no ductwork in the attic also showed significant cooling energy savings.[ii] Significant savings due to radiant barriers were also measured in controlled laboratory experiments, with and without duct systems in the attic.[iii] Numerous other studies have established the energy conservation characteristics of a radiant barrier system, with

[1] This material is excerpted from a paper presented at the Building Envelope Conference in 2010. (Stovall et al, 2010)

and without the impact of ducts.[iv,v,vi,vii,viii] As expected, these studies point out the importance of multiple factors in determining the potential energy savings, most importantly: the climate, the presence or absence of ductwork in the attic, and the amount of insulation on the floor of the attic.



Photos from Ref viii, showing temperature and heat flux monitor locations in test houses at Fort Irwin, California, 2010

Most of the field tests have been done with clean radiant barriers. Laboratory measurements have shown that dust on the surface of aluminum foil increases the emittance and decreases the reflectivity. This means that dust or other particles on the exposed surface of a radiant barrier will reduce its effectiveness. Radiant barriers installed in locations that collect dust or other surface contaminants will have a decreasing benefit to the homeowner over time. When radiant barriers are newly installed and clean, some testing shows that the attic floor application will work better than the roof applications.

How did we estimate the savings shown in this fact sheet?[2]

It's not possible to test radiant barriers in every city and in every type of house. To understand their performance in other locations, the attic simulator computer program, AtticSim, was developed to calculate the radiative, convective, and conductive energy exchanges in a specific attic geometry, with or without ducts.[ix,x] This model has been benchmarked against experimental data from controlled laboratory experiments, showing excellent accuracy for attics without ducts and moderate accuracy for attics with ducts.[iii, xi, xii] The attic model requires that the air temperature below the attic floor and the temperature and timing of air entering the ductwork be specified. To provide these values, a whole-building energy model, EnergyPlus, was used. This whole-building model includes leaking attic ducts and radiant energy exchange within the attic, but does not yet include radiant exchange between the attic surfaces and the duct surface.[xiii] These programs were coupled by using the same physical geometry and materials, the same weather data, and the same rate of duct leakage to calculate the energy lost and gained in the attic for each combination of duct condition, attic insulation level, and radiant barrier use. The building model shown here was used as a base building for this study.[xiv] The building is a 57 ft × 27 ft single-story house with one conditioned zone, an unconditioned attic, and a vented crawl space.

[2] This material is adapted from a paper to be presented at the Building Envelope Conference in 2010.(Stovall et al, 2010)

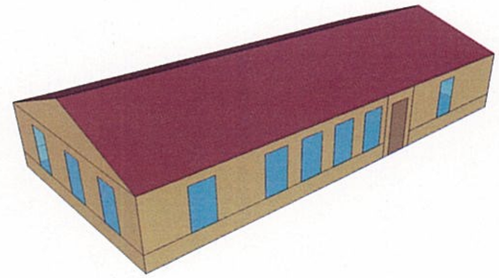


Figure 1 Schematic of house used in EnergyPlus and AtticSim

The analysis was performed for eight cities, representing the eight ASHRAE climate zones.[xv] For all climate zones, an interior 21°C (70°F) heating set point temperature and 24°C (75°F) cooling set point temperature were used. Two levels of building quality were evaluated, one with adequate ceiling insulation (new), and one with minimal insulation (old). The new homes were taken to have code-level insulation, corresponding to R-30 for climate zones 1 to 3, R-38 for climate zones 4 and 5, and R-50 for climate zones 6 to 8. An attic insulation level of R-19 was used for the older home in all climate zones. The study considered three cases for attic ducts, representing situations with no ducts (and therefore no duct losses), insulated and relatively tight ducts, and uninsulated leaky ducts.

To estimate the energy savings attributable to radiant barriers, four values of emittance (ε) for the downward-facing side of the interior attic space and the gable ends were considered; 0.05, 0.1, 0.2, and 0.9. The upward-facing floor of the attic (that is, the top surface of the attic floor insulation) was given an emittance of 0.9. The building thermal load with no radiant barrier ($\varepsilon = 0.9$) was compared with the thermal loads with $\varepsilon = 0.05$, 0.1, and 0.2 to calculate the radiant barrier energy savings.

To evaluate the potential economic savings due to radiant barriers, state average fuel prices and representative HVAC system efficiencies were applied to the calculated energy savings. For heat pumps and air conditioners, the seasonal efficiencies required in the 2006 Department of Energy standards were used, a Seasonal Energy Efficiency Ratio of 13 and a Heating Season Performance Factor of 7.7, to translate energy savings to electricity savings. For gas furnaces, an efficiency of 0.85 was assumed. These tables show the energy prices used for each analysis location. For climate zones 1 to 6, all-electric heat pumps were used. For climate zones 7 and 8, gas heat with electric air conditioning was used.

Energy Prices Taken From EIA 2008 State Average Residential Retail Prices

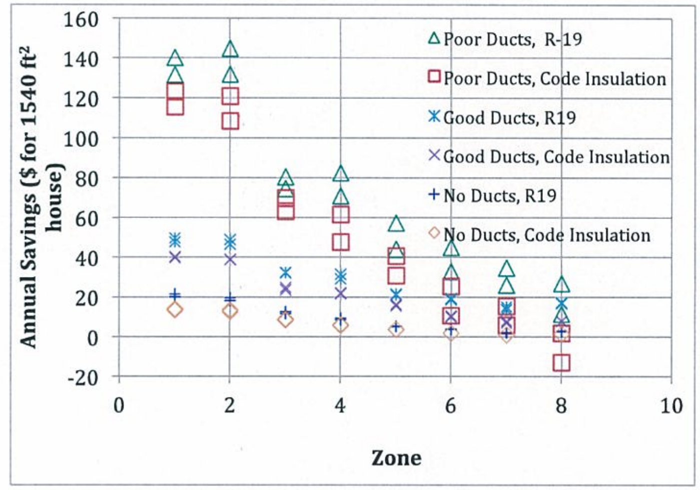
Zone	City	Electricity (¢ per kWh)	Natural gas ($/1000 ft^3)
1	Miami, FL	11.65	21.29
2	Austin, TX	13.04	13.79
3	Atlanta, GA	9.93	18.5
4	Baltimore, MD	13.84	16.05
5	Chicago, IL	11.07	12.09
6	Minneapolis, MN	9.74	11.3
7	Fargo, ND	7.51	10.34
8	Fairbanks, AK	16.55	8.72

Time-of-Day Prices

City	Off-Peak price	On-peak period	On-peak price
Miami, FL (FPL, Rate code RS-1)	$0.074/kWh	Nov.1 to March 31: Monday-Friday 6 AM to 10 AM and 6 PM to 10 PM excluding holidays April 1 through Oct. 31: Monday-Friday 12 Noon to 9 PM excluding holidays	$0.13396/kWh
Austin, TX (Experimental voluntary residential summer time-of-use rate, 02/17/2010)	$0.0456/kWh	May 1 to Oct. 31: Monday-Friday 2:00 PM to 8 PM excluding holidays	$0.1825/kWh

The results of the parametric evaluation showed that the savings estimates are most sensitive to the climate, then the presence and condition of the ductwork, and third – the effective emittance of the downward facing surface of the roof sheathing. Analysis shows that the effective emittance of the downward-facing roof surface is very similar for roof sheathing materials with a foil-covered interior surface, and liquid-applied low-emittance coatings. Furthermore, the savings for an emittance ranging from 0.05 to 0.2 were very similar, so consumers are advised that these two approaches, as well as the use of aluminum foil or metalized film-faced materials stapled to the bottom surface of rafters, should provide similar savings.

Annual savings for a radiant barrier calculated using a coupled Attic-Sim / EnergyPlus model and state average energy prices for a 1,540 ft^2 house. The two values shown for each entry are for radiant barrier emittances of 0.05 and 0.20.



When looking at these results, keep in mind that they represent a single, simple, house geometry and that duct conditions in real houses can vary widely and are seldom well characterized. Factors that could make your savings larger than the ones calculated would be: a summer thermostat setting lower than 24°C (75°F), lower efficiency air-conditioner or heat pump, and higher fuel prices. Factors that could make your savings less than the ones calculated would be: a summer thermostat setting higher than 24°C (75°F), light colored roof shingles, shading of the roof by trees or nearby structures, higher efficiency furnace or air-conditioner, and lower fuel prices.

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