Cornell University
College of Human Ecology
Design and Environmental Analysis

Answers to Frequently Asked Energy Questions

Professor Joseph Laquatra and Extension Associate Mark Pierce compiled a list of frequently asked energy questions that Extension Educators across New York receive when they conduct workshops on energy efficiency. Laquatra and Pierce have written answers to each of these questions. To see answers you can simply click on the specific question, or scroll down the page.

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Q: Why do my windows "sweat" when it is cold outside?

A: This is what happens when warm, moist air comes in contact with a cold surface. In this case it's a cold window. As warm, humid indoor air moves close to the window, its temperature drops. When that happens, its moisture-holding capability also drops. When this air touches the window, the water vapor in that air condenses as water on the window. We can see the same thing happening on a warm and humid summer day, when warm, humid air condenses on cold beverage bottles, cans, or drinking glasses.

To minimize or prevent moisture condensation on windows, decrease the relative humidity of indoor air. The best way to do this is to use exhaust fans when moisture is produced – over a kitchen stove while cooking and in a bathroom while showering or bathing. And clothes dryers should always be vented to the outdoors. Another solution is to raise the temperature of the condensing surface. If the window is single-glazed, add a storm window or a temporary plastic window covering. If the window is to be replaced, do so with an Energy Star window.

Q: What is a sealed combustion central heating system?

A: To understand a sealed combustion heating system, first consider a conventional furnace, which heats and distributes air through ducts and registers, or boiler, which heats water and distributes hot water or steam through pipes, baseboards, and radiators. The conventional system draws air from around the unit into the burner and combustion chamber to support the flame. This air that supports combustion is air from inside the house. It travels through the burner, the combustion chamber, and the heat exchanger, and is then exhausted with combustion products up and out the chimney. It travels up and out the chimney through the natural force of rising warm air and can cost 45 cents out of every dollar spent on fuel in old systems, less in newer systems, but at least 15 cents of every dollar spent on fuel.

Sealed combustion systems have one pipe in two sections – a pipe within a pipe. Or two separate pipes. One section of the pipe-within-a-pipe, or one of the pipes in a two-pipe system, brings in outdoor air for the combustion process. A sealed combustion system has two heat exchangers, so more heat is extracted from the combustion gases. After the gases pass through the second heat exchanger, the gases are cool enough to exhaust to the outside through the pipe, much like a clothes dryer vents through a wall. The term “sealed combustion” is used to denote that the combustion process is sealed from indoor air.

In addition to a higher level of energy efficiency, a sealed combustion system does not bring a house under negative pressure. The conventional system does, because the house air that leaves the house as it exits the chimney places suction pressure on the house. That causes outdoor air and soil-based air to be drawn into the house through cracks and other openings in the building shell. See the stack effect question.

Q: What is the stack effect?

A: The stack effect refers to the situation that occurs when a house comes under negative pressure. During cold months of the year, warm inside air naturally rises to upper levels of a house. That warm air escapes through upper levels of the house in cracks around windows, doors, attic hatches and where dissimilar building materials meet. As that warm air escapes from the house, it has to be replaced. So it puts suction pressure on the lower levels of a house, including the basement. That negative pressure will pull in radon and other soil gases into the house.

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Q: What is the recommended R-value for attic insulation in New York State?

A: The U.S. Department of Energy has developed recommendations for insulation levels based on climate zones. New York has climate zones 5 and 6, depending on location within the state. Recommended R-values for attics in homes in Zone 5 are between 38 and 60. For Zone 6, the recommendation is R-49 to 60. You can enter your zip code to find recommendations for your home here:
http://www.ornl.gov/~roofs/Zip/ZipHome.html

Q: How often should my central heating system be serviced?

A: Servicing of central heating systems is essential to keep the system operating at its highest possible level of energy efficiency and for safety. A technician cleans the interior parts of the furnace or boiler to remove residues that build up as fuel is burned. The technician also inspects crucial parts of the system to make sure that combustion gases – carbon monoxide and others – cannot leak from inside the furnace and into the house. A fuel oil-fired system should be serviced every year. A natural gas or propane system should be serviced every two years. And if you use a wood-burning stove or fireplace in your home, those systems should be cleaned (including the chimney) and inspected every year.

Q: Would switching my heating fuel from fuel oil to gas save me money?

A: This question does not have an easy answer. There are many variables that affect your heating bill, including the efficiency of your heating system, your thermostat temperature setting, how airtight your house is, how much insulation you have in your attic and walls, efficiency levels of your windows, and more. The fuel type is just one of those variables. If you want to focus on that, here is a link to a Housing Fact Sheet that can help you through the calculations: http://www.human.cornell.edu/dea/outreach/loader.cfm?csModule=security/getfile&PageID=47808

Q: Why does turning CFLs on and off frequently lower their useful life?

A: When a CFL is turned on, there is a surge of electricity that is equivalent to what the CFL uses in five seconds of operation. So turning it off and on frequently decreases its useful life. The U.S. Environmental Protection Agency recommends that when you turn on a CFL, leave it on for at least 15 minutes to maximize its useful life.

Q: What does the temperature of a compact fluorescent lamp (CFL) refer to?

A: This chart from the U.S. Department of Energy illustrates temperatures that are used to describe the color quality of CFLs. Technically, lamp color is referred to as the Correlated Color Temperature and is measured in degrees Kelvin. Here are some color temperatures: typical desk lamp: 3,600K; the sun: 5,800K; blue sky: 6,500K. So you can see that as the color temperature increases, it moves from reddish to bluish.

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Q: What is an effective way to provide ventilation for my home?

A: For most homes in New York State, spot ventilation is effective. That means that mechanical ventilation is provided anywhere that moisture is produced: a bathroom exhaust fan ducted to the outdoors; an exhaust fan over the kitchen range and oven that is ducted to the outdoors; and a clothes dryer with a duct to the outdoors. Houses that are exceptionally airtight may need an air-to-air heat exchanger, also called a heat recovery ventilator. This is a whole-house unit that exhausts stale, moisture-laden indoor air to the outside, while it brings in fresh air from the outside. In the core of the heat exchanger, as the exiting house air passes the incoming fresh air, a series of conductive plates transfers the heat from the outgoing air to the incoming air. Moisture from the outgoing air condenses in the core and is directed to a drain. If a house with a heat exchanger has a furnace, the furnace duct system is also used to move air out of and into the house. If the house does not have a furnace, a separate duct system may be necessary.

Q: What happens if you over-insulate a house and get very bad moisture problems?

A: It is not possible to over-insulate a house. But it is possible to under-ventilate a house. Contrary to what you may hear, houses do not need to "breathe" through cracks and openings in the building envelope. Houses should be built airtight with techniques that assure they are airtight. If you depend on accidental ventilation – ventilation through cracks and other openings in the building envelope – to provide ventilation air for a house, consider what regulates this: topography, wind speed, and vegetation around the house site. In other words, occupant control features are lacking. Mechanical ventilation – either spot ventilation or that provided through an air-to-air heat exchanger – allows house occupants to exhaust moisture produced from showers, cooking, cleaning, and other activities and still have a house with a high level of energy efficiency.

Q: What is an orphaned water heater and what can be done to avoid problems associated with an orphaned water heater?

A: "Orphaned" water heater is a term used to describe a storage tank style residential domestic hot water heater that gets left alone as the only combustion appliance vented to a chimney after a furnace or boiler is removed. This usually happens when an older furnace or boiler is replaced by **a** new and much more efficient model. These newer heating systems capture more heat from the combustion process than older systems. The result is that the temperature of the flue gasses in newer systems is much lower compared to older, less efficient systems. Since the temperatures of the flue gasses are cooler, it makes it possible to vent them directly to the outdoors via a plastic pipe. A fan, built into the furnace or boiler is used to blow combustion gasses through the vent pipe directly to the outdoors.

To understand how orphaned water heaters can create problems, it is useful to first think about how a chimney works. A chimney is basically a hollow vertical column with an opening at the top that is exposed to the outdoors. The chimney also has an opening near the bottom that is typically accessed through the basement wall of the house. Exhaust gasses from combustion appliances are directed to this hole near the bottom of the chimney via a metal duct called a flue. Combustion appliances that are relatively inefficient loose lots of heat to the exhaust gasses. It is the heat contained within the combustion gasses that create the natural forces-hot air rises- that draws exhaust gasses up and out of the chimney. If the combustion gasses being directed to the chimney by a combustion appliance are not hot enough, or do not create a sufficient volume of hot air to initiate the draft of the gasses up the chimney, then the combustion gasses spill back into the home. Combustion gasses contain many harmful chemicals, including lethal carbon monoxide, so spillage of those gasses into a home can be very dangerous. And exhaust gasses from natural gas or liquefied petroleum gas (propane) appliances are virtually odorless and invisible. This means if spillage is occurring regularly in homes with orphaned gas water heaters, occupants are usually not aware of the problem until they begin experiencing negative health effects.

Spillage is not the only problem that can occur. Since combustion gasses contain significant amounts of water vapor, there is now a risk of condensation forming within the chimney. For example, on a cold winter day, the walls of the chimney may be cold enough so that the water vapor contained within the combustion gasses will condense. When this occurs over time, the acidic condensate can destroy the chimney.

How to avoid problems associated with an orphaned water heater:
The best method is to avoid the orphaned water heater in the first place. That is, replace your inefficient naturally vented water heater at the same time you replace an inefficient boiler or furnace. If you are replacing an old boiler this is easy. Simply have a new efficient boiler installed that also has an indirect tank and coil for heating domestic hot water. This is one of the most efficient ways to heat domestic hot water. Efficient boilers are vented directly to the outdoors, completely eliminating the need for the chimney.

If you are replacing a furnace, then you will also need a water heater. A typical storage tank water heater has an energy rating of only 59%. But there are other options for heating hot water more efficiently with water heaters that are direct-vented. Two good alternatives are demand (tankless) water heaters and condensing tank style water heaters.

Demand (tankless) water heaters are about 80% efficient and are also-vented directly to the outside. This eliminates the danger of combustion gas spillage inherent to naturally vented tank-style water heaters. For more information about on-demand water heaters see the question: What are the pros and cons of tankless/on demand heaters.

The other option is condensing tank style water heaters. This type of water heater is over 95% efficient. Condensing water heaters also vent directly to the outdoors and use a fan to blow exhaust gasses to the outside. This eliminates the risk of exhaust gasses spilling back into the home.

The drawback for many consumers is the cost of these efficient models. They cost 2 to 3 times as much as a typical tank-style naturally vented water heater. So if you purchased your standard storage tank water heater shortly before it became orphaned you may not want to go to the expense of replacing it right away. But you must be absolutely certain that your newly orphaned natural vented water heater can produce enough heat in the exhaust gasses to draft and draw exhaust gasses out of the house. This is not a job a homeowner can perform. Heating contractors trained and certified by an organization such as the Building Performance Institute or the National Comfort Institute follow a combustion safety protocol to test and verify that an orphaned water heater is safe. Be absolutely certain the heating technician you hire to do this work is certified. You and your family's lives may depend on it.

If your orphaned water heater fails the combustion safety test, you have two options. It may be possible to have a metal chimney liner placed in the existing chimney. This will decrease the diameter of the existing chimney, making it more likely that the flue gasses can produce enough heat in the chimney to create a draft. Stainless steel chimney liners are available and they are not susceptible to rust and corrosion, thus eliminating the problem of deterioration of the chimney caused by acidic flue gasses. Keep in mind that the cost of the liner and installation may be more than replacing the heater with a direct-vent model.

The other option is to replace the natural vent water heater with a more efficient, direct-vent water heater. As noted above, they are more expensive, but spending a few extra dollars will protect your family's safety and provide the added benefit of reducing water heating costs.

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Q: Weatherizing mobile homes - what can be done and how?

A: : In a 1990 study funded by the U.S. Department of Energy[1], researchers tested 10 weatherization measures on 3 different manufactured homes. All of these homes were manufactured prior to 1976 thermal standards set by the U.S. Department of Housing and Urban Development. Researchers placed each of the three homes in a large warehouse that was equipped with a climate control system that allowed the control of conditions the manufactured homes were exposed to. After establishing a baseline measurement, a single weatherization measure would be installed in each of the homes. Tests were then done for

[1] Judkoff, R.D., Hancock, C.E., and Franconi, E. (March 1990). "Testing the effectiveness of mobile home weatherization measures in a controlled environment: the SERI CMFERT Project". Prepared for the U.S. Department of Energy by the Solar Energy Research Institute. Golden Colorado. Date of access: February 22, 2011. Available from: 22http://www.nrel.gov/docs/legosti/old/3629.pdf

several days to determine the effect. This pattern was followed for all ten of the weatherization measures.

The ten weatherization measures were:

- Blower-door-directed air sealing and duct repair
- Furnace tune-up
- Interior storm window panels
- Window repairs and replacements
- Belly blow (fiberglass and cellulose)
  In manufactured homes there is a plastic or asphalt based membrane installed to protect the underside of the home from water while it is being transported, and also acts as a rodent barrier once the home is placed on site. This membrane is typically referred to as the "belly". Belly blow refers to blowing insulation into the underside of the home between the belly material and the underside of the floor.
- Belly wrap
  Belly wrap refers to covering the underside of the home with vinyl backed 6 inch thick fiberglass insulation.
- Skirting
- Roof blow (fiberglass and cellulose)
  In a manufactured home there is a small space between the top of the finished ceiling and the underside of the metal roof. Roof blow refers to blowing either fiberglass or cellulose insulation into this space.
- Roof cap
  Roof cap involves installing foam based rigid insulation board on top of the existing roof and then covering the rigid insulation with a new roofing material such as an elastomeric membrane.
- Wall insulation

The items that were found to be the most effective were:

- Blower door directed air sealing and duct repair
- Furnace tune-up
- Interior storm window panels
- Belly blow
- Roof blow (Investigators for this research project note roof blow is only recommended for manufactured homes in dry climates. This observation agrees with the experience reported by the weatherization director I contacted. His experience was that roof blows typically result in leaks in the thin gauge metal roof typical of so many manufactured homes.

Study authors also noted that skirting, insulated skirting and roof caps were less cost effective than the measures listed above. In addition they found that window and door replacement was never a cost effective option except when repairs would be more expensive than replacement costs. Interior storm panels were found to be much more effective than window replacements.

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Q: What causes ice dams?

A: Ice dams are caused when heat and warm air escapes from the heated living areas of a house into unheated attic areas (to learn how this warmer air is pushed out of heated areas of a house and into an unheated attic, see the question on the thermal stack effect). The escaping heat and warm air build up in the attic and increase the temperature enough so that any snow on the roof above the attic begins to melt. The melt water runs down the roof to the overhang area at the roof edge. Since there is no heat under the overhang, the melt water freezes. After a few days the melt water continues to freeze at the roof edge and builds up a thick layer of ice. This ice layer creates a dam behind which a puddle of melt water forms. Eventually this melt water works its way underneath roof shingles and into the house.

Fixing ice damming problems requires addressing 3 primary factors.

1) Prevent warm air in living spaces from infiltrating into the attic with a good air barrier between the heated portion of the house and the attic.

2) Prevent conductive heat loss between living areas of the home and the un-heated attic by making certain that attic insulation levels are adequate and that insulation is correctly installed. Remember that most insulation products work by trapping air. If all penetrations, cracks, and small holes in a ceiling are not plugged with an air impermeable material, the air leaking from the house will destroy the ability of the insulation to reduce conductive heat loss. And the warm heated air leaking out of the house and into the attic will increase heating costs and increase roof snow melt causing ice buildup at the roof edge.

3) Provide ventilation of non-heated attic spaces. The building code requirement is to provide 1 square foot of ventilation for each 300 square feet of attic area (flat ceilings). This is a minimum amount, and will only be effective at helping reducing ice damming in homes that have a good air barrier at the ceiling plane. For cathedral ceilings there should be soffit and ridge vents that provide air flow just under the roof deck in every cavity. A minimum two-inch airspace between the underside of the roof deck and top of the cavity insulation should be provided.

The time to address these issues is when a home is constructed. Making the above changes to existing homes is difficult and expensive. Buyers of newly constructed homes should insist that the builder meet ENERGY STAR requirements. It is not uncommon for newly constructed homes that meet energy code requirements to have ice damming problems. There are several reasons for this, but the primary reason is that codes lag several years behind the latest building science information.

If you would like more detailed information about roof ice damming and attic condensation problems and how to correct them you can down load the Housing Fact Sheet, *Causes and Cures of Attic Condensation and Roof Ice Damming Problems* at: http://www.human.cornell.edu/dea/outreach/loader.cfm?csModule=security/getfile&PageID=47813

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Q: What are the pros and cons of tankless water heaters?

A: Tankless, also called instantaneous or on-demand water heaters produce hot water only when a hot water faucet in the home is turned on. When hot water is called for, cold water flows into the tankless heater and travels through a series of coiled pipes. At the same time this is occurring, large gas burners turn on and apply a burst of heat to this coiled pipe. The result is that the cold water entering the coil, exits the coil as hot water.

Tankless water heaters, while common in Europe for decades, are relatively new to the United States. And while tankless water heaters are gaining popularity, storage tank style water heaters remain the most commonly used water heaters in the U.S. Tanks sizes typically range from 20 to 80 gallons. When a hot water faucet is turned on, hot water is drawn from the top of the tank and cold water flows into the bottom to replace the amount used. This method provides a large reservoir of hot water always ready to be used. However, because energy is required to keep this reservoir of water hot, tank type hot water systems consume energy even when you are not actually using hot water.

The energy efficiency advantage of a tankless heater, compared to a storage style water heater comes primarily from the absence of a large tank of water that requires frequent inputs of heat to keep the water in the tank hot. The energy losses of storage style water heaters are reflected in their low energy ratings, typically 59%. When you compare this to the 80% efficiency rating of a typical tankless water heater, you begin to understand the potential energy savings a tankless could provide.

However, there are other factors that should be considered before switching to a tankless style heater. One factor to be aware of is that there are other options for heating water that are more efficient than tankles heaters. Homes that use a high efficiency boiler for space heating can have an indirect tank and coil for heating domestic hot water installed. These systems have efficiency ratings above 90%. But this method only works for homes heated with a boiler.

Using a solar water heating system can significantly reduce hot water heating costs. The U.S. Department of Energy estimates that a solar hot water heating system can decrease the water heating bill for a typical household by 50% to 80%. The biggest drawback of a solar water heating system is the high initial cost to purchase the system components and have them installed.

Condensing storage water heaters are relative newcomers to the residential water heating market. These water heaters have efficiency ratings well above 90%. They do have a large storage tank to hold a reservoir of hot water, but the similarities with typical storage tank water heaters end there. They have a sealed combustion system and have a primary and secondary heat exchanger. These two heat exchangers pull so much heat from the combustion gasses that the water vapor contained in those gasses condenses. This phase change releases even more energy which is also transferred as heat to the water in the storage tank. In addition to the high efficiency of these water heaters an additional advantage is that the flue gasses are cool enough to be vented directly to the outside via plastic pipe. This means combustion gas spillage and other issues related to an orphaned conventional water heater do not apply to condensing storage water heaters.

Other pros and cons of tankless water heaters:

Venting/Safety

- Gas fired tankless water heaters are direct vented with a special fan that actively pushes combustion gasses out of the home, making them much safer than naturally vented storage tank style gas water heaters.

Durability/Life Expectancy

- Life of a storage tank style heater is about 7 to 10 years
- Life of an on-demand water heater is about 10 to 20 years.
- Some condensing type water heaters have long lasting stainless steel storage tanks.

Flow-Rates

Marketers like to claim that tankless water heaters will provide an endless flow of hot water. But this is true only if the demand for hot water is not greater that the heaters flow rate. For example, a 185,000 BTU gas on-demand unit can heat water at an incoming temperature of 75° to an output temperature of 120° and maintain a flow rate of about 6.5 gallons per minute. A dishwasher consumes about 1.5 gallons of hot water per minute and a showerhead about 2.5 gpm. So a demand water heater of this size, increasing incoming water by a temperature of 45° could easily maintain a flow of hot water for the dishwasher and a shower indefinitely. And there would be enough capacity to also supply hot water to a low-flow faucet for hand washing. But what if the incoming water temperature is 45°, typical of wintertime water temperatures in our region? Then the heater must increase the water temperature by 75° to get to the output temperature of 120°. In that case the 185,000 BTU demand water heater could maintain a flow rate of just 4 gallons of hot water per minute. Now the shower and dishwasher consume the entire flow rate of the on-demand heater. And if the person showering wanted an extra hot shower, a shower water temperature above 104°, the heater would not be able to supply the amount of hot water being demanded. If a homeowner wants a higher flow rate than this, then an on-demand heater with a larger burner size would need to be installed.

Other issues to consider:

If considering switching from a typical storage type heater to a tankless (on-demand heater) be aware that a larger diameter gas line will likely be required. In addition, demand style water heaters require a 115 volt electric line. So in addition to the cost of the new heater and installation costs, there will also likely be costs related to installing a larger gas line from the meter. In addition the services of an electrician may be required to run a wire to the new heater (typical storage tank water heaters do not require electricity).

Switching from a typical storage tank water heater to a tankless water heater can reduce your costs for heating hot water. And because these units are direct vented and use a fan to blow exhaust gasses out of the house, they are likely to be safer than standard storage tank heaters. But you must do your homework to make certain this type of heater will meet your needs. The most important item to consider is the flow rate of the unit. Homes on well systems will likely see entering water temperatures at 55° year round. And all homes across New York will likely experience entering water temperatures at or below 55° during colder months of the year. So be certain the unit will provide you with an adequate amount of hot water even when the entering water temperature is 55° or colder. And be certain that any price quotes you receive from contractors include all costs of installation, including larger gas lines and any wiring work required.

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Q: What's the verdict on solar tubes or solar tunnels? They don't use energy, but do they increase heating costs by allowing heated air to escape from a house?

A: Solar tubes, also referred to as tubular skylights or sun-tubes, are similar to skylights. They direct outdoor light through the roof of a house into interior spaces of a house (See Figure 1).

Figure 1: Light tube

The sun-tube is constructed from light gauge metal, similar to that used for heating duct work. As you can see from Figure 2, the top portion of the tube penetrates the house roof. A plastic or glass cap, called the dome, sits on top and lets light into the tube, but keeps rain and snow out. The tube extends through the attic of the house and penetrates the ceiling between the living area of the home and the attic. A plastic or glass diffuser is placed at the base of tube where it penetrates the ceiling. These devices work very well to get daylight into interior parts of a home and they are much easier to install than typical skylights.

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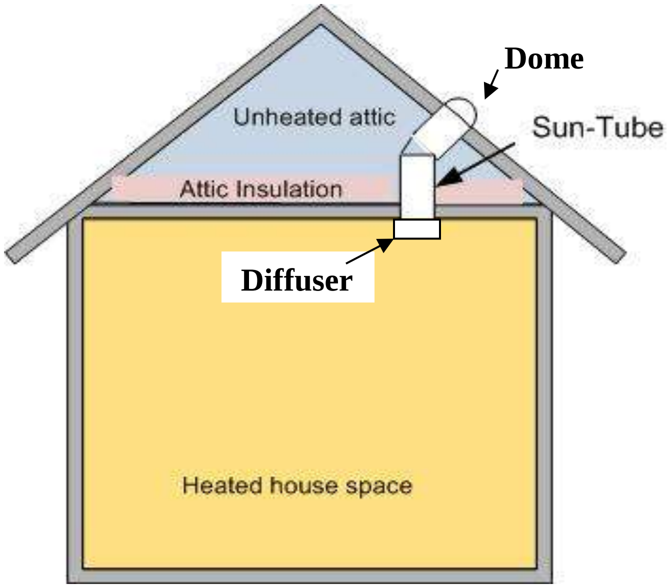

Figure 2: Parts of a Sun-Tube

As you can see, during cold months there is a potential for heat and warm air to escape from the home up the light tube. Since the walls of the light tube are very light gauge metal, heat from the home could quickly be lost into an unheated attic through the sides of the sun tube. However, many tubular skylight manufacturers provide diffusers that are designed to tightly seal to the tube and prevent any heated air from escaping from the house and getting into the light tube. Tubular skylights can also be purchased with diffusers that have multiple layers of glass or plastic with a sealed air-space between each layer. This significantly decreases conductive heat loss from the house into the light tube and eventually to the unheated attic.

If you are planning to purchase a tubular skylight for your home, be certain to buy one that has been rated by the National Fenestration Rating Council (NFRC). The NFRC is a non-profit organization that provides neutral third-party verification on the energy performance of windows, doors and skylights. And this includes tubular skylights. While manufacturers are not required to have their products rated or labeled by the NFRC, virtually all manufacturers that produce quality products do. So do not purchase a tubular skylight that does not have a NFRC label (see Figure 3).

Figure 3: NFRC Label

How to read the NFRC Label:

- U-Factor shows how well the tubular skylight prevents conductive heat loss. It is typically expressed as a number of 1 or less. The lower the U-Value, the better the product is at reducing heat loss.
- Solar Heat Gain Coefficient (SHGC) shows how well the product blocks incoming heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat the product lets into the house
- Visible Transmittance (VT)
  VT measures how much light comes through a product. VT is also expressed as a number between 0 and 1. The higher the VT, the more light transmitted indoors.
- Air leakage
  This is a measure of how much air leaks into/out of the unit through cracks in the assembly.
- Condensation Resistance
  This is a measure of how well the product resists the formation of condensation on its interior surface. The CR rating is listed as a number between 1 and 100. The higher the number, the better the product is at resisting condensation.

Building codes require a SHGC of 0.40 or less for skylights and tubular skylights in southern areas of the country where cooling loads are highest. In cold climates where heating costs are higher SHGC is not as important as the U-Factor. So there is no minimum requirement for SHGC in cold climates. However, there is a minimum building code requirement of U 0.45 or lower in cold areas of the country.

Consumers should be aware that code requirements are an absolute minimum. Many times products can be purchased that have efficiency ratings well above those required by code, and often the price of more efficient products is no more than less efficient products. Purchase ENERGY STAR labeled tubular skylights whenever possible. They have a U-Factor of 0.30 or less. You can determine which tubular skylight products meet this requirement by looking for and reading the attached NFRC label.

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Q: If compact fluorescent lights (CFLs) contain mercury and incandescent lights do not contain mercury, then how can CFL's be "green?"

A: Background Information on Mercury and Fluorescent Lights
All fluorescent lights, including compact fluorescent lights (CFLs), contain a small amount of elemental mercury. Electricity is passed through mercury vapor in a glass tube coated with phosphor. This causes the phosphor to fluoresce and creates what we call fluorescent light. It requires very little mercury to make this process work. For all fluorescent lights the average amount of mercury contained in each is about 4 milligrams (mg). However it is important to note that there are some CFLs on the market that contain as little as 1 mg of mercury per light.
Mercury is an element listed on the periodic table of chemical elements. Known as elemental mercury, it is used in thermometers, barometers, electrical switches, and is an essential component in fluorescent lighting. Mercury is also used in dental fillings. Called dental amalgam, it is composed of 40 to 50% mercury. The Centers for Disease Control report "scant evidence that the health of the vast majority of people with dental amalgam is compromised" (Mercury and Human Exposure, 2008).

Mercury is the only metal that occurs as a liquid at typical ambient temperatures. It can also occur in gas form at typical temperatures. Mercury is also contained in many organic and inorganic compounds. Of the various forms of mercury, methyl mercury is the most toxic (USGS, 2000).

Natural sources of mercury in the environment come from volcanoes, geological deposits and volatization of mercury from oceans. Human-created sources of mercury in the environment include combustion of coal and oil, cement production, lead, zinc, steel, and gold production; and incineration of municipal, chemical and medical wastes.

Combustion of fossil fuels -- mainly coal in utility, industrial, and residential boilers -- is the largest source of mercury in the environment (Pacyna *et al.*, 2006). And of these

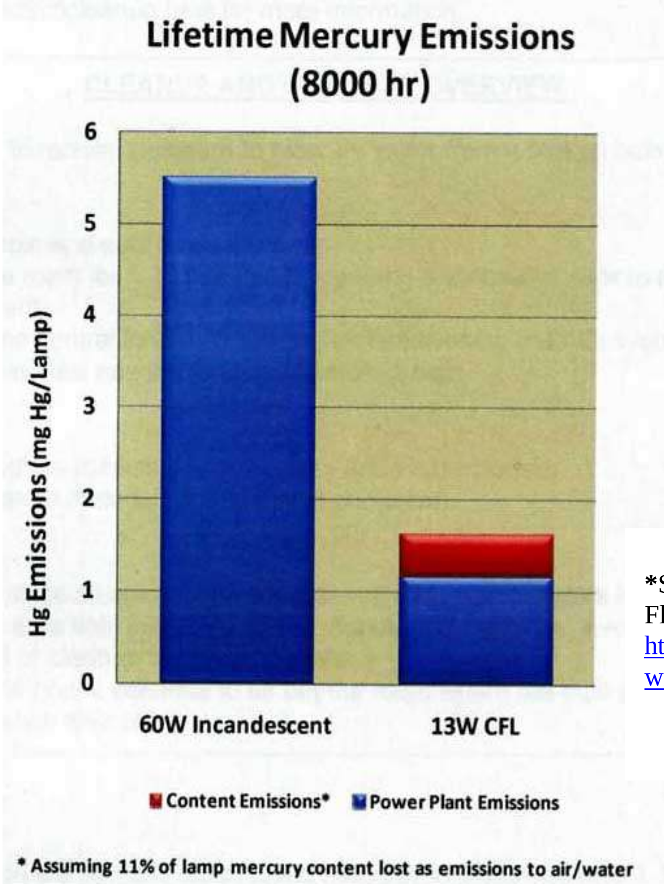
human created sources, the single largest source of elemental mercury in the atmosphere is from emissions of coal-burning power plants used to create electricity (U.S. EPA). Coal contains mercury, and when coal is burned to generate electricity, mercury contained in the coal is volatized and emitted into the atmosphere as elemental mercury.

The most common source of non-occupational exposure to mercury is from eating fish that have been contaminated with methyl mercury. Methyl mercury is created from atmospheric elemental mercury. Methylation of elemental mercury is a complex process, but basically works as follows: Rain washes elemental mercury from the atmosphere and it eventually finds its way into rivers, lakes, and oceans. Bacteria take up mercury from water and convert it to methyl mercury. These bacteria are consumed by the next organism up the food chain and so it goes, with each organism accumulating the methyl mercury consumed by all previous organisms. This process, known as bioaccumulation, concentrates mercury levels in the fish at the top of the food chain. In commercial fish species the highest amounts of methyl mercury are found in sharks, swordfish, king mackerel and albacore tuna. These are also some of the most commonly consumed fish that people eat.

In New York State many game fish contain levels of mercury so high that they are considered unsafe to eat. In fact, most lakes in the Adirondack region have an outright ban for women under 50 and children under age 15 for eating fish caught from those lakes. In addition, women over 50 and men over age 15 are advised to eat no more than 1 meal of fish per week from most of these lakes. To learn more about fish-eating advisories in New York waters go to: http://www.health.ny.gov/environmental/outdoors/fish/fish.htm#advisory
What does all of this have to do with using CFLs instead of incandescent lights? It has to do with the fact that the use of fluorescent lights instead of incandescent lights significantly reduces the overall amount of mercury in the environment. For example, a 60 watt incandescent light will produce almost 300% more mercury in the environment compared to a 13-watt 8,000 hour CFL (see Figure 1).

Other advantages of fluorescent lighting are that it produces the same amount of light as incandescent lighting, but consumes 75% less electricity. Since a typical household spends about 20% of annual electrical costs on lighting, homeowners can reduce their annual electric bills by 15% just by switching from incandescent to fluorescent lighting. There likely is no other step for reducing annual energy costs in a home that is as easy, or as inexpensive, to carry out.

To summarize, fluorescent lights produce 300% less mercury in the environment than incandescent lights; they produce four times more light per watt of electricity used, and they reduce the average homeowner's electricity consumption by about 15%. All of this is strong evidence that using fluorescent lighting is much greener than using incandescent lighting.



*Source of graphic: : U.S.EPA Information on Compact Fluorescent Light Bulbs (CFLs) and Mercury, Nov. 2010 http://www.energystar.gov/ia/partners/promotions/change_light/downloads/Fact_Sheet_Mercury.pdf

Figure 1: Comparing mercury emissions of CFL with incandescent lamps

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Q: Thermostat setbacks reduce heating costs. The standard advice is that for each 1 degree reduction per 8 hour period there is about a 1% reduction in annual heating costs. Is this an accurate prediction?

A: There can be no question that turning down the temperature setting on a home thermostat during the heating season will reduce heating energy consumption and thus save money on home heating costs. We know this from basic physics – heat always travels from warm to cold and the higher the temperature difference across a surface-- a wall that separates warm areas from cold areas for example-- the higher the heat flow will be. Reducing the temperature difference across a wall that separates heated from unheated space will always reduce heat flow. It is fairly easy to calculate how much heat will flow from the warm side of a wall to the cold side of a wall using heat-load calculations or computer energy modeling. Using those tools we can make predictions on energy savings of various thermostat settings. We can also estimate the dollar amount of these savings.

There have also been research projects that have compared actual houses as a way to determine how much heat energy can be reduced from various thermostat setbacks. One such project was done by the Canadian Center for Housing Technology (CCHT). This organization conducted itsinvestigation using two identical houses. They examined both wintertime and summertime thermostat adjustments to determine cost savings related to decreased thermostat settings. Below is a brief description of this research and the findings. Note that only the heating scenarios are discussed here. To see a more detailed description of the study go to http://www.homeenergy.org/article_full.php?id=566

Two identical 2-story homes built in 1998 with identical specifications and both constructed by the same builder were used in this study. During the heating season of 2002-2003 the CCHT conducted a series of tests on these two homes to determine the effectiveness of various thermostat set-backs One of these two houses was designated as the reference house, the other as the test house. Three different thermostat settings in the test house were compared to the baseline setting of 72° F in the reference house. Gas consumption of the furnaces was measured as well as the electrical consumption of the air handler (the fan) within each furnace.

The three thermostat set-backs settings were

- One 7-hour set-back period per day from 11 pm to 6 am. The set-back was 8°- from 72° to 64°. This was done in the test house for 13 days. Gas and electrical consumption of the test house was compared with that of the reference house where the thermostat always remained at 72°.

- Two 7-hour thermostat setbacks per day, for a total of 14 hours each day when the thermostat setting was reduced by 8°. One setback period was from 9am to 4 pm and the other was from 11 pm to 6 am. Again, both setbacks went from 72° to 64°.
- The same two 7 hour thermostat setbacks per day as listed in case 2, for a total of 14 hours each day. But in this case the setback was 11°: from 72° to 61°. This scenario was implemented for a period of 7 days.

Study Results:

- The greatest savings occurred on the coldest and cloudiest day when the low temperature of the day was minus 15°F and the high was 4°F.
- All setbacks reduced the furnace fan and furnace run time, reducing both gas consumption and electricity consumption.

From study results the investigators projected the following savings over an entire heating season.

- For the single nightly set-back of 8° for a seven hour period, researchers estimated annual savings of 6.5% for gas consumption and 0.8% for electrical consumption from reduced run time of the air-handler fan, for total annual energy savings of 7.3%.
- For two 8° set-back periods per day, one at night, the other during the day, both for seven hours. Annual estimated gas savings were 10.4% and electrical savings were estimated at 1.9%.for a total annual energy savings of 12.3%.
- And for the two 11° set-back periods per day, one at night, the other during the day, both for seven hours, the estimated annual gas savings was 13.4% and the electrical savings was estimated at 2.3%, for total annual energy savings of 15.7%.

How do the above results compare to the U.S. Department of Energy prediction that, "by turning your thermostat back 10° to 15° for 8 hours, you can save about 5% to 15% a year on your heating bill – a savings of as much as 1% for each degree if the setback is 8 hours long" (http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720

The results of the CCHT study support the DOE prediction. For example, the CCHT study showed an annual savings on energy consumption for heating of 7.3% for a single nightly setback of 8° for a seven- hour period. This represents a savings of 1% per year for each degree the thermostat was setback for the seven-hour period.

For the two seven-hour setback periods of 8°, the CCHT study calculated an annual energy savings on heating costs of 12.3%. While this was a bit shy of the 1% per year for each degree of thermostat set-back, it is still very close to the upper level of savings that DOE predicts. And the 15.7% energy savings for the two 11° set-backs over separate seven hour periods, while not at the upper end of DOE prediction of savings, certainly fell within the range of savings that DOE predicts for thermostat setbacks. A 15.7% savings on an annual heating bill of $ 2,000 works out to be $314, certainly a significant savings.

Keep in mind that predictions on the amount of savings for thermostat set-backs are very general. Houses are all different. They have varying levels of insulation, different north-south orientations, and many other differences that would affect savings due to thermostat set-backs. While it may not be impossible to precisely predict annual energy savings for thermostat set-backs for a specific home, you can be absolutely certain that thermostat setbacks will result in significantly lower annual heating bills in your home.

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Q: Should attic insulation be added before or after a roof replacement job?

A: Usually it makes little difference whether or not insulation is added to a home before or after a roof replacement. However there are some circumstances where adding insulation just prior to a roof replacement project can have definite advantages. For example, it is often extremely difficult to add insulation to attic areas of existing Cape Cod style houses. As you can see from Figure 1, this style house does not have a full second story, but instead uses the underside of roof rafters as part of the enclosure of the second floor space. Cape Cod style homes also have roof dormers that further complicate the job of retrofitting insulation into this style home.

Figure 1: Cape Style House

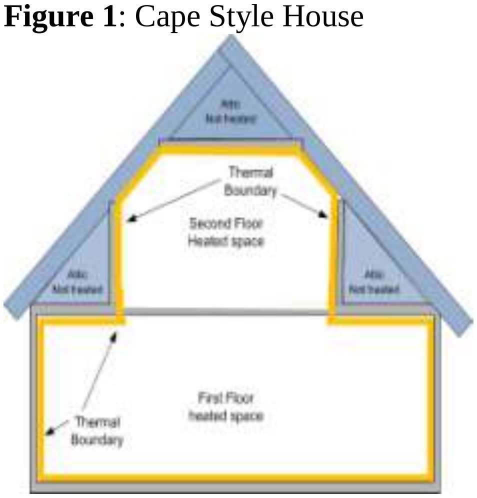

Figure 2: Section drawing of Cape Style House

As you can see from looking at a Section of a typical Cape-Cod style house, (See Figure 2) adding insulation to the tiny attic above the second floor living space would be extremely difficult in an existing home. There is usually not enough room for a person to get into the space and do the work. Holes can be drilled in the ceiling from the interior of the house and insulation can be blown in via those holes, but that makes a mess and is disruptive to the homeowner family. And since this method requires more work of the contractor to protect living spaces from insulation dust and to patch holes when finished, it is also expensive.

By insulating when the roof is being replaced, the insulation work can be done from the outside (see Figure 3, on page 2). The old roofing material would be stripped and then roof boards could be removed or holes could be drilled in roof sheathing to allow insulation to be blown into these difficult to reach spaces. roofing material. .

Figure 3: Installing attic insulation from the roof.
Photo by Steve Culpepper,
Fine Homebuilding magazine

Of course this would require coordination between the roofing contractor and insulation contractor. The insulation crew would immediately go to work after the roofing crew stripped the roof. Once the insulation work was done the roofing crew would install the new

Figure 4: Italianate Style House

There are other types of houses besides Capes where this method might allow the most convenient access to an attic for insulating purposes. Italianate style houses were popular in the late 19^{th} century across much of upstate NY (See Figure 4). These houses had shallow pitched, hip-style roofs, making them very difficult and sometimes impossible to work in to add insulation. Adding insulation in conjunction with a roof replacement would also work well for this style home.

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Q: Does the strategy of setting back the thermostat to save money on heating bills of 1% per year for each 1° set-back per 8 hour period translate to similar savings with air conditioning during summertime? In other words, can you save the same percentage on A/C by adjusting the thermostat UP?

The short answer is no, the 1% annual savings per degree setback per 8 hour period does not translate to A.C. savings. More detailed information is provided below:

A search revealed much less information available concerning the effect of air-conditioning (A.C.) thermostat "set-ups" compared to heating system set-backs. I found many sources that recommended setting the A.C. thermostat as high as possible, while still maintaining comfort for occupants. And many sources recommended turning off the A.C. when occupants are not at home. The state of California Energy Commission states that 1% to 3% per degree can be saved for each degree the thermostat is set above 72°. But no research was cited to back up those numbers.

In searching I also found a research article published by Marianne Armstrong[2] with the *National Research Council Canada*, located in Ottawa, Canada. She did this work at *Twin House Facility* at the *Canadian Centre for Housing Technology* built in 1998. "It consists of two identical two-story houses" (Armstrong, p.38, 2008). Armstrong called one house the "reference house" and the other the "test house". She varied thermostat settings in the test house and compared results (indoor relative humidity, energy consumption and fan run times/electrical consumption) in the test house to the reference house to determine effects of various thermostat setting strategies. Armstrong did this for both the heating season and the cooling season. I will report findings only for the cooling season.

Armstrong tested two types of thermostat setting strategies for saving electrical consumption for running the A.C. system during the cooling season. One, which was called a "Day Setforward" strategy involved setting the thermostat up during the day, when occupants would typically be at work, from 72° to 77° and then tuning it back to 72° when occupants would normally return home. The other strategy involved keeping the thermostat at 75° instead of 72°, basically a higher setting all the time.

The "Day set-forward" strategy did produce significant savings on sunny days - about 21%. But on cloudy days the savings amounted to just 2.8%. Another drawback to this strategy, especially on sunny days, was that at the end of the day, when occupants would return and set back the thermostat from 77° to 72°, it took several hours for the house to get down to the lower temperature. The author notes this could possibly affect occupant comfort on hot summer nights. At the conclusion of the article the author states

> "*with current house technology, it is much easier to add heat to an indoor environment than to remove it. For this reason the summer energy saving strategy needs to be different from the winter energy-saving strategy. During the cooling experiments, the higher temperature setting produced consistently greater savings than the setforward strategy"…."furnace*

[2] Access article at: http://www.homeenergy.org/show/article/id/566

circulation fan and A/C electrical savings of 23% for the cooling season were calculated based on monitored results (p.42)".

So by simply keeping the thermostat set-point at 75° instead of 72°, an annual savings of 23% was realized.
It should be noted that the cooling system tested in this study was a central air system with an outdoor coil/compressor and an indoor coil located within the furnace supply air plenum. The furnace air handler fan circulates the cooled air throughout the house. This is a probably the most common type of central A.C. system. However, ground source heat pumps are becoming more common and likely operate differently from the system tested in this study. In addition ducted mini-split systems are also becoming more popular. The point being, we probably cannot assume the results of this study translate to other types of whole-house cooling systems. And they certainly should not be compared with window type air-conditioners.

Air conditioning (AC) accounts for just 1% of energy consumption in New York households, which gives some perspective on how much attention to give cooling during the *Save Energy Save Dollars* classes. However, it is important to note that 73% of New Yorkers use either central AC or window AC units during the cooling season. And according to *Climate Change Facts*, New York State has seen an increase in the number of summer days at or above 90° and this upward trend is likely to continue (http://www.nrcc.cornell.edu/climate_change/climate_earth.pdf
So we can expect that cooling costs will likely increase in the future as a percentage of the typical New Yorkers annual home energy consumption/cost. Empower educators may want to point out to workshop participants that the most effective strategies for significantly reducing heating energy consumption; insulation and air sealing improvements to the buildings enclosure, are also the most effective methods for reducing cooling costs.

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Q: If you know the temperature is going to plummet overnight – say it's 35 F when you go to bed, but you know it will be below zero when you wake up – does it make sense to heat your house more in the evening before so it's not working so hard in the morning?

The short answer is no, this strategy will not reduce heating consumption. Many folks do not realize that a house is constantly loosing heat to the outdoors during colder months. While it seems to make sense that if we heat our home to a higher temperature prior to an extra cold night we can "store" some of that heat and our heating system will not have to work as hard during a bitter cold night. But heat cannot be "stored" by doing this. Heat constantly travels from warmer areas to colder areas and the higher the temperature difference between warmer indoor spaces and the colder outdoors, the faster the flow of heat out of the house. So if I set my thermostat at 80° when the outdoor temperature is 35°, I am not really storing heat in my home. What I am doing is heating my house to a warmer temperature compared to the outdoor temperature and creating a greater temperature difference between indoors and outdoors. This greater temperature difference, much warmer indoors compared to outdoors, increases the rate of heat flow from my heated indoor spaces to the colder outdoors. So by following this strategy you would actually use more heat, not less.

Detailed Answer:

For those that want to understand the details behind the short answer I have set up examples that use simple heat loss calculations developed by engineers to show that no heat energy is conserved by following this strategy. I have used two different heat-loss formulas to illustrate heat flow from inside a house to the outdoors at various outdoor temperatures. One of the formulas is used to calculate heat loss due to conductive heat flows; the other is used to calculate heat loss due to air leakage into/out of a house via small holes and cracks in the building enclosure. Most of us call air-leakage "cold drafts"- building scientists call it "infiltration/exfiltration".

The formulas used to calculate heat loss related to conduction is:

$$\mathbf{Q = \frac{A}{R}\ X\ (\Delta T)}$$

Don't let the above symbols scare you. They represent everyday terms we are all familiar with.

Q = heat loss from conduction in BTU per hour
A = the area of the wall assembly we want to calculate heat flow for
R = Total R-value of the wall assembly we are calculating heat flow through
ΔT = simply means the difference in temperature between the indoors and the outdoors.

The formula used to calculate heat loss related to infiltration/exfiltration is:

$$\mathbf{Q_i = (0.018)\ (N)\ (V)\ (\Delta T)}$$

Q_i =	Heat loss due to infiltration/exfiltration
0.018 =	Heat capacity of air
N =	Number of natural air changes per hour between indoors and outdoors,
V =	Interior volume of the house
ΔT =	Inside temperature minus outside temperature

To obtain numbers to plug into these equations I used data I collected from a home my sister recently purchased in Cazenovia NY. Her home was built in the early 1970's and is a single story (ranch style) home that measures 42 feet x 24 feet with an interior ceiling height of 7'-8". I calculated the area of the stud cavities of the wood-frame walls, the area of the portion of the walls that are solid wood, the area of the windows and the exterior doors. I also calculated the area of the ceiling/attic. To simplify my example I assumed no heat loss thru floor areas. I determined the R-values of each of these areas, and to determine the rate of heat loss due to infiltration/exfiltration I did a blower door test on this house and then calculated what its natural air exchange rate is between indoors and outdoors. All of this information is listed in Table 1.

Table 1: Area and R-values of house enclosure components

Component	Net Area	R-Value
Wall cavities	685 sq. feet	R-10.3
Solid wood portion of walls	121 sq. feet	R-5.3
Windows	165 sq. ft.	R-3
Doors	40 sq. feet	R-7.5
Ceiling: Rafter cavities	857 sq. ft.	R-6.8
Ceiling, solid wood (at rafters)	151 sq. ft.	R-9.8
Natural air exchange rate between indoors and outdoors: (ACH_N) = 1.1		
Volume of interior heated space: 7,721 cubic feet		

Now it is just a matter of plugging these numbers in to our formulas at the various temperature differences between indoors and outdoors:

With outdoor temperature at 35° and the house thermostat (T-stat) set at 70° we have a temperature difference between indoors and outdoors of 35° (this is the ΔT value).

Conductive heat loss formula is: $Q = \frac{A}{R}$ X (ΔT)

°

Conductive heat loss: inside temperature 70, outside temperature: 35					
	Area (sq. ft)	R-Value	A/R	ΔT	Q (BTU/Hour)
Wall cavity	685	10.3	66.5	35	2327.67
walls-solid wood	121	5.3	22.8	35	799.06
Windows	165	3	55.0	35	1925.00
Doors	40.0	7.5	5.3	35	186.67
Ceiling-Rafter cavities	857.0	16.5	51.9	35	1817.88
Ceiling @ Rafters	151	6.8	22.2	35	777.21
				Total =	7833

Infiltration/Exfiltration Heat Loss of Residence					
Qi =(0.018) (N) (V) (Delta T)	Heat capacity of air	ACH^N	N	Delta T	Qi (BTU/Hour)
	0.018	1.1	7721 Cu. Ft.	35	5,351

For each hour the temperature difference between inside and outside is 35°, 13,184 BTU per hour is needed to keep the indoor temperature of this house at 70°. (7,833 BTU to make up for conductive heat losses, plus 5,351 to make up for infiltration/exfiltration heat losses).

What happens if we set the house thermostat at 80° while the outdoor temperature is 35 to build up heat in the house in anticipation of the outdoor temperature dropping? In this case our ΔT will be 80 – 35 = 45°

conductive heat loss: inside temperature 70, outside temperature: 35					
	Area	R-Value	A/R	Delta T	Q
Wall cavity	685	10.3	66.5	45	2992.718
walls-solid wood	121	5.3	22.8	45	1027.36
Windows	165	3	55.0	45	2475.00
Doors	40.0	7.5	5.3	45	240.00
Ceiling-Rafter cavities	857.0	16.5	51.9	45	2337.27
Ceiling @ Rafters	151	6.8	22.2	45	999.26
				Total =	10072

Infiltration Heat Loss of Residence					
Qi =(0.018) (N) (V) (Delta T)	air cap.	Volume	ACH^N	Delta T	Qi
Q_i = Infiltration heat loss	0.018	7721	1.1	45	6,879

For each hour the temperature difference between inside and outside is 45°, 16,951 BTU per hour is needed to keep the indoor temperature of this house at 80°. (10,072 BTU to make up for conductive heat losses, plus 6,879 to make up for infiltration/exfiltration heat losses).

What would happen to the rate of heat loss in our example house if the outdoor temperature fell to minus 10° and we have our thermostat set at 70°, creating a temperature difference between indoors and outdoors (ΔT) of 80°?

Conductive heat loss: inside temperature 70, outside temperature: -10°					
	Area	R-Value	A/R	Delta T	Q
Wall cavity	685	10.3	66.5	80	5320.388
walls-solid wood	121	5.3	22.8	80	1826.42
Windows	165	3	55.0	80	4400.00
Doors	40.0	7.5	5.3	80	426.67
Ceiling-Rafter cavities	857.0	16.5	51.9	80	4155.15
Ceiling @ Rafters	151	6.8	22.2	80	1776.47
				Total =	17905

Infiltration Heat Loss of Residence					
Qi =(0.018) (N) (V) (Delta T)	air cap.	Volume	ACH^N	Delta T	Qi
Q_i = Infiltration heat loss	0.018	7721	1.1	80	12,230

In this case the temperature difference between inside and outside is 80° and 30,135 BTU per hour is needed to keep the indoor temperature of this house at 70°. (17,905 BTU to make up for conductive heat losses, plus 12,230 to make up for infiltration/exfiltration heat losses).

Plugging this information into our two different heat strategies we find:

Strategy 1: No adjustment made to thermostat in expectation of a bitter cold night.

8:00^{AM} till 8:00^{PM} (12 hours) the outdoor temperature is 35°, then at 8:00^{PM} the outdoor temperature drops to minus 10° till 8:00^{AM} the next morning (a 12 hour period). During this 24 hour period we keep the home thermostat set at 70°.

8:00^{AM} till 8:00^{PM}	**8:00^{PM} till 8:00^{AM}**
Indoor Temperature 70°/ Outdoor Temperature 35°	**Indoor Temperature 70°/ Outdoor Temperature minus 10°**
Heat required for this period: 158,208 BTU	**Heat required for this period: 361,620 BTU**
Total heat needed for this 24 hour period: 519,828 BTU	

Strategy 2: Thermostat is set at 80° during the 12 hour warmer portion of day (to "build-up" heat) in expectation of a bitter cold night.

8:00^{AM} till 8:00^{PM} (12 hours) the outdoor temperature is 35°, then at 8:00^{PM} the outdoor temperature drops to minus 10° till 8:00^{AM} the next morning (a 12 hour period). During this 24 hour period we keep the home thermostat set at 70°.

8:00^{AM} till 8:00^{PM}	**8:00^{PM} till 8:00^{AM}**
Indoor Temperature 80°/ Outdoor Temperature 35°	**Indoor Temperature 70°/ Outdoor Temperature minus 10°**
Heat required for this 12 hour period: 203,412 BTU	**Heat required for this period: 361,620 BTU**
Total heat needed for this 24 hour period: 565,032 BTU	

As you can see this strategy does not help us conserve heat. It actually causes more heat loss, 45,204 more BTU than if we had left the thermostat alone.

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Q: If you use a non-vented propane heater are you doubling its efficiency because it's not venting outside, so all heat is staying inside?

Non-vented propane and natural gas space heaters are more efficient than vented heaters, but not twice as efficient. Manufacturers of non-vented space heaters claim they have a combustion efficiency of 99.9%. Vented propane and natural gas space heaters have a combustion efficiency of about 80%, making the non-vented types of heaters about 20% more efficient. **Note:** *The high efficiency of non-vented heaters is not because the heater is not vented, but because the heater has been manufactured to be so extremely efficient that it's not absolutely necessary to vent it to the outdoors.*

Non-vented heaters are manufactured to create the near perfect mix of fuel to air to obtain very close to 100% combustion. For example, complete combustion of propane requires exactly 1 part propane to 24 parts air. If the propane heater always operates extremely close to this precise fuel to air ratio nearly 100% combustion is obtained. Complete (100%) combustion means that every last bit of fuel is burned (combusted). With 100% combustion there are none of the by-products of incompletely burned fossil fuel – carbon monoxide, sulfur oxides or nitrous oxides.

Nearly 100% combustion does deliver nearly all of the heat content of the fuel to the interior spaces of the home. This may make it seem like a good idea to purchase a non-vented propane or natural gas space heater. But building scientists and indoor air quality experts discourage their use – for two primary reasons.

- First, even with 100% complete combustion, there are still by-products of the combustion process. Those by-products are carbon dioxide and water in the form of water vapor. A non-vented heating appliance dumps both of those combustion by-products directly into the homes indoor air. Manufacturers address the carbon dioxide emissions by installing oxygen sensors on the heaters. If the sensor detects that a room's percentage of oxygen is falling below a set percentage, meaning that CO_2 levels are increasing, the sensor shuts off the heater. But there is no such device that monitors water vapor levels, and the combustion process generates a lot of it. For example a 20,000 BTU heater produces 20 ounces of water vapor if it burned continuously for one hour. If it burned an average of 6 hours during a 24 hour period, it would add 120 ounces (3.75 quarts, which is almost one gallon) of water vapor to the air each day. That is a lot of water vapor, and typically will create condensation and potentially mold problems in homes.
- Secondly, non-vented space heaters, when operating correctly, are 99.9% efficient. This means there is still a small amount of fuel that is not burned, and as mentioned this incomplete combustion will generate some carbon monoxide, sulfur oxides or nitrous oxides. At 99.9% combustion, the amounts of these pollutants will be very small. Small enough that in New York State it is legal to install a non-vented natural gas or propane space heater in your home. But since there is no vent directing the combustion gasses to the outdoors, even those minute levels are dumped directly into the indoor air of your home.

Purchasing highly efficient heating appliances is an important step in reducing home heating costs and increasing comfort on bitter cold nights. But maintaining good indoor air quality is also very important, especially during the heating months when homes are closed up as tight as possible. I agree with the point of view that it makes more sense to purchase a vented portable propane or gas heater and sacrifice a bit of combustion efficiency, but reap the benefit of better indoor air quality as a result. But the final decision on whether to buy and use a non-vented space heater is up to individual homeowners. As long as they are making an informed decision and are aware of the both the benefits and drawbacks of using a non-vented heater, then it's their business. I would say to someone that plans on buying a non-vented heater to carefully read the directions that come with the appliance. I would also strongly recommend the use of a digital hygrometer to monitor indoor relative humidity levels (they should not be much above 50%). And don't forget to purchase and install a carbon monoxide detector/alarm.

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Q: Are they eventually going to stop making incandescent bulbs? If so what happens to all the appliance light-bulbs (refrigerator, oven, etc.)? Can they be CFL or LED?

As of January 1, 2014 manufacturers will stop making standard incandescent 60 and 40 watt bulbs. Standard 100 and 75 watt incandescent bulbs were phased out last year. But manufacturers and retailers are still allowed to sell existing inventories so you will likely be able to purchase these types of bulbs for months to come. Also, halogens, a different type of incandescent bulb will continue to be manufactured. Halogens use 28% less energy than standard incandescent lamps, but have many of the features that people like about typical incandescent bulbs, including their ability to be dimmed.

40 watt incandescent appliance lamps are exempt from the phase-out, so will continue to be available for stoves and refrigerators. Incandescent black lights, yellow bug lights and plant grow-lights are also exempted which means they will continue to be manufactured and available for purchase.

Some new refrigerators are already using LED bulbs and as the price of LEDs drops they will likely replace incandescent bulbs as appliance lamps in refrigerators. However, it is not as clear what might replace appliance lamps in ovens. Fluorescent and LED lamps do not do well in high heat environments, even in enclosed ceiling light cans, so it seems unlikely they will soon be showing up as oven appliance lights.

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Q: What are the issues related to accidentally breaking a fluorescent light in your home?

A: Many media stories have brought to the public's attention that fluorescent lights contain elemental mercury which is a toxic metal. This raises the question about potential harm within your home if a fluorescent light is accidentally broken. Does a broken compact fluorescent light (CFL) pose a significant risk of exposure to elemental mercury? The United States Environmental Protection Agency (EPA) notes that risk from exposure to elemental mercury is related primarily to the risk of inhaling mercury vapor that evaporates from the released mercury vapor. It is important to realize that we are always exposed to a basic background level of elemental mercury. In the United States, the level of elemental mercury in the outdoor air across the country varies between 2 nanograms (2ng/m^3) and 10 nanograms per cubic meter of air (10 ng/m^3). A nanogram is equal to 1 billionth of a gram. The EPA sets the **Reference Concentration (RfC)** for exposure to elemental mercury at 300 ng/m^3 [i]. Basically this is EPA's best estimate, based on current research and risk assessment calculations, of exposure to mercury in the air that does not impose a significant risk to human health over a lifetime of exposure. This includes sensitive sub-groups such as children, infants and pregnant women.

The RfC is guidance for long-term exposure risks. What about short, but relatively high exposure levels? For work exposures, the current Occupational Safety and Health Administrations (OSHA) permissible exposure level (PEL) for mercury vapor is 100,000 ng/m^3[ii]. This means that a worker should not be exposed to this level of mercury vapor even for a very short period of time.

What about short, but high exposures outside the workplace? No exposure level has been published. Therefore, there is some guidance for homeowners on what constitutes a long-term exposure risk to elemental mercury, but none for short-term, relatively high exposures. And release of mercury vapor from a broken CFL would create a short term exposure. This raises the question; just how high is the typical short-term exposure to mercury from a broken CFL? Findings published in the *Maine Compact Fluorescent Lamp Breakage Study*[iii] help answer that question. This study was conducted in 2007 by the Maine Department of Environmental Protection (Maine DEP).

Maine DEP investigators monitored the levels of elemental mercury in the air when CFLs were broken in a room that was 11’4” x 12’1” with 10’ceilings - a room similar in size to an average bedroom. There were windows on three sides of the room, but only one 30-inch x 38-inch window was opened for the breakage scenarios that included ventilation of the room. New CFLs from seven different manufacturers and various wattage levels were intentionally broken to measure the amount of mercury vapor released. A total of 35 CFLs were broken over different types of flooring: wood flooring, short-pile carpeted flooring, and long pile (shag) carpeted flooring. Never-used lights were broken by smashing them with a hammer. This was done to obtain the highest possible mercury concentration levels, because new CFLs contain higher levels of mercury than used CFLs. Immediately after each break, air concentrations of elemental mercury were measured with analyzing equipment. Mercury measurements were taken at a 1-foot height and 5-feet height directly above the breakage spot. The 1-foot height was selected as it is in the breathing zone of a crawling infant, and the 5-feet height was selected because it is in the breathing zone of the typical adult.

Researchers measured the initial spike in mercury concentrations immediately after each CFL was broken at both the 1-foot and 5-feet levels above the floor. They also measured mercury concentrations at intervals of every 5 seconds for a period of one hour immediately following the break. Those readings were averaged to obtain a mercury air-concentration over a one hour period. Table 1 provides the average mercury concentrations for all 35 breaks the Maine DEP researchers reported in Appendix A, Table A- Summary Results for All Scenarios. Data summarized for this article includes the breaks where ventilation and recommended cleanup guidelines were followed, and the worst case scenario breaks – breaks where no ventilation was supplied, and no cleanup was done.

Table 1

Initial Spike (ng/m^{3})		**Average concentration over 1 hour (ng/m^{3})**	
5 feet above floor	**1 foot above floor**	**5 feet above floor**	**1 foot above floor**
2,523 ng/m^3	**19,318 ng/m^3**	**733 ng/m^3**	**940 ng/m^3**

The mercury concentrations listed in Table 1 are the amounts of mercury in billionths of a gram per cubic meter of air (ng/m^3). Such small metric numbers are difficult for most of us to understand. To put these numbers in perspective, it is helpful to compare them to the likely dose of mercury a person would receive from eating a meal of fish. It is well known that fish - both from fresh water lakes and streams and commercial seafood - contain significant amounts of methyl mercury. The Federal Food and Drug Administration (FDA) warns "women who might become pregnant, women who are pregnant, nursing mothers, and young children[iv]" to not eat more than one 6-ounce meal of albacore ("white") tuna per week, because of the typical amount of methyl mercury contained in that fish. Methyl mercury is considered much more toxic than elemental mercury.

The likely dose of methyl mercury from eating a 6-ounce meal of albacore tuna is about 63,344 ng of methyl mercury. A two ounce portion would contain about 21,448 ng of methyl mercury. Looking at Table 1 it can be seen that the average spike in elemental mercury concentrations immediately following, and just 1 foot above a broken CFL is 19,318 ng/m$^{3)}$. Therefore eating just a 2-ounce portion of albacore tuna would result in a higher exposure to a more toxic form of mercury than being 1 foot above a CFL at the very moment it is broken and inhaling every nanogram of elemental mercury following the break.[v]

In 1999-2000 there was a National Health and Nutrition Examination Survey conducted by the Centers for Disease Control. As part of that study the CDC tested a large sample of humans to determine blood-level concentrations of methyl mercury. That survey found that – "*16 to 49-year old women showed that approximately 8% of women in the survey had blood mercury concentrations greater than 5.8 ug/L (which is a blood mercury level equivalent to the current RfD). Based on this prevalence for the overall U.S. population of women of reproductive age and the number of U.S. births each year, it is estimated that more than 300,000 newborns each year may have increased risk of learning disabilities associated with in utero exposure to methyl mercury.*[vi]" Reducing the amount of mercury emitted into the environment from burning coal to produce electricity will reduce the amount of methyl mercury in our lakes, streams, and oceans. This in turn will reduce the amount of methyl mercury contained in fish and seafood. Using fluorescent lights instead of incandescent will actually reduce our exposure to mercury.

It would be incorrect to draw the conclusion from information in this article that precautions do not need to be taken if a CFL is accidentally broken in your home. Data from the Maine DEP project illustrated that mercury concentrations in indoor air were much higher after a CFL break if clean-up guidelines were not followed. In a worst-case breakage scenario, Maine DEP researchers smashed a 26-watt CFL with no ventilation of the room. For clean-up, only the larger pieces of the broken CFL were picked up. But they were not removed from the room. They were placed in the trash within the room where the break occurred. The smaller pieces of the broken CFL were then cleaned up using a vacuum with a beater attachment. This acted to further disperse the mercury into the air of the room. As can be seen from the information in

Table 2, this resulted in relatively high levels of mercury suspended in the air of the room above the breakage site.

Table 2: Worst Case Breakage Scenario

Initial Spike (ng/m^3)		Average concentration over 1 hour (ng/m^3)	
5 feet above floor	1 foot above floor	5 feet above floor	1 foot above floor
23,720 ng/m^3	133,955 ng/m^3	16,814 ng/m^3	21,262 ng/m^3

Comparing information about exposure to elemental mercury related to a broken CFL obtained from the Maine DEP study to exposure of methyl mercury related to eating fish illustrates that the risk of mercury exposure related to broken CFLs has been exaggerated in many media reports. However, some consumers continue to struggle with the choice of whether to use energy efficient fluorescent lights that contain a small amount of mercury, or much less efficient incandescent lights. People want to feel safe and secure in their homes, so media reports that lead people to believe that a broken CFL might threaten their well-being and that of their children are alarming. The dilemma is that if most of us choose incandescent lighting over more efficient fluorescent lighting, then we all become exposed to higher levels of mercury.
There are solutions for those consumers extremely concerned about accidentally breaking a fluorescent light in their home: At the time of the Maine DEP study, CFLs contained on average 4 mg of mercury (Calwell & Banwell, 2008).[vii] But in 2007 some manufactures were producing CFLs that contained as little as 1.5 mg of mercury. Maine DEP researchers noted that when they broke a CFL known to have lower mercury content, results showed that it produced low mercury concentrations in the room where the break occurred. This is important information for consumers because there are currently CFLs available that contain as little as 1 mg of mercury. Therefore consumers can purchase CFLs with low levels of mercury as a method to limit exposure to elemental mercury if a CFL is accidentally broken (see listing of sources for low-mercury CFLs at the end of this document).

For consumers who just cannot bring themselves to use fluorescent lighting in their homes, screw-based LED lights for use in incandescent fixtures are now available. The efficiency of LED lighting is approaching that of fluorescent lighting, and is expected to get even better in a few years. While these lights are expensive, they do provide a method for consumers to maintain a zero risk of exposure to mercury within their home (if they also do not eat fish) and also reduce the atmospheric load of mercury that affects all of us.

Resources:

- For Guidelines on how to safely clean up a broken fluorescent light go to: http://www.epa.gov/cfl/cflcleanup-detailed.html

References:

[i] **United States Environmental Protection Agency. Technology Transfer Network Air Toxics Website. Mercury Compounds. http://www.epa.gov/ttnatw01/hlthef/mercury.html Accessed May 31, 2011.**

[ii] United States Department of Labor. Occupational Safety and Health Administration. Occupational Safety and Health Guideline for Mercury Vapor. http://www.osha.gov/SLTC/healthguidelines/mercuryvapor/recognition.html Accessed May, 2011.

[iii] Maine compact fluorescent lamp study report, February, 2008. Study was conductedby the Maine Department of Environmental Protection, Bureau of Remediation & Waste Management. http://maine.gov/dep/rwm/homeowner/cflreport.htm. Accessed March 3, 2008.

[iv] What you need to know about mercury in fish and shellfish (March 2004). Accessed on 6/15/2011., http://www.fda.gov/food/foodsafety/productspecificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115662.htm

[v] These numbers were calculated with information obtained from the document, Mercury Levels in Commercial Fish and Shellfish. U.S. Food and Drug Administration http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115644.htm Accessed, June 9, 2011.

[vi] United States Environmental Protection Agency. Mercury Human Exposure. http://www.epa.gov/mercury/exposure.htm. Accessed May 31, 2011.

[vii] Calwell, V. Banwell, P., CFLs, Mercury and Mayhem! The energy efficiency community responds. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

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