How Homeowners Can Cut GHG Emissions

December 2021, by Court Olson, colson@optimumbldg.com

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INTRODUCTION

To reduce the carbon footprint of a home there are a few low-cost and simple things listed below that can be done right away. Other more costly steps can be accomplished in scheduled phases over time as outlined farther below. Nearly all of these steps will reduce greenhouse gas (GHG) emissions. Most steps will also shrink a homeowner's combined utility bills.

With interest rates currently close to all-time lows, those homeowners having good credit would be wise to consider using a home improvement line of credit to fund at least some of such improvements. Homeowners with low income may wish to apply for funding assistance offered by the State of Washington's Weatherization Programs; you can find those program details at https://www.commerce.wa.gov/growing-the-economy/energy/weatherization-and-energy-efficiency/ .

Also, utility incentives and rebate programs may help reduce the cost of some of these investments.

RIGHT AWAY:

1. Make an improvements implementation schedule and a financing plan for phasing GHG cutting improvements over time. (See phased improvements list below).
2. Replace old style incandescent light bulbs (no matter how new) with LED bulbs.
3. Discuss conservation habits with all family members, including the following.
    a. Turn off lights in unoccupied spaces, or install motion detectors to do that for you.
    b. Turn off radios, TVs, computers and other appliances when not in use.
    c. Minimize the opening of refrigerator & freezer doors.
    d. Minimize use of hot water. Use cold whenever possible and set the hot water temperature low to avoid scalding, but still be comfortably warm.
    e. When possible, dry clothes on clothes lines or drying racks rather than a clothes dryer.
    f. Run only full loads in dishwasher, clothes washer, and clothes dryer.
    g. Cook more with microwave oven rather than conventional oven.
    h. Keep doors and windows closed tightly when fresh air is not desired.
    i. Caulk and seal around any exterior wall penetrations (i.e. doors, windows, light fixtures, ducts and piping).
    j. Don't leave water running and minimize water use with conserving faucet heads.
4. Weather strip doors and windows so that they seal tightly.
5. If night lights are in use, make sure that they have motion sensors so that they turn off when spaces aren't in use.

PHASED IMPROVEMENTS:

Note: The order of items listed in this section corresponds roughly with the greater GHG reduction potential going first. This doesn't mean that it is necessarily wise to do them in this order.

1. **Heat pump space heating**. Switching to electric heat pump for space heating saves on heating bills, and it substantially lowers a home's carbon footprint. Plus, heat pumps have the advantage of being able to both heat a home in winter and cool it on warm summer days. That said, it is wise to seriously tackle weatherization issues before buying a new space heating system. (See Paragraph #6, below). That's because if your home is poorly insulated, and/or leaky, correcting those issues first may allow you to downsize your new space heating equipment, and thereby save some purchase cost. Also, the weatherization improvements will allow your new heating system to run less often, which will save you in utility bills year after year, and likely make the new system last longer.

   There are other additional reasons to plan ahead for the switch to a heat pump system, too. Don't wait until your current furnace dies, because some advanced planning is needed to make the switch. In homes with gas or oil heat, a heat pump will add electrical load, so a larger electrical panel may be need to be installed before the switch is made. (See paragraph #2, below.) In any case, heat pump installation should be scheduled before the predicted end of life of the existing gas or oil furnace. Also, it is best to schedule the work for a mild weather season, since the home may be without heat for a day or two while the switch is made.

[Note: Because many heat pump systems currently use hydrofluorocarbon refrigerants that have very big climate-warming greenhouse impacts if they get released into the atmosphere, be sure that the installer carefully checks the heat pump refrigerant piping for leaks before they charge the lines with refrigerant. That said, new regulations that I understand will go into effect some time in 2022 will require the use of refrigerants having much lower potential GHG impacts.]

a. Ducted heat pump split systems are good for replacing existing furnaces that burn gas or oil and feed an existing circulating air duct network in the home. These typically cost more than a new gas furnace, but their operating costs for heating tend to be lower, so operating savings may offset the higher initial purchase cost. Also, heat pumps add a cooling option. (Note: If a heat pump system is replacing a gas furnace, the size of the electric panel in the home may need to be increased. See more in paragraph #7 below.)

   i. Air-to-air split systems are the most common type of heat pump space conditioning. They typically have two separated units, hence the name "split system." The interior heat pump unit sits inside the home where the old gas or oil furnace was; it has within it a fan to circulate conditioned air through the home's existing duct system. Circulating refrigerant piping connects the interior unit to an outdoor unit that looks much like a conventional air conditioner. (The outdoor unit has a heat exchanger coil inside it with a fan that blows air over it). The interior unit also has a condensate drain discharge line; that condensate water is typically piped to a floor drain or pumped out of the home with a small pump that is attached to tubing that carries the condensate outside. Most of today's air-to air heat pumps can work when outside temperatures drop to as low as 20^{o} F.

   An example of an air-to-air split system is shown below.

Inside unit ->  Outside unit-> 

(The inside unit sits on the old gas furnace pad, and its blower connects to existing air ducts.)

ii. Ground source heat pump systems are an alternative to air-to-air systems. They are effective regardless of the outside air temperature, since they exchange heat with the ground rather than with the air. (FYI, below 3ft, the ground stays a steady temperature of about 55° F year-round). A soil test must be done beforehand to determine if the local soil type is suitably conductive. These systems circulate a fluid through underground piping which is typically installed in drilled holes. (Coiled lines that lay flat below the ground surface are a less common option). Ground source heat pump systems are typically more expensive to install than air-to-air systems. That said, in September 2021, I saw a ground source system being installed at an existing 1950s era home in the Lake Hill Bellevue neighborhood. (See photos below.)

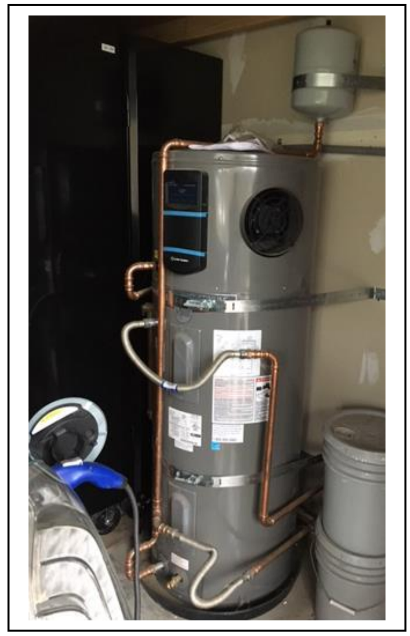
Drilling rig for a ground-source heat pump's circulating refrigerant lines.

b. Mini split and through-wall ductless units. Ductless heat pump systems are a good option for homes that don't have existing forced air ducts. Ductless heat pumps may be as simple as a single through-the-wall unit, like we see in many hotel rooms. However, there are also ductless "mini-split" systems that can connect to multiple parts of a home. Even with multiple interior units, the mini-split systems typically have a single exterior condensing unit (much like the one pictured above for the air-to-air system). The exterior condensing unit connects through refrigerant lines with up to four or five interior wall mounted units in different parts of a home, depending on the manufacturer's recommendations.

Pictured here is a typical wall mounted unit. Each interior wall mounted unit has a fan that circulates and conditions the air in the room where it is located. Such mini-split systems are a good concept for replacing baseboard electric heater systems because they use much less electricity. Though they are typically quiet, some people don't like the idea of taking up interior wall space with such units.

2. **Upsizing the home electrical panel** may be necessary to accommodate the added electrical load created by switching from a gas furnace to a space heating heat pump system. Adding other electric appliances may increase the power demands, too. This panel work should be done before the old gas or oil furnace is replaced. A new electrical panel may add a thousand dollars or more to the cost of switching to a heat pump. However, an enlarged electric panel is a one-time expense that can also allow the homeowner to add electrical outlets, and/or add other electric appliances (e. g. water heaters, electric stoves, E.V outlets, etc.). In addition to adding such extra benefits, a larger panel also adds value to a home.

3. **Heat pump water heaters.** After space heating, hot water heating is usually the next biggest energy demand in the home. Typically, heat pump water heaters save energy over conventional water heaters, and their life-cycle cost is competitive with natural gas water heaters. So, it makes sense to replace either a conventional electric water heater or a gas water heater with a modern heat pump water heater. They cost a little more than conventional water heaters to buy and install, but they typically save in operating costs. When the electric grid is largely renewable power sourced, heat pump water heaters can greatly cut greenhouse gas emissions.



   Heat pump water heaters "steal" their heat from the air in the room where they are located. (BTW, if you don't want the room to be cooled, split systems are available with a separate outdoor air heat exchanger, but these are more costly than the commonly available packaged units). Heat pump water heaters are electric, so they require an electrical hookup. They also need a condensate discharge line which can either flow by gravity into a floor drain, or be pumped outside the home using a small pump.

   Be sure to schedule the replacement of your conventional water heater well ahead of its life expectancy expiration (which may be as little as eight to ten years). Because many plumbers don't readily have immediate access to heat pump water heaters in their warehouses, and because an electrician is required to connect them to your electric panel, even in an emergency you may have to wait several days to get one installed. Consequently, it is best to have the switch out all planned in advance so that you are only without hot water for a few hours, instead of days. By the way, if your favorite plumber can't get one right away, some local big box stores (e. g. Home Depot) do typically have heat pump water heaters in stock.

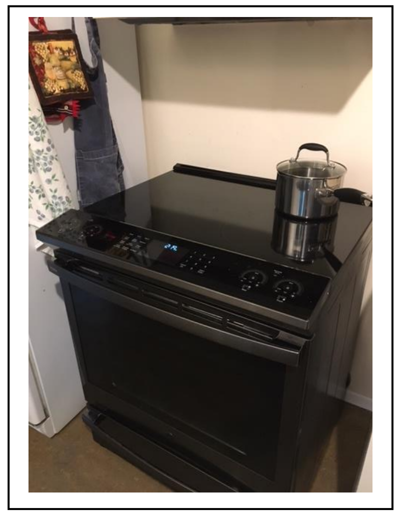
4. **Hot water circulation pumps** can be installed to avoid excessive hot water waste while waiting for the shower water to get warm. They can be switched on a few minutes before using the shower, so, without any waste, they will circulate the cool water in the line through the hot water tank to get it hot. These typically cost under $500, but they do require an electrical outlet close by, and a spliced tap into a circulating hot water line, which you'll probably want a plumber to do for you.

5. **Energy efficient electric appliances**. Newer appliances with good Energy Star ratings are typically more efficient than older ones.

   a. Refrigerators and freezers are the next biggest energy demanding item in the home, after space heating equipment and after water heaters. If you have an older one, replacing it with a new one that has a good Energy Star rating may cut your energy consumption significantly, and thereby lower your carbon footprint.

   b. Clothes dryers are typically the next most energy demanding appliance in the home. Energy efficient heat pump clothes dryers have recently become available. Based on the prices I see online ($900 to $1500), they are more expensive than traditional dryers. While I suspect that they are a lot less expensive to operate, I haven't yet seen comparative data. I expect that they will significantly lower a home's carbon footprint, especially if you use the dryer a lot, or if you have a gas dryer right now. Of course, the most energy conscious alternative of all is to air dry your clothes on a rack or a clothesline.

   c. Electric induction stove tops are great for conserving energy. They typically boil water faster than a gas stove. More importantly, they don't have the unhealthy and hazardous combustion by-products that gas stoves have, so they are better for your health. Induction stove tops are also much more energy efficient than conventional electric stove tops, so they will cut your carbon footprint, regardless of what type you have now. Their glass tops are also much easier to keep clean.



   Fully combined range and oven stoves are more expensive than conventional stoves, but they do save on energy bills. For renters or those with very tight budgets, separate single or double "burner" induction units that sit on a countertop are available. One thing to remember is that only steel pots and pans work with induction stove tops, so you may need to buy a few new pots and pans; you'll want to make sure that they have thickened steel bottoms to avoid having them warp when heated up rapidly.

   d. Other appliances, especially older clothes washers and dishwashers, should be replaced with Energy Star electric models that have high efficiency ratings. Also, to further conserve energy, all plug-in electronic devices should have automatic shut off timers for when they're not in use.

6. **Heat loss improvements, or "weatherization".** Whatever the type of space heating equipment a home has, it will run a lot less often and use less energy if the home is well insulated, weather tight, and has highly rated window assemblies. If you are considering replacing your heating equipment with a heat pump system, taking steps to first reduce heat loss and gain through the exterior building envelope might save some money by allowing you to downsize the new space heating (and cooling) equipment. Envelope improvements will also save money in energy bills month after month.

   a) Heat loss background. As you review improvement options, you should keep in mind that heat can travel through the exterior envelope of homes (and other buildings) in five ways:

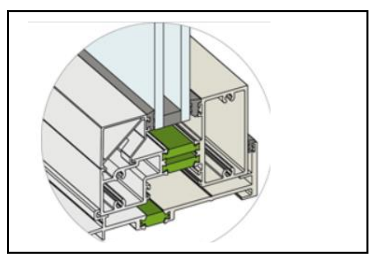
i. by thermal conductance through rigid materials;
ii. by radiant heat from a heat source;
iii. by air leakage passing through cracks and gaps;
iv. by circular convection air currents moving on wall surfaces --even those inside an empty wall space; and,
v. by sunlight beaming through windows.

b) Detecting heat losses. Infra-red camera imagery is a fairly easy and low-cost way of identifying where heat losses are occurring across exterior wall surfaces. Images are best taken on a cold winter day so that the temperature variations will be clear and distinct. Well insulated portions of a wall will have cold exterior surfaces that will appear dark blue in color. Somewhat warmer surfaces will be green, and still warmer surfaces will be yellow. Very warm surfaces will be red. For about $250, a homeowner who is adept at reading instructions for electronic devices may choose to purchase their own infra-red camera and then take the photos themselves. However, that money might be better spent hiring a consultant with good knowledge of construction wall assemblies to take the photographs, since a trained professional will probably be better able to interpret the photos and offer hypotheses on the causes and possible solutions to the temperature variations that are revealed.

c) Thermal conductance through solid materials can be slowed by choosing building materials that don't conduct heat rapidly. Everyone knows that metals are fast heat conductors and wood is a slow heat conductor, but even wood can conduct heat from one side of a wall to the other. We call such conductance through a wall a "*thermal bridge*". To reduce heat conductance through a wall we need to interrupt heat flow through any solid thermal bridging material. The way to do that is to create a gap in such solid materials which we call a "*thermal break".*

For example, not long ago, aluminum framed windows were popular in homes. Few of them had a thermal break inside of the frame, however, so the metal on the inside face of the window frame was continuously connected straight through the wall to the outside air. Consequently, heat was conducted straight through the wall. Often, on cold days, the water vapor in the air of an interior room would condense on the cold metal window frame, making them appear to "sweat". Window frames made of wood, fiberglass, or vinyl are much less conductive than metal, and typically aren't cold to the touch, especially if they also have a thermal break inside of the frame that interrupts conductance from the interior to the exterior of the wall. Also, they don't "sweat".

To the right is an example of a thermally broken metal window frame.



d) Vapor barrier considerations are very important when insulating a home. Otherwise, water vapor travels through walls from the warm inside toward the cooler outside (in fall, winter and spring), and it will condense at the dew point temperature inside of the wall, thereby giving mold an opportunity to grow in the wall cavity at that point. Many interior wall paints are available that will create a vapor barrier. (Check the label.) However, just painting the walls with the right paint isn't enough. You must also make sure that all wall edges and intersections are completely sealed. That means having good sealant around window and door openings, and also at the intersection of the floor surface and the wall. There is often a gap left between the flooring and the wall, and that gap is typically hidden by floor edge molding; you can usually easily remove the edge molding, seal the gap with backer rod and caulking, and then replace the edge molding.

e) Insulation. Properly installed insulation will retard heat loss through a building's enclosure (that is its walls, roof, and ground interfacing surfaces). Insulation itself is not very expensive. Neither is the installation, provided that there is easy access. Continuity of insulation is very important; inconsistencies and gaps are great opportunities for heat loss, and they are fairly common. (Infra-red imagery will usually pick up such gaps, if there are any.) If your home is over 50 years old, it may have very little insulation, because earlier building codes didn't require much. For example, my Bellevue home that was built in 1957 originally had no wall insulation.

   i. Insulating walls. If there is no insulation in the space between a home's inside gypsum wall board (GWB) and the exterior "skin" material, then convection currents in the hidden air space will transfer heat between the inside and outside planes of the wall assembly. If insulation is installed in that air space, it will keep such convection currents from developing.

   The Washington building code didn't require insulation in that empty wall space prior to sometime in the 1960s. Also, until very recently, wood framed homes were built using 2x4 lumber onto which both the interior gypsum wall board and the exterior skin were directly attached; that allowed the wood framing in the wall to conduct some heat from one side of the wall assembly to the other. Consequently, when there is insulation in the spaces between the studs, on a cold winter day, an infra-red camera image will outline where the wood framing meets the exterior wall material.

   In a typical older home with 2x4 framing, if a contractor blows fiberglass, mineral wool, or cellulose into the nominally 4-inch wall air space (through small drilled holes), the highest achievable insulation rating is about R15. A higher rating may be achieved if a contractor sprays expanding (foaming) chemical insulation in the cavity, but my personal preference is to avoid such products because of the vapors that they give off. Mineral wool (also called "rock wool") and cellulose are the most environmentally friendly insulation options, so I prefer them. Be aware that, if the insulation by itself has an R15 rating, the wall assembly won't rate that high; that's because the wood framing takes up space in the wall and it is not as good an insulator. Today, walls in new homes must have R21 insulation. Also, new homes typically have a 6-inch insulated air space that is created using staggered 2x4 studs, so that the studs are covered by insulation on one side or the other, and, therefore, they have no direct "bridge" between the inside and the outside wall planes.

   If you want to have more than R15 wall insulation in your existing home, and you want to reduce the conductance of heat through the wood framing, you'll need to have a contractor thicken your walls and install insulation in a way that covers over the wood framing, thereby inhibiting the thermal conductance or "bridging" effect of the wood. Doing that is considerably more expensive that just blowing insulation into the existing wall cavities. However, if you choose to do that, you can also easily add plywood sheathing over the wood frame to improve seismic resilience, and then cover that plywood with a tight weather barrier that will help cut down air leaks.

The photo here shows one approach to thickening the wall insulation in a 1950s era home. After new windows were installed, new siding is shown being attached to vertical furring strips that hold up rigid rock wool insulation boards which cover over the weather barrier wrap (Tyvek, in this case) which covers over plywood sheathing (hidden from view here) which is nailed onto the existing 2x4 wood framing after batt insulation was installed in the empty air space between the wood studs. This assembly leaves a free draining "rain screen" air space between the siding and the rigid insulation. That air space is open at the bottom, such that any moisture that penetrates the siding or the window framing assembly will drain down and out of the wall (over the metal flashing at the base of the wall, which is tucked under the Tyvek sheet). This air space allows the wall assembly behind the siding to dry out in the event that moisture ever gets in.

The second photo shows how the window framing was trimmed out on the same project.

Putting on a new building "skin" like this example also provides a good opportunity to add new windows and get them properly sealed into the wall assembly. The cost to remove the existing exterior siding, install insulation between existing studs, nail on plywood sheathing, install the building wrap, add two or three inches of rigid insulation board wrapping around the whole house, and then add furring and new siding, might be about $75,000 for a 1200 sq. ft. rambler. Add in new triple pane windows for another $25,000 to $30,000. (All costs are based on 2021 prices).

ii. <u>Insulating attics and roofs</u>. Because warm air rises, homes typically lose a lot of heat through the roof. Today, new homes are required to have R49 above the ceiling. Adding insulation in an attic space is easy and highly recommended. If you don't have an attic, you can have insulation blown into the space between roof joists (from holes in your ceiling, not the roof membrane). Then, whenever you replace your roof (which typically happens about every 20 years or so) you can have rigid insulation board put down on the roof deck before a new roof membrane is applied over the top. You might achieve R20 with blown insulation in between the joists, and perhaps another R21 with six inches of rigid insulation added above the roof framing. (FYI, rigid rock wool insulation comes in 2, 3, 5 and 6-inch thicknesses.)

iii. Insulating basements & crawl Spaces. If you have a basement, you'd be wise to add insulation to the walls. Typically, that means furring out the walls with wood framing, putting in batt insulation between studs, and then adding paneling or GWB to cover the studs and insulation. Putting in a raised basement floor and adding insulation in the air space created beneath the raised floor will also reduce heat loss.

If one has only a crawl space below the ground level floor, adding insulation in between the joists that support the floor is a good idea. In the crawl space, it is wise to insulate the foundation walls with rigid insulation, too. It's also important that you have a vapor barrier installed over the bare ground and lap it up the foundation walls to keep out moisture.

f) Air leakage is a common problem in all but brand-new homes. That's because until very recently, the State building code did not require homebuilders to test for air leakage during construction. Consequently, most of us with homes built under previous editions of the State building code are losing a lot of energy though drafty joints around wall openings, and in gaps that occur at the seams and edges of the building enclosure materials.

Today, there are consultants in the market place who will do what is called a blower door test that will tell you how tight or leaky your home is. When they are performing such tests, they can also do what are called smoke tests, using smoking wands, to see where the air is coming through the walls. Those are the places where the application of sealants or other weather barriers should be undertaken. A good consultant will recommend the best corrective measures to take.

g) Windows. The heat transferring qualities of glass and of window framing assemblies have been greatly improved in recent decades. If a home has old windows, even if they are double glazed, replacement should be considered. For starters, a quick refresh of paragraph 6-c (above) on thermal conductance is recommended.

Several different types of windows are available today. Windows may be single, double or triple pane. Single pane windows allow a lot of heat transfer, so they are not recommended. Glass variations include tempered, safety, film coated, tinted and even self-tinting types. Today, solar reflecting films are commonly applied to a glass surface to impede solar heat gain. These coatings are usually found on an inaccessible surface that is inside of a double or triple pane window assembly. Gaps between multiple glass panes are commonly filled with air or with Argon gas; Argon reduces the heat transmission somewhat better than air does.

Frames can be made of aluminum, steel, vinyl, fiberglass, wood or some combination of these. Any frame type should be thermally broken to cut down heat loss. Vinyl plastics are especially vulnerable to deterioration from sunlight over several years, though some newer plastics have additives that inhibit this.

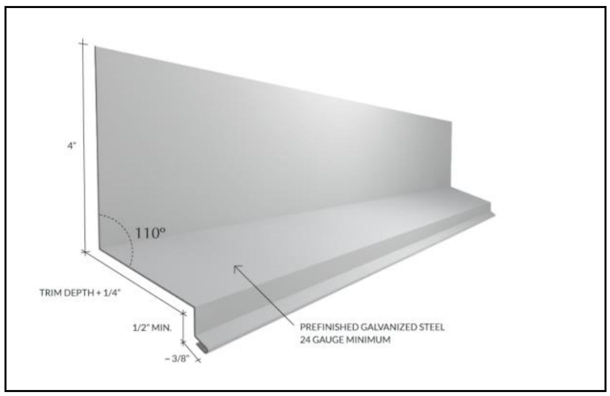
When looking for new windows, carefully check for the "U-value" rating of the window ***assembly*** –not the glass by itself. (The lower the U-value, the better the insulating qualities). The current code for new homes requires a U-value below 30. I recommend a U-value below 25. Some double pane windows with special solar reflective coatings can get a rating that low. Triple glazing is more costly, but typically has lower U-values and is better insulating.

The degree of a window's ability to reflect solar radiation is categorized by its Solar Reflectance Index (SRI). This is more important on windows that that receive a lot of sunlight in the summer. Some homeowners may also be concerned about a window's sound transmitting qualities, which are indicated by the window's STC rating.

A big concern in replacing existing windows is getting a proper air and moisture seal around the window opening –on all sides. Properly sealing and flashing at the head, sill, and jambs (sides) is quite tricky, especially if you are not also replacing the exterior surface of the building at the same time. Even if you are, it can be messed up and lead to moisture and mold problems down the road. To give you an idea of the complexities, here is a link to one flashing tape manufacturer's installation video: https://www.youtube.com/watch?v=I5ooeVc39XY.
There are a few other flashing tapes like the one shown in that video, but there are also liquid applied flashing products, as shown in this video:
https://www.youtube.com/watch?v=vV3DbVDg83E

Though a slightly sloping sill frame is not shown in the above demonstration videos, my architect (George Ostrow with Velocepede Design) recommends them because, if any moisture gets inside of the window-frame-to-wall-frame joints, it will drain down to the sill. A tilting and protruding wood sill framing piece will direct the water out and away from the window opening and from the wall assembly. This sloping sill piece should be flashed first (like the sills in the referenced videos), before the jambs and the head flashings are applied.

By the way, my architect also recommends a protruding (metal) head flashing which should be tucked under the building wrap material, just above the window. Such flashing is not shown in the videos above, but it is pictured to the right, here.

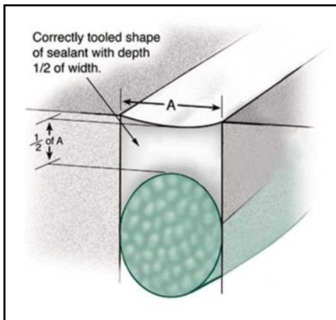


After the framed window opening is properly flashed, it is important that the window be installed midway between the interior and exterior surfaces of the wall. For this reason, and the fact that any nailing at the sill and head would compromise the flashing membrane and could thereby lead to moisture penetration inside the wall, the use of nailing "fins" that surround the edges of some window frames is discouraged. (If the new windows come with nailing fins attached, in most cases they can be easily removed, as pictured to the right).

Removing a nail-fin from a vinyl window ...

Once a window is set into place, it is important that any gaps between the window frame and the flashed window opening be filled with insulation.

Backer rod and caulking should be applied around both the interior and exterior edges of the framed opening, too, except that no caulking is applied at the sill on the exterior side, so that any water intrusion will be able to drain out across the sloping sill frame there.



Caulk and backer rod in ideal 'hour-glass' configuration.

7. **Shading** is an important tool for reducing the solar warming of a home in the summer --especially on the south and west facing walls. As our summers get warmer, and more people install heat pumps or air conditioners, shading will help reduce electric loads. Deciduous trees are best for summer shading, since they lose their leaves in the winter, and thereby allow the sun to warm the home in the heating season.

8. **Chimneys and fireplaces** are problematic sources of heat loss. They often pose moisture control problems, too. Traditionally wood burning fireplaces were used to heat homes. However, most fireplaces in homes today are rarely used, drafty, and, unless logs are burning, they are typically sources of significant heat loss. Most fireplace dampers do not seal the chimney tight, so hot air escapes up the chimney. Even if the damper does seal relatively tight, there is typically no insulation in the damper to impede heat transfer, so heat still rises up the chimney. Also, as masonry chimneys age, the mortar joints can deteriorate allowing moisture in; furthermore, roof flashings around chimneys can be leaky. So, given these issues, and the fact that today we often have burning bans in effect, it can make good sense to remove a fireplace and chimney. The most opportune time to do this is when a roof replacement is being done. For a single-story home, that might cost $5,000 to $7,000 (in 2021 dollars), assuming that you do this at the same time as installing a new roof.

   By the way, both log-burning and gas fireplaces have potentially significant carbon footprints. Consequently, their removal makes sense from a GHG emission reduction standpoint.

   If the esthetic value of a fireplace is important, there are many electric fireplace wall-inserts available today that can come close to the look of a real fire.

9. **Roof replacement.** Regardless of the roofing type, its replacement will eventually need to be scheduled. Depending on the type, a roof may last 10 to 25 years. When replacement is scheduled, the type of new roofing should be carefully chosen. That is also an opportune time to consider other related improvements.

   Choosing a light color roofing material can not only reduce a home's heat gain in the summer, but it can also have an environmental benefit by increasing the earth's reflectance of sunlight. (All of our roofs add up to be a significant area of the earth's surface.) To determine a roofing material's reflectance rating, go to https://coolroofs.org/ .

As mentioned earlier, especially if the home has no attic, roof replacement provides a very important opportunity to add insulation underneath the new roof membrane. (See paragraph 6-e-ii above). Also, as mentioned above in paragraph 8, this is an opportune time to consider removal of a chimney and fireplace.

Another thing to consider when choosing a new roof is the possibility of collecting solar energy. As discussed below in paragraph 10, a homeowner may want to consider how best to install solar photovoltaic panels on the roof sometime in the future. Alternatively, solar shingle systems are a potential option to investigate.

10. Solar panels have become a somewhat popular addition to homes in recent years. Solar panel installers have certainly strongly promoted them, and several cities have encouraged group discounted purchasing through local "solarize" programs (which have been eagerly facilitated by the solar industry). Much of their popularity is probably attributable to the potential cost savings that such investments offer, given the available incentives. Also, the visual impact that they afford gives the impression of a progressive home owner making an environmentally sound improvement. Consequently, with all of the popular hype, the cost savings potential, and the human tendency to "keep up with the Jones's", many folks have put solar panels on their wish lists. However, there are a couple of reasons to hesitate putting them high on the list of home improvement priorities.

<u>Potential roof damage</u> is one reason to hesitate. Solar installers are quick to put holes through roofing materials that allow them to mount racks that hold the solar panels in place. (They must be held down tightly to avoid sailing off in the wind.) While such roofing penetrations can be plugged with sealant, sealant doesn't last forever. Every roofing penetration is an opportunity for a leak sometime in the future. Also, such penetrations probably violate any roof warranty.

There are a couple of roof types that can support solar panel racks without penetration of the roofing material. On a flat roof, ballast (e. g. concrete blocks) can be used to hold down the solar panel racks without any membrane penetration. On sloping roofs with standing seam metal roofing, solar panel racks can be clamped onto the standing seams without compromising the integrity of the roof. So, if contemplating a new (sloping) roof, a standing seam metal roof provides an option to easily install solar panels at any later time in the future.

<u>Environmental priorities</u> provide another reason to hesitate. As our society moves to replace fossil fuels with electricity, unless we aggressively conserve at the same time to offset that transition, society will have to pay utilities to invest more in growing the electric power infrastructure.

The times of peak electricity demand on the power grid determine the necessary sizing of the power generating capacity and the transmission lines infrastructure that get built. While solar panels do help reduce the peak electric demand on the grid in the summer, they don't in the winter because at our latitude the sun is so low in winter that solar panels hardly collect any energy then. Furthermore, at least for the time being, the peak load on the electric grid occurs in the winter, not the summer. (This could change with further global warming.)

In a broad sense, solar panels do cut total power consumed on the electric grid. However, they hardly help at all to mitigate the peak winter load which determines how much generating and transmission capacity our society will have to build and pay for as we transition off fossil fuels.

Consequently, cutting a home's power demand in the winter time is the key to slowing the need for greater power generation and transmission capacity on the electric grid. That's why some would say that, from an environmental standpoint, cutting the home's winter heat losses (while at the same time switching to a heat pump system) is a higher priority than installing solar panels.

11. **Batteries** are starting to gain in popularity, but they don't actually save energy --they only store it. (Saving electricity definitely cuts greenhouse gas emissions, as long as the electric grid isn't 100% clean). Batteries in homes can help bridge power outages, so that is the primary reason to consider purchasing them. If and when local utilities decide to adjust electric rates according to the time of day when it is used, then batteries will make homeowners much more aware that they can help mitigate the peak hourly demand on the grid by switching to their own battery power, rather than purchasing grid power at that time. Once electric rates are adjusted according to the time of day, then batteries can save the homeowner money by switching to them during peak rate hours.

12. **ERV & HRV fresh air circulation systems with heat recovery.** Even if a home has an existing ducted heating system, that system only circulates the air that is already within the home. Well-sealed homes with very little air leakage, may be in need of fresh air infusion and stale air exhaustion to preserve healthy air levels. This is especially true if there are gas appliances in the home. In such tightly sealed homes, it is wise to consider the installation of either an Energy Recovery Ventilator (ERV) or a Heat Recovery Ventilator (HRV) with a separate ducted fresh air distribution system that runs at a very low air velocity.

    These fresh air circulation systems are commonly located in an attic space. The small ducts in such systems provide fresh air circulation to (ideally) all rooms, and exhaust to the outdoors. Heat energy loss is kept low by running the intake and outflow air streams through heat exchanging coils within either an ERV or HRV.

    The essential difference between an ERV and an HRV unit has to do with their ability to control humidity. There are differences of opinion regarding whether that humidity control is important here in the coastal northwest. Humidity control is thought to be of more concern in the parts of the U.S. that have warm and very humid summers.

    One other potential advantage of such fresh air systems is that they do filter the outdoor air brought into the home. If a very fine "MERV 13" filter is installed in the ERV or HRV, and is frequently replaced, then these units are able to filter out smoke in the outdoor air as it is brought into the home.

    Such a fresh air circulation system may cost four to seven thousand dollars in a single-story home with eight rooms and an attic (based on 2021 dollars).

    In conclusion, a heat pump air conditioning system, coupled with such a fresh air circulation system, can keep a family warm in the winter, and comfortably cool indoors on the very warm and smoky days that are becoming increasingly frequent here in the western U.S.