How Does a Net-Zero Energy Home Work?

By Andrew Mills

A Net-Zero Energy or NZE home is one that, on average, generates as much energy in a year as it consumes. In this article we will explore how NZE homes work. We will cover some of the elements of an NZE home and how they can be brought together to make an efficient home.

One of the defining features of an NZE home is that is generates its own energy.

Generation of Energy

To offset the amount of energy used in an NZE home there needs to be a source of renewable energy that is produced on-site. This will nearly always be electricity produced by a solar photovoltaic (PV) system. In the country you may see wind used as the source of energy, but zoning laws (height and noise) typically preclude wind turbines in towns and cities. Other renewable energy sources, such as biogas and hydro are typically not available for generating on-site energy unless your home is on a farm or in the country.

Any energy that must be brought in from off-site (such as firewood) subtracts from the net-zero calculation. In a city or town, the only practical source of on-site energy is solar PV.

The good news is that solar PV systems are much more affordable. Solar PV modules are 80% cheaper than they were 10 years ago, and, in some jurisdictions, there are incentives that can offset the purchase price even further.

In Alberta, the *Micro-Generation Regulation* allows a homeowner to generate as much electric energy as they would normally consume in a year. This can include the electric energy needed to heat and light the home as well as for an electric car.

In order for an NZE home to generate the energy needed in a year the home needs a practical amount of roof area to support a suitably sized solar array. Very efficient homes may only need a small solar array while less-efficient homes may require a solar array that is too big for the available roof. Other issues, such as roof orientation, slope, complexity, and shading, may also reduce the practical roof space for a solar array. If there is not enough roof space for sufficient solar then it is sometimes possible to add solar to a garage, shed, pergola, wall, or other structure.

1. A solar pergola with translucent solar modules.

The next sections talk about reducing the home's energy consumption. The more efficient the home, the less energy generation is needed, and the more likely that the solar array required for NZE will fit on the roof of the home.

Efficient Use of Energy

2. An air source heat pump water heater.

NZE homes start by being all-electric, and then make an effort to be electrically efficient. By using energy efficient appliances, an NZE home reduces the amount of energy that needs to be generated in a year. Most NZE homes will feature the latest in energy-efficient appliances and will have purchased the best Energuide-rated refrigerator, clothes washer, and dishwasher. We also commonly see LED lights, air-source heat pump water heaters, and drain water heat recovery (which reclaims heat from shower water). We are also starting to see air source heat pump clothes dryers and induction cooktops. Every unit of energy that is saved through efficiency is one less unit that needs to be generated.

Source of Heat

Since the energy we can generate is in the form of electricity from a solar PV system, the net-zero energy home heating source will need to be electric. All current NZE homes are heated electrically. There are three main ways of electrically heating an NZE home.

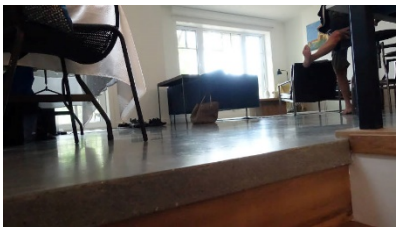
1. Some NZE homes use super-insulation such as double-stud walls (R40+) to reduce heating loads to the lowest possible value. In these homes it can actually be practical to use simple baseboard heaters for heating. Baseboard heaters are typically 100% efficient with each kWh of electric energy producing in 1 kWh of heat energy. Baseboard heaters are the least expensive type of electric heat to install.

2. A ground-source heat pump (GSHP also called Geothermal or Geoexchange) uses a refrigeration cycle to pump heat out of the ground and into the home. Ground source heat pumps can be up to 400% efficient; for each kWh of energy used by the heat pump they can deliver up to 4 kWh of heat. Ground source heat pumps require an array of liquid-filled tubes in the ground to gather the heat (placed vertically or horizontally depending on space available).

3. An air-source heat pump (ASHP) uses a refrigeration cycle to pump heat out of the outside air and into the home. The efficiency of air-source heat pumps varies according to the outside air temperature; from an efficiency of 500% at 18°C to an efficiency of 100% at less than -20°C. Overall they are significantly more efficient than baseboard heaters. An air-source heat pump will be less expensive to install than a ground-source heat pump as there is no drilling required for underground tubes. An electrical air-source heat pump is currently the most popular method for heating NZE homes.

3. An air source heat pump unit on a garage suite.

Passive Solar



4. A concrete floor and south facing windows for passive solar gain.

Another way to add heat to a home is to use passive solar techniques. Passive solar uses a combination of thermal mass (such as concrete), efficient windows, and carefully designed shading to gather heat when needed (and exclude heat when it is not needed). Passive solar usually needs to be included in the original design of the home. The most typical arrangement is to have a concrete floor in the main south-facing room to gather heat. Insulated windows and a carefully designed overhang admit as much light as possible in the winter but prevent the concrete floor from overheating in the summer.

Active Solar Thermal

There are a number of ways to collect heat directly from the sun. Some solar thermal systems pre-heat air coming into the home with a solar collector. Other systems collect solar to heat the domestic hot water tank. Solar thermal systems are not as popular as they used to be since the price of photovoltaics has dropped so much. We still see some interesting solar thermal collectors on homes, which can help reduce the grid energy consumption in a home.

5. Solar thermal collectors for domestic hot water and hydronic heating.

Insulation

A home designed for NZE will usually be at least 60% more efficient than a regular code-built home and often 80% more efficient. The main way this is done is through insulation. NZE homes use higher levels of insulation in walls and ceilings. NZE homes will also pay particular attention to insulating the basement. Basement walls will often be as well insulated as the main floors and there will usually be insulation below the basement floor.

A standard 2x6 wood wall would normally have R22 insulation. An NZE home would typically have more than R30 in the walls and we commonly see values closer to R40. A super-insulated NZE home could have walls with insulation values as high as R60.

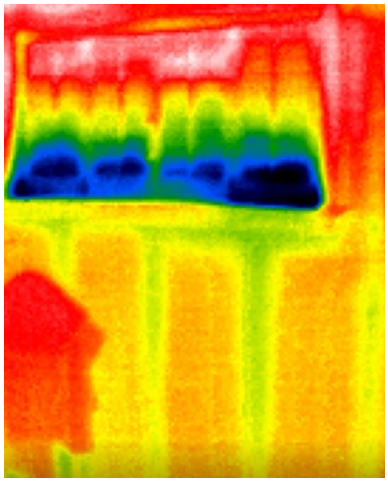
6. Double stud walls and triple pane windows in the basement

NZE homes add significant insulation to the ceiling, and it is not uncommon to see ceiling insulation values close to R100.

In standard construction, basements are typically not well insulated (if at all). In an NZE home the basement walls are usually insulated to the same high level as the walls of the main floor. The basement is also insulated below the floor with expanded polystyrene insulation.

At high insulation levels the effects of thermal bridging become more apparent. Thermal bridging is where the heat flows through the studs (bypassing the insulation). Thermal bridging can be reduced by building a double-stud wall where the inside and outside studs are offset. It is also possible to place rigid insulation on the outside of a regular framed wall to reduce bridging.

The last aspect of insulation is windows. Windows are needed to bring light into a home, but they interrupt the insulation in the walls. A normal double-pane window will have an R value of only R2. Putting an R2 window into an R40 wall is not very efficient. Modern triple-pane windows can be closer to R5 and there are some windows available now with values of R11 or higher (at the centre of their glass).



7. Thermal camera image of an inefficient window, blue is cold air coming in the bottom of the window. The green in the wall shows the thermal bridging of the wall studs.

Air Sealing

One of the most important aspects of an energy-efficient home is to keep the heat in. Air sealing is measured in air changes per hour (ACH) at a pressure difference of 50 Pascals (equivalent to a 30 km/h wind) and is a measure of how often the air inside the home is exchanged with outside air. Air that is exchanged needs to be heated so a home with higher ACH loses heat more quickly. A home built to the current building code would typically have 3 ACH, which means that all the air inside the home is lost to the outside 3 times in an hour. That sounds like a lot, but we need fresh air in our homes to control humidity and to exhaust stale air.

Reducing heat loss often includes improving the air sealing of a home. Many NZE homes will have air sealing levels of below 0.5 ACH, and some are as low as 0.1 ACH. A new technique being used is a method where the home is pressurized and then filled with an aerosol which seals the tiniest air gaps. This is typically done in new homes after the building envelope is completed but before the interior finishing begins.

8. A heat recovery ventilator (HRV).

While sealing a home helps to retain heat, there is still a need for fresh air in a home. That is usually met with a heat recovery ventilator (HRV). An HRV brings fresh air into the home and exhausts stale air. The HRV uses a heat exchanger to extract the heat from the air leaving the home and add it to the air entering the home. Using an HRV provides fresh air to the home while retaining heat. Most new homes now have HRV units and NZE homes will typically have the most advanced HRVs available.

Renovation

We saw our first net-zero homes in Alberta in 2008. The first NZE homes were purpose-built and featured exceptional insulation as solar PV was still quite expensive. Adding insulation was significantly cheaper than adding more solar and double-stud walls were common. Now the price of solar has made it possible to get to net zero with less insulation.

9. A town home wrapped with new exterior insulated panels.

Extra insulation is still a good idea and there are a number of insulation techniques for renovations. A common method is to remove the interior drywall and then add interior insulation (such as spray foam). Recently we are seeing the growth of exterior insulation techniques. The exterior techniques work well and create less disruption; however, some homes do not have sufficient side yard space to add to the outside walls.

10. This 1949 home has R14 walls but still gets to net-zero with geothermal heating and a large solar array on the custom garage.

But with lower solar PV system prices it is possible to get to net-zero without adding significant extra insulation. Some homes are now adding very large solar arrays to older homes that are not particularly well insulated. With a suitable source of electric heat, it is possible to get to net-zero without a heavily insulated home.

What Next?

A net-zero energy (NZE) home can be a significant part of your efforts to reduce your carbon footprint and can reduce (or even eliminate) some of your utility bills. If you are considering a new NZE home then we suggest you contact the builders that sponsor the Eco-Solar Home Tour.

To renovate your home to NZE you will need to hire a certified energy adviser to model your home and to help you choose the systems that will get you to net-zero. The energy advisor will do an assessment of your home and then list the updates that would work in your situation.

Of course, the best way to see net-zero energy homes is in person. The Eco-Solar Home Tour hosts an annual tour of energy-efficient and net-zero homes so that you can meet and ask questions of the people that have already done their research and built their home. The Eco-Solar Home Tour takes place each year in June.

About the Eco-Solar Home Tour

The Eco-Solar Home Tour Society of Alberta is a non-profit society that organizes annual free tours of homes and businesses that display practical and timely examples of sustainability. The Tour is organized by a group of volunteers who have a passion for the environment and sustainability. Through the tour they can share this passion and educate and encourage others to consider the sustainable choices in new technologies and building practices. This year we are showing 36 homes in three cities across Alberta.

2024 is the 24th Eco-Solar Home Tour. The tour is free and does not require registration. For times and details go to www.ecosolar.ca