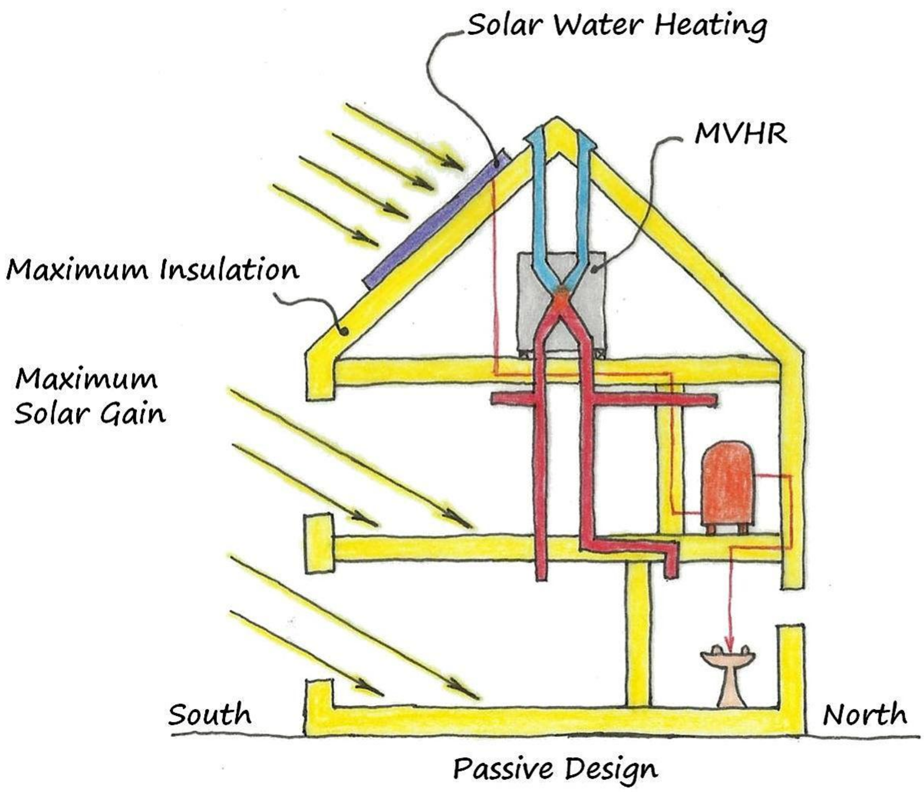
PassiveDesign.org

Principles of Passive Design



About:

This handout contains the information from the "Principles of Passive Design" topic pages on passivedesign.org.

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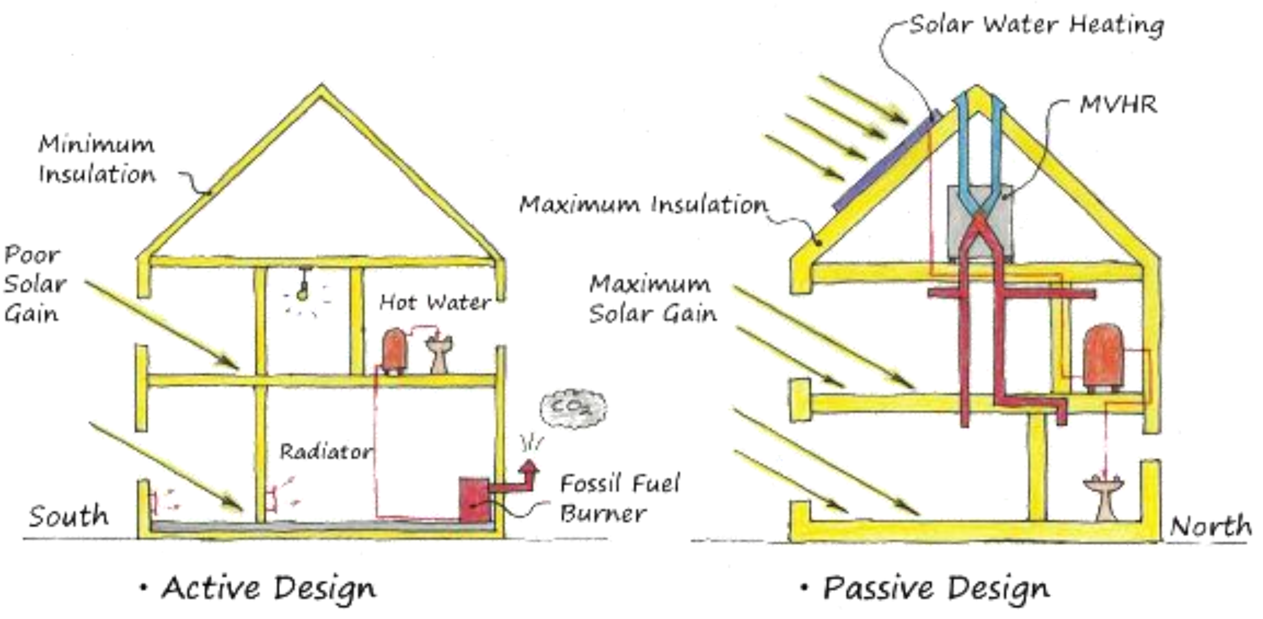
Principles of Passive Design

What is Passive Design?

Passive Design is a method of construction where a comfortable interior environment can be created using very little energy; simply by eliminating the reliance on active heating or cooling systems.



History of Passive Design

The Passivhaus standard was created at the beginning of the 1990's by Professors Bo Adamson and Wolfgang Feist; with residents moving into the first prototype Passivhaus building in 1991.

In 1996, Dr. Wolfgang Feist founded the Passivhaus Institut; a research institute to further develop the Passivhaus standard and to promote its adoption internationally.

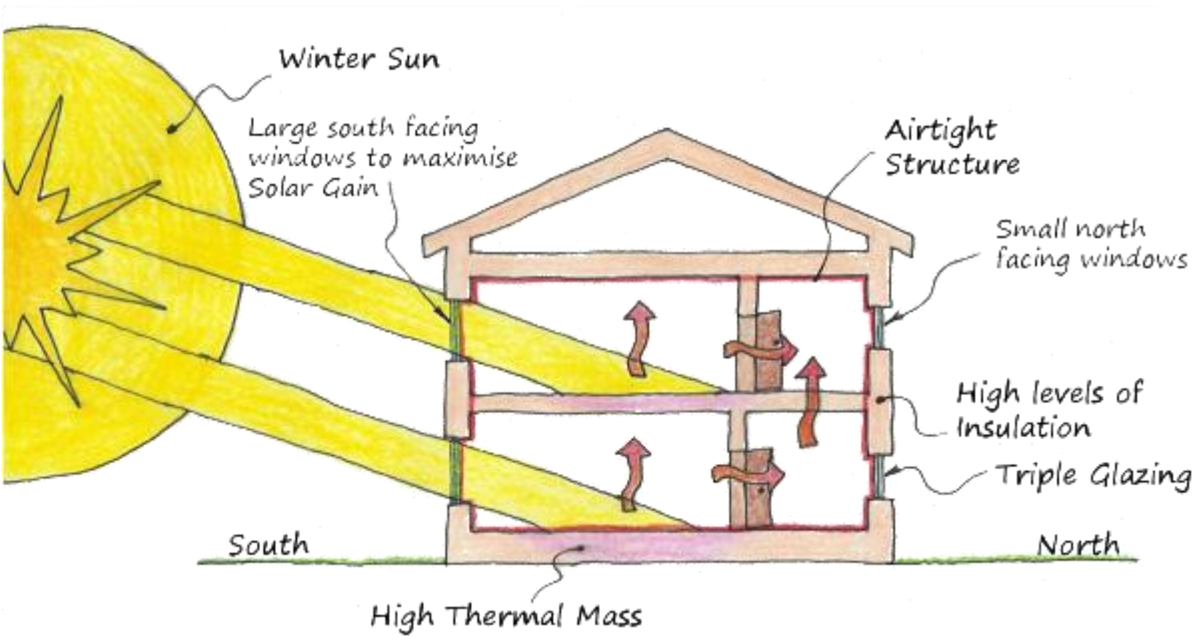
How does Passive Design work?

Passive Design works on a specific set of principles:

1. Solar Gain
2. Thermal Mass
3. Super Insulation
4. Airtightness
5. MVHR

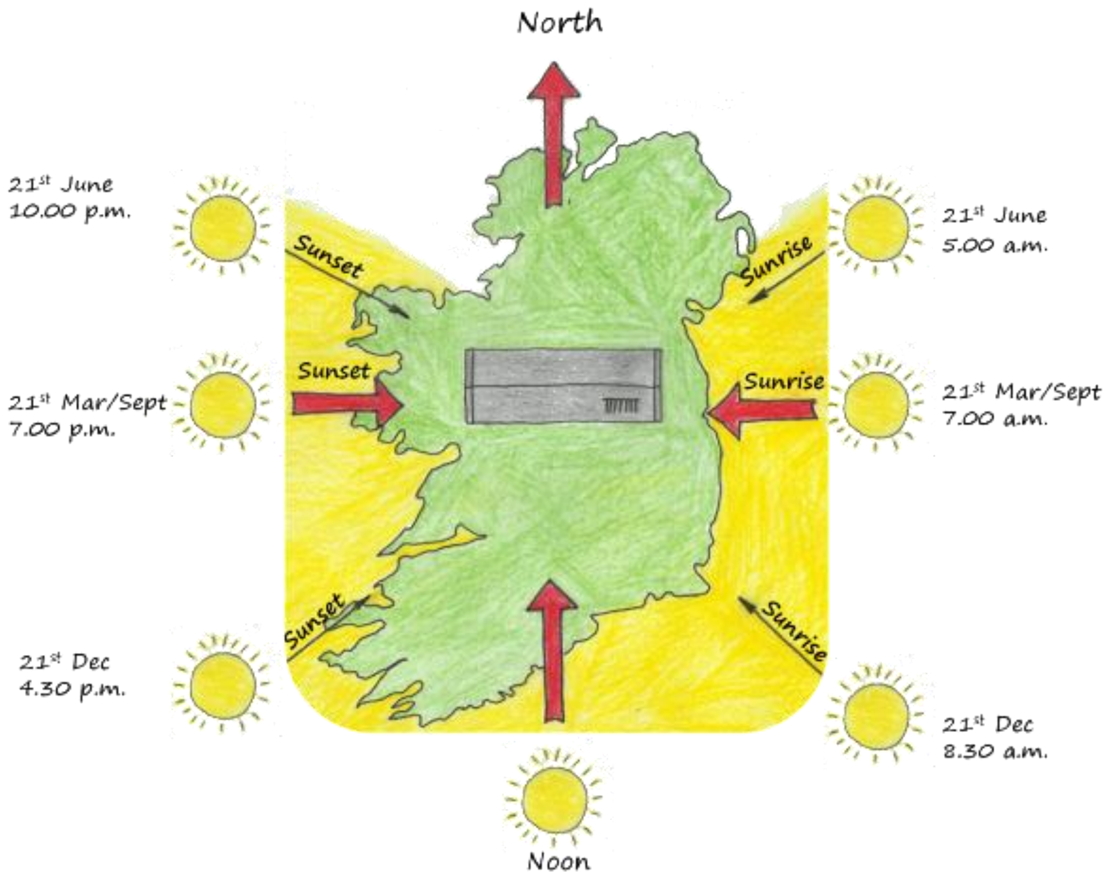
Solar Gain

Solar gain is a fundamental principle of Passive Design. Passive Design utilises the sun's energy to create a comfortable internal environment; as the sun's energy can provide most of the light and heat needed in a Passive House.



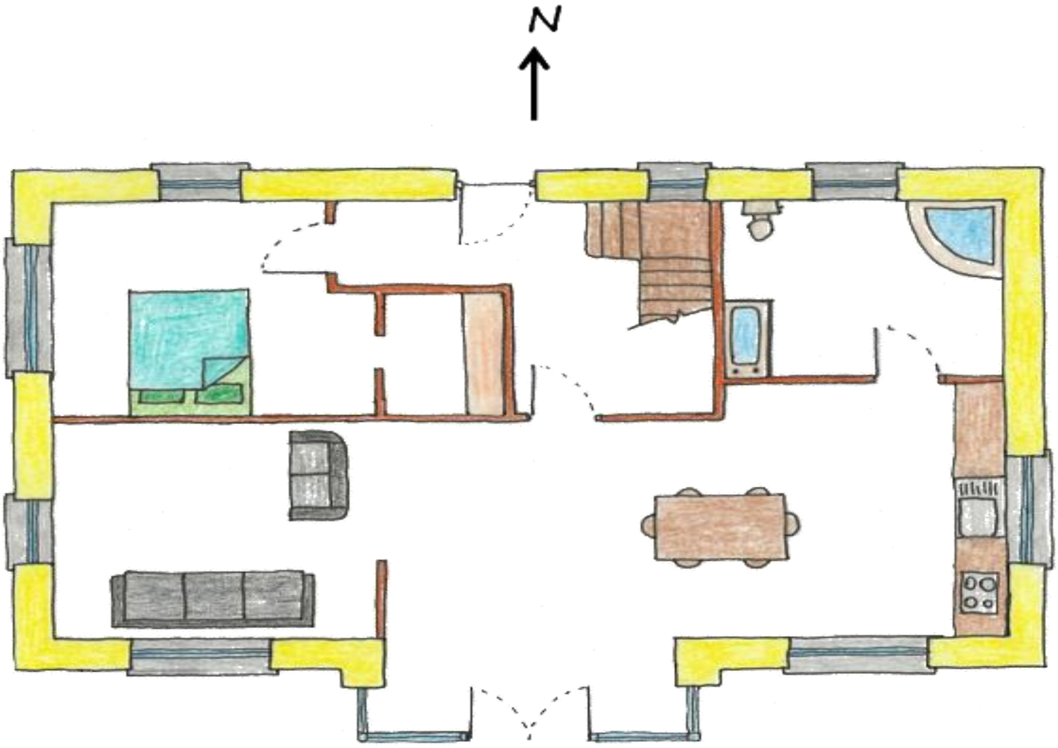
From the sketch on the previous page we can clearly see how a Passive House benefits from solar gain; however we need to understand the underpinning concepts.

Orientation is a key concept involved in maximising solar gain. Ireland, being in the northern hemisphere means that the sun will rise in the East and set in the West. Therefore to maximise solar gain a passive house should be orientated so that its long facade faces south. This south facing facade should have maximum glazing whilst glazing on the north facade should be kept to a minimum.

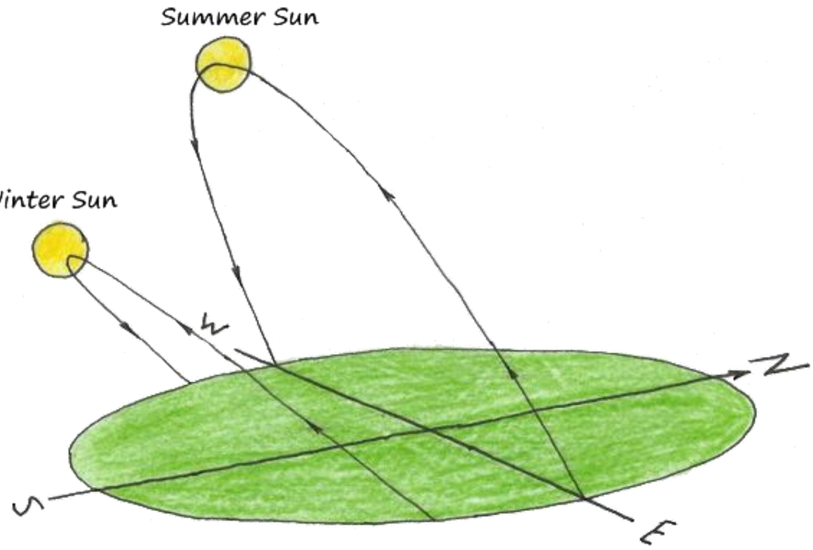


To reap the benefits of the suns energy the plan should be narrow and rectangular in shape so that the sun can shine deep into the house. For comfort, the rooms that are used most (living room, kitchen, etc...) should be situated on the south side of the plan whilst rooms which are used least (toilet, utility, etc...) should be situated on the north side.

Below is an example of the plan of a passive house which maximises the suns energy.

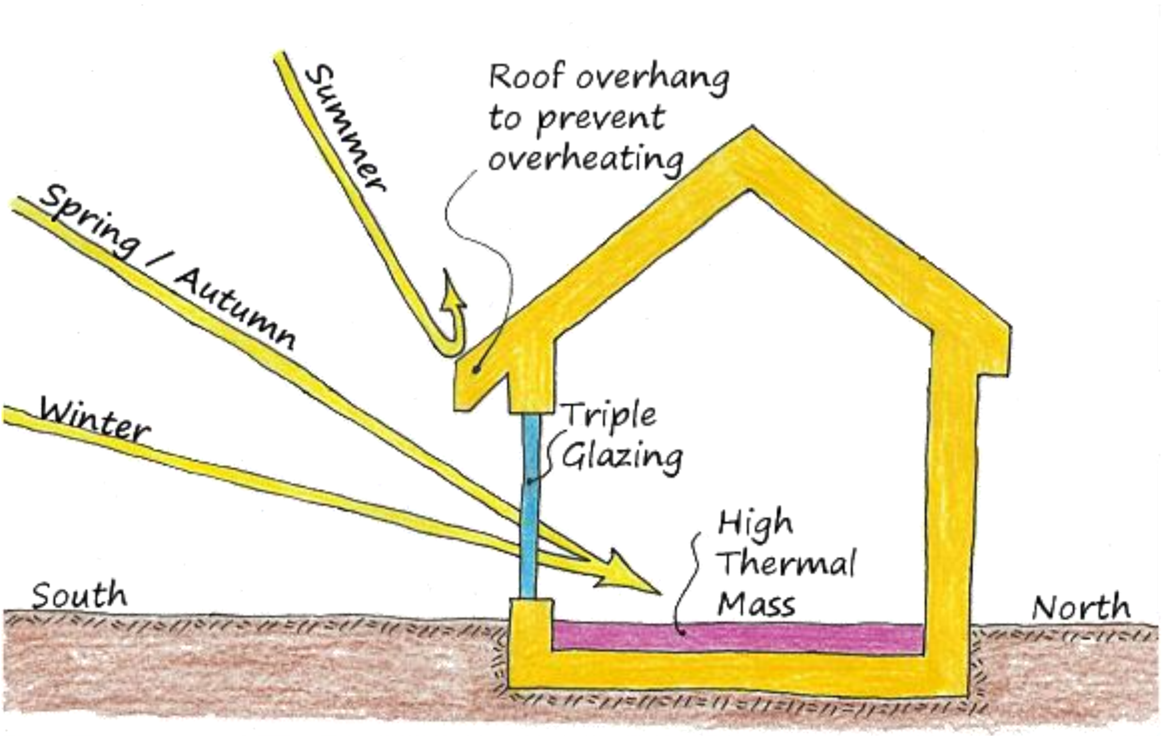


We now have a base understanding of orientating a passive house to reap the benefits of the suns energy; we now need to understand the suns path and the effect this can have on the performance of a passive house.

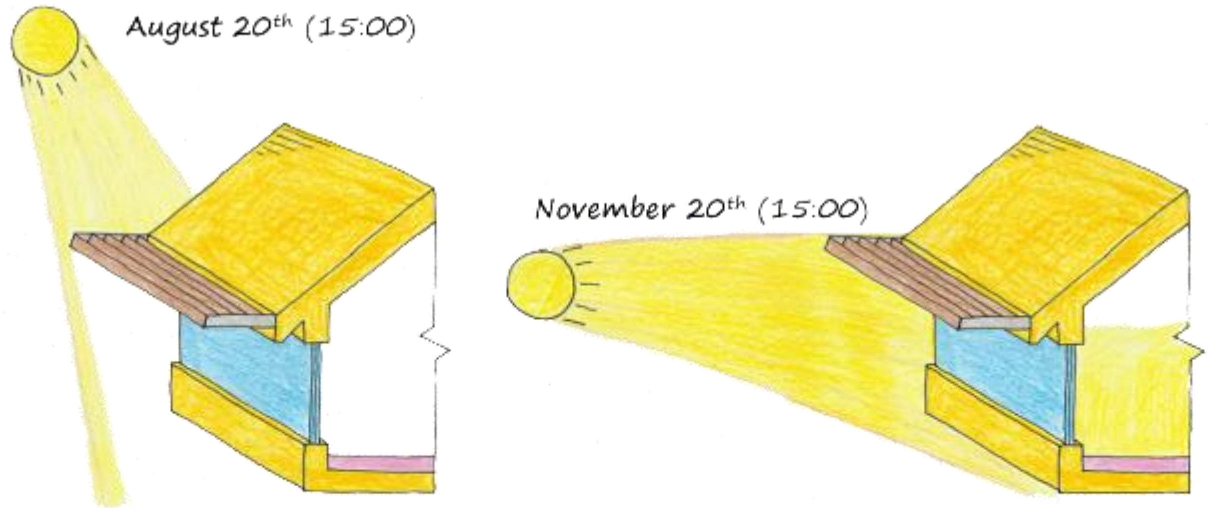


From the previous sketch we can see the difference in the suns path between summer and winter. In winter the sun is lower in the sky but further away; as a result of this the solar energy is quite weak, hence it is vital that there is maximum glazing on the south facade to maximise this light and heat gain.

In summer the sun is higher in the sky and closer than the winter sun. In the afternoon it is at its most effective; putting the passive house at a risk of overheating. To prevent this occurring passive houses utilise overhangs or a brise soleil on the southern side of the house.

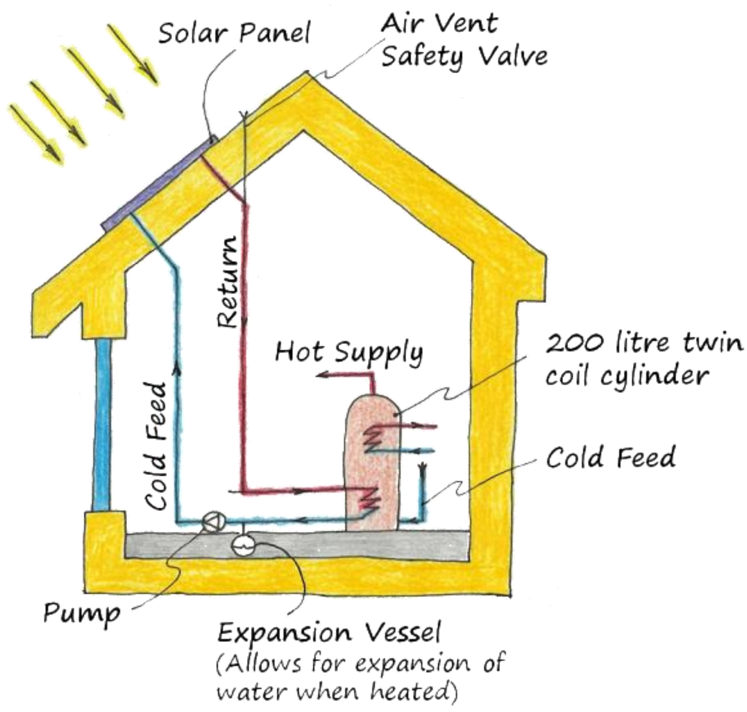


In the above sketch we can see how a passive house can utilise an overhang to prevent overheating by blocking the summer afternoon sun from entering the house. In this sketch there is also a label called thermal mass; this refers to a material (e.g. concrete) that has high thermal mass enabling it to store the heat energy and release it steadily throughout the day.



The sketch above shows how a passive house can utilise a brise soleil (sun-breaker) to prevent overheating. It again works on the same principles of the overhang; preventing the summer afternoon sun from entering the house whilst ensuring that the sun can shine deep into the house when it is not at such an intense heat (e.g. morning summer sun, winter sun, etc...).

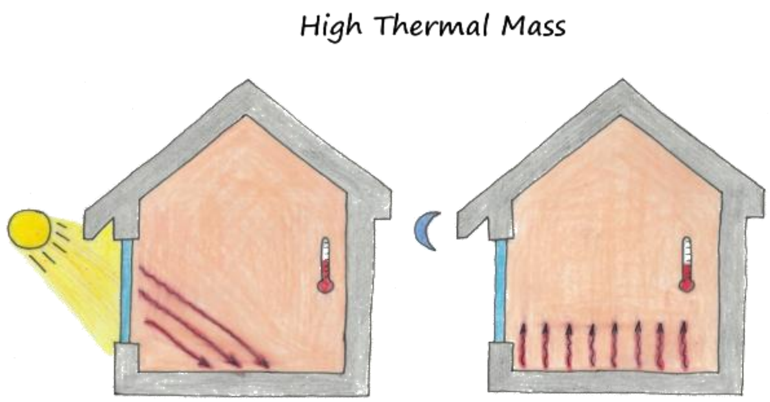
The last aspect of solar gain is solar water heating. This aspect is not mandatory to passive design however it is a very common occurrence. Solar Water heating simply uses solar panels (collectors) to heat the water. The suns energy is used to heat the solar collectors; cold water is pumped into the solar panel (heating up the water) which is then pumped back into the cylinder.

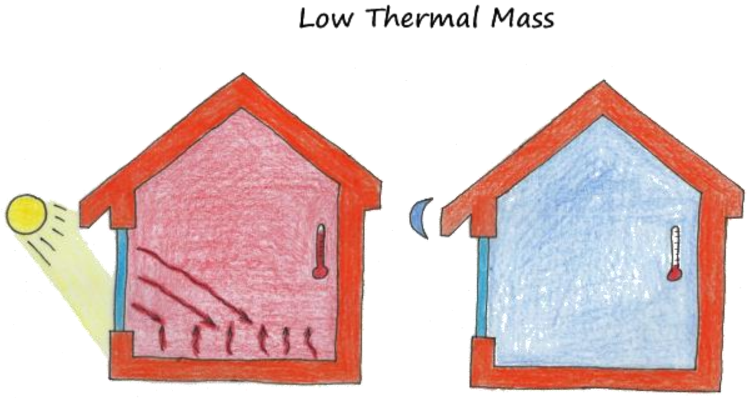


Thermal Mass

Thermal Mass is a property that enables building materials to absorb, store, and later release significant amounts of heat. This is very important in a passive house in terms of heat control from solar gain as it moderates temperature fluctuations.

The sketch on the right shows the effect of high thermal mass on a building. The building material has a high thermal mass so the building heats absorbs the heat, stores it and can release it steadily over a period of time. This ensures that there is minimum temperature fluctuation and the heat remains at a steady temperature throughout the day and night.





The sketch to the right shows the effect of low thermal mass on a building. The building material has a low thermal mass so the building heats up quickly; however this heat is not absorbed, so the temperature rises and fluctuates greatly as the building loses its heat.

With regards building materials, concrete is one which is high in thermal mass. This allows it to absorb heat and release it slowly throughout the day. In comparison timber and insulation and materials which are low in thermal mass.

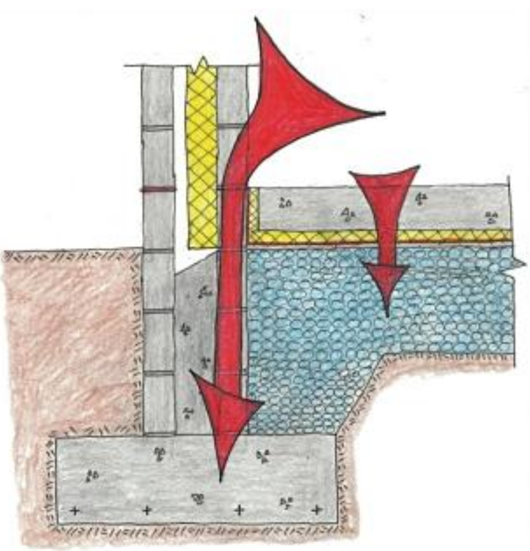
Super Insulation

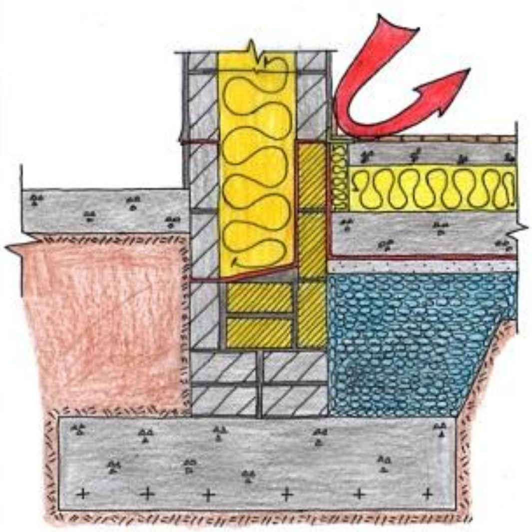
Super Insulation is a crucial aspect of Passive Design. In a standard build the levels of insulation are not sufficient to satisfy the passive standard of between 0.10 - 0.15 W/m^2K; also in a standard build there is a high level of thermal bridging and air leakage throughout the structure which is not feasible when trying to obtain the passivhaus standard of 15 kWh/m2 per year for energy demand.

A Thermal Bridge is created when materials that are poorer insulators (e.g. concrete blocks) than surrounding materials come in contact, allowing heat to flow through the path created. In passivhaus construction the dwelling is super insulated and thermal bridging is eliminated to prevent heat loss; ensuring the Passivhaus standard is met.

A prime example of thermal bridging is in the strip foundation detail; this is evident in the sketch below. There is heat loss down the inner leaf and also through the floor (due to the minimal amount of insulation).

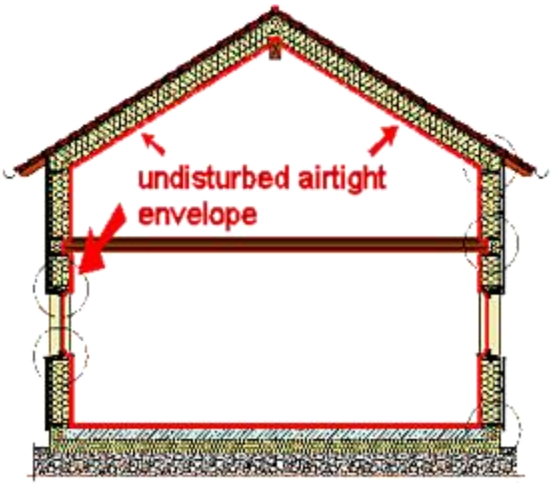
A passivhaus foundation cannot achieve the passivhaus standard with these heat losses. One such foundation detail is the passive strip from integrated energy; it eliminates thermal bridging down the inner leaf with the use of lightweight insulated concrete blocks (yellow blocks in sketch). The foundation also uses 150mm of insulation underneath the floor to prevent heat loss; the end product of this being a strip foundation that can be used in passivhaus construction.



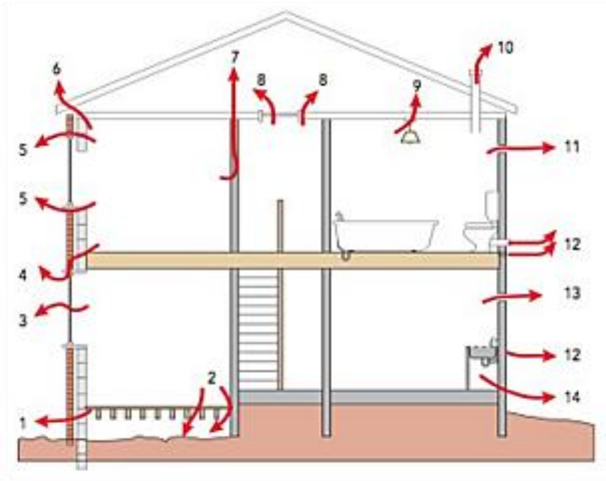


Airtightness

Airtightness is simply the control of airflow within a building. This means there is no unexpected air leakage (losing warm air) or no cold air infiltration.



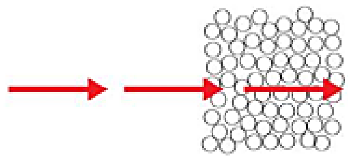
Airtightness



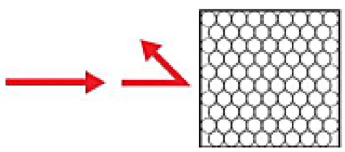
Air Leakage

In passive construction the building is made airtight in order to prevent the unwanted movement of air. This has many benefits, some of which include:

- Reduced heat loss.
- Reduced energy costs (Space Heating).
- Improved thermal performance of the structure. (Prevents wicking of insulation-diagram to right)
- Improved thermal comfort. (A steady temperature is maintained throughout the building).



If air moves within insulation it substantially effects the thermal performance.

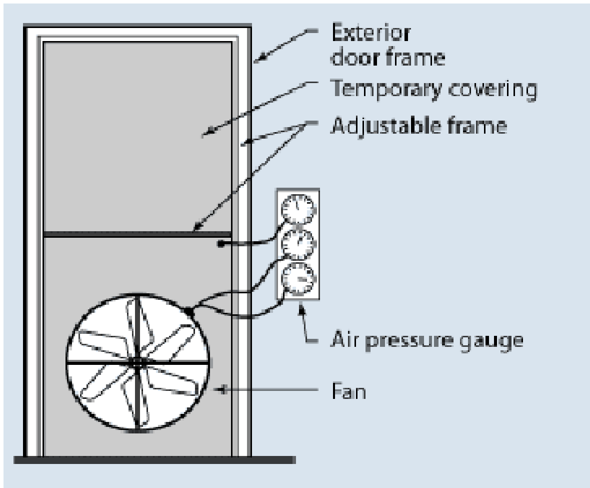


When it is protected with an airtightness barrier it performs to its optimum level

To gain Passivhaus certification a building must reach the standard of 0.6 ach^{-1} @50kPa; this simply means that there must be less than 0.6 cubic metres of air change per hour for every square metre of floor area when the difference in air pressure between the inside and outside is fifty Pascals.

When building a passive house it is important to get an accurate measurement of the airtightness; to obtain this a "Blower Door Test" is used.

- The blower door fan is set up in the doorway of the main entrance of the dwelling.
- Windows and doors are closed while vents and fans are sealed.
- The fan is then turned on and tested for overpressurisation; the house is subjected to 50 Pascals of pressure for one hour whilst the air flow rate is measured.
    - The goal of the first stage is for the dwelling to maintain the excess pressure of 50 Pascals.
- The fan is then turned around and the test is repeated; this time testing for underpressurisation; 50 Pascals of pressure is pumped out of the house. The results of the test are based on the buildings capability to maintain this negative pressure
- The average of the two tests are then calculated to determine the airtightness of the building.



Airtightness: Block Cavity System

There are two main methods of making a concrete block cavity structure airtight:

1. Plastering

The first method is plastering. This is by far the most common method and a more preferred option amongst Irish builders.

To begin, it is important to understand that concrete blocks are porous; this means they are not airtight in their own right. As a result the inner surface is parged (covered with plaster) to ensure airtightness. It is vital that the entire surface is thoroughly parged from the bottom of the wall to the very top. If the surface area is not fully covered there will not be an airtight seal.

Once parged, the wall is usually skimmed (covering with a thin coat of skim); again the skim needs to be applied to the total surface area of the wall. Providing that this is done adequately; the surface will be airtight and protected from any possible air leakage.



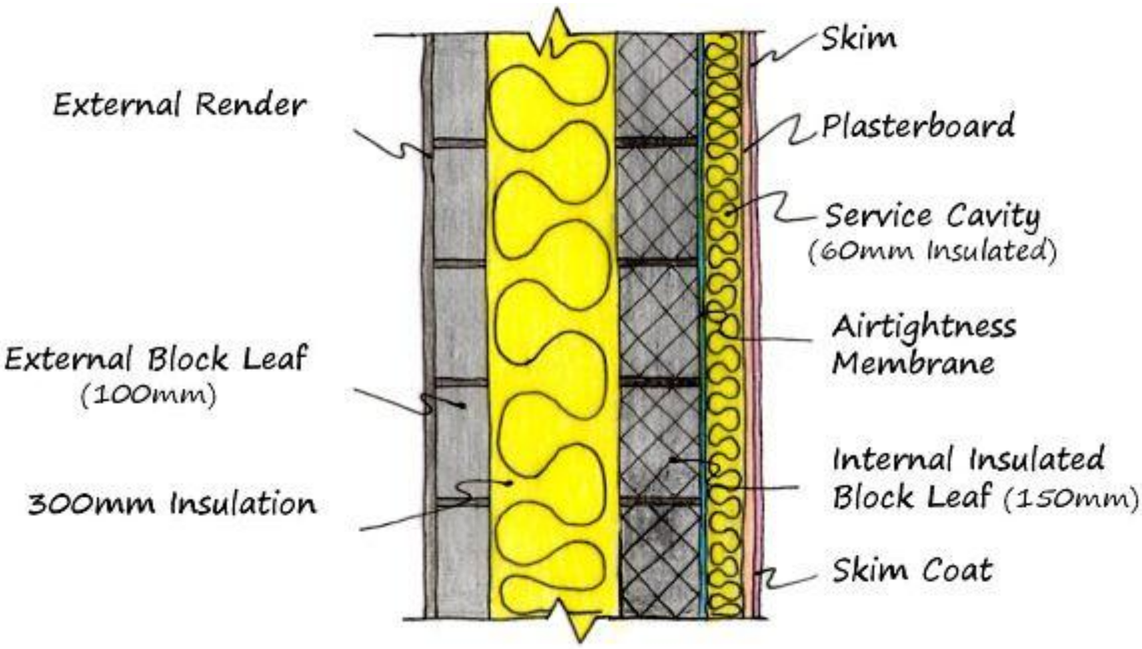
2. Service Cavity

The service cavity is typically associated with a timber frame structure however many passive block constructions are using this method.

This method uses an airtightness membrane fitted against the inner leaf (blue). This will prevent any air penetration from the concrete block.

There is then a service cavity; this can vary in width but is typically around 60mm. This service cavity is filled with services (e.g. conduits, pipes) and insulation.

Plasterboard is then applied and skimmed; ensuring to cover the entire surface area. This ensures an airtight structure.

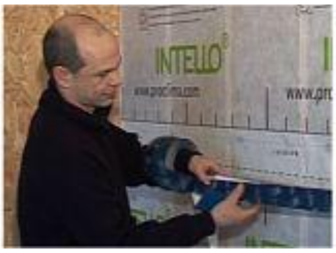


Airtightness: Timber Frame Structure

When constructing a timber frame passive house there are two methods of achieving airtightness which are commonly used:

1. Using a service cavity:

This is the most common of method. The first step is to make the timber frame itself airtight. The load bearing stud is insulated and an airtightness membrane is installed throughout the entire structure. In some structures there is an OSB board applied to the studs and then an airtightness membrane is fitted; this provides further airtightness as the OSB boards are airtight in their own right. The airtightness membrane which is applied prevents air penetration; ensuring airtightness (if fitted correctly). Installing this airtightness membrane relies on high quality workmanship and attention to detail; every joint must be carefully taped or sealed (with mastic) to ensure it is airtight.

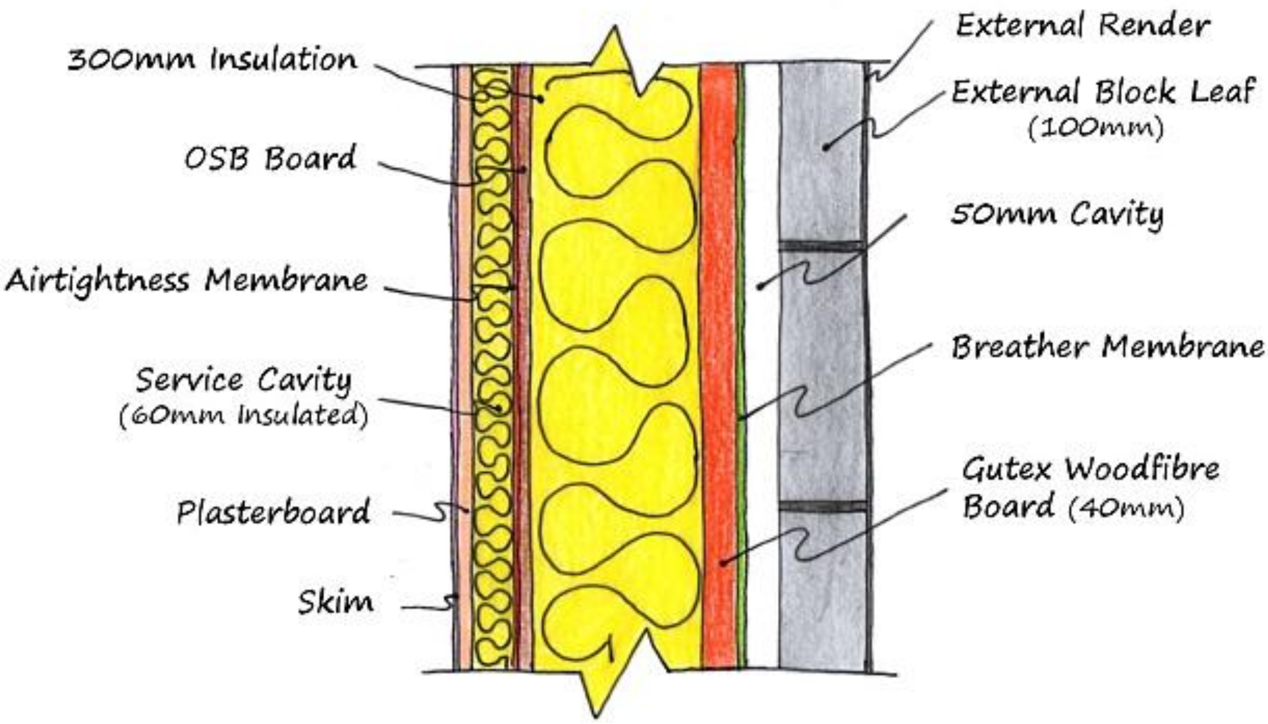



Where there are any breaks in the airtightness membrane (for example from services which pass from the internal through the external leaf); grommets are applied to prevent air leakage. Grommets are rubber seals within an airtightness membrane or tape which make the penetration point airtight.


Once the airtightness membrane is installed; work usually begins on installing the service cavity. The service cavity is simply battens which create a small cavity outside the airtightness layer. It is important to note that services are not installed until the structure is checked to ensure its airtightness reaches the passivhaus standard of 0.6 ach^{-1} @50kPa.

Airtight stud wall with service cavity
(Airtightness Membrane fitted onto studs – No OSB Board)

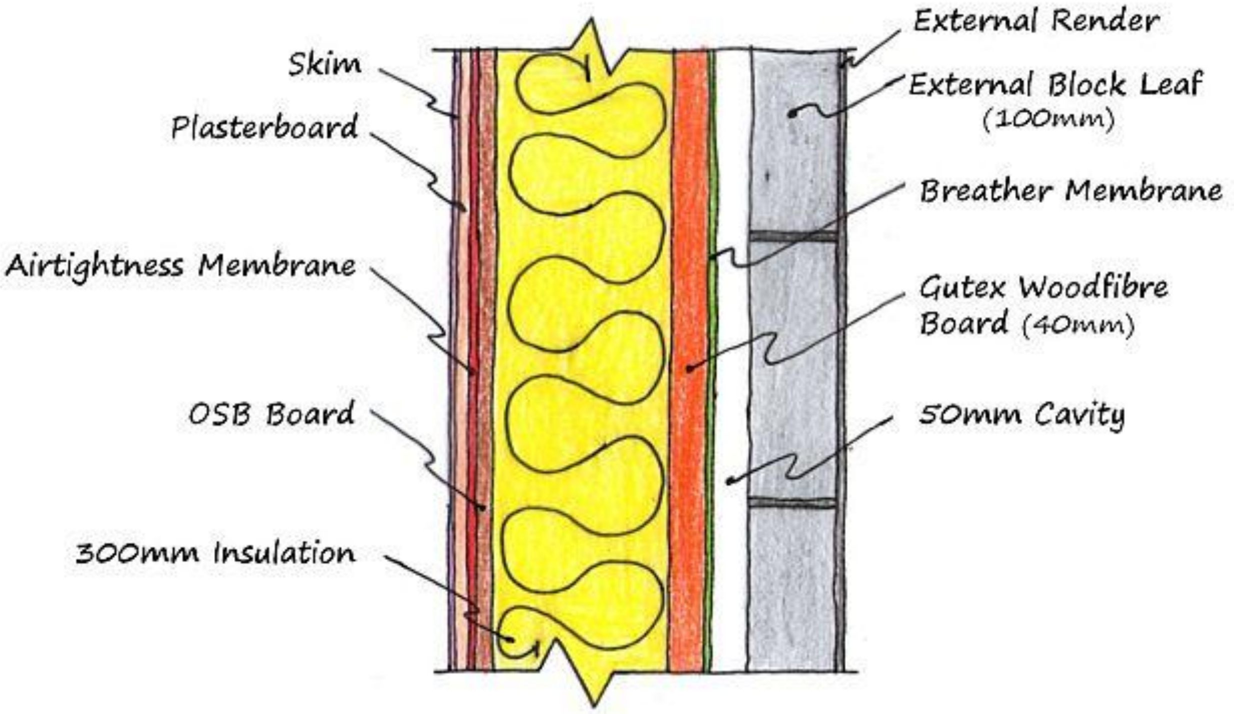
Once the structure has succeeded in obtaining an airtightness level below 0.6 air changes work can begin in the service cavity. The services are installed and the service cavity is insulated. Plasterboard is then applied and skimmed; ensuring that all the surface area is covered, guaranteeing a high airtightness level.



2. Making the inner leaf airtight:

The most common method of making the inner leaf airtight is by using airtightness membranes.

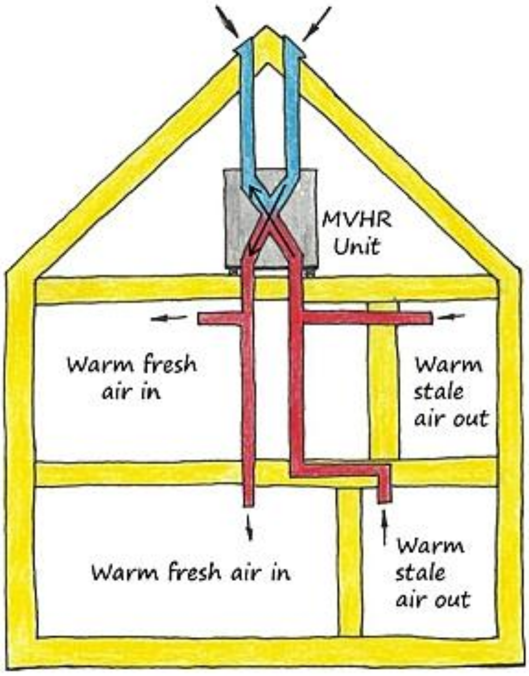
This system does not use a service cavity, instead the services (conduits, pipes, etc...) are run within the loadbearing studs and then the studs are insulated. An osb board (airtight in its own right) and an airtight membrane are then applied or alternatively an airtightness membrane can simply be applied to the stud without the osb board (image on the right); as the membrane once installed correctly, can prevent airleakage.



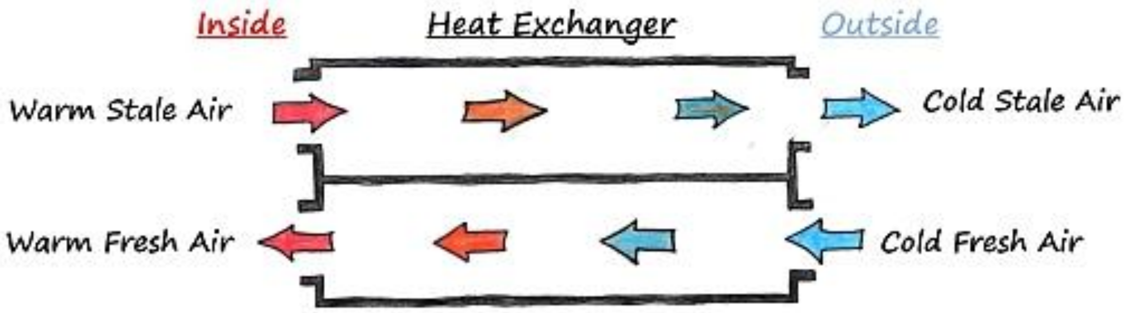
Where the services penetrate the airtight membrane grommets are applied; these prevent air leakage through the penetration of the airtightness membrane. The plasterboard can then be applied and skimmed ensuring to cover the entire surface area; this further ensures airtightness in the structure.

MVHR

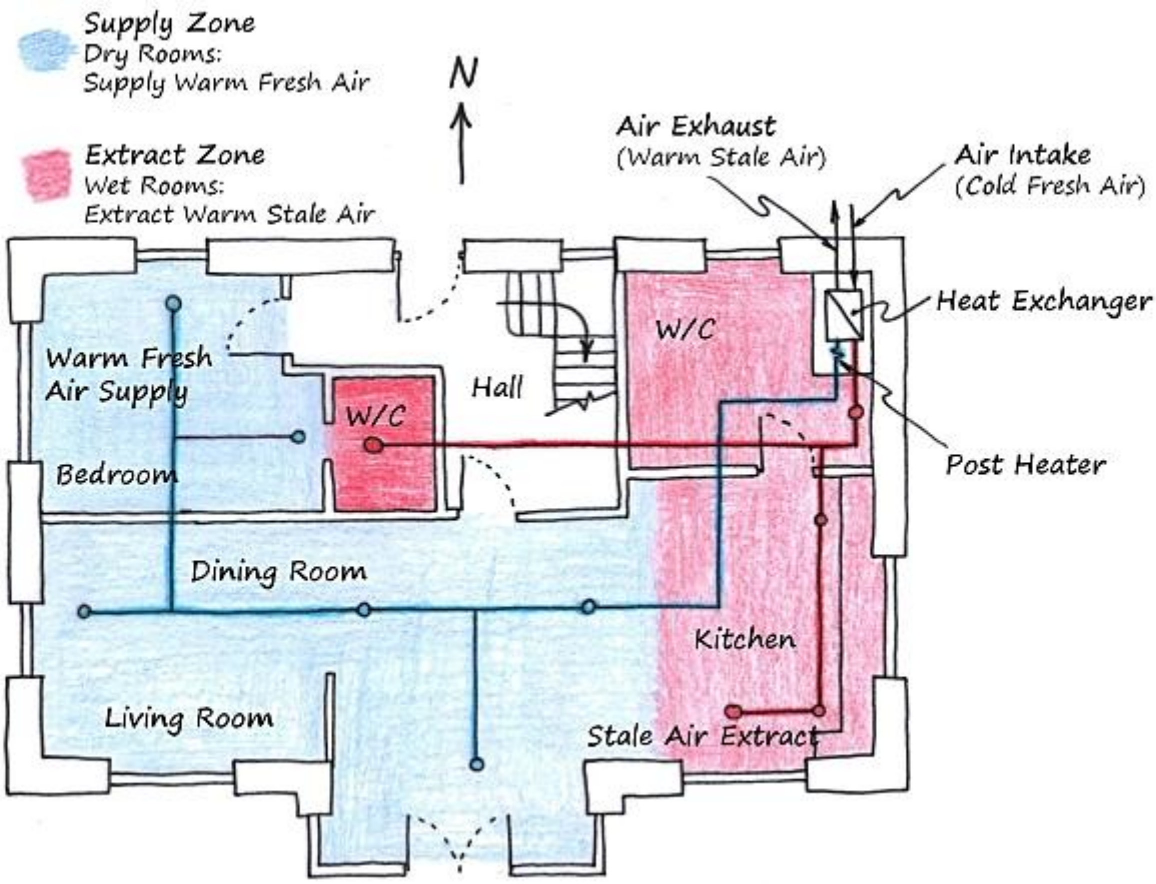
A Passive house being airtight and super insulated means that there is a significant need for ventilation; hence a Mechanical Ventilation Heat Recovery unit is used.



A Mechanical Ventilation Heat Recovery unit or MVHR is used to take advantage of these conditions in a passive house; it brings fresh cold fresh air into the house, using the heat from the warm stale air exiting the house to heat up this fresh air. It is crucial to understand that the fresh air and stale air do not mix; so the air coming into the house is warm and fresh.



The MVHR works on the concept that it takes stale air out of "wet rooms" (e.g. Kitchen, Bathrooms, etc...) and provides "dry rooms" (living rooms, bedrooms, etc...) with fresh air.



The MVHR systems are usually about 80% - 90% effective and some can run on as little as 15watts per hour. This system reduces energy consumption, CO2 emissions and heating costs.