Passive Home Design

A guide to remodeling and building highly energy efficient and eco-friendly homes

Passive Home Design Report

Evan Sawyer

Advisor: Robert Krueger

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Introduction-

This manual is intended to inform a homebuilder, designer, or owner of many of the important differences between the production and design of a passive home and typical house construction. Increasingly, energy conservation and eco-friendly products are becoming more attractive to owners and builders who wish to build sustainably without sacrificing comfort or style. This building technique, when applied properly can develop homes which require no off site energy input annually.

In my own life I was confronted with the extremely of nature during a devastating ice storm which destroyed major sections of my home in December, 2008. Rebuilding was a priority for my family but with a new perspective of creating a better living environment which was designed to tolerate possible extremes from the exterior environment. I was ultimately able to rebuild a structure which was completely inadequate with current building codes to impressive new standards of function and efficiency. This experience prompted me to contribute this knowledge to other builders and designers looking to achieve similar efficiency who weren't aware of the impressive traits of the passive home.

It is very important to recognize that every site comes with a completely different set of challenges; homeowners and designers need to be aware of the complexity of designing and engineering a home capable of such high efficiency standards. Failure to understand these challenges and the synergistic nature of the building systems will result in losses in potential efficiency standards. I arranged the information in this manual to help to illustrate the connections between these different areas of construction. The six sections that follow show the construction path of a renovation or new construction of a typical residential building, with a focus on the building requirements of the Northeast.

The first section of the manual discusses the building envelope and insulation. Also included here is a roadmap of site development and rough construction. Everything from the foundation to the roof is discussed in great detail here; the focus is to explain the critical link between each of the different rough elements of the structure as one complete building envelope. This section doesn't separate these elements because they must be considered together and foremost when designing a passive home; the ultimate goal is to achieve a plan that ensures a safer and more rigid structure with incredibly high efficiency standards.

The next section provides information about the kinds and types of plumbing systems which should be considered as the next piece of the puzzle. Heating and cooling are the most energy intensive operation of the home. These systems will have to be designed to reflect the mechanical needs of the structure while also minimizing these costs. A passive home would rely on the coordination of envelope design, and natural energy production to ensure that heating, cooling, and domestic water production can be accomplished inexpensively and eco-consciously.

The third section extensively covers the electrical systems within the home; also includes in this section is the telecommunications infrastructure used to link the audio, visual, security, and smart elements of the home together. The electrical system is also essential in delivering and maintaining power inside the home. These systems should also be designed to maximize the potential of existing natural energy production. Coordinating the design of electrical systems with the other elements described above can create an automated, efficient, smart home.

The fourth section explains the important elements of weatherization and weather protection. This is included because protecting the investment of any home is just as important as location. Utilizing these techniques will ensure that the home can continue to perform at high standards for longer periods of time. Water, snow, and air break down the envelope of the home but advanced weatherization options work to combat harmful natural forces. Failing to recognize weatherization as a main component of this process will result in premature exposure and break down of critical building components.

The final two section feature in interior and exterior environment of the home. These two sections describe various ways in which the builder or designer can achieve higher efficiency standards while making these areas comfortable and modern. These spaces often express personal tastes and styles and can be coordinated to accomplish this while still utilizing all the natural abundances of the particular site. Despite these two sections being the final parts of this manual they contain information that will resonate throughout the design and build process. Functionality and efficiency are mainstays of these designs and are only enhanced by choices made in the interior and exterior environments.

1. - Insulation & Building Envelope

One critical building element which distinguishes a passive house from a traditional home is the building envelope and insulation structure. The building envelope is the contiguous structure which separates the interior environment from the exterior environment (ACEEE). New building techniques enable builders to achieve a much higher R-value, the measure of thermal resistance of the home against natural climate, which can have a tremendous impact on energy consumption over the life of the home. The higher an R-value a home can achieve, the more energy efficient and comfortable it will be. Also import in understanding the efficiency of a modern home is the HERs rating system or home energy rating system. This is an index, based 150 to 0, which describes the overall energy efficiency of the building according to the amount of energy input it requires or is projected to require. The average home scores roughly 100 on this index while a properly built passive home can easily score 0, or not need any outside energy input annually (ResNet).

The building envelope consists of several elements which must be coordinated and designed to minimize heating and cooling losses. In a typical stick built home, or a home with a wooden skeleton, these elements would include:

- Foundation
- Walls
- Vapor barrier
- Insulation
- Windows and doors
- Roof

Utilizing the right materials and technologies in designing these systems enables a designer or homebuilder to better control the environment within the home while ensuring it is extremely energy efficient (Oberlender, 258). There is no set building code or design manual that dictates the kinds and types of materials which should be used to maximize efficiency (Daniels & Daniels, 370). The next section of this manual will contain information for making choices when designing and picking manufactures for these elements. The extremely variable nature of home design may require creativity and ingenuity when assimilating all the various components of the building envelope.

1.1- Foundation

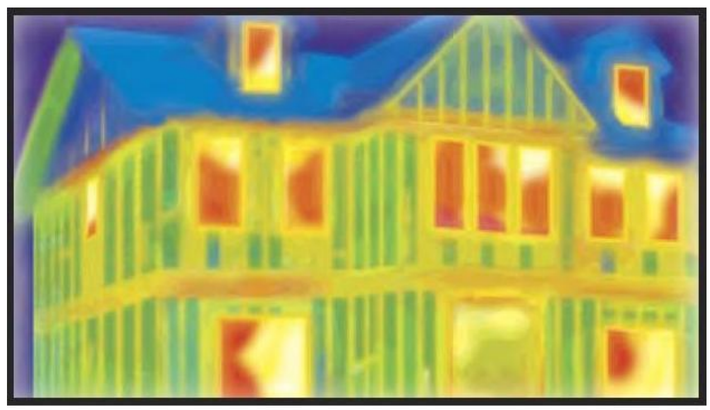
This section is the natural first place to start when designing a home. The foundation is not only responsible for footing the entire structure but also serves as a barrier between the soil and the living space. It therefore must be solid, waterproof, and energy efficient. The latter is typically not considered when creating a foundation; however, new methods of construction have produced different methods for creating foundations. The typical foundation (on any home with a level below grade) is created by pouring concrete into wooden forms, when hardened these concrete walls are usually one foot thick and laced with metal rebar for support. A layer of tar is then painted onto the exterior of the walls to ensure they are water tight (Green Edmonton).

The passive home still utilizes concrete walls as its foundation but the process of pouring them is very different from that of traditional building. Insulated concrete forms are now the preferred method of building. ICF's as they are called use high density foam building blocks to create the form structure which the concrete will be poured into. The blocks are simply locked together by hand and stacked until the dimensions of each wall are achieved (Figure 1). The blocks are then linked together internally for structural integrity. Once each form is set concrete is poured into the space between the forms. The finished product has high density foam on both sides of the block and boasts an R-value of 23 compared to bare concrete walls which only achieve an R-value of 2-3 (ICFA).

Utilizing ICF's for foundation building can improve efficiencies, save time on installation, and act as a barrier for losses through conduction. When pouring the floor, a 6 mil vapor barrier should be placed directly into the concrete. This will prevent water movement through the porous concrete of the floor and also helps to prevent losses due to conduction (Palmer).

1.2- Walls: ***Vapor barrier & Insulation***

The walls are of critical importance when designing a passive or highly energy efficient home. They make the connections to all windows and doors as well as the roof and foundation. Infiltration and air leakages can account for 35% of heat loss in a home (Formisano). Finding and sealing these air leaks within walls is critical to their overall performance.



Many typical stick frame homes generally have either 2x4 or 2x6 walls giving any exterior wall an overall width of about 6 ½ and 8 ½ inches respectively. These walls generally have a rough plywood facing upon which the façade or exterior cladding is hung. The interior of the wall features studs placed usually every 16 inches on center between which fiberglass insulation is placed. This design, despite being the predominate form of homebuilding, is extremely inefficient. Air leakages and thermal breaks, or places where air is conducted from the outside of the structure causing changes internally; cause a significant amount of air infiltration in and out of the structure. These constant air changes during the seasons keep mechanical systems running for longer periods of time and cycling on and off more frequently (USDOE). The average wall has a lower R-value than the insulation it retains, R-13, because of all these losses. The image (figure 2) depicts heat losses through walls and windows (Home Sweet Home Inspections).

Any passive home has to address the inefficiencies of traditional wall designs through insulation, and design changes. Many different insulation technologies exist and different combinations of them will perform differently when combined. Major insulation types include: cellulose, fiber, high density foam (HDF), polyethylene, Mylar, polyisocyanurate, polyurethane, and polystyrene. Different insulation types can and should be used for specific purposes; expanded polyurethane is very good for attics but performs poorly over a foundation wall (BuilditSolar).

For any remodel or new structure HDF is extremely desirable in the walls. Its expanding properties will seal air out from gaps and cracks and help to achieve an overall barrier. In general, it is difficult to achieve high efficiency standards according to current building standards. The addition of a second wall inside the original wall gives enough depth for the required insulation. Proper caulking should be done between the two walls to ensure there are no air gaps between them. This should be done with fireproof caulking or whatever local building code dictates for filling voids created by mechanical systems in the walls. Air flow between the floors of the home is extremely undesirable for the building envelope.

The new wall will be 12 inches in depth and will allow for 3 inches of HDF, sprayed in, with 9 inches remaining for cellulose insulation. Spray in HDF contains no harmful chemicals and is relatively inexpensive when used sparingly (i.e. thinner than a thicker layer) for the thermal protection it provides. Cellulose insulation comes in many different forms but is often a recycled material made from newspapers or blue jeans. It is incredibly effective when used as an interior insulation, because it has no moisture protection of its own but boasts a very high R-value. The resulting wall should be very effective, and have absolutely no holes through which air can pass giving them an R-value of 50 (McEvers).

Another important facet of the building envelop and the walls is the vapor barrier. This layer acts as a layer of insulation but also keeps all moisture from entering the building. Most building codes dictate the use of a vapor barrier. The best way to achieve a truly sealed barrier on the exterior of the building is to completely seal all seams between the barriers whether it be plastic or some other form. If OSB (pressboard plywood) is used then a plastic sheet should be used as the barrier; 10-20 mil plastic is sufficient for this purpose. Alternatively, the zip system works very effectively as a moisture and air barrier. This is OSB plywood which is faced with a plasticized coating. Special zip tape is then used over the seams of the plywood facing. The tape is an extremely durable and highly malleable adhesive foil backed tape which has been tested under extreme conditions and will not break down or unseal. The result removes the step of adding a vapor barrier to the exterior of the framing saving time but more importantly completely sealing the exterior of the structure. The image below shows the zip system on both a roof and walls (figure 3). It also eliminates the need for felt paper or house wrap, commonly called Tyvek saving additional costs to the project (Fink).

It is also important to test the quality of the wall before it is completed and buttoned up. This would include using a fogger or smoke tester to detect minute air leakages. If the roof has been installed then a negative pressure test would be a very good indication of the performance of the various barriers. The house should have no air flow. Minute leaks in the building envelope undermine the efficiency of the various technologies. Any passive home that is completely wrapped should not pull air flow through it, thusly special ventilation units need to be installed to replace the home with fresh air when a bathroom fan or hood vent is switched on (McEvers).

1.3 -Windows & Doors

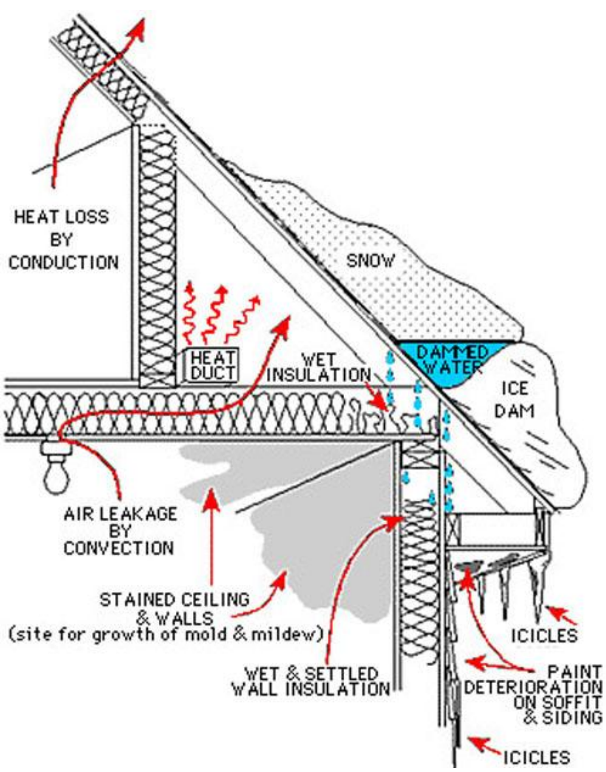
Windows and doors are just as much a part of the functionality of the home as they are part of the thermal barrier of the home. Simply placing windows and doors for aesthetics can actually harm the overall efficiency of the home. It is as important to locate windows and doors properly as it is to install them correctly. Too many windows can leave the home unprotected from the harsh rays of the sun while too few can leave old uncirculated air in the home. Windows and doors account for 18-20% of average home heat loss (Formisano). Designing this layout should be left to a qualified professional as to maximize both the efficiency and aesthetics of the design. The orientation of the home and the windows, IE northern or southern exposure, maximizes or minimizes the impact solar energy can have on heating the interior structure.

Window technology and construction has progressed a tremendous amount in recent years. New products include: double pane, triple pane, vinyl, and wood. Triple pane windows are the newest product to emerge on the scene and feature two thermal barriers of air encased between three panes of glass. The thermal breaks between the glasses are then pressurized with an inert gas which is less reactive to heat than just plain air; these gasses include argon and krypton. Highly efficient windows are slightly more expensive than traditional replacement windows but deliver an exceptional thermal rating. They can be ordered to mimic almost any finish to fit nearly all design criteria. Doors should likewise be of a high quality. Metal doors tend to conduct heat in and out of the home and should be avoided in favor of a Fiberglass or a wood composite door. Fiberglass doors are extremely rigid and capable of handling tough climates; they come prefinished and are already pre-insulated to certain standards. All exterior egresses, and bulkheads if applicable, should utilize high quality insulated doors or wood if desired (USDOE).

When installing windows and doors it is important to fully insulate the space surrounding the unit. Expanding foams of any kind can over-expand and jar the unit causing it to function improperly. Generally fiberglass strips sandwiching cellulose insulation provide a perfect barrier. It is also important to extend the vapor barrier so it meets fully and completely with the unit. Drip edging should be installed prior to the façade so the unit is completely watertight.

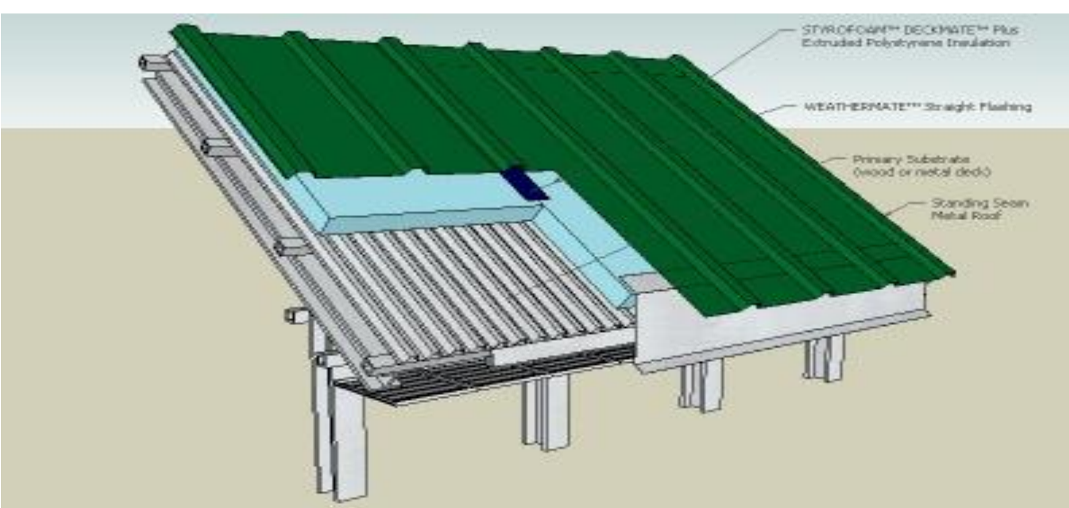
1.4- Roof

The final section of the building envelope is roof which can be extremely variable in design. There are two major types of roofs, the hot roof and the cold roof. The cold roof is deemed so because the attic of the dwelling is opened along the soffits to allow for ventilation into the attic. This type of system has dominated traditional building because it allows for ventilation under the roof which typically gets superheated and causes the failure of building materials (adhesives, shingles etc.). The hot roof is dubbed so because it lacks the very ventilation of the cold roof. This type of roof is completely closed and allows for no air flow. Most roofs aren't as inefficient as one would expect and usually only account for 10% of heat losses (Formisano). The image below (figure 4) depicts some of the potential issues a ventilated space in the attic can create; it will be a potential site for many other issues during the life of the building and is unadvised for a passive home (McElroy).



The passive home requires that the roof achieve a very high R-value. The average cold roof can only achieve an R-value of 40 while its counterpart boasts an R-value of 75 (McElroy). A properly insulated attic space can lower the temperature differential between the home and the exterior environment causing less heat loss overall. This helps in dozens of ways by putting less stress on the interior building envelope. Mechanical systems can then be configured in the attic without issue. A sealed attic space also ensures that moisture, insects, and pests are kept out of the dwelling and away from systems which they can pollute and destroy.

The passive home should use a 2X12 inch beam in the attic space with at least one thermal barrier and another 2x4 cavity above that. This would result in 5 inches of HDF, (many building codes have minimum limits for HDF in hot roofs) and 13 inches of blown in cellulose supported by Mylar backed polystyrene. If a metal roof is preferred, which this manual recommends, it should have several layers and a minimum of 3-5 inches of foam core. The metal roof is more thermally conductive than a shingle roof in the winter months which is offset by the many layers of polycyanurate foam board and thermal barriers. The metal roof is extremely popular in the Northeast because of its ability to shed snow (MCA).



2. -Plumbing systems

This section includes information about the various plumbing and interior mechanical systems which support potable water throughout the home and in some cases provide the heat and cooling sources for the home. These systems are designed and coordinated to be as hassle free, and as efficient as possible. The following two sections will describe the recommended designs for these systems. Mixed heat and hot water designs may be used; however, this manual does not recommend them because of efficiency requirements. Oil and other fossil fuel dependant systems are less compatible with current green technologies like solar thermal hot water, and solar electricity, and are not recommended.

2.1 -Heating & Cooling

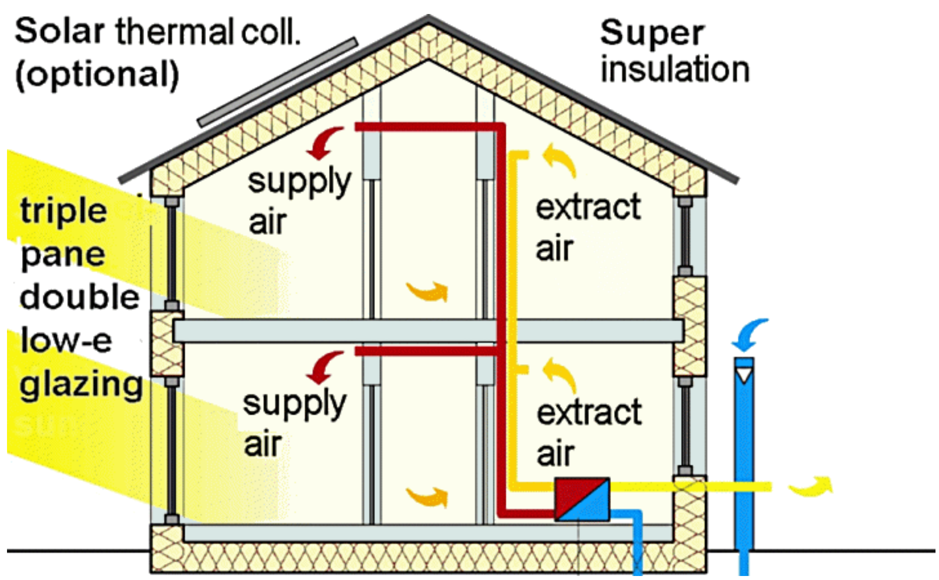
One of the most important plumbing systems in the house regulates the temperature and relative humidity of the environment inside the home. The systems for heating and cooling can be extremely varied in their type, setup, design, and installation; choosing the appropriate mechanical systems is critical for overall energy consumption and desired comfort. In the northeast, both heating and cooling loads can be quite varied throughout the year; most prefer to have separate systems to deal with these loads independently. This necessitates the installation of an HVAC unit, and ductwork, as well as a separate heating system. In some northern states forgoing an HVAC unit all together or installing room units can mean a much lower overall building and operating costs.

One of the most attractive features of the passive home, inherent in its design, is the extremely limited heating and cooling load. Super insulating the structure drastically eliminates the heat exchanges from the exterior environment. This ensures that the home retains the heated or cooled air almost indefinitely. Heat exchangers installed into the air circulation systems are tremendously efficient and work to keep the air in the home fresh and circulating it when an interior fan is switched on. The extreme air tightness of the home means that it is pressure negative and switching on an interior fan necessitates fresh air be brought in from outside. If built correctly a passive home of this design should only require heating or cooling a few times, often once or twice, a season. This is the overall reason energy consumption for a passive home can be so minimal 90-100% of energy is conserved over a modern home (McEvers).

Ventilation is a mainstay of this design. Air flow through the home creates an even homogenized internal environment. This means that all the rooms are at the same temperature and humidity. Air exchanges through the entire structure should occur roughly every two hours or .5 air changes/hr. This means the air inside the home is very fresh but facilitates the installation of a heat recovery unit to recover heat from interior air before it is exhausted. Computerized control modules accurately monitor and route air through the home as necessary. Filtration is typically built into these units offering superior air quality throughout the interior. Opening windows to capture the temperature and humidity of a nice day can be maintained or replicated in the home because of the efficiency of these systems (Eian).

In almost all cases of either new home construction or a full building remodel, one of the best solutions for heating and cooling is an air source heat pump. This technology utilizes the difference in temperatures from interior to exterior to heat your home in the winter and cool it in the summer. Operating temperatures may vary slightly but they provide substantial heating and cooling power from just below zero to well over one hundred degrees. They are often wall mounted and don't require any ducting. These units are energy efficient and optimally suited to this job (Eian).

Other forms of heating or cooling may boast different advantages but aren't necessary. The complexity of the building envelope as compared with a modern home achieve standards, even in the northeast, in which the solar thermal energy captured internally each day is greater than the thermal energy lost. On days when this is not true small electric heaters (800-1500 watts) could easily handle the load, while air source pumps are perfect for controlling the temperature more accurately.

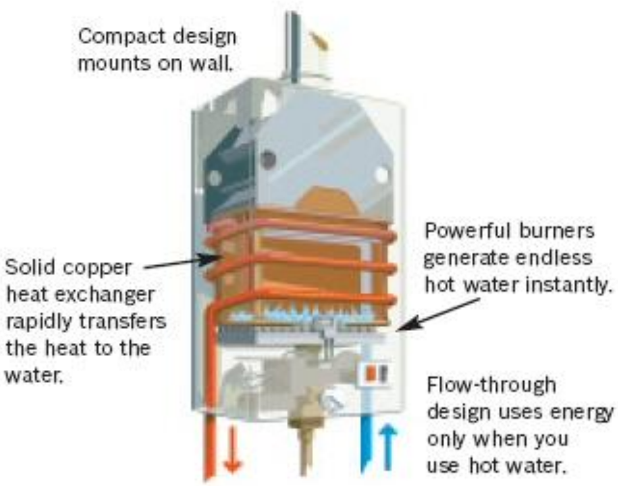


Installing or maintaining larger more complex systems may be more hazardous and less beneficial in the long run (BuilditSolar).

2.2 -Hot Water

The hot water system is one of the most active mechanical systems in the home. In many traditional designs the hot water system can be responsible for domestic hot water needs, showers etc., and the heating loads of the structure. This can be achieved by forced hot water through floors (radiant), radiators (steam), or heat exchangers (air/duct/vented). This process requires heating and reheating water then pumping and circulating it throughout the home. In other cases a hot water unit (hot water tank/instant water heater) supplies the home with its hot water needs because there is no need for a permanent heat source. In almost all instances of domestic hot water generation and storage, a large volume of water is preheated to be used instantly; it is then reheated continuously and stored in a thinly insulated container. The process requires huge thermal energy input. These systems are too energy demanding for the requirements of the passive home and should not be used (USDOE).

There are several dependable domestic hot water solutions this manual recommends depending on the size and needs of the home. Smaller homes (1-3 persons) do not use much hot water throughout the day and could quite easily utilize a wall mounted tankless instant water heater. These units can be either electric or gas and can easily handle demands of the small home. Even more appealing about this system is that it can save 50-70% the energy of a traditional unit. Utilizing an electric



unit can also be advantageous for the home which has solar panels. The electrical output of a typical solar array can easily handle the electrical consumption of these units and the air source heat pumps. The combination of these two systems is low cost, virtually maintenance free, and incredibly energy efficient (USEIA).

For homes which have a larger daily demand, over 150 gallons, hot water use rises dramatically. This likely represents the highest impact activity within the home next to overall heating. These high impact activities are more harmful to the environment than the consumption behaviors that drive them by a factor of ten (Brower& Leon, 108). The need for pre heating and storing hot water becomes essential with energy input rising similarly. To alleviate the negative symptoms of hot water generation the passive house again uses the power of the sun. Solar thermal water collectors, we recommend those manufactured by Sun Drum, located underneath the solar electric panels help to provide preheated water to the home. These solar collectors increase the efficiency of electric solar panels by cooling the underside of them, while simultaneously preheating the hot water system to over 100 degrees on average. A solar thermal system is recommended even without the use of solar electric panels (USEIA). A solar thermal water system requires pumping either water (closed loop system), or a glycol mixture (open loop) which prevents freezing, up to the roof to heat then down to the mechanical room. Preheating the water for the home can then be stored and heated to temperature when called upon.

Other large demand applications could use different green hot water options. Geothermal is one such option, it utilizes the ambient temperatures of the earth to preheat domestic hot water. There are many differing styles of geothermal wells, open and closed loops, horizontal and vertical systems to name a few. One innovative design uses a geothermal well to capture and preheat fresh air being circulated through the ventilation system (GEO). Preheating air to the ambient temperature of the earth allows for a smaller temperature differential between the fresh air to be heated and the existing internal environment.

While there are many options for various plumbing and mechanical systems it is very important to be selective about which technologies will work most synergistically in a passive home. The limited energy demands of this type of design require balanced, low energy systems; consulting with experts for ultimate design, installation, and setup is critical to long term performance.

3. -Electrical Systems

Historically, electric systems stand alone in the home providing power for all the various lights, fixtures, and outlets in the home. More and more frequently other wired systems are installed and run in conjunction with the individual home power grid. Examples of these systems include: multimedia devices, fire protection devices, home monitoring equipment, security systems, and temperature control systems. These systems are increasingly being integrated, delivering total access and control to the user. The complexity and depth of these systems can ultimately be chosen by the builder/designer/owner. These systems are highly automated and efficient allowing for endless possibilities of home electronic control.

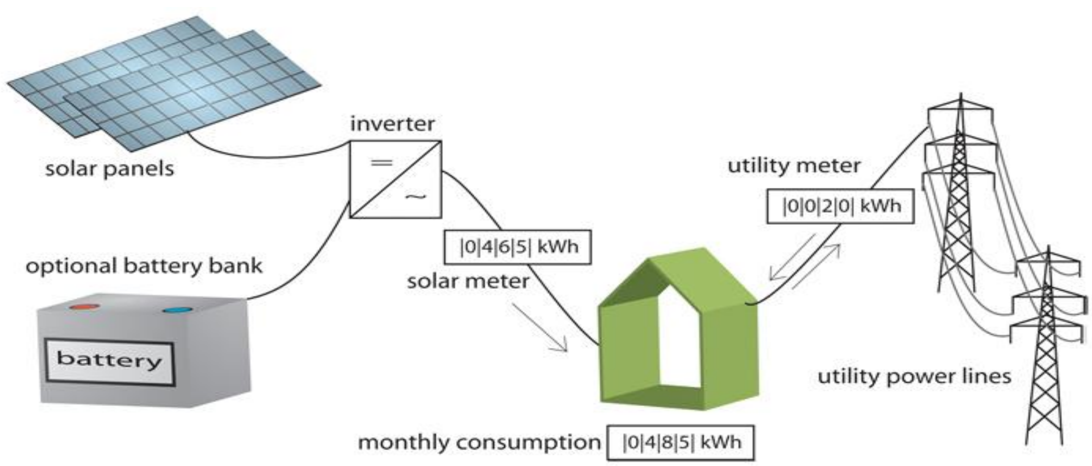
3.1 -Electrical Generation

Energy consumption is one of primary motivating factors behind the design of the passive house. One of the goals of the design of these homes is to generate all or most of the energy the home requires annually, on site. Onsite electrical generation is therefore one of the priorities of design. Regulatory trends currently support solar electric generation, allowing it to be a cost effective and viable element of design. Wind power or other methods of onsite power generation remain too inconsistent to be considered as viable on the residential scale. These technologies simply require too large an investment at this time to be considered competitive with the benefits of solar electric generation (BuilditSolar).

In general there are two distinct types of solar electric generation, thin film solar and semiconductor plates. Thin film solar is a semi flexible paper thin material which can be rolled over many surface types. Thin film can therefore cover an entire roof surface completely in solar collecting material. The obvious advantages are: flexibility, size advantage, ease of installation, and aesthetics. Less obvious is that this product is more easily manufactured and recycled, whereas traditional panels are notoriously difficult to recycle. The disadvantage of thin film is that it can be nearly half as efficient as traditional panels, requiring nearly twice the square footage for similar electrical output (Solar Consumer Reporting).

Conventional solar panels, paired with new mounting technologies, can be placed virtually anywhere. They have become more affordable and increased installations especially in recent years have led to a broad network of manufactures and accessories. Solar collaborative initiatives as well as federal and state refunds can help to offset the overall costs of these systems. In the northeast, 20-30 typical 3’x5’ solar collectors can be installed on a small roof to achieve between 5-7 kW of power. This size or larger system can support the daily, monthly, and annual energy needs of the home. Despite thin film solar being an environmentally advantageous material, this manual recommends the use of traditional panels. When linked with a solar thermal water system, like that of Sun Drum Solar, both systems perform optimally allowing for ample electrical production for a typical residential dwelling.

In situations where the home is located near the centralized power grid it can be very easy to support green energy production. Net metering (not available everywhere) is a process which allows small residential energy producers the option to sell power to the transmission company. This gives producers the flexibility to produce power without having to store and maintain it, a process which can be very costly. The same cannot be said for buildings which are located away from the centralized power grid, or looking to be independent. These structures will have to have an additional investment for storage devices and power management systems (DSIRE).



3.2 -Lighting, Appliances, & Fixtures

Establishing lighting for the passive home is as critical a design element as insulating it. Lighting must be highly efficient and arranged to not be overburdening on the electrical system. Proper lighting techniques allow for a large lighted surface area with minimal adverse light intrusion. Minimizing electrified fixtures where possible can reduce energy consumption and bring more natural light into the home. Appliance location can equally help to reduce consumption costs (Kolle).

Daylighting is now a common building method which works to make the most effective use of natural light in the home. Light cans, which funnel light from the roof into a particular room in the home, and skylights, are examples of non-electrified daylighting techniques. Other techniques like passive lighting can further assist in lighting the interior space without the need for electricity. Advanced phosphorescent paints and lighting strips can illuminate high traffic areas simply by releasing solar energy the paint captures throughout the day. These systems can be especially useful in mechanical spaces like garages, basements, and utilities rooms or used in emergency situations, like power outages because they require no electrical input. Properly placed and utilized these solutions along with the window plan for the home can adequately light the interior space for longer periods of time without the need for electrified fixtures.

Electric fixtures in the house are responsible for most annual electricaly consumption. The lamps in these fixtures could utilize high efficiency **L**ight **E**mitting **D**iodes, or compact fluorescents. LEDs tend to be more expensive than compact fluorescent light bulbs but are in fact much more energy efficient, much longer lasting, and better performing. Most compacts are manufactured with mercury and can be very toxic. The LED bulb can last almost indefinitely and isn't harmful to recycle, making it a clear choice for electrified fixtures. These new style high efficiency bulbs represent a tremendous energy saving when compared with traditional lighting techniques.

Appliances are the last large draw systems which need to be discussed. The inherent heat retention of the passive home means that heat generating appliances inside the home (fridge, dryer etc.) contribute significantly to the heat inside the home (Wilson). This fact necessities the placement of appliances in the home to be arranged thoughtfully to maximize air flow and circulation around the unit. A centrally located kitchen brings these appliances into the center of the dwelling. Energy star qualifications and appropriate appliance sizing must be considered when purchasing these units. Different lifestyles may prompt the addition of extra appliances which may be too large for the capabilities of the solar generation array. These different factors must be considered when making final decisions about appliances.

3.3 – Monitoring Equipment

Another distinct difference between a passive home and a traditional home is the level of automation among mechanical systems. There can be a number of sensitive systems which continually adjust to ensure the smooth operation of the home. These systems and the computer monitoring systems which control them represent new hardware not found in traditional homebuilding. These systems are intrinsically tied to other networks like data, fire protection, and temperature. Monitoring equipment built into these mechanical systems constantly record activity over the various systems and translates that data into information the owner can use to adjust the efficiency of the home. Data loggers can be linked into the home network to deliver the results of this monitoring in real time. This network can be very broad, from security to ventilation, and allow the homeowner to have total control from the home or abroad. The home then becomes something more than mechanical switches and relays, it becomes intelligent (Kolle).

There are many other types of smart home systems which can be integrated into the home network to further expand automation or monitor performance. A few different manufactures have created products which manage phantom power, or power sources which draw energy even when switched off. These systems use comprehensive data sets to eliminate unwanted energy consumption in the dwelling. Once used regularly these mechanical systems and monitoring equipment ensure the smooth and flawless function of the environment.

4. - Weather Protection

Weatherization and weather protection are critical building elements to consider when constructing in any environment. The structure must be capable of performing to the highest standards of efficiency and comfort despite drastic or erratic changes in the local environment. Designing the physical structure to resist these changes while maintaining a balanced interior climate is paramount. The structure must also be designed so it is completely tolerant of the climate. Moisture, ultraviolet exposure, and wind damage are all forces which the home must be effectively protected from.

4.1 -Exterior Design

The exterior faces of the home are under constant assault from the elements outside. These materials must be picked to maximize their longevity in the environment of choice. The latest generation of building materials is far advanced than the strait cut lumber your grandfather used. Composite materials come in stunning arrays of design and color. Many of these options can be tremendously eco-friendly, from finish trim boards made entirely of post consumer recycled plastic which will never rot, to recycled concrete aggregate. Proper weatherization techniques cut down on potential waste in the long and short term, a trait that benefits the environment twice (Silberstein &

Maser, 94). Products which boast ease of installation, superior protection, and eco-friendliness are no longer a thing of the past. In New England, composite hardy board products retain the natural look of building materials used in this area for centuries but can be permanent if maintained properly. Materials which don't break down, and aren't susceptible to insect intrusion are the best choice for these homes. It is also important to use proper finishing techniques for whatever system is desired. Low volatile organic compound paints can have quadruple the UV protection of competing brands. Superior technologies like these can help to protect the home for longer more predictable periods of time.

Passive home builders need to be experts in modern weatherization techniques. Utilizing and installing these new age building materials can be a difficult process; as with the mechanical, electrical, and other systems of the home a highly qualified installer with experience with these systems should be used. These professionals will have recommendations for each specific design instance. For example, built or assembled window and door awnings can protect these areas from moisture accumulations and shade them during intense heat. Properly pitched roofs have the effect of shedding ice or snow during freezing months. The building should also be fitted with a properly designed rain catchment system. This allows the home to use gravity to divert storm water away from the perimeter of the home to designated locations. This water could then possibly be used in cistern tanks to recharge the ground water (underground storage and use) or above ground for plants (above ground storage and use) (Davis & Masten, 281). Other methods can be employed to maintain the internal environment, glazed and coated windows can help to reduce solar infiltration in warm climates, but these methods are complex and should be determined by a professional. In general, these features can be designed to maximize aesthetic presence and functionality, keeping the home fully protected from constant assaults of the exterior environment.

5- Interior Environment

The interior space is the most subjective portion of building a passive home. Differing designs, layouts, and special flows can each have different merits that enhance a specific design. The interior area needs to be an efficient use of three dimensional spaces while remaining true to the aesthetic preferences of the owner. High quality products and building techniques will ensure this space is completely functional without indicating how different these structures are from traditional ones.

One of the most central interior design elements is air flow and circulation. The efficient and circulation of air throughout the home is one of the key reasons the passive home is able to achieve such impressive standards of efficiency. Heat must be able to freely reach complete mixture through the home. Obstructions, like permanent walls and doors, cut the home off from potential heat supply zones leaving areas of the home unheated (Wilson, 2). Proper air ventilation and subsequently circulation is the difference between a home which can achieve HERs rating of essentially zero and a home that will have significant energy input requirements.

Another key element which designers must confront is possible sources of heat loss and gain within the home. As mentioned previously, appliances radiate heat, some continuously which can be used as heat inside the home. Other materials, like natural stone and brick, can store heat in an unanticipated way in these homes. Designers must coordinate with the owner about these types of design choices as they can dramatically affect the overall performance of the structure. Wood doesn't have the thermal capacity of most building materials and can be used very effectively in these homes. Natural wood floors for instance generally feel more comfortable than stone or tile and represent a much more sustainable material choice. Different heat sources can and should be explored. Radiant in-floor heat may be a better choice for a home with a larger heating demand, while cooled ceilings could be necessary in a hot environment. Different designs and backup, or interim systems, can be combined for the same overall effect. Anticipating the way materials and appliance will react in the home, especially how they interact with the air circulation of the home is essential to creating a continuously comfortable environment (Kolle).

One of the last interior building elements refers to the actual building materials themselves. In almost all cases the building materials used could originate from hundreds if not thousands of product manufactures worldwide. A passive and indeed sustainable homebuilder must scrutinize each different product and manufacturing outfit to ensure the building materials up to the quality of the design of the home. Locally sourced materials should be used if possible and available. People often respond more positively to these materials and more willing to buy or feel comfortable with them because of person connection (Gardener & Stern, 120). These materials are often high quality, directly support of your local community, and require far less energy to get to site than other materials. In Massachusetts, natural wood products are locally abundant and inexpensive to obtain. It is also much easier to inspect products and processes which operate locally than it is to observe those abroad.

Product quality can have a huge impact on the final build product. In the past, building materials originating in countries where manufacturing requirements are less stringent. Substandard building materials can have hazardous chemicals in them, as was the case with Chinese sheet rock found to be off-gassing formaldehyde into homes (Hanna). Using materials from trusted sources should therefore be an import consideration for the builder instead of simply a material list. Other products, such as those which are trusted sustainable and other safety items, like paints which release no volatile organic compounds support and enhance the green achievements and quality of the home.

6- Exterior Environment

The exterior space encompasses the lot and footprint on which the building will sit when complete. This space should be oriented to optimally facilitate the function of the home on the available land. This has ramifications for the placement of the home, proximity and location of vegetation, location of mechanical services, as well as other considerations. Proper coordination of these elements is highly important for the function, and anticipated energy efficiency of the home. Other considerations such as vegetation type should be considered when designing a landscape. In climates with large annual rainfalls, water sequestering vegetation would be the best choice. Generally, vegetation can be used to ensure that rainwater is absorbed and used rather than staying near the perimeter of the foundation or home (Viessman, Hammer, & Perez, 73). This step should be one of serious thought and testing before final plans are decided.

One of the most critical elements which have been discussed throughout various sections of this document is proper site location and building orientation on the lot. This decision has impacts for the overall function and efficiency of the rest of the home. Also highly important to many homebuilders is the aesthetics of each lot configuration. These two elements must be weighed so one doesn't compromise the other. Solar exposure and building orientation must be the first consideration when choosing ultimate site location. A southern facing exposure can maximize the infiltration of solar radiation into the home and solar energy generation in the Northeast for instance. In warmer climates this orientation may not be as favorable (Wilson).

Also important to ultimate site design is the composition of vegetation upon final build completion. Choosing existing vegetation, if applicable, to maintain through a build may be an import part of overall site design. An existing tree, for instance, could help to prove a specific valuable dollar figure for the eco-system services it provides to the home. This could be in the form of UV protection, weather protection, shading or cooling, or other specific efficiency impacting measures. Evaluating and determining these potential values could provide even greater savings if these elements can be properly coordinated into the overall site plan.

The final section of the exterior environment which this manual will describe is the landscaping in close proximity to the home. This area, when properly arranged, can help to promote the overall function of the home and the interior systems by alleviating problems, primarily caused by drainage inadequacies, which plague typical construction homes. One area where drainage is always essential is the driveway space approaching the home. Typical construction homes generally have a blacktop, or petroleum asphalt, driveway laid down abutting the garage space, which may be subterranean. This design doesn't allow for water penetration and may even divert water toward the dwelling. Furthermore, this and other types of driveways don't allow for water percolation or catchment. A permeable pavement system eliminates virtually all of the listed issues. This system allows rainfall to percolate down through the pavement so it can be used in a below ground storage tank or simply recharge the groundwater

(Viessman, Hammer, & Perez, 74). Rainwater should be conserved at all costs. Utilizing this resource can significantly reduce energy and water consumption, while eliminating potential drainage issues.

Conclusion-

Widespread dissemination, adoption, and practice are the fastest ways for these building techniques to penetrate into the market. Substandard, inefficient traditional homebuilding practices can no longer be an option in our 21st century economy. Energy still represents one of the most expensive parts of the American budget, adoption of the techniques described in this manual represent an edge in a changing world economy reeling from the impacts of energy fluctuation. These success stories will direct others to follow the same path for energy freedom and advance the cause of passive home building and design (McKenzie-Mohr, 74). The overall purpose of this movement is to educate people to design and build eco-friendly homes that work within the constraints of the environments that surround them instead of impacting them. The Passive Home represents a union between the environment and the occupants where diligent planning and coordination will produce an efficient, maintenance free, comfortable home for decades to come.

Green Product Installation and Manufacturing Guide

Developed 11/20/2011 in Worcester, MA for:

Passive Home Design MQP- Worcester Polytechnic Institute

A guide to shopping for passive home construction materials specifically focused on the Greater Worcester, Massachusetts region.

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