DESIGNING NET-ZERO HOMES WITH LOGIX

LOGIX®
INSULATED CONCRETE FORMS

Good. Solid. Green.®

Forward

Since its inception LOGIX Insulated Concrete Forms has been used across North America to build thousands of energy efficient, durable and comfortable homes and buildings of every shape and size.

In the last decade we've witnessed the emergence of the rising Green Building tide which has changed the face of construction around the world. Construction methods have been revolutionized, building codes are becoming more stringent and, now, net-zero homes and buildings have emerged as the cutting edge of green building.

Net-zero builders gravitate to LOGIX because they need durable super-energy efficient building envelopes that are quick and easy to build. Many net-zero homes have already been built using LOGIX. Although every home is different and every builder and designer has their own unique approach, along the way we've gained considerable insight into the best practices for net-zero building.

We've prepared this whitepaper for those building owners, designers and contractors who want to build cutting edge net-zero homes. This whitepaper contains guidelines and suggestions only. The contractor and designer of record assume full responsibility for the competent design and construction of the construction project. However, we would like you to benefit from the experiences and insights gained from the exciting LOGIX net-zero projects that have already taken place.

There are numerous contributors to this whitepaper and LOGIX would like to thank each and everyone. In particular we would like to thank Vera Novak for her extensive contributions to this document. Ms. Novak has served as the Technical Director of the Insulating Concrete Form Association and is currently pursuing a PhD in Construction at Virginia Tech. Ms. Novak's deep understanding of building science and its specific application to ICF technology has added tremendous depth and perspective to this paper.

Welcome to LOGIX Net-Zero Homes.

SECTION 1 – The Evolution of the LOGIX Net-Zero Approach

Introduction

Energy savings, climate change, carbon emissions. These are very hot political topics, replete with extremists on both sides of the issue. Yet underlying all the debate are some common realities, which can guide collective goals.

From the perspective of national security and economic stability, there is no doubt that sourcing fuel from politically unstable countries poses a risk. Regardless of ones' beliefs as to the causes of high wind events, or terrorism targeting our energy-distribution networks, the reality is that these all pose risks to our water and energy supplies. And there is no question that overall increase in consumption can overload the existing power producers and create blackouts.

These world and natural events play out in the cost of utilities to the homeowner. While mortgages are a fixed and known monthly expense, utilities are the real wildcard for consumers. As costs rise, most homeowners have no choice but to pay up, in order to provide minimal levels of thermal comfort. But what happens when electricity bills increase 30 – 40%, as they did in Florida and Texas during the recent oil price spike? What will happen when electricity bill increase by 50% over the next five years as predicted by the government of Ontario, Canada. Even an extra $200 a month is enough to drive some people out of their homes.

There is a better way: reduce the reliance on external energy for basic thermal comfort, or livable conditions. Energy efficient building methods can produce homes which need very little supplemental energy to sustain basic comfort levels. The remaining energy demand, now greatly reduced, can be more economically procured through renewable energy sources. Not only does this provide an insurance against future rise in utility costs, but also a level of security for passive survivability in the case of an extended power outage or loss of heating.

One approach to gaining energy independence while still enjoying the benefits provided by power companies is called grid-tied "net-zero," a goal which is far more challenging than the 15 – 20% energy savings goal of Energy Star or EnerGuide. "Net-zero" is quickly being adopted by governments and individuals alike, as studies have shown that currently available high-performance technologies such as LOGIX can reduce a building's energy consumption and CO_2 emissions by 30%–50%, [1] and the remaining energy needs supplied by a combination of renewable resources.

Defining "Net- Zero"

Just as there are many shades of "green" construction, so are there multiple definitions of "net-zero." At its core, "net-zero" refers to an accounting net balance between consumption of energy and generation of energy from renewable resources.

[1] USGBC Research Committee. 2007 (revised 2008). *A national green building research agenda*. http://www.usgbc.org/ShowFile.aspx?DocumentID=3402

The Most Encompassing Definition of Net-Zero

The most encompassing definition of “net-zero” considers the environmental footprint of a building on the planet’s eco-system. From this perspective, buildings should compensate not only for their operating energy, but also for the embodied energy of all the building materials used in construction.

To meet the rigorous requirement of this version of “net-zero,” a building would need to generate power in excess of its operating energy. However, few power companies currently offer a net metering agreement which compensates for power generated in excess of that consumed by the building,[2] so there is no economic basis for the purchase of extra power generating equipment. And, to be completely true to concept, this net-zero approach would also necessitate an equivalent use/return for water and land lost to agriculture or biological uses.

However difficult to achieve this goal with the current infrastructure, it may be helpful to keep an eye on a future in which water capture offsets water consumption, building surfaces serve as mini-power plants, and available land is returned to community gardening. In the words of Amory Lovins, of the Rocky Mountain Institute: “We mean to speed the transformation from pervasive waste to elegant frugality, from causing scarcity by inattention to creating abundance by design, from liquidating energy capital to living better on energy income.”[3] Pieces of this future picture are already coming together, such as the emergence of a free market trade of Renewable Energy Credits (REC) separate from energy generation, which can provide a income stream for solar panel installation.

Another lesson learned from this approach to net-zero is the consideration of the embodied energy costs of the building materials. The single most important factor in reducing the impact of embodied energy is to design long-lived, durable, and adaptable buildings. The environmental footprint of the building is then amortized over the longest possible service life and this maximizes the net environmental benefit of the long term energy savings. This perspective guides our decisions and trade-offs in construction materials and installation.

The Most Common Definitions of “Net-Zero”

One approach would be to define Net-Zero on the basis of Energy Cost, in which case the revenue generated by the sale of energy back to the grid equals the cost of energy purchased from the grid. Because energy is often bought by utilities at a much higher rate than the selling price, this would require a lower amount of energy you will need to produce.

A more commonly used definition is that a net-zero house produces as much energy as it consumes on an annualized basis.[4]

[2] http://www.dsireusa.org/summarytables/rrpee.cfm
[3] Lovins, Amory, Reinventing Fire: A New Vision, Rocky Mountain Institute, http://www.rmi.org
[4] Dept. of Energy definition for ZEH: The U.S. DOE’s Zero Energy Homes research initiative …combines state-of-the-art, energy- efficient construction and appliances with commercially available renewable energy systems…[that] can result in

While this is an admirable goal, there are several challenges to achieving this benchmark given the current realities of energy sources and distribution systems. For starters, consider the difference between off-grid homes, and grid-tied homes.

Zero Energy Homes have a number of advantages:

- Improved comfort—an energy-efficient building envelope reduces temperature fluctuations.
- Reliability—a ZEH can be designed to continue functioning even during blackouts.
- Security—a home that produces energy protects its owner from fluctuations in energy prices.
- Environmental sustainability—a ZEH saves energy and reduces pollution.

Zero Energy Homes optimize a variety of features:

- Climate-specific design
- Passive solar heating and cooling
- Energy-efficient construction, appliances, and lighting
- Solar thermal and solar electric systems.

Moving Toward Zero Energy Homes - US DOE – Energy Efficiency and Renewable Energy

Off-Grid Homes vs Grid-Tied Homes

Off-grid homes are not tied to the electrical delivery infrastructure. This occurs typically in rural areas where the distance to the closest power line makes it too costly or impractical to connect to the grid. As a result, any electricity used in the home must be generated on-site. A battery bank stores electricity generated until it is consumed by occupant use

Off-grid houses achieve a net-zero by definition, since they can't consume power which isn't produced. However, the off-grid lifestyle is more restrictive tends to be somewhat more Spartan than grid-tied, as additional power can only be generated through significant capital outlay for renewable energy generation, such as solar PV panels.

Grid–tied homes, on the other hand, use the grid, a.k.a. the electric power provider, as the energy buffer. The amount of power generated is sold to the grid, and power consumed is purchased from the grid, in unrelated quantities. This is called "net metering." However, it is important to note that some power providers still do not offer net metering agreements, so the grid is not always available as a buffer, even when one is grid tied. In this case, a battery bank is still needed.

net-zero energy consumption. A ZEH, like most houses, is connected to the utility grid, but can be designed and constructed to produce as much energy as it consumes on an annual basis.

Today's Road Blocks's to Net-Zero

Road Block #1 - Energy Buy-Back Limitations

One snag in this net-zero formula of energy in equals energy out is the limitation of the renewable energy generation to only electric power, as that is the only type of fuel which offers a buy-back arrangement. While there are formulae for kWh equivalencies for other fuel sources which could be plugged into a net zero formula, this only works on paper, since there is no option for compensating the actual consumption of the other fuels.

To achieve net-zero per the annualized equivalent definition, the home would need to be an all-electric home, and consume the exact same amount as it produces. Since net metering agreements typically only credit generated power only up to the amount of the consumed power, it does not make sense to produce more energy generation than needed. Also, it is very difficult to predict exact power consumption, as this is very dependent on lifestyle of the occupants.

The future may hold some solutions for this conundrum, as some areas are now allowing third party purchasing of the renewable energy credit, decoupling this from the utility company use charged. Indeed, the entire power grid distribution structure is studying options to restructure from a very cumbersome and vulnerable centralized system to a more nimble decentralized "Smart Grid" approach. While the power generation at small power producers, such as PV panels on homes, is currently a very small percentage of total power generation, improved technology may increase the significance of decentralized power generation.

Road Block #2 – Photovoltaic Technology Is Still Evolving

However, installing sufficient photovoltaic panels for a full energy offset today can be very costly and requires a lot of available roof space. The state of photovoltaic technology today can be likened to calculators in the 70's, cellular phones in the 80's and satellite dishes in the 90's – big, expensive and not as efficient as they need to be.

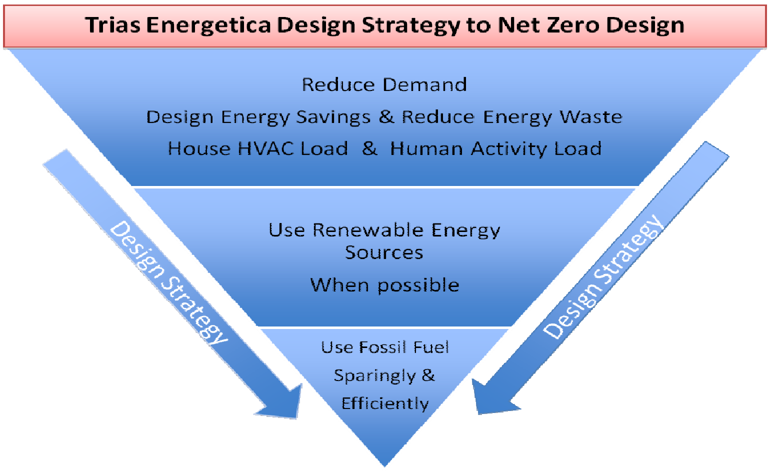
A similar technology curve will likely produce a fully market viable photovoltaic solution in the medium term future, perhaps likely in the 2015 – 2020 timeframe.

The PV's efficiency level refers to the percentage of solar energy that can be converted to electricity. Today the typical efficiency rates hover in the 15-17% range. There are some systems on the market that offer efficiencies up to 21-23% and they should offer a higher yield. It is thought that the current generation of PV technology has a maximum efficiency potential of 25%. This level of efficiency is expected to be on the market at around 2015.

The Trias Energetica Path to Net-zero

Energy advocates are converging on an approach best expressed in the sequence of progressive steps outlines in Trias Energetica .[5]

1. Reduce demand by avoiding waste and implementing energy saving measures.
2. Use sustainable sources where possible.
3. Produce & use fossil energy as efficiently as possible.



Following this stepwise approach helps keep the design process focused on efficiency and reduced demand. It provides a decision framework for renewable energy technologies, and also acknowledges the role which fossil fuels continue to play in our current infrastructure.

Separating HVAC Load From Human Activity Load

A further level of differentiation in the first step of the Trias Energetica is that of *energy efficiency vs conservation.*

Energy efficiency refers to the measures which help squeeze the most usefulness out of every unit of energy By contrast, conservation calls for the reduction of use. This comes initially from the reduction of wasteful energy use which doesn't contribute to comfort, and then a measured decision of relative discomfort by avoiding the power use.

[5] Lysen, Erik H., **The Trias Energica:** Solar Energy Strategies for Developing Countries

Examples of efficiency are high SEER A/C units; conservation by avoiding waste is not running the A/C while a window is open; and conservation from an environmental motivation is setting the thermostat more in keeping with the outdoor temperature. All of these measures have economic benefits, but represent different decision making processes and parties.

For this reason, we suggest a strategy of calculating the house (HVAC) load separately from the human activity load. This strategy recognizes the differences between the management of these two load types. HVAC loads are affected principally by *energy efficiency* measures determined in the design and construction phase, with some additional impact from the *conservation* efforts of the occupants. Conversely, the human activity load is primarily influenced by *conservation* efforts of the occupants, which can be facilitated by efficiency measures built in at the time of design/ construction.

For the house load, the ability to maintain a house at a livable temperature is dependent on somewhat predictable elements, such as historical temperature variations, humidity levels, or sunlight. These can be plugged into computer models for relatively reliable modeling. The resulting load calculation is used to determine the sizing of the HVAC, and can also be used to determine an appropriate sizing of solar panels.

On the other hand, the energy used for human activities (such as hot water, lights, cooking, plug loads) varies quite a bit depending on the lifestyle of the occupants. For example, consider the use rates of a large, active family compared with that of a single professional. The family may consume far more power through hot water, lights, computers, TVs and repeated opening of refrigerator doors than a single person. Some of this activity load can be addressed through design and construction, such as the hot water system or timed light switches. However, the total amount of energy used cannot be well predicted for future occupants.

Once both sources of energy loads have been reduced through design and conservation, sustainable sources of energy are applied wherever possible. As we shall discover, there are options for on-site sourcing as well as central utility company options. Any remaining energy consumption is then sourced from the most efficient use of fossil fuel energy, which might take into consideration currently available technology for efficient appliances, or costs of transportation for fuel types.

Introducing “NET-ZERO” Ready

All of this brings us to a very important point. It is technically possible to “buy-in” to net-zero, by covering the entire house, garage, and yard in solar panels – and not doing *anything* to increase the energy efficiency of the house.

From a kWh accounting standpoint, this might work, but it doesn’t really make economic sense. And there are regulations to consider as well, as many US States and Canadian provinces limit the KwH generation allowed under net metering.[6]

[6] http://en.wikipedia.org/wiki/Net_metering

But the primary reasons for addressing the quality of the thermal envelope are comfort and durability. A well built home should have comfortable temperature set points of 68 degrees Farenheight in the winter and 78 degrees in the summer. And the temperature variation within the home should be no more than 3 degrees from the set point.

Energy inefficient buildings typically have very leaky walls. Not only is this a problem with direct air penetration, but air drafts also carries moisture, and leaky walls are more prone to rot and mold. For a builder, this means call-backs. For a home-owner, this affects comfort levels and increases utility costs.

And what about passive survivability? Grid-tied solar panels do not function as a back-up source of power during a power outage, as the inverters have an automatic cut-off switch when the lines are down. This prevents electrical charges which could endanger line workers and affect their readings when working to restore power. A leaky house will feel the effect of the weather within hours, with heat migrating through the walls, typically in the wrong direction from the standpoint of comfort.

Reducing basic energy needs in buildings also makes sense from the larger perspective of power producers. Power companies are tasked with building facilities to cover peak demand, even when this far exceeds the average demand. The single largest load component driving the growth in electric utility peak period loads nationwide is the power consumption from cooling equipment.[7] But the culprit here can also be the solution. While the sun may cause A/C units to kick in, it can also provide the extra power needed at that time.

Stretching out the life of existing fuel sources while the technology is improving for alternative sources is also critical from a national, or even global perspective. It makes us less vulnerable to other countries politics, and strengthens our national security. Energy saving measures support the key premise of net-zero, that the greenest energy is that which is not used. [8]

For our purpose, we accept that an appropriate approach to net-zero starts with the reduction of energy usage through design and consumption, with the capability to source the remainder energy through renewable sources. This is often referred to as "Net-zero Capable[9]" or "Net-Zero Ready".

[7] Federal R&D Agenda for **Net-zero** Energy High-Performance Green Buildings, 2008, pg 28
[8] Federal R&D Agenda for **Net-zero** Energy High-Performance Green Buildings, 2008, pg 24
[9] Austin, TX Resolution for all homes to be net-zero capable by 2015, defined as "homes that are energy efficient enough to be net-zero energy homes with the addition of on-site or its equivalent, energy generation. This level of energy efficiency is approximately 65% more efficient than homes built to the City of Austin Energy Code in effect in November, 2006."

The LOGIX Net-Zero Approach

We draw on these concepts and examples of recent Net-Zero projects across the nation to define the LOGIX Net-Zero Approach as follows:

1. Build a LOGIX Net-Zero Ready Building Envelope. Reduce the house HVAC load by 40 - 60%, by leveraging the LOGIX walls with other thermally efficient shell components. Continue to improve the thermal performance of the building envelope until such point as when the home's energy needs can be provided more cheaply by renewable energy sources.

2. Use Renewable Energy sources where possible and add-on when they become affordable. Continue to integrate them into your home over time as they become more efficient and affordable.

3. Provide a ventilation system for replacement air.

4. Build-in the most efficient design/ appliances to help occupants manage the human activity load.

5. Offset remaining HVAC & Human Activity load with central source "green" power, and other energy sources. When necessary, use fossil fuel energy as efficiently as possible, or other fuel sources.

This approach has many advantages.

Many of the existing Net-Zero projects are based in the south, reliant primarily on A/C cooling, which allows for an all-electric house. The LOGIX Net-Zero approach accommodates non-electric fuel to be part of the energy mix, which accounts for local fuel sourcing (cost, transportation) and varying fuel efficiencies of appliances (heating, hot water).

The LOGIX Net-Zero required range of energy efficiency improvement allows for climate differences, some having greater potential for energy savings than others. The requirement for 40 – 60% reduction in HVAC load calls for a considerably better thermal envelope, which makes the commitment to renewable sources a more reasonable cost proposition.

The focus on the human activities load is on efficient design and appliances, vs. a call for conservation. This approach helps the builder define how to contribute to this area of savings, while recognizing that the remaining conservation efforts are out of the home builder's control. In this sense, it can also communicate to a potential homeowner the division of responsibility in achieving a net-zero outcome.

Finally, the LOGIX Net-Zero approach acknowledges that while PV and wind farms may be most cost effective on a large scale, many of the other renewable energy sources are best implemented on a site specific level. Also, as we've already noted, some areas will lack net metering agreements. For these reasons, the appropriate commitment might be to invest in geothermal, solar thermal, other on-site sources, or to support utility company "green power."

SECTION 2 – BUILDING SCIENCE CONSIDERATIONS

2a) The Movement of Air, Heat and Water

Moving from a minimally code compliant house to a net-zero house triggers the need to plan the whole house as a system, and this in turn, triggers the absolute need for an Integrated Design Process as outlined in Section 6 of this document.

The tight walls provide both the barrier and protection needed to maintain the house at a comfortable temperature and humidity.[10] The natural forces at play here are air, heat, and water and the study of their interaction with a building envelope is the domain of building science.

Air, heat and water flow are drawn on blueprints when contained in HVAC ductwork or plumbing. But what about the free flow of these elements? Air goes just about anywhere, unless restricted by an airtight barrier. Air can carry vapor, which may condense out into water upon delivery to a cooler location. Air carries heat, but heat can also be transferred through airtight barriers – such as when heat is delivered through radiation, or conducted through building materials.

The flow of air, heat and moisture can a good or bad thing, depending. On the plus side, passive solar design harnesses the beneficial sun heat in the winter months. If not designed with proper overhangs, this same sun heat can be a detriment by causing summer overheating. In cold climates, uncontrolled exchange of air between the inside and outside of a building can be responsible for up to half of the total heat loss; and in hot-humid climates, air leakage can be a significant source of indoor humidity.[11]

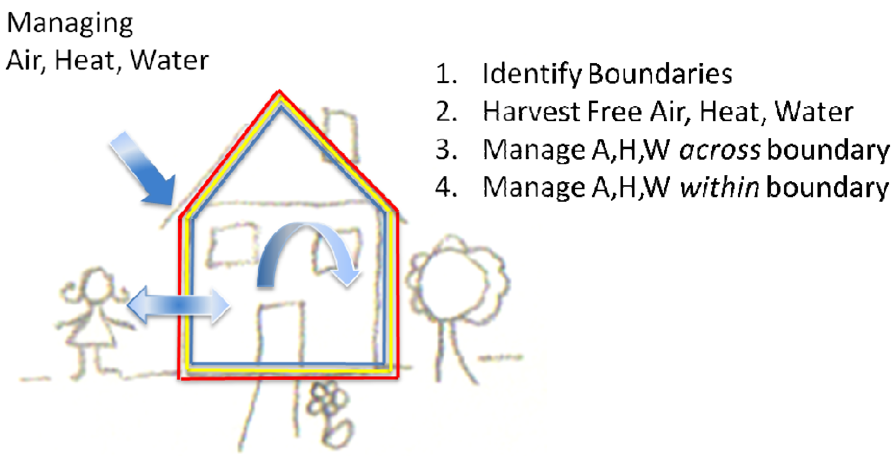
Managing these elements starts by identifying the location of the boundaries in the building envelope. They are not necessarily on the same plane. For example, the water boundary may show the initial waterproof barrier on the outside of wood siding, with a secondary barrier on the outside surface of the sheathing. The air barrier may end up on the inside, with an airtight sheetrock installation. The heat boundary should ideally be plane of continuous insulation, not disrupted by any thermal breaks other than windows.

<u>To be fully effective, the air and thermal boundary must be in full and continuous contact with each other</u>.

The identification of these air, heat and water boundaries helps in the second step, which is to determine if any of these natural elements can be harnessed for the benefit of the thermal comfort and which way the element is to flow – inward or outward. This is most often captured in the site design and initial house layout.

[10] ASHRAE Standard 55

[11] United Nations Environmental Programme. 2007. *Buildings and climate change: Status, challenges and opportunities.* www.unepsbci.org/Ressources/ReportsStudies



One of the lessons learned from energy efficient case studies is the importance of the elements of air, heat and water in the choice of materials and the sequence and detailing of assembly.

One way to simplify this process is to choose “manufactured” materials which already provide several functions. Using fewer types of materials overall simplifies the number of installation crews, and also reduces the potential failures at the points of connection. Dissimilar materials will have different rates of shrinkage, expansion and contraction due to temperature, and moisture handling.

The engineered LOGIX ICF wall system offers not only a solution to the complexity of the component integration, but also a benefit of performance synergy. ICFs can be used for foundation, above grade walls, and even roofs.

The International Codes recognize the increase in thermal performance due to continuous insulation and mass walls. However, the benefit of reduced air leakage is difficult to quantify in a building material, but can offer significant energy performance improvements. It is worth reiterating that the air barrier must be continuous from the ICF walls into the ceiling or roof plane.

The additional bonus of this system is the long service life which can be expected of the energy efficient features. A concrete wall is not affected by wind pressure, damage by workmen or later remodels, as would be the case with a thin paper layer. The R-value of EPS foam is not affected by time, nor does it absorb water, which is the downfall of many other insulation types. And, as the very nature of the wall avoids concerns with interstitial condensation, the LOGIX ICF wall can be expected to be very durable, and provide a long service life of high performance.

2b) Minimizing The Movement Of Air

Air leakage, or the unintended movement of air across the thermal boundary, contributes to the majority of energy loss in conventional framed construction. Air can transfer heat and moisture not only through the envelope, but in the case of framed construction it may enter into the cavity wall, introducing a conductive current which decreases the thermal value of the insulation.

Sealing air leaks can be very complicated. Building paper and spray or blown insulation may help seal some gaps initially, but complete air sealing requires additional detailing of gaskets, sealers at the sill plates, and continuous attention to repair holes made by tradesman. This adds a layer of complexity to the building process, and requires a level of attention to detail which is difficult to achieve on most construction sites.

Also, the points of air penetration in a framed wall cavity, such as sheathing joints, floor/wall joints, and insulation gaps, only get worse over time, as the wood framing shrink and shift. Air barriers joints and seams also need to withstand positive or negative pressures from wind, stack effect and mechanical ventilation. [12] Sealants at the time of construction only provide minimum protection against future air leaks.

The best defense against air leaks is to build with a material which by its very composition has no air leakage, independent of the skill of the workforce. This is the case with the concrete core of a LOGIX wall. As the ready-mixed concrete is placed on site, it forms a monolithic concrete wall which is virtually air tight. Penetrations in the wall, such as windows and doors, or utility service pipes, are clearly identifiable and can be sealed for air tightness.

The continuity of the air barrier should be carefully detailed to extend into the “cap” of the conditioned space. This can be a flat ceiling in the case of a vented attic, or the ceiling of a cathedral ceiling. Typical points of air leakage are through can lights, at the juncture of the wall to the ceiling, and around penetrations for fans, fireplaces, and appliance stacks. The IECC provides several options for compliance, including gypsum board (airtight drywall approach), closed cell foam (1.5 inches thick), or open cell spray foam (4.5 inches minimum).

Once the design approach is determined, it is important to provide clear details to the contractor crews, as even a small hole in the air barrier can negate the effectiveness of the air barrier. Further information is provided the Guidelines for Building Envelope Materials and Detailing.

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[12] 2012 IECC Section 502.4.1.1 The air barrier shall be continuous for all assemblies which are the thermal envelope of the building and across joint and assemblies. 502.4.1.2.1 Materials – lists cast-in place concrete as one of the compliance materials.

2c) Managing The Movement of Vapor/Water

The discussion of vapor barriers first emerged in the 30s and 40s, and was not distinguished from the function of an air barrier. The intent was to protect the water sensitive materials in the conventional wood frame envelope, which are susceptible to rot, decay and mold. Prior to this time, if warm, moisture-laden air entered the wall cavity, the air circulation and leakage to the outside could dry out the cavity without any damage to the walls.

The air dry system came at a great price for comfort and energy efficiency. With the addition of insulation in the walls, this moist air was now detained in the cavity, where it could cool to the point of condensation, or dewpoint. The solution was thought to be adding a vapor barrier to prevent vapor movement.

However, the codes have shifted over the last years, recognizing that the first defense it that of an air barrier, which will stop the moisture laden air from moving into the space. Codes now call for vapor retarders (as opposed to barriers) only in the cold climates (Zone 7 & 8), to be installed on the warm interior side of the wall. In all climates, rooms with high moisture, such as bathrooms, should have a fan to eliminate moisture, but vapor barriers may also be added under the sheetrock, as a precautionary measure.

LOGIX ICF walls eliminate the concern on every count. The continuous EPS insulation backed by the concrete provides an impenetrable air barrier and the continuous insulation provides a combination of vapor resistance and temperature drop across the foam which typically precludes interstitial condensation. And even if there were moisture transfer into the wall, neither concrete nor expanded polystyrene (EPS) foam has available organic matter to support mold growth, so the specific temperature gradient through the wall becomes less critical.

2d) Minimizing The Movement Of Heat (The LOGIX ICF Effect)

LOGIX walls are a logical choice for a durable, long lasting, airtight and energy efficient building envelope.

Insulated Concrete Forms in general provide a level of thermal performance that is generally accepted to be greater than the sum of its parts. This enhanced level of thermal performance is known as “The ICF Effect”.

LOGIX has built on “The ICF Effect” and taken it even further. With the introduction of cutting-edge XRV Panels and Platinum Series technology, LOGIX provides the highest levels of thermal performance in the industry.

This is why LOGIX and Net-Zero are the perfect match.

Introduction to The ICF Effect

We all know that insulation is a major factor in contributing to an energy efficient, comfortable building.

However, in terms of energy efficiency the performance of a wall assembly is more critical than the insulation alone. This fact is supported by a well known study that concluded that exterior walls made with insulated concrete forms (ICFs) require 44% less energy to heat, and 33% less energy to cool, compared to wood framed walls of similar insulation value. Despite the similarity in insulation values, ICF walls contribute to a much more energy efficient building than framed walls. This attribute of ICFs is known as the "ICF Effect."

So what is it about ICFs that create the ICF effect? Three properties:

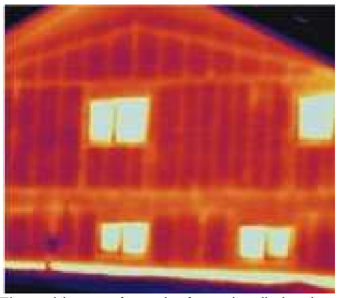
Continuous insulation
Air tightness and
Thermal mass

Compared to framed, and even masonry construction, ICFs are the only wall types that inherently encompass all three properties. LOGIX and the ICF Effect are discussed in detail below.

CONTINUOUS INSULATION

Discontinuities in the insulation, such as gaps between the insulation or where the thickness of the insulation decreases, can reduce the overall insulation value of the wall assembly.

For example, R-19 batt-insulation in framed walls will not provide an R-19 wall assembly. Framed walls consists of batt-insulation between studs, which means the insulation is only effective between the studs. Therefore about 20 percent of the wall is not insulated. Wood studs provide little insulation value, and act as a thermal bridge where heat can pass through the wall increasing heating and cooling loads.



Thermal image of exterior framed wall showing heat escaping through the studs. Studs act as a thermal bridge through which heat can pass through the wall increasing heating and cooling loads.

Thermal image of exterior LOGIX wall showing no heat escape through the wall. Continuous thick insulation with a solid concrete core wall prevents thermal bridging and heat escape through LOGIX walls.

Building energy codes in the US, such as ASHRAE and IECC, require an additional layer of continuous insulation in framed walls to make up for the insulation loss. In 2012 new energy codes in Canada will have similar requirements.

LOGIX is continuous by its very nature as a concrete forming system and the foam is of a consistent thickness. Thus the stated R-Value of the panel is representative of the actual R-value installed in the wall. In addition, the form ties within LOGIX walls do not act as a thermal bridge. As a result, the R-value remains constant throughout the wall assembly.

Building energy codes in the US, such as ASHRAE and IECC, recognize the value of continuous insulation, for example by specifying that an R-20 cavity wall insulation is the equivalent of an R-13 cavity wall when it is combined with an R-5 continuous insulation layer. In 2012 new energy codes in Canada will have similar provisions.

The building industry is responding to this requirement through the use of insulated sheathing boards. While this may address the code required thermal values, the difficulty of sealing these boards to achieve a durable air barrier will still require considerable supervision and detailing.

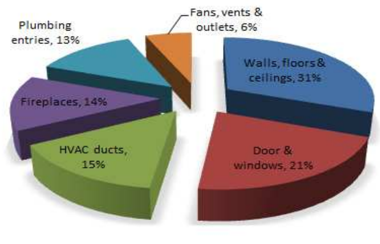
Where R-values measure resistance to heat flow, U-values measure how well a material allows heat to flow through (thermal conductance). The higher the U-value the better the material is at allowing heat to pass. The more heat that passes through a material then the less effective it acts as insulation – the lower the R-value. In other words, as the U-value decreases the R-value increases, and vice versa (U-value is simply the inverse of the R-value). To determine the U-value, simply divide 1 by the R-value.

Window and door manufacturers often use both R- and U-values to grade their products. For windows and doors, the lower the U-value the better it is at keeping out heat and cold. Metals and expanded polystyrene (EPS) are good examples of materials that conduct and resist heat well. Most metals conduct heat, therefore, are bad insulators (high-U value, low R-value); EPS does not conduct heat well, therefore, are good insulators (low U-value, high R-value).

AIR TIGHTNESS

Air leakage in framed buildings contributes to the majority of energy loss. As more air infiltrates through the wall the less effective the insulation becomes. Framed walls are basically hollow structures offering many places where air leakage can occur (i.e., through sheathing joints, floor/wall joints, and insulation gaps to name a few). Overtime, wood framed walls tend to shrink and crack leading to more potential sources for air leakage. Building paper and spray or blown insulation can help seal most gaps but will not guarantee all leaks have been addressed, or that it will block future air leaks.

Compounded with continuous foam insulation panels sandwiching a solid concrete wall, LOGIX provides a virtually air tight structure. Air leakage in a LOGIX wall are easily identifiable and sealed (service penetrations, windows and doors). No air leakage through the walls ensures LOGIX maintains its insulation value.



Energy loss contribution of typical residential home.
Source: U.S. Department of Energy

THERMAL MASS

High mass wall structures such as concrete have the added benefit of increasing the energy performance of a building despite having a low R-value. Essentially concrete can provide a thermal lag as it absorbs the temperature differential between the indoor and outdoor temperatures. This property of concrete is known as the “thermal mass effect.”

Building energy codes in the US recognize the energy saving benefits of mass walls, and thus requires less insulation for buildings that use high mass exertior walls, than framed walls.

The thermal mass effect is influenced by differences between the indoor and outdoor temperatures. Since heat flows naturally from a warmer place to a cooler place, two scenarios can occur that impact the mass effect of concrete:

1. Outdoor temperatures fall above and then below indoor temperatures
2. Moderate climates and the shoulder seasons that occur between the heating and cooling seasons.

Scenario 1

In the high desert areas of the American Southwest, diurnal temperature swings often cycle above and below the desired indoor temperature within a 24 hour period. This can create a conflicting demand on the HVAC system calling for heating at night, and cooling during the day, a requirement which many HVAC systems are not equipped to handle.

Native Indians responded to this changing environment with the use of heavy adobe walls, which would act as a flywheel for the temperature changes fluctuations.

Similarly, the concrete in the LOGIC ICF wall moderates the temperature swings. During a hot summer day, the heat will be absorbed by the concrete as it moves towards the cooler interior side of the wall. However, when the nighttime outside temperature falls below the indoor set point, the heat now stored in the concrete will reverse direction and move to the cooler air outside. As a result, the interior of the building stays a more constant temperature, reducing the peak cooling loads.

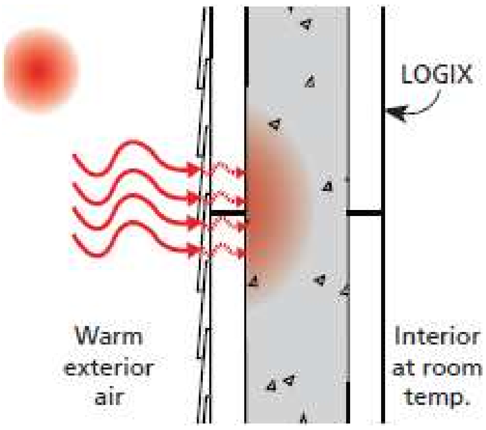
The added benefit of the LOGIX ICF insulation on both sides of the concrete wall is that it serves to moderate and delay the heat absorption and radiation from the concrete mass. For example, once the concrete has reached full heat absorption, or steady state, the heat would then transfer directly into the interior space. However, the additional foam on the interior may delays this transfer long enough for the nighttime temperatures to reverse the flow. Similarly, once the concrete is cooled – it would provide no thermal resistance for escaping warm interior air. In this case, the exterior foam provides the necessary R-values.

Scenario 2

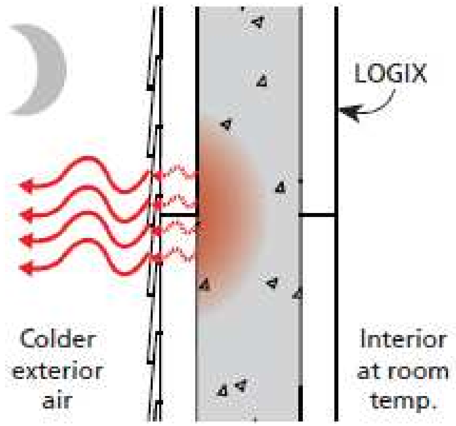
In moderate climates, the shoulder season may provide the same challenges for HVAC systems. Some weeks may require heating, but are followed by days of cooling. As most thermostats require a manual switching from heating mode to cooling mode, this should season is often marked by some level of thermal discomfort.

The heat absorption capability of the concrete, coupled with the thermal resistance of the EPS insulation provide the same temperature moderation as described above, albeit in a longer time frame. This thermal lag may be sufficient to handle the temperature variations, and reduce the indoor temperature swings. Eventually, as the exterior temperatures stabilize on either side of the interior set point, the concrete will reach a steady state, with limited influence on heat transfer.

The combination of the thermal mass of concrete, the high insulation value of the form panels and the air tightness of the system has the effect of creating an R-value of the wall assembly that can be greater than the tested R-value of the insulation. This is known as the “effective R-value” of ICFs.



During warm summer days, heat is absorbed into the concrete core wall of LOGIX, but must first travel through a thick layer of insulation impeding the heat absorbtion. (See Scenario 1)



At night temperatures fall below the interior temperature, which causes the heat absorbed during the day to flow to the colder exterior side of the wall. (See Scenario 1)

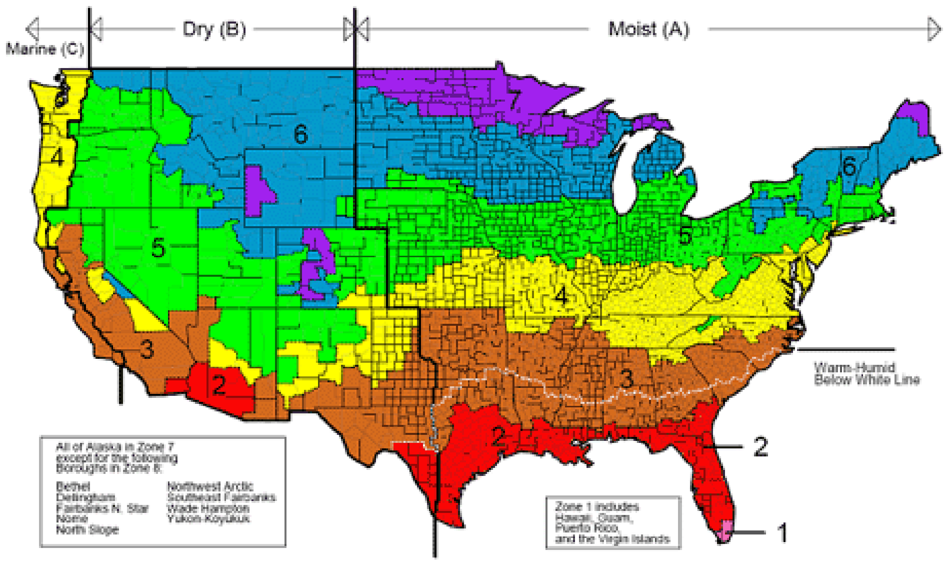
Climate Zones

The thermal mass effect of concrete walls will have a greater impact in areas where the outdoor temperature cycles above and below the desired indoor temperature within a 24 hour period, as described in Scenario 1. This is because little or no heat reaches the interior of the building resulting in very little cooling loads.

Areas such as New Mexico and Arizona, where high cooling loads dominate, would benefit most from the mass effect of concrete. In colder climates, such as northern parts of Canada, where the temperature typically remains below the desired indoor temperature in a 24 hour period, mass effect would have less of an impact. (Although, thermal lag, as described in Scenario 2, would still delay heating loads)

Consequently, the thermal mass attribute in the ICF Effect has a greater impact in the southern parts of the US, and a lesser effect as the climate changes northerly towards the colder climates of Canada.

The influence of mass effect in different climates is consistent with the Climate Zone Map found in ASHRAE 90.1-2007 and other building energy codes. Mass walls require less insulation than steel and wood framed walls. The insulation requirements increase from Zone 1 (hotter climates) to Zone 8 (colder climates).



Climate zones in the United States.

Eight specific climate zones are located in the climate zone map for North America. Zones 1 and 2 are located in the hotter climate regions of the southern United States, and progresses northerly where Zones 6 to 8 are found in the milder and colder northern parts of Canada.

The R-value of LOGIX foam insulation panels, which are available from R-23 to R-66, easily comply with the insulation values required in every climate zone. A comparison of LOGIX forms to the required insulation values in different climate zones are shown in the attached tables (See Building Energy Codes - Minimum Recommended R-values).

Perhaps the most exaggerated claims often heard in the ICF industry is the R-value of an ICF product being R50 or more.

These claims are based on an independent study conducted in 1996 by CTL, Inc. The study looked at the thermal mass performance of ICF homes in different climate zones throughout the US and Canada, and compared the results to wood framed homes of similar size. It concluded that in the southern parts of the US wood framed homes would need to be insulated to at least an R50 to be as energy efficient as an ICF home of similar size. As you move further north the equivalency decreases.

So can an ICF perform to an R50? Consumers should first be aware that R50 is not the tested R-value of the insulation, but an equivlency to framed walls, as noted above. It's also important to note that this claim only applies in hotter southern climates of the US where cooling loads dominate. There is no doubting that ICFs perform beyond their stated R-value due to the ICF Effect, but to substantiate claims of R50 or greater, which is far more than a typical stated R-value of R24, further independent research would be needed.

In an effort to validate the ICF Effect, LOGIX has launched the Greenbate Program, which monitors and collects energy consumption data from LOGIX home owners throughout North America. The program aims to have sufficient data that can accurately quanitfy energy use on ICF buildings for energy modeling software. In addition, a more accurate comparison of LOGIX and other walls systems can then be modelled.

Growing environmental concerns and Increasing oil prices has shifted the focus in building construction to produce the most energy efficient buildings, and has prompted building energy codes to create more stringent requirements.

ASHRAE 90.1-2007, which most energy codes are based on, has increased the R-value requirements for walls by 30%. In Canada, new energy requirements are being implemented for the first time into the 2010 National Building Code requiring some walls to have R-values of up to R29.

The ICF Effect is what enables LOGIX to exceed current and future energy demands. It's not just about R-values that create energy efficient buildings - it's the ICF Effect.

SECTION 3 - Design Guidelines for a LOGIX Net-Zero Ready Home

3a) Guidelines for Site Design

Energy efficient design starts with the awareness of the opportunities presented by the building site and proximity to existing infrastructure. The orientation of the building will determine the amount of air, heat, water and light which can be harvested for the benefit of the building comfort.

Site Design Guidelines for Heating Dominated Climates

Homes in northern climates will seek to harvest the maximum passive solar and day-lighting opportunities. For example, buildings may be built on a long east/ west axis providing plenty of southern exposure. A sun tempered south-facing space could help to capture more of the heat, which can be diffused into the remainder of the house.

The eastern facing room might be a good location for a breakfast nook, while the entire north side could be designed with narrow horizontal windows placed high in the north wall for diffuse day-lighting but minimal heat loss.

Natural air flow patterns on a site should also be noted. Strong wind patterns might call for extra attention to wind-loaded sides of the building to protect against driving rain, or pressure induced air infiltration. This might not be the best location for doors or operable windows, and extra attention should be given to the installation of the rain screen and airtight building components.

Site Design Guidelines for Cooling Dominated Climates

Building design in hot climates will want to protect the Southern face with appropriate solar shading, and perhaps design extensive patios on the East and West face of the house.

As well, western facing windows should be minimized.

A good design will also manage these elements in the immediate vicinity of a home. Deciduous trees can help shade a home and reduce the heat gain. Evergreen trees or bushes with sufficient access to water can be placed in the path of an incoming breeze, acting as a natural evaporative cooler, and cooling down the walls or roof of the house. This air may also be introduced into the house in appropriate dry climates. This is one of the few instances when water, in the form of water vapor would be welcomed into the house. Typically, a house is designed to not allow moist hot air to permeate the boundary of the building.

Water Management

Water management at the site also affects a net-zero house, not only in the overall environmental footprint, but also in the cost of water and energy requirement to distribute the water. Rainwater harvesting is increasingly endorsed by municipal codes, and can be set up with simple flow valves for watering. In dryer climates, low-water landscaping is supported by more efficient sprinkler heads and weatherstation controllers which draw from historical weather patterns as well as rain-sensing devices.

3b) Guidelines for House Design

Designing For Re-Use and Flexibility

Houses are like books – they are outdated as soon as they are built. This is often why house remodels are so drastic. Yet some of this can be minimized, at least from an energy efficiency standpoint. The key is to build the house in separate components layers, in a way that allows for remodel of one component while leaving the rest undisturbed.

The layer which is usually the most permanent and most expensive to remodel is the building shell. It makes sense to put the money and effort into airtight and durable construction, with continuous insulation appropriate for a net –zero goal in the specific climate. If this step is taken, the relative amount of supplemental heating and cooling is reduced, which can eliminate the need for remodeling of the exterior envelope for anything other than aesthetic reasons. Keeping all mechanicals bundled and accessible also simplifies future equipment adaptations.

The other component layers are generally the interior demising walls and the mechanicals. LOGIX structures offer the advantage of being able to fully support the floor and roof on the exterior bearing walls.

This is an advantage when looking at the adaptive reuse of the spaces, as all interior frame walls may be non-bearing and thus easily moved around. Depending on the floor type, this may also provide broader options for HVAC ductwork.

This brings us to our third component - the mechanicals. Designing the HVAC, wiring and plumbing with an eye to future space reuse is generally accomplished by clustered plumbing, central HVAC ductwork, and electrical circuits which run primarily through the floor / ceiling.

The next step in providing for the future would be to wire/ plumb for the renewable energy sources which are available now, even if not currently in the budget. For example if you are planning to install a combined solar thermal hot water heat / radiant floor in the future, then install the PEX tubing while placing the concrete floor. The expense is minimal compared the cost of a future retrofit.

Providing options for future electrical needs are sometimes the least expensive to install. For example, electrical hybrid hot water heaters are fast becoming as efficient as gas heaters and likely future replacements. Plug-in electric cars are making great strides in developments, which calls for a plug in the *back* of the garage, to avoid tripping on extension cords. In the meantime, this can certainly be used for other power tools.

Most of these crystal-ball installations are minor costs when incorporated in the original construction, but can be significant once the drywall is up.   Of special note is the placement of 240 volt outlets, which are needed for appliances such as clothes dryers, ranges, ovens, cook-tops, heaters, air conditioners, and water heaters.

Size and Shape Considerations

Size Considerations

One of the most effective measures for both energy efficiency and affordability of construction is the size of the home. According to the North American Association of Home Builders, since World War II, the average amount of floor space per person in a North American home has more than tripled:

1950   292 sq ft per person
1970   478 sq ft per person
1990   780 sq ft per person
2008   960 sq ft per person

Bearing this in mind, when designing your new home you should very carefully consider the amount of floor space you are going to require in order to enjoy your new home.

Shape Considerations

Square box shapes produce more square foot of floor than the same linear feet of wall in a rectangular shape. Minimizing the wall space also reduces the related heat loss through the walls. However, beyond approximately 32 ft square, some variable of rectangle may be a more economical option, given the standard sizing of roof trusses.

A more compact overall size also promotes good design for air flow and exchange, perhaps through a central stairwell. It also allows for better light flow and even temperature. In temperature climates, the design of the house can also take advantage of natural cooling, and design the windows and doors for cross ventilation.

While smaller is better from a heating standard, this does not necessarily mean giving up functionality. Minimizing hall space, providing double function for rooms, avoiding two story spaces, and a host of other design tools are well described in the series of “Not So Big House” books by Sarah Suzanka (Taunton Press).

One of the key features of improving the energy efficiency of the building envelope is continuous air and thermal barrier insulation to prevent the transfer of heat across the boundary.   This is much easier to achieve with a simple roof design, few penetrations in the wall (such as balconies, bays), stacked walls (no cantilevers). Invariably, these complexities of framing result in a dense mass of timbers, leaving no room for insulation. And, as the house ages and this wood dries and shifts, all these areas are more prone to develop air leaks and open paths for moisture.

While LOGIX construction solves the wood problem, it doesn't avoid the difficulties of the detailing of the multiple angles and connections.

You may also wish to consider located all of the bedrooms on the 2nd floor of the home. This allows you to effectively split your home into two distinct zones – one which is conditioned during the day and the other conditioned at night.

Window Area to Wall Area Ratio

A standard guideline for energy efficient windows is to keep within a 18 % window to wall fenestration rate. This is based on standard double pane windows with a U-value of .35.

However, higher performance windows with U-values of .20 and lower are now available, and coupled with Solar Heat Gain Co-efficent of each window specific to the window's orientation and natural shading, windows are far more efficient.

While this would theoretically allow for a higher percentage of glazing, windows should only be designed where they serve a function – daylighting, view, egress.

Indirect lighting and diffuse lighting can enhance the amount of light gain.   This improves not only energy efficiency, but comfort as well.

Shading Considerations

The following table provides useful recommendations for overhang depth in order to avoid excessive solar heat gain:

		Vertical distance between bottom of overhang and top of window sill				
		≤ 7' 4"	**≤ 6' 4"**	**≤ 5' 4"**	**≤ 4' 4"**	**≤ 3' 4"**
Climate Zone	**1 & 2 & 3**	2'-8"	2'-8"	2'-4"	2'-0"	2'-0"
	4 & 5 & 6	2'-4"	2'-4"	2'-0"	2'-0"	1'-8"
	7 & 8	2'-0"	1'-8"	1'-8'	1'-4'	1'-0"

Solar Gain and Daylighting Considerations

In an average household, energy loss from windows may account for 10 – 25% of overall heating costs. Ironically, the house may still not have sufficient daylight. There may be sufficient glazing, but in the wrong location and without appropriate shading, which may result in requiring window coverings to block out the glare – and the light.
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Early in the design phase, windows placement should be designed to harness the available light due to site specific and seasonal sun location, as well as seasonal vegetation.

The floor plan should reflect the available daylight with the appropriate room use. For instance, in cooling dominated climates you should consider locating your kitchen and primary living areas on the southeast corner, so they are exposed to the less intense morning sun.

Shading to avoid inadvertent heat gain from direct solar access can be achieved from landscaping, awnings or shutters.

Daylighting techniques are well described in the Whole Building Design Guide [13] and the Daylighting Collaborative[14], a program of the Energy Center of Wisconsin to incorporate daylighting into mainstream design and construction.

Installing lighter colored floors and countertops will reflect the incoming daylight and will reduce the need for energy consuming lighting. Alternatives solutions to bringing daylighting deep into a house are the Solartubes, and the newly developed fiber optic lighting.

Skylights should be used sparingly, but can be quite effective in locations which are shaded by trees to avoid summer heat gain. However, heavy tree cover directly above the roof should be avoided, to prevent skylight damage from falling branches.

If the building was properly designed to the site, heat can be intentionally introduced across the building envelope through direct solar access – such as radiant heat through a window on the south side of the building. Even moderate amounts of thermal storage can be incorporated to provide an interior temperature stabilizer.

On the flip side, shading for unwanted sun or light needs to be incorporated into the house design – and protected from budget eliminations as the project draws to the end. These shading elements, such as landscaping, awnings or shutters, need to be designated as functional elements and not as optional decorative accessories.

As part of a heating strategy, air can be naturally pre-heated and then introduced into the living space, through the use of a sunroom/greenhouse space or a solar wall. Air flow can also be supported through the use of the venturi effect or stack ventilation for removing hot, stale air and drawing in fresh air.

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[13] National Institute of Building Sciences, Whole Building Design Guide, www.wbdg.org/resources/daylighting.php

[14] Daylighting Collaborative, http://www.daylighting.org/

Plumbing and Appliance Considerations

Much can be done in the design phase to provide for indoor water conservation. Clustering and stacking rooms which require water use will allow for a centralized location for the water heater, and minimize the runs for delivery. Engineered plumbing calculations can help determine the optimal delivery system to ensure the minimum amount of standing hot water.

Locating the mechanical room in the center of the home will necessitate shorter, more energy efficient runs.

After the electrical loads used for HVAC or hot water, refrigerators are next largest consumers of electricity and will be a large draw when trying to achieve a net-zero house. Designers can help improve the efficiency of the refrigerator by placing them where they will be kept cool – away from sources of heat such as stoves or direct sunlight. Also, the cooling coils on the back need air flow to help dissipate the heat. This is not a problem with free-standing appliances, but built-in installations may have the air flow obstructed by the surrounding cabinets.

3c) Guidelines for Building Envelope Materials and Detailing

3c.1) Build Tight

There is a general convergence of practitioners of net-zero that the energy design strategy is to detail and construct a house to be as air tight as is economically reasonable. In humid climates, particular care should be give to points of penetration in areas of moisture susceptible materials, such as roof framing. Replacement air is then brought in purposefully, in a controlled manner.

There is no one target number for the air tightness, measured in Air Changes per Hour (ACH), nor an agreement on ventilation air flows. The PassivHaus, a benchmark designation developed in Germany, recommends a very low .6ACH@50 (about .03 ACH Nat), and restricts the amount of site energy generation. The Building America approach doesn't specify the air tightness, nor the insulation, choosing instead to focus on a reduction of energy consumption over current code.

The LOGIX Net-Zero Approach recognizes the merits of both programs, and turns to guidance from the goals of the Trias Energeticas. The first goal is to reduce HVAC demand by designing energy efficiency measures and reducing energy waste. The LOGIX Net-Zero Approach adopts the Building America target range of 40% – 60% as a significant commitment to improvement of the building envelope.

This reduced HVAC demand improves the economic feasibility of the second Trias Energetica goal, site generated renewable power. We find no reason to limit the site energy generation, but apply the rational of economic feasibility to determine the point at which the cost of site energy sources would meet the home's energy needs more economically than additional improvements to the thermal envelope. Since reduced air infiltration is the least expensive approach to improving the building envelope, a tightening of the envelope will typically generate greater savings than the additional purchase of solar panels, and thus be the more economical choice.

Based on numerous case studies of LOGIX houses, we recommend a target ACH@50 of 1.50 or less, with ventilation strategies to accommodate the house occupancy (ASHRAE 62.2 or current code).

This level of airtightness is proposed by LEED-H for maximum credit (EA 3.3) for Zone 8, which is the Canadian climate. We support this very low level of air infiltration for the same reason cited by the founder of Passivhaus[15], to avoid the interstitial condensation which can damage the structure, and which has been an area of concern historically for energy efficient houses.

3c.2) A Word About Insulation Requirements

Growing environmental concerns and increasing oil prices has shifted the focus in building construction to produce the most energy efficient buildings, and has prompted building energy codes to create more stringent requirements.

ASHRAE 90.1-2007, which most energy codes are based on, has increased the R-value requirements for walls by 30%. In Canada, new energy requirements are being implemented for the first time into the 2010 National Building Code requiring some walls to have R-values of up to R29.

A net-zero house calls for an even higher efficiency envelope. The levels of insulation recommended by the LOGIX Net-Zero Approach are determined by the climate and the goal of achieving a 40 -60% reduction in HVAC loads up to a point of pricing parity with the cost of renewable energy sources. Rules of thumb used by Building America are R-5 for windows, R-10 for sub slab, R-20 for below grade walls, R-40 for above grade walls, and R-60 for ceilings/ roof. (5/10/20/40/60). PassivHaus recommendations are similar.

Taking into account the improved energy performance of the ICF Effect, and the continuous insulation of the ICF from foundation through the above grade walls, the LOGIX Net-Zero Approach may be able to achieve a similar levels of energy performance with lower wall R-values.

Due to the vast differences in climate zones across North America, this determination can best be made with the use of energy modeling software. However, you should bear in mind that existing modeling software may not accurately reflect the entire boost in thermal performance due to "The ICF Effect". (Case in point – a study on the thermal mass of ICF's done by the CMHC in Canada is due to be released in February 2012. The advance word is that the study will conclude that the thermal boost due to the thermal mass in ICF walls is higher than is currently generally accepted by the modeling community.)

[15] AECB in conversation with Dr Wolfgang Feist , http://www.aecb.net/feist_videos.php

Exterior Walls

The building science highlights the importance of the choice of materials and the sequence and detailing of assembly of the building envelope.

One way to simplify this process is to choose “manufactured” materials which already provide several functions. LOGIX is a good example, as it provides the structural, the continuous insulation and the air barrier.

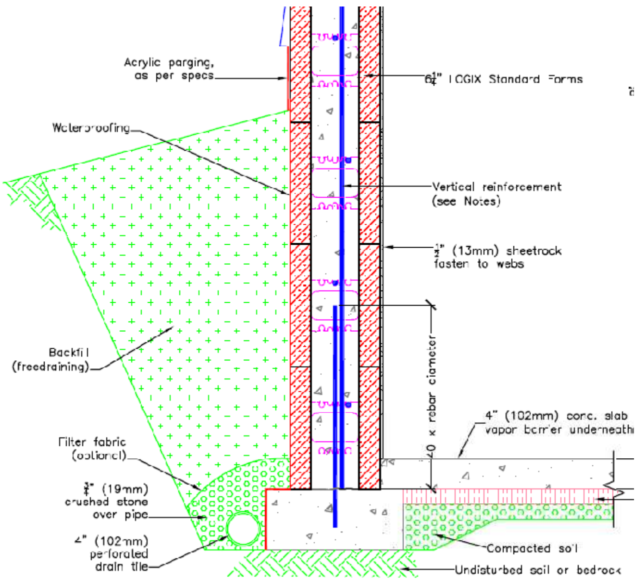
Using fewer types of materials overall simplifies the number of installation crews, but also reduces the potential failures at the points of connection. Dissimilar materials will have different rates of shrinkage, expansion and contraction due to temperature, and moisture handling. This is an excellent benefit for the use of ICFs for foundation, above grade walls, and even roofs.

With LOGIX, the air barrier and heat resistant plane are contained in one product. No air will pass through the monolithic concrete, and heat must pass through with the two layers of continuous insulation.

A point worth discussion is that of dewpoint, or a condensation, of any vapor transfer. Awareness of dewpoint has escalated in the North American because of the prolific use of water sensitive materials in the conventional wood frame envelope, which are susceptible to rot, decay and mold.

With LOGIX walls, even if there were moisture transfer into the wall, neither concrete nor expanded polystyrene (EPS) foam has available organic matter for mold to grow, so the specific temperature gradient through the wall becomes less critical.

A waterproof membrane must be used on the exterior surface of below grade LOGIX walls. This membrane should lap over the footings to direct moisture to the weeping tiles.



<u>In order to reach the levels of energy efficiency needed for net-zero LOGIX is recommended for the below and above grade walls.</u>

There are a variety of product lines within the LOGIX family that you can choose for your below and above grade wall solution. All LOGIX product lines are available in a wide range of concrete core thicknesses. Sufficient load capacity is the primary consideration in choosing the appropriate concrete core thickness.

LOGIX Pro

LOGIX Pro is the original LOGIX product line. LOGIX Pro is made with Type 2 EPS foam and offers an R-Value of 24 in the minimum wall assembly. LOGIX Pro is recommended for both heating and cooling dominated climates.

LOGIX Pro TX

LOGIX Pro TX is available in the USA only and is treated with Imidacloprid to safely protect LOGIX EPS panels from termites.

LOGIX Pro Platinum

LOGIX Pro Platinum is made with Neopor by BASF. Neopor contains millions of graphite infrared absorbers and heat reflectors that reduce thermal conductivity.

Thus LOGIX Pro Platinum creates walls with a superior R-value of R27 in the minimum wall assembly. This is 23% to 60% superior to most other insulated concrete forms and is why LOGIX Platinum products are uniquely suited for net-zero homes in northern and heating dominated climates.

LOGIX Platinum products are also the only ICF products in the world that are Greenguard™ certified for indoor air quality, which is an additional compelling reason to select LOGIX Platinum.

LOGIX KD XRV Panels

LOGIX KD XRV Panels are offered in thicknesses of 4”/5”/6”/7”/8”.

With LOGIX KD XRV Panels you can select the thickness of the interior and exterior foam panels. Thus you can create a custom LOGIX wall assembly with an R-Value of up to a staggering R77. Energy modeling software can help identify the optimal thickness for the desired level of energy savings.

Roof Systems

Vented Attic Systems

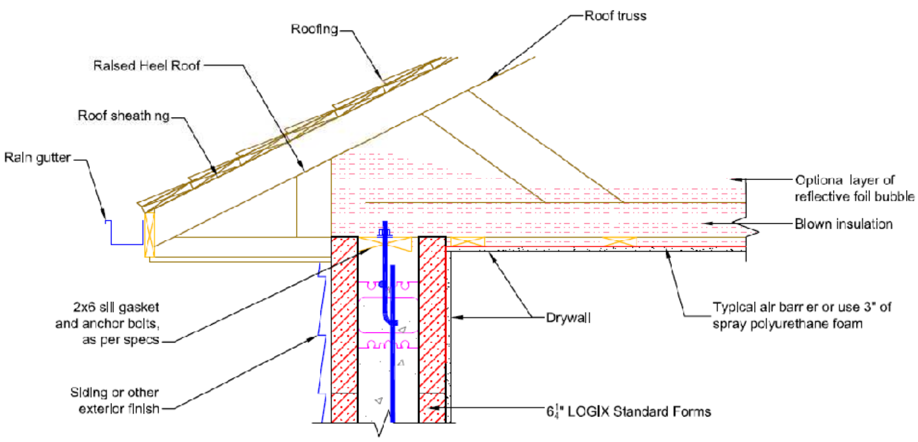
The air and heat barriers inherent in the LOGIX wall must be continuous through the rest of the envelope. One of the areas of particular concern is the connection area of the wall to the ceiling or roof, where the outer layer of ICF insulation should be continuous to that of the ceiling/roof, whichever was designated as the top edge of the conditioned space.

The top exposed area of concrete of the ICF wall should lie within this continuous envelope, or else its effectiveness as a heat sink may be compromised. A raised heel truss (also called energy heel) will provide the space needed to continue the thickness of the ceiling or roof insulation all the way to the exterior edge of the LOGIX foam.

It should be noted that both Canadian and US energy codes call for a higher R-value for vented attics (ceilings with attic space). This approach attempts to compensate for the lack of continuous insulation to the outer edge of the wall. The LOGIX Net-Zero approach recommends the “Energy Heel” vs the “Achilles Heel.”

In cold weather, the main strategy when designing roofs is to eliminate air movement in order to keep moisture from condensing under the roof sheathing or causing ice dams.[16] An air barrier at the ceiling plane is crucial, with all air penetrations into the roof space well sealed. This includes flashing around the fireplace or appliance flues, sealing the headers of interior walls, around can lights, electrical and other penetrations. Strict adherence to fire rated material requirements is important.

Once this is done, the ceiling joist should be insulated with a minimum of R50 blown-in insulation, capped with an additional layer of kraft paper or a layer of reflective foil (to provide additional reflective thermal performance) to prevent cold air “washing.” Air baffles placed on the underside of the sheathing will provide an air path for the soffit vents, further protecting the insulation for convective air loss. You may also wish to consider a layer of 3” spray-in polyurethane for extra insulation, and a fast and effective sealing air barrier.



Roof truss pitch may be based on standard pitch, or may be matched to the proper pitch for solar panels, typically the latitude at the location.

16 Roof Design, Building Science Corporation R0404

Conditioned Space Systems or Cathedral Ceilings

There are many factors to consider when deciding whether to have a ventilated attic or an enclosed conditioned space.

In cold weather, the main strategy when designing roofs is to eliminate air movement in order to keep the roof sheathing free from moisture problems and ice dams. [17] Enclosing the attic space is an opportunity to add square footage or at least storage to the home.

In hot and humid climates, a conditioned attic is recommended to manage the humidity, and to accommodate the A/C ductwork which is often located in the attic.

A conditioned space roof with 2x10 rafters should be insulated with blown-in dense-pack insulation to provide a complete air barrier in contact with the sheathing. A minimum of R-38 might be sufficient in moderate climates, with recommendations of R-50 to R-60 in cold climates. An alternative approach would be to use 8" Structural Insulated Panels insulated with Neopor foam which would provide R38 as well.

To avoid condensation at the ceiling peak, or moist air from infiltrating into the roof peak, an additional vapor barrier at the ceiling peak is recommended, and HVAC should be designed to with a return vent at the peak to draw the warm most air from this area.

It should be noted, that as an alternative, designers could choose to design the main floor with a taller ceiling, and locate the duct work in a dropped ceiling, for example in a central hallway. This brings the ductwork into conditioned space.

A vented roofing material (such as concrete tile or metal roofing) or a light colored or solar reflective roof can also help lower the temperature on the roof sheathing.

It is important to note that a conditioned attic is not permitted by building code in Canada.

Ceilings Without Attic Space

Ceilings without living space, such as cathedral ceilings should, at minimum, be insulated to R31. Once again, if Structural Insulated Panels insulated with Neopor are available, then they would provide additional insulation to R38.

Floors, Crawlspaces, Slabs

The concept of continuous insulation continues below grade. For slab on grade construction, the exterior edge of the slab should be insulated to R10, ideally extending down to the bottom of the slab. Otherwise, the heat from the surrounding ground will wick into the concrete and up into the LOGIX concrete core. The underside of all slabs should be insulated to a minimum of R5 or R10.

[17] Roof Design, Building Science Corporation R0404

Window And Door Buck Systems and Flashing Details

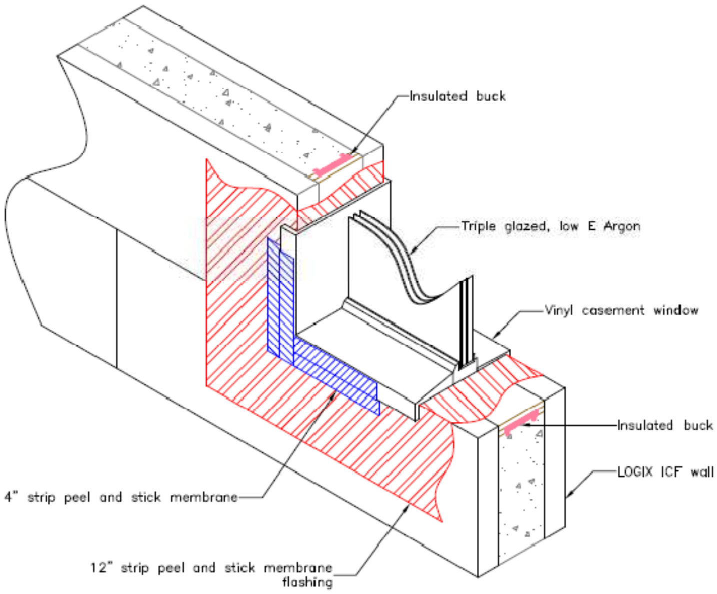
Window and door openings should be framed with an insulated buck system to minimize thermal bridging.

Also, care must be taken to properly flash windows and doors to redirect water to the designated drainage plane of the chose exterior finish.

One effective flashing detail is to apply 12” wide strip of waterproofing membrane around the opening and over the exterior LOGIX surface immediately after the concrete pour for maximum adhesion.

A bead of low expansion foam should be used to seal the window frame to the flashed opening.

Then a 4” peel and stick strip of membrane is installed over the flange and onto the original 12” flashing strip. The order of attachment is one strip across the bottom, then the two side strips which overlap the bottom, and finally a top strip overlapping the sides. In extreme wet climates, an additional layer of protection can be provided by a flashing strip in which the short leg is cut into the foam, prior to the attachment of the final top 4” strip.



Windows and Doors

Window types affect the thermal performance of the window.. Fixed, non-operable windows are the most air tight. Also, Casement or hoppers windows tend to seal like a fridge with weather stripping on both sides of the seal.

Double hung windows are the hardest to seal, and become increasingly leaky over time.

Window framing materials and thermal breaks also affect the energy efficiency. The lowest conductive materials, in order, are fiberglass, wood and vinyl.

Fiberglass has an additional advantage. Windows often fail at the seal of the frame to the glazing. Since fiberglass has the same coefficient of expansion / contraction as glass, it is least likely to fail at the seal, thus keeping its U-value effectiveness the longest. Fiberglass comes in several colors and requires no painting or other maintenance.

Similarly, the best choice of doors are insulated, fiberglass, with minimal glazing. Sliding glass doors should be avoided as they are very leaky, reduce thermal comfort, and are also difficult to seal against water intrusion. French doors are a much better option, with one door fixed, as this provides a superior seal. All doors should be installed with weather sealing.

Skylights have been graded by a lower standard for Energy Star specifications, but there are manufacturers who can offer U.28 with appropriate SHGC. .

Glazing – Heating Dominated Climates

In heating dominated climates triple glazed, low E Argon windows provide the highest R-Value, likely in the R6.8 to R7 range. Low E Argon allows heat transfer but filters out UV rays. Also, Heat Mirror technology can be used in lieu of one of the panes of glass, which provides the same results with less weight.

South facing windows used for passive solar heating need a Solar Heat Gain Co-efficient of .750 or more.

Glazing – Cooling Dominated Climates

In cooling dominated climates, it is best to use Solarban 60 glass or Cardinal 366 glass which is coated to reduce ultraviolet light while still allowing visible light transmittance. A low Solar Heat Gain Coefficient of .40 or lower on south and west is preferable as it reduces solar heat transmittal through the glass. Exterior shading of windows by means of vegetation, awnings, or shuttered blinds can further reduce overheating.

3d) Guidelines For Mechanicals and HVAC

The LOGIX Net-zero approach to Heating/ Cooling

We support the approach first defined by Amory Lovins:

> *"They want lighting, heating, refrigeration, mobility. The trick is to reframe the question as, "What are we trying to do, and what's the best and cheapest way to do it?" **natural capitalism**: shifting from producing goods to providing services. For example, by providing "cooling services" instead of selling air conditioners, a company would be free to find the cheapest way to keep its clients comfortable—an arrangement that is likely to produce more innovative and responsive solutions, and save money (and energy) for all parties."*[18]

In a LOGIX Net-zero home, the HVAC load is targeted to have been reduced to a 40 – 60% improvement over code, based on the building envelope improvements. Additional energy savings are then available through the thermal comfort design and the subsequent choices of renewable energy and HVAC equipment.

A LOGIX Net-Zero home offers many new opportunities for HVAC solutions. The design should factor in the particulars of the home, which might include:

- Reduced overall heating / cooling load
- Minimal stratification of temperatures
- Reduced and delayed peak loads
- Freedom of duct placement
- Replacement air requirements
- Room air exchange and balancing

The LOGIX shell, coupled with airtight, well insulated roofs and high performance windows greatly reduces the overall heating and cooling requirements. While typical houses suffer from drafts caused by leaking walls and inadequate window, well built LOGIX houses experience little stratification in the indoor temperatures and virtually no unwanted air flows.

This allows the HVAC designer more options for fine tuned air delivery. For instance, if the LOGIX walls are combined with high performance glazing and appropriate solar shading, the supply registers may no longer need to be located under the windows. One approach may be to place supply vents high and return vents low in the interior wall, or even both high on the wall, with the proper spacing and directional baffling.[19]

[18] Lovins, Amory, Reinventing Fire: A New Vision, Rocky Mountain Institute, http://www.rmi.org

[19] Lstiburek, J. (2000). "Advanced Space Conditioning" Building Science Report 0007, pg 21. www.buildingscience .com

Other options include a central house exhaust, with a supply sources down low in the house, and transfer ducts between floors and connecting spaces. Whatever the option, it is helpful to draw the intended air flow on the plans, to clarify the design intent and identify any potential clashes.

In some super-insulated houses in mild climates, the HVAC needs could be met by the use of passive solar design, supplemented by a heat recovery ventilator (HRV) tied into a small central duct system. A secondary filtration ventilator unit can provide additional levels of filtration and circulation, if the house is somewhat larger. The next supplementary level might include a radiant floor heater, either electric or water, tied to either PV panels or a solar thermal system.

In all cases, an airtight LOGIX Net-Zero home must be designed and installed with a replacement air ventilation system. Replacement air can be brought in to the return side of the HVAC ductwork based on an estimate of replacement air needed to meet ASHRAE ventilation standards. The volume of airflow can also be controlled by linking the incoming air to exhaust fans from the various rooms, or by means of a pressure balancing valve. This may also be linked with a heat recovery ventilator (HRV) which equalizes the air intake with the exhaust air.

Air filtration for better residential construction is generally recommended at a MERV 10 or better, which meets the American Lung Association Health House standard. This level of filtration can catch mold spores, dust, pollen, pet dander and smoke. While this MERV level is still produced as replacement for the standard filter, the HVAC fan must be sized to compensate for the additional friction of the airflow.

These can be pleated filters which can be installed in central heating and/or cooling system ducts. HEPA (High-Efficiency Particle Arresting) filtration offers the highest particulate removal available, 99.97% of particles that pass through the system, and is installed with a supplementary fan to push the air through the filter.

There are challenges of obtaining appropriately designed ventilation equipment, in an HVAC industry which is proficient in equipping for heating and cooling, but not as versed in the "V" – Ventilation and Air Handling.

To ensure that the HVAC equipment is right-sized to provide sufficient run time for good air circulation, builders should insist that ACCA Manual J and Manual D calculations are run, not only to determine overall equipment sizing, but also room by room air delivery measurements and duct sizing.

The Portland Cement Association has also developed a commonly available and very useful HVAC Sizing Software For Concrete Homes. Version 4.0 has just been released and is updated to the latest code requirements.

Designing for multiple zones, and the use of variable speed (EFM) fans can further support the delivery of the good air quality and quantity, and reduce operating costs.

Homes built with LOGIX walls may also experience a delay in peak load, which can further affect the sizing of the HVAC systems. All of these calculations should be factored in the design, and measured upon implementation.

Proper HVAC sizing is especially important in hot humid climates. If the A/C system is sized only for the sensible heat (temperature), it may not cycle on for long enough to sufficiently dehumidify the indoor air. While it is tempting with LOGIX homes to simply downsize the tonnage on an A/C unit a better option for long term operating efficiency and comfort may be a variable speed motor or a split tonnage system.

A properly designed HVAC unit will run for long cycles. Humidity levels can initially be managed by removing excess moisture from point sources (showers, cooking) and controlling the amount of humidity brought in by replacement air.

Also, LOGIX homes with radiant heating still need to have ducted ventilation which can cycle on independent of the heating/cooling requirement and will circulate the air through a filtration system. A ducted ventilation system will also help distribute any heat gain from passive solar heating.

It is imperative in a tightly sealed LOGIX home to use ONLY sealed-combustion appliances – such as hot water heating, furnaces or fireplaces. While the replacement air sources provide sufficient replacement air over the average, then the house can go temporarily into negative pressure, e.g. when all the exhaust fans are turned on (ie lots of showers, and the stove at the same time). This pressure differential will seek to pull in air from the easiest sources, such as an open exhaust on a hot water heater, drawing both air and the fumes into the house. Use ONLY sealed –combustion appliances.

Mechanical space heating and cooling choices are based on a combination of factors. The fuel efficiency, measured in AFUE (Annual Fuel Utilization Efficiency) measures the effectiveness of energy delivery for any given fuel, including losses during start-up and cool down.

An AFUE of greater than 94% is reasonable, achievable, and relevant to the bigger issue of limited natural resource reserves. Note that electricity is very dependent on the production source (ie coal vs hydroelectric), and can further be modified by on-site production.

In addition to all these design measures for energy efficiency, there is also the opportunity for the homeowner to participate in energy conservation through a thermostat with an energy setback option. If the air replacement was designed as an air intake coupled with one or all of the house fans, the thermostat may also be wired to provide this ventilation through a "fan" setting.

Also, there will be point penetration for replacement air intakes as well as exhausts vents from bathrooms and kitchens. Fresh air intakes should avoid being located near car parking, or upwind from any of the exhausts.

Domestic Water Heating

Hot water heating efficiency is based on heating the minimum quantity at the right time. This calls for reducing the load through energy efficient features and plumbing distribution, but also for a design based on the estimated usage pattern.

For example, an efficiency apartment with few occupants might have a relatively limited demand for hot water. Vacation homes might have long periods of time with no water demand.

This is the most critical factor in the decision between traditional tank, solar plus tank, tankless or the new condensing hot water heaters.

Typically, appliance choices are based on a combination of fuel efficiency (AFUE) and usage patterns. For example, condensing gas hot water heaters are able to return a 98% efficiency, vs just a 82% for a standard gas tankless. For a moderate to high-use family, the 98% efficiency is the right choice. However, for low-use situation, the tankless may be the better choice, as there are no stand-by loads.

On the other hand, solar hot water and electric heat pump (both electric) have a 2.0 energy factor, which overcomes even the 30% penalty of electricity transportation loss, and perhaps even the low AFUE of the source fuel (for example, coal).

SECTION 4 - Guidelines For Renewable Energy Sources

First, a look a renewable energy.

By definition, this refers to the capture of energy from a natural resource which does not get depleted in the process. We typically think of wind, solar or hydroelectric plants.

Power generation on site typically means photovoltaics (PV), or small wind turbines, but combined heat and power (fuel cells, natural gas, etc) biogas, biomass, microhydro power and other forms of generation may also be viable choices.

Most of the renewable energy sources are conversions of natural forces to electricity, or to a fuel. However, there are other applications which directly use the resource in its natural stage, such as the heat in water and air. All are valuable contributors to a net-zero solution.

Centralized or "Macro" Applications

Power companies are increasingly investing in large scale solar and wind farms, offering consumers the opportunity to buy into this "green" power. From an overall accounting standpoint, the return on investment of these centralized plants far exceeds that of individual home PV installations. They are more cost-efficient and the power production into the grid can be centrally managed.

Large scale windmill farms typically gather more power at night, and can balance out the daytime generation of solar panels. New technologies such as wave generators are also being explored. These all point to investing in and supporting centralized sources of renewable power plants.

Individual or Home Applications

Homeowners using conventional energy sources face a very important underlying fact – and that is – that a very large portion of their carbon footprint and their ongoing energy costs is tied up in the transportation required to get the energy to them.

This is a very power motivator for homeowners to investigate the options for on-site renewable energy sources.

4a) Photovoltaic Panels (PV)

Overview

On-site PV panels offer a different level of solutions. Power companies and governments offer incentives for on-site PV panels in order to help create an awareness of personal energy consumption, and a motivation to equalize the power usage and consumption.

From a bigger picture, on-site PV panels are a step toward a system of dispersed sourcing of energy, which prepares for the not-so-distant future when more powerful alternative solar sourcing will be developed. Local sourcing would also improve the efficiency of electrical distribution, which now loses up to 30% efficiency in long distance wire transportation.

There are some other aspects of PV panels which need to be kept in mind when designing the sustainable sources of energy for a building.

PV panels tied to the grid have an automatic shut-off if the grid power goes out. This is to avoid any charge on the wires when for the safety of the workers on the line. However, for sake of passive survivability, these PV panels provide no back-up power. This emergency back-up power is only provided if the panels are linked to a battery bank, which is currently not a very environmentally friendly choice, due to the high embodied energy and short service life.

Developments on the horizon suggest that the battery bank in hybrid automobiles might be able to be used for this back-up purpose.

One of the challenges of PV power is that electricity is not easily stored, and it is not evenly consumed. It may be helpful to link it to moderating some of the peak loads, such as air conditioning - which kicks on at the same time when the sun is out and can provide the power through solar panels.

One last factor to consider – PV panels have to be cleaned on a regular basis (ie once every year or two). As PV panels get covered in dirt, their efficiency decreases.

How PV Works

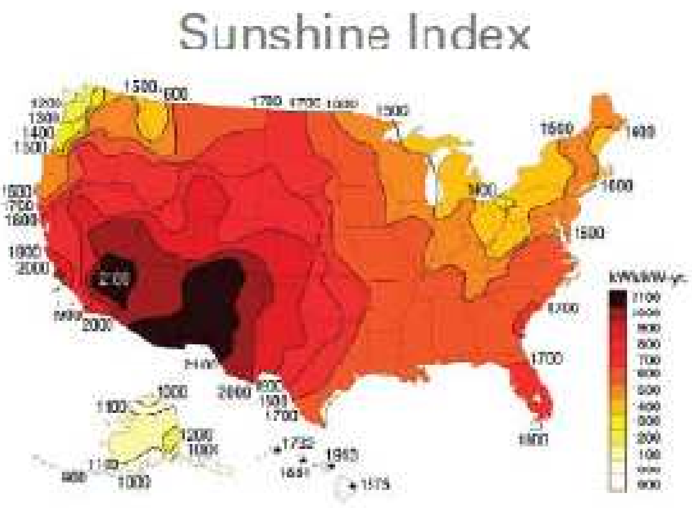
Solar panels, usually mounted on your roof, change sunlight into direct current (DC) electricity. The DC electricity travels through wire to an Inverter which changes the electricity into AC electricity commonly used in homes and businesses. A meter is attached which tracks the energy (kWh) produced, used or sent to the utility.

A PV's size is rated in kW and 1kW to 5kW is a typical range for a home PV system. This is known as the "kW of PV"

At today's efficiencies, a 5 kW system can typically involve about 25 roof mounted solar panels that would take up about 325 square feet of roof area.

Calculating the Yield of a PV System

Below is the Sunshine Index for the USA. This map provides an estimate of the regional intensity of the sunshine (kwH/kW-year), based on a typical PV efficiency rate:



(Source: US Department of Energy)

To determine the yield of your PV system, use the following formula:

Elect Prod/PV – (kW of PV) x (kWh/kW-year) = kWh/Year

If you had a 5 kW PV system and you live in Denver, your expected annual yield would = 5 x 1900 = 9,500 kWh/year.

Payback of a PV System

The typical payback of a PV system today is about 17-20 years, depending on the amount of PV incentives are offered in your location.

Roughing In For PV

You may elect to pass on PV at the time of building but want to leave your options open for a PV installation down the road. You should then design your roof pitch angle to be equal to the latitude you are located at, as this is the optimum angle for PV efficiency.

You should also prep your electrical panel for a PV tie-in at the time of construction as well.

4b) Solar Thermal (Solar Hot Water)

One of the quickest paybacks (5-7 years with state incentives, and 8-9 years without) and most developed technology in the renewable energy field is that of solar thermal.

Typically, solar thermal can provide 50% to 80% of your domestic water heating energy. To reach this level of efficiency a good guideline is to position the roof top “solar collectors” at a 45 degree angle and they should face within 45 degrees of due south.

How Solar Thermal Works

The typical solar thermal installation for culinary water a closed loop system in which the sun’s heat is captured in a liquid or gas transfer medium in a roof-mounted solar collector.

The heated solution is pumped through the heat exchanger in the hot water tank. Typically, this is combined with a standard tank water heating system which should be > .85 Efficiency.

The heat exchanger heats the water in the tank and the solution is re-circulated back to the rooftop solar collectors, and the cycle continuously repeats.

An alternate approach is to provide this heat transfer in an insulated holding tank, which allows for maximum heat capture from the medium, which then feeds into a tankless, on-demand hot water heater. Gas or electric can work for this, as long as the temperature range for activation can be as low as a degree or two of actual output temperature. Electric on-demand are often limited in output because of the temperature differential between source water and output temperatures, which is solved by the solar preheat.

Some solar thermal systems also provide the heat for radiant heat systems, given the proper capacity of the tank. However research this closely, as this can add over $6000 to the cost of the solar thermal system and in some cases can disrupt the stratification in the storage tank thereby reducing the system’s overall efficiency.

Finally a simple solar thermal application for swimming pools can be as easy as cycling the water through black garden hoses coiled on a rooftop. A similar system, called an open loop, can be used to preheat hot water for domestic use.

Roughing In For Solar Thermal

To rough-in for a future solar thermal installation you should pre-size your solar thermal system at the time of construction. This will tell you how much roof space to allocate for the solar collectors (usually about 55 sq ft for the average home). You will then be able to rough-in the roof’s plumbing penetrations and perhaps pre-install the stand-off’s/mounting apparatus. This is easier to do at the time of construction.

4c) Geothermal Systems

Overview

The earth absorbs heat energy from the sun on a constant basis. Consequently the average ground and water temperature of the earth hovers at 54.2 degrees Farenheight.

Geothermal systems are also known as GeoExchange Systems (GXS). They draw upon this constant source of “Earth Energy” to heat and cool the home.

It seems like a very low carbon footprint option, a simple loop of tapping into the earth’s constant temperature. However, there is still electricity used for this pump. Typically 2.5 units of heat are generated for every unit of electricity in a geothermal system. Thus this could still be a good move, if the source is hydro, wind or solar.

However, if it is coal or nuclear powered, the carbon footprint reduction may not be as pronounced. In order to offset the cost of the electricity in this case, the heat pump would need to have a Coefficient of Performance of 3.7 or better.

Geothermal manufacturers claim their systems will reduce the energy required for heating by about 67%.

The cooling cost is similar to that of a high efficiency A/C. Also look for variable speed fans and two speed compressors. Geothermal systems can be efficient, and outlast air source heat pumps.

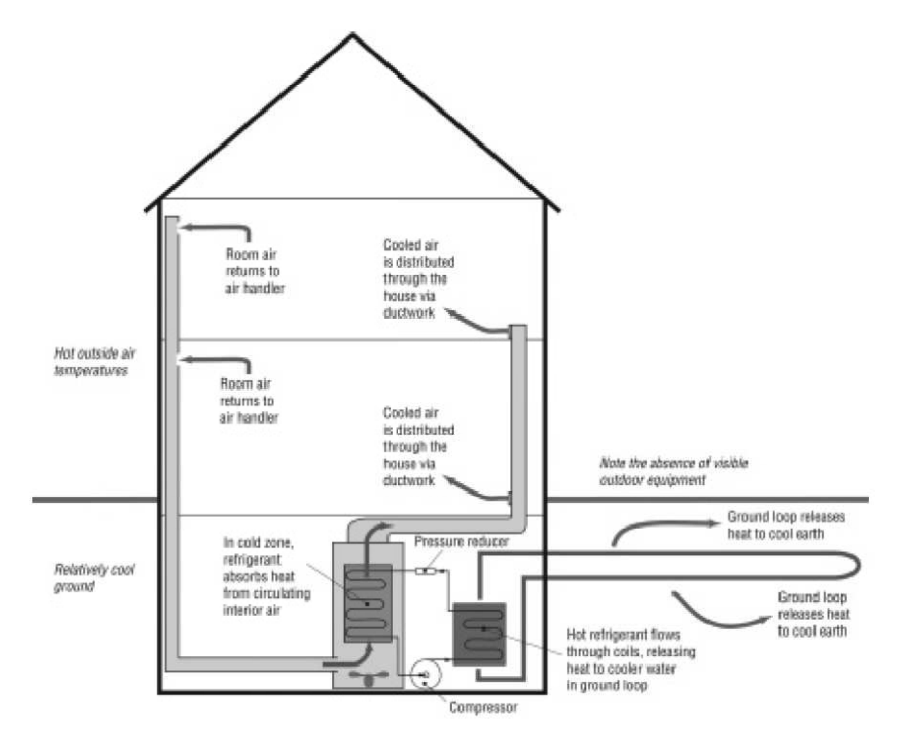
Typically the cost of the heat pump would be the equivalent to the cost of a conventional furnace and air conditioning unit. The added initial cost is for the “ground loop”.

The initial cost of investment for a geothermal is often warranted in the energy savings cost, and the service life of the components, which is 50yrs for the ground loop. If natural gas is not an option, a GXS system typically has a 5- 10 year payback. This payback increases to about 17 years, however, if natural gas is available.

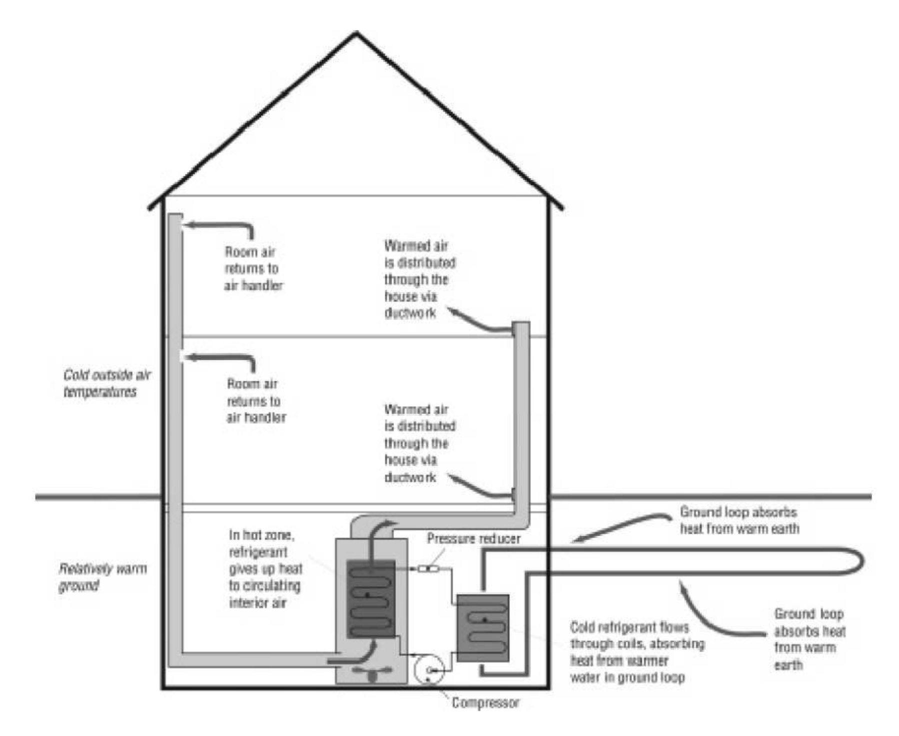
However, a small LOGIX Net-Zero home may not have the heating / cooling demand to warrant the investment and may not have sufficient temperature fluctuation to activate the pump. This can be especially problematic in a radiant floor application, which may be easily overheated.

Geothermal may work best on larger properties, and with systems that have a narrow range of variability in temperature flow.

Residential GeoExchange System (Cooling Mode)



Residential GeoExchange System (Heating Mode)



(Source: Canadian GeoExchange Coalition)

Basic Components of a GXS

The three main components of a GXS are the loop, the heat pump and the distribution system. Essentially the loop captures the Earth Energy. The heat pump extracts that energy and directs it to the distribution system which heats and cools the home.

1) The GXS Loops

There are two types of loops – open and closed.

Open Loops

An open loop system pumps ground water or well water directly through the heat pump. The well water is extracted from a Source Well and returned to a Return Well. Both wells need to be reliable and have water that contains few dissolved materials that can clog the system.

In the coldest part of winter, it will take about 5,000 to 7,000 gallons of water per day at a flow rate of 1/8 gallon per second to heat a 1500 square foot home.

Closed Loops

A closed loop system constantly re-circulates the same mix of water and anti-freeze. This mix, called the “heat transfer fluid” is heated by the Earth Energy and is pumped through the heat pump.

There are three variations of Closed Loops – Vertical, Horizontal and Lake.

Horizontal Closed Loops

These loops are buried horizontally at a depth of 6 to 9 feet on average. In terms of size of the loop area, you will typically need 2 to 4 times the square footage of your home for the amount of ground area, so not every lot will suffice.

Vertical Closed Loops

Vertical loops can cost 3-4 times as much as a horizontal loop. In this case the loops are placed in a number of bore holes that are drilled vertically into the ground. Bore holes are generally 60 to 200 feet in depth, depending on the bedrock configuration. Each borehole requires about 200 sq feet of available lot space.

2) The Heat Pump

The heated water from the loop is pumped into the heat pump and the energy from the water is transferred to a refrigerant. The refrigerant, in turn, delivers the heat energy to the Distribution System.

In selecting the appropriate heat pump, a typical requirement is that the GXS must have at least the heating capacity to supply at least 90% of your total annual heating requirement.

A typical 5 ton heat pump draws 17 amps on an ongoing basis but draws 80 amps for 3/10 of a second when it starts up and that is too much load for a PV source to provide. Therefore the heat pump must be grid-tied.

3) Distribution Systems

Forced Air

In a forced air GXS, in a heat exchanger, air is heated as it is blown over the refrigerant. This heated air is then directed through ducts to heat the home.

A GXS is usually designed to raise the heat of the air by between 20 and 30 degrees Farenheight, as compared to furnaces which raise it by 40 to 60 degrees.

As this means that a GXS must move more air through the home, it is recommended that acoustic insulation be installed inside the plenum and there should also be a flexible connection between the heat pump and the main duct to ensure quiet operation.

In an air conditioning/cooling application this process works in reverse. Warm air from the home is drawn into the heat exchanger, where the heat in the air is absorbed by the refrigerant. The refrigerant then flows through coils and releases the heat into the cooler water in the ground loop.

Hydronic (Radiant) Systems

Typically heat pumps today can heat water to no more that 50 degrees F. This usually rules out radiant baseboards which usually require the temperature of the water to be at least 65 degrees F.

In floor radiant systems can be designed to operate at 50 degrees F and so this is becoming an increasing popular choice. If the system can be designed to operate at 40 degrees F, which is possible in some cases, then it will be 25% more energy efficient.

Therefore, to maximize efficiency, you should consider installing a “outdoor reset” control system that lowers the water temperature as the outdoor temperature rises.

A hydronically heated high-mass concrete floor is more suitable to a northern climate with consistent outdoor temperatures. On the other hand, a hydronically heated low-mass floor system is more suitable to more moderate climates with variable outdoor temperatures. A low mass floor system, such as a wood sub-floor should have a layer of an effective heat-transfer medium such as light gauge aluminum to maximize thermal conductivity.

4d) Air Source Heat Pumps

Overview

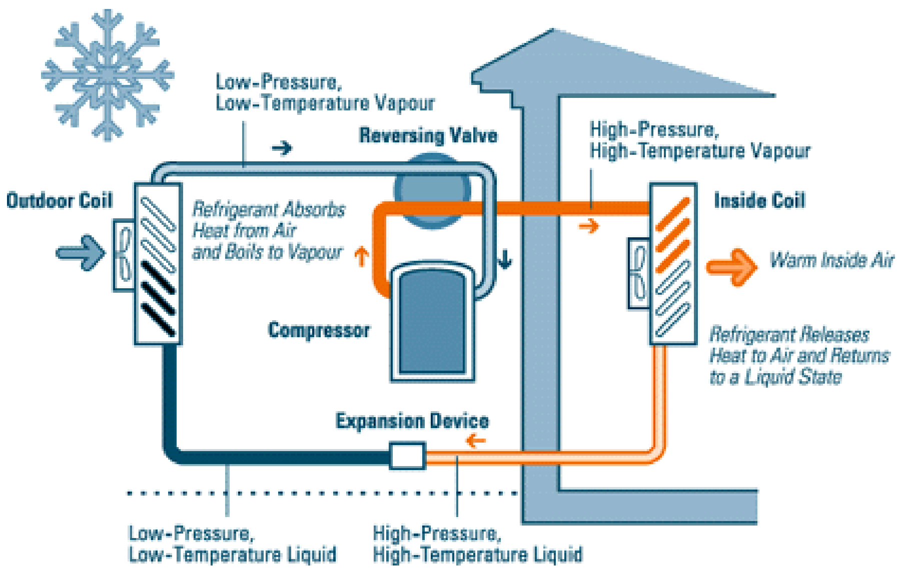
Air Source heat pumps provide another alternative which has similar coefficients of performance (COP) to GXS systems, can be sized smaller, and can be directly incorporated to a ventilation system.

These heat pumps can be used to heat air or water. They tend to either perform better on the A/C end, than on the heating side. Air source heat pumps are best suited to moderate climates.

Air source heat pumps can boast a COP of 4, however the COP reduces down to 1 when the outdoor temperature is at freezing. In colder climates, a back-up electric heater or small traditional furnace is thus coupled with the unit. Heat Pumps with > 18 SEER are recommended.

The COP is also reduced when heat pumps are used to heat water to excessively high temperatures.

How Air Source Heat Pumps Work



(Source: www.reuk.uk)

An air source heat pump has an outside coil, an inside coil and a compressor that is located outside the home.

It uses refrigerant in a closed loop system and the refrigerant continually changes states from liquid to hot gas and from gas to a cold liquid.

Air source heat pumps can be used in heating mode and cooling mode.

Using Heat Pumps to Heat Domestic Water

Both air source and water source heat pumps can be equipped with a desuperheater, which transfers excess heat to pre-heat water and provide 30-50% of the energy required for the heating of culinary water. However, this may be of somewhat limited benefit, as the air source heat pump has excess heat in the summer, while hot baths are typically more common in the winter.

4e) Alternative Renewable Energy & HVAC Strategies

High performance LOGIX Net-zero homes offer an excellent opportunity to adapt some of the lesser known HVAC strategies such as:

- Solar Air Heating
- Solar Thermal Radiant Heat
- Nightime Air Cooling
- Evaporative Cooling

Some of the most durable strategies are the simplest, which rely on a more direct transfer of the natural resource to the intended use. For example, radiant heat from the sun can be transferred by air or to a mass material for direct use.

Air cooling can be as simple as channeling air to breezeways to cool a house; air can also be channeled underneath roof tiles to provide a cooling effect in the summer and avoid ice dams in the winter. On a sloped building site, air can be funneled along a hillside, into the basement and up through the house. This was the design used by Thomas Jefferson's to provide cooling for Monticello.

In solar air heating, heat is captured from the air and moved directly into an interior living space, such as with the Solarwall Technology,[20] or into thermal mass heat sinks of rock beds (for example in greenhouses), trombe walls, or water – which are all design techniques developed for passive solar design.

In climates with wide diurnal temperature swings, such as the high desert plateaus of the American West, the nighttime air can be captured to cool down an internal thermal mass. This can be as simple as installing a central house exhaust fan, and opening the windows a little bit at night to pull in the cool air. This cool air can also be pulled into the house with any type of intake fan, including the Nighttime Air cooling design by Davis Energy. [21]

Areas with dry outdoor temperatures can take advantage new two stage evaporative cooling, [22] which don't produce the humidity levels as high as that produced by traditional single-stage "swamp" coolers.

Solar thermal for swimming pools can be as easy as cycling the water through black garden hoses coiled on a rooftop, with a gravity feed. Water can be harvested from rooftops and released in a spray for cooling and also for gardens, which can be grown as shade, proving more cooling.

A good source for keeping track of new technology can be found on the PATH Toolbase website, www.toolbase.org/TechInventory. Another tool which is can help determine the best system selection is the Manual S, developed by the HVAC Contractor association, ACCA. However, the best use of this tool would be by a designer or general contractor, before one chose a specific HVAC company, as they typically represent only one type of equipment.

[20] http://solarwall.com/en/home.php
[21] http://www.davisenergy.com/technologies/nightbreeze.php
[22] http://www.toolbase.org/TechInventory/techDetails.aspx?ContentDetailID=789

SECTION 5 – GUIDELINES FOR REDUCING HOUSE LOADS

5a) Plumbing Guidelines

Hot water pipes should be insulated to prevent heat dissipation. For fixtures located further away from the central source, a recirculating pump may avoid both energy and water loss associated with waiting for the hot water to reach the faucet.

Low flow fixtures should be carefully chosen for functionality. New pressure assisted toilets have solved many of the problems of earlier low flow models, but it should be noted that they require a power outlet.

Low flow shower fixtures are of two types. Aerated, the most popular, mixes air into the water stream and can be cool down towards the floor of the shower. Non-aerating adds a pulse to the water stream; maintaining temperature and delivering a strong spray. The effectiveness of both can be improved by controlling the heat within the shower compartment. Adding insulation around the stall, installing a heat register to blow into the shower compartment and thereby heat up the tiles, or other approaches to keeping the shower room warm may all help reduce the amount of time spent in getting the shower stall to a comfortable temperature. It reduces the wasted water and the waste in heating this water.

Heat can also be extracted from wastewater, such as drains from showers or tubs, for use as preheat to incoming hot water. On larger projects, the heat in sewer pipes can be tapped in a manner similar to geothermal heating.

5b) Electrical Appliances and Lighting

After the electrical loads used for HVAC or hot water, refrigerators are next largest consumers of electricity. ENERGY STAR model are at least 20% more energy efficient than the federal standards. The most efficient models are between 16 and 20 cubic feet, with top freezer compartments more efficient than bottom freezer or side-by-sides. Of course, the biggest factor is the frequency and duration of opening the door. New hydrocarbon “Greenfreeze” refrigerators, developed by Greenpeace in 1993 and sold throughout the world, are hoped to soon be approved by the EPA for distribution in the U.S. This will finally provide a non-ozone endangering coolant alternative to the existing CFC and HFC refrigerants

Washing machines and clothes dryers can also be are large users of power. Front-loading models are generally more energy efficient. With a dryer it is particularly important to not buy an oversized model as this will result in inefficient performance. A typical residential “full dryer load” is 8 lbs, so a dryer rated for 14 lbs would be very suitable for that size load after accounting for the required “tumbling room”.

Builders in dry climates with no indoor humidity issues might also provide space for drying racks, making sure to also install an exhaust vented to the outdoors.

Alternatively, you may consider a "ventless" dryer. A ventless dryer has a couple of important advantages: 1) They are generally condensing dryers which have virtually no risk of causing a dryer-fire, 2) they can be placed anywhere in the home and, 3) they do not expel conditioned indoor air to the outside, thereby saving energy.

Energy loads from cooking may be the next largest load. Cooking with magnetic induction is the most energy efficient, at 90 percent, as compared to resistance electric at approximately 65-percent efficiency, and open-flamed gas which measures in the 55-percent efficiency range. This is, of course, greatly dependent on the amount of cooking done. Electric tea kettles transfer 100% of the heat directly to the water.

Using new lighting technologies, such as motion detectors or timers, can further reduce lighting energy use in your home by 50% to 75% for the remaining existing load. Switching away from heat producing incandescent or halogen bulbs to cooler compact fluorescent or LED bulbs can further reduce any unwanted heat gain.

5c) Phantom Loads

Phantom loads from appliances on stand-by have become an increasing draw on power. A total house power management system can be built in to monitor this load. A less expensive option is to return to the traditional wiring system of connecting electric receptacles to a wall switch, which can be turned off along with the light switch when leaving a room. This makes it easier for occupants to manage the phantom loads of several appliances at once.

SECTION 6 – SUPPORTING RESOURCES AND PROGRAMS

6a) The Design and Construction Team

In its report, *A National Green Building Research Agenda*, [23] the USGBC notes the need for integrated, transformational solutions: "…to achieve Net-zero Energy buildings, prescriptive, independent measures will no longer suffice. Leaps forward in building performance require design that fully integrates building systems…" While a combination of existing measures have achieved impressive savings of 30 – 50% beyond code, the next level of savings will be a quantum leap, with savings of 70%.

To get to this next level will require a quantum shift in the process of building and design, as well as the level of interaction with the various team members. The very identification of team members will grow to include the full spectrum of parties involved on the project. This may include not only the owner, but perhaps also early consultations with city building officials, neighborhood organizations, or other community resources. It also calls on reaching out to the tradesmen, or craftsmen, to early design development, soliciting their tacit knowledge on constructability, efficiency and durability.

Assembling the entire team around the table at the beginning of the design process is a good first start. The importance of this cannot be exaggerated. A high performance net-zero home has to operate as a holistic system and all the parties have to be involved early in the design process.

This will typically need some facilitating to get new relationships established, experiment with new patterns of document development, and provide ongoing support to keep an open loop of communication. A good leader may need to provide extra encouragement and spend more time in developing relationships in order for the team to mesh.

The success of the project lies in the ability of the team develop a flexible and robust construction process, one which can adapt to new technology or methods while maintaining a lean flow of work. Without a team effort, net-zero can still be achieved, but at a much higher cost.

The methodology and training for this integrated approach to design and construction is well described in many resources, including the Whole Building Design Guide ,[24] USGBC LEED-H program, or the recent book by David Johnston & Scott Gibson: "Toward a ZERO Energy Home."

Finally, an important component of high performance buildings is the importance of construction detailing, and the installation of the products and systems as designed. This requires good forethought to details pertaining to building science, and participation on the part of the trades. Most of all, it requires good team communication.

[23] USGBC Research Committee. 2007 (revised 2008). *A national green building research agenda*. http://www.usgbc.org/ShowFile.aspx?DocumentID=3402

[24] National Institute of Building Sciences, Whole Building Design Guide, www.wbdg.org

6b) Role of Energy Modeler and Energy Modeling Software

Achieving energy savings at the levels needed for Net-Zero calls for a full integration of the building envelope. Energy modeling is the planning tool which informs the choices of types of energy savings measures which provide the greatest savings, and the cumulative and combines results of the chosen measures. Much like a structural engineer is hired to provide a level of planning and risk management to the building structure, so can an energy modeler provide an informed energy process.

Energy modeling is a relatively new profession. Most of those currently employed in the trade are energy raters, technicians who are trained to inspect the thermal envelope and test the house for air tightness. A few programs, such as the BPI Building Analyst Certification also provide some training on assessment of existing structures to make recommendations for retrofits.

Ideally, an energy modeler would be involved with the design process, and help shape the construction plan for energy savings features. Sometimes HVAC engineers will branch out into this field and some architectural drafting programs also have energy modeling features.

There are a few publicly available software programs. The simplest program for quick calculations of overall U values, is RESCheck www.energycodes.gov/**rescheck**. This freeware can be customized by current code with US locations. The building envelope components are entered, and assessed based on the “UA Trade-off” compliance method. This allow for a quick assessment of just the building envelope first, and then a combined assessment with the addition of the equipment. Insulating concrete forms are listed as a drop-down option for wall types.

For Canada, the Natural Resources of Canada provides a freeware modeling tool, Hot3000.[25] Easy to understand screens progress through the design components of the house. While LOGIX and ICFs are not listed as wall options, a recommendation is to choose the R-value, and then enter the LOGIX wall value both on that same screen and also on the effective R-value entry on the “detail” pop-up screen. This program does offer a choice of fiberglass windows, which RESCheck only lists as “other” and therefore does not capture the full U-value.

It is important to note that currently available energy modeling tools do not always, in our opinion, accurately model the thermal performance of ICF walls as was outlined in Building Science Considerations section of this whitepaper. ICF technology has been prevalent in the market for about 20 years and many of the current software modeling tools were developed prior to the introduction of ICF’s.

Another more detailed energy modeling and verification tool, but also an easy to learn spreadsheet format, is the HVAC Sizing tool, which can be purchased for a nominal price through a LOGIX representative or the Portland Cement Association.[26]

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[25] http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools/hot3000.html
[26] HVAC Sizing for Concrete Homes, Portland Cement Association, Item Code: CD044

6c) Green Building Rebates.

Tapping into incentives and rebates can also help smooth the transition as the teams are adjusting. An updated list of all federal, state and energy provider incentives can be found on www.dsireusa.org. Know what documentation needs to be submitted in order to collect the information during the process, rather than leaving it to the end. The documentation can also provide verification, and a chance for dialog with the contractor to gather any verbal information which could be useful to the new homeowner.

Canadian Green Building Rebates are not collected in any central databank or resource. However, LOGIX has prepared a detailing listing of available greenbuilding incentives which are available upon request.

Other References:

PATH Seven Steps to a ZEH, PATH

1. Reduce energy requirements for space heat, cooling and water heating
2. Increase efficiency of furnace (or heat pump) and air conditioner
3. Install a solar hot water pre-heat and an efficient distribution system
4. Install efficient lighting fixtures
5. Install efficient appliances
6. Install a proper PV systems
7. Turn off lights, computers, and appliances when not in use.

Johnston, D. and Gibson, S. (2008). “Green from the Ground Up.” Taunton Press, Newton, CT.

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Pettit, B. FAIA (2005) “Affordable Housing - Toward Zero Energy.” Building Science Research Report – 0507, Building America.

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Parker, Danny S. (2008). " Very Low Energy Homes in the United States: Perspectives on Performance from Measured Data." National Academy of Sciences
Publication Number FSEC-RR-302-08 , Florida Solar Energy Center, Cocoa, FL.

Christensen, C. (NREL), Horowitz, S. , Givler, T., Courtney, A (University of Colorado), Barker, G. (Mountain Energy Partnership), (2005). “Conference Paper BEopt: Software for NREL/CP-550-37733 Identifying Optimal Building April 2005
Designs on the Path to Zero Net Energy.” ISES Solar World Congress, Orlando, FL.