Does Passive House Have a Home in the Deep South?

"Every building is a forecast. Every forecast is wrong." [1]
— Stewart Brand[2]

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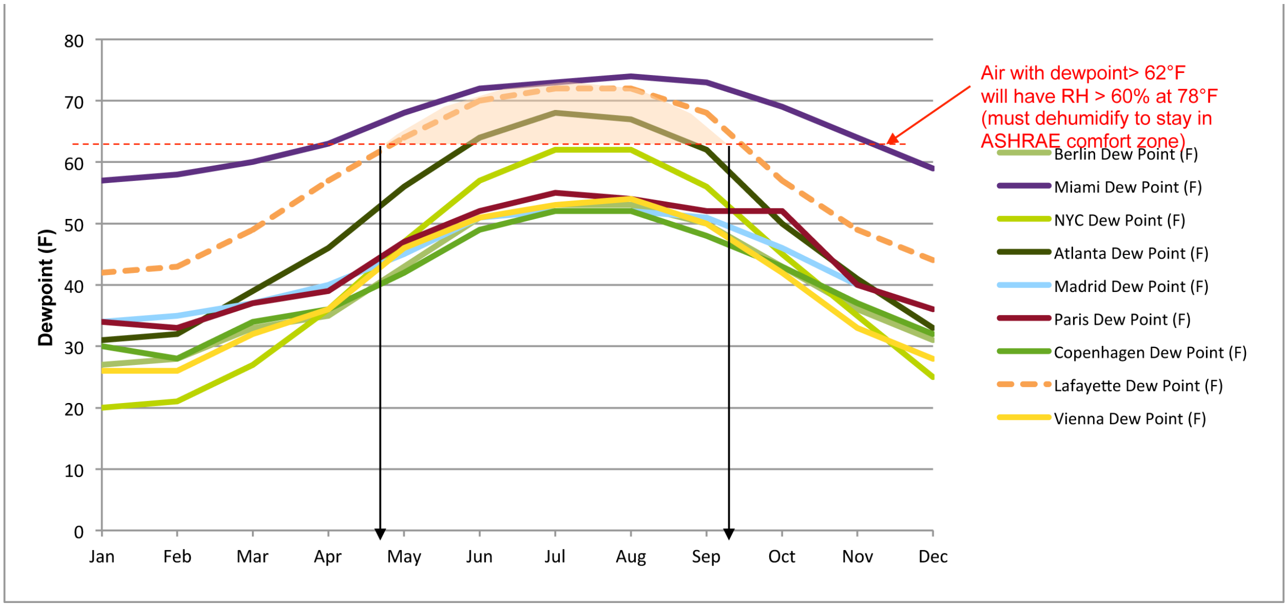
OVERVIEW

The Passive House Planning Package (PHPP) provides the primary energy modeling for Passive House certification and has been honed through a feedback loop that integrates practical lessons learned from built projects into the modelling since the mid-1990's. The vast majority of these carefully tracked, built examples, however, come from the relatively low dew point regions of central Europe. In the 2000's Passive Houses were showing up in the United States for the first time but even by 2010 there were scarcely a dozen certified and only one in the deep South. This paper reviews the performance of that first deep South Passive House, the LeBois House, through 18 months of logged energy and comfort data.

The translation of the Passive House standard from central Europe to the American South is not a simple comparison because of the dramatic effect that the increased latent loads have on the typical ventilation and distribution strategies. Because of its climate specific systemization in and around Germany, the Passive House standard was optimized as a sensible load strategy and primarily for heating dominated climates. By minimizing conduction and infiltration losses and controlling solar gain, the heating requirements for a building can largely be taken care of by internal gains (people & equipment) and tempering the ventilation air. In climates where cooling and dehumidification loads dominate, the U.S. Deep South for example, the Passive House strategy must be modified to manage the latent loads. These loads, surprisingly, can be 6 to 8 times that of the sensible load. And while peak loads in the Deep South can be matched by many, more northerly climates, the yearly cumulative load for the South remains a category apart. The need to expend any energy on latent load management does not even come up for most of central Europe, as shown in Figure 1.



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The ventilation air and the energy demand caused by the latent load within it is of fundamental importance when designing an efficient strategy to maintain comfort in the hot/humid climate zones. The latent load must be handled separately from the sensible load to be able to efficiently provide comfort. In a Passive House, this is complicated because conventional cooling systems are not designed for majority latent load management. While an ERV is able to recover 80-90% of energy required to temper intake air during heating season, during the cooling season ERV efficiencies are typically much smaller: 35-50%. This is due to smaller DT and higher latent load. The achievable dehumidification performance of a stand-alone dehumidifier is considerably less than the 16 SEER (that is, 16kBtu/kWh) or higher performance levels we are used to thinking about for cooling systems. A 'high-performance' residential-scale dehumidifier may be rated at 2.4 liters/kWh, which translates to just 5.5 kBtu/kWh (5.5 SEER). And to get this pseudo-high performance equipment there can easily be a 5-10 times cost increase. Not only is the equipment considerably less efficient, but the homeowner is really paying for the privilege. Then the cooling system must extract the heat the dehumidifier has deposited in the building as a by product of its dehumidification efforts, requiring more energy consumption.

The difficult situation of the hot/humid climate zone is bore out in the Ventilation Load Index (VLI) and the work of Lew Harriman.[3] The VLI is a cousin of the heating/cooling degree day (H/CDD) indexes and chronicles "the load generated by one cubic foot per minute of fresh air brought from the weather to space-neutral conditions over the course of one year"[4]. What this effectively does is give a breakdown between latent and sensible ton-hours per cfm per year and allows a quantification of the latent effect. The (VLI) indicates that in the deep South, over 80% of the load for ventilation air is latent, not sensible. If we use a good-performing dehumidifier to handle most of the latent load and the conventional AC system to handle mostly sensible loads, we predict that ventilation loads alone for our test 120 m2 house will be 15 kWh/m2/yr, before we even get to loads due to the envelope or internal gains from occupants. We estimate that meeting total cooling

Figure 1: Monthly average dew point temperature comparison of various locations in the US and Europe. It is based on a diagram that Henry Gifford shows and developed to its current form by C. Saft and Z. Smith.

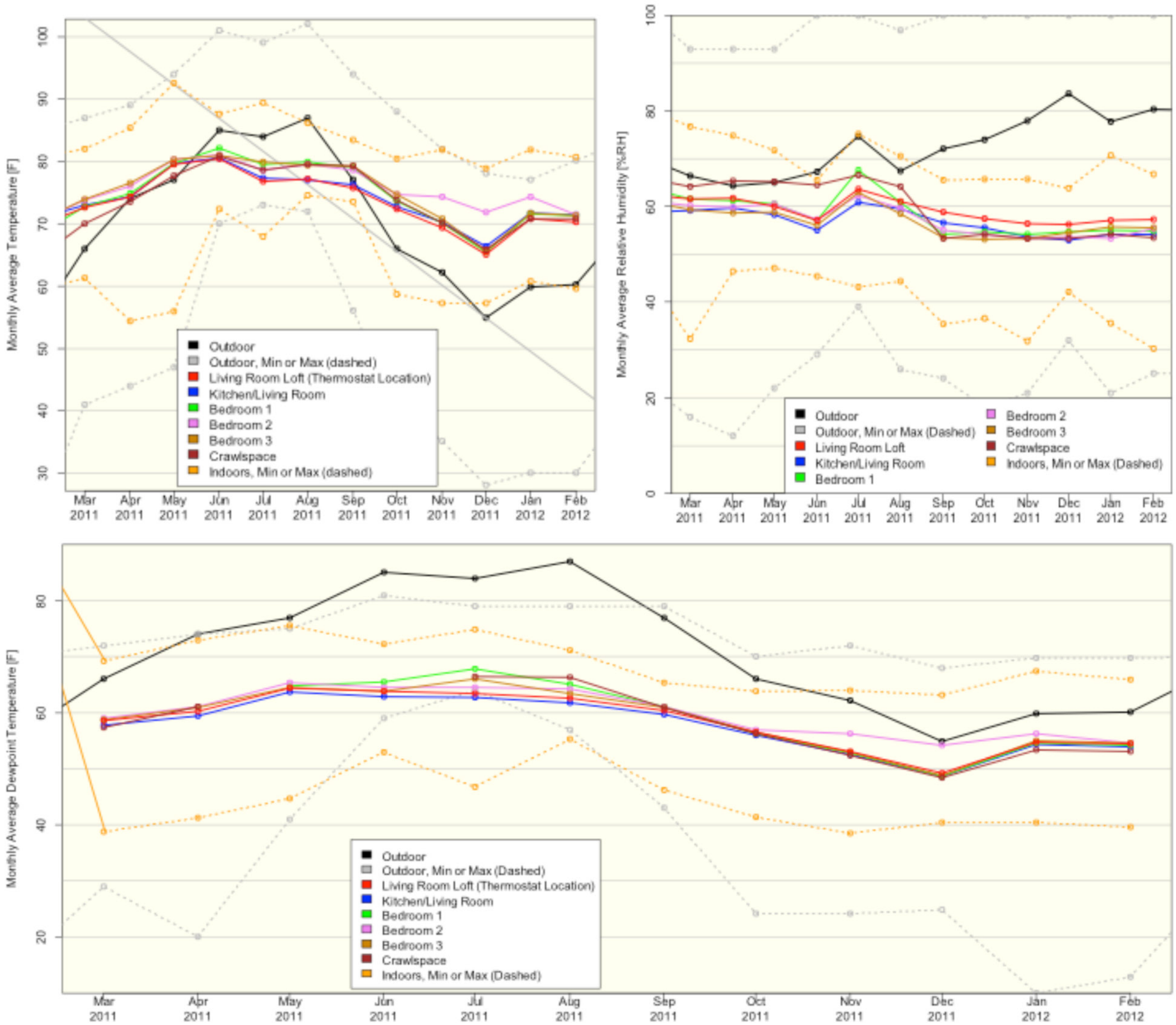

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Figure 2: Monthly average a) temperatures, b) %RH, and c) dew point temperature.

loads (latent + sensible) could exceed 30kWh/ m2/yr. The PH target for annual site energy for heating (15kWh/ m2/yr) is based on what was achievable with good design and best equipment. For hot-humid climates this same criteria has yet to be quantified but clearly it must be conceived relative to the unique conditions of a hot/humid environment.

LEBOIS

The LeBois house is a 120 m[2] three bedroom, two bath home with a large double height space. It was completed in January of 2010 in Lafayette, LA. The volume of this small two-story home has a volume comparable to a 186 m2 (2,000 SF) house with eight foot ceilings. There is a 1.5 ton mini-split heat pump with single head in the living room and an ERV that provides 70 cfm of continuous tempered outside air to the bedrooms and living room. The ERV exhausts stale air from the bathrooms and kitchen. The home has been occupied by three college students for the past 3 years.

The home was monitored with twelve Onset H08 and H14 temperature and humidity loggers on 3-6 minute intervals set throughout the house/basement/exterior and in each of the four ERV ducts. One Onset logger used current

Table 1

	Total Energy Use [kWh]	Mini-Split [kWh]	Net Energy [kWh]	PV Generation [kWh]
Mar-11	576	1	178	-398
Apr-11	715	113	281	-434
May-11	555	94	30	-525
Jun-11	694	2	235	-458
Jul-11	669	249	296	-373
Aug-11	822	284	328	-493
Sep-11	988	207	557	-431
Oct-11	621	61	199	-422
Nov-11	652	24	360	-292
Dec-11	439	14	227	-212
Jan-12	735	17	480	-255
Feb-12	720	15	502	-218
12-Month Total [kWh/a]	**8,185**	**1,342 (cool=1,271 heat=71)**	**3,674**	**-4,511**
Specific 12-Month Total [kWh/m^{2}a]	**68.3**	**11.2 (cool=10.6 heat=0.59)**	**30.7**	**-37.7**

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Table 2

	PHPP Specific Energy Use [kWh/m^{2}a]	Measured Specific Energy Use (Mar 2011 - Feb 2012) [kWh/m^{2}a]
Primary Energy	116	184
Cooling	15	10.6
Heating	8	0.6

2

Table 1. Monthly total electrical energy use and generation.

Table 2. PHPP modeling and 12-month measured energy data.

transducer to estimate the energy use of the ERV. A 4-channel The Energy Detective (TED) system measured and recorded grid energy, PV generation, and the mini-split energy. Eric Helton of Bloomfield Research Labs LLC, and co-author on a previous publication of the data included here, was jointly retained by Corey Saft and the PHIUS as a third party analyst of the data.

The home was modeled and certified using the PHPP and was predicted to need 8 kWh/m2/yr heating, 15 kWh/m2/yr cooling, and 116 kWh/m2/yr annual source energy consumption. We have now collected 18 months of energy and comfort data and present an analysis here.

RESULTS - COMFORT

Average monthly indoor and outdoor temperature, relative humidity, and dew point temperature are shown in Figure 2. Thermal comfort in the LeBois house is characterized by two distinct thermal areas within the house: open/public areas and closed/private spaces. The thermostat in the public area was set lower than ideal to maintain comfort in the bedrooms. In the summer, the mini-split heat pump was frequently operated to keep the open spaces up to 5 or 6 °F (2-3 C) cooler than the bedrooms. While both zones could be kept in the ASHRAE comfort zone, the public areas generally were a bit cooler than optimum, and the private areas a bit warmer. The public space was typically near the center-left of the ASHRAE comfort zone with temperatures in the mid-70's °F (low-mid 20's C) and RH mid-50%. The bedroom spaces often hovered at the far right side of the ASHRAE comfort zone with temperatures occasionally hitting 80 °F (27 C) with RH typically in the lower 50%. The ERV- and dehumidifier-pretreated ventilation air was the main conditioning for the bedrooms, especially when the doors were closed. Convection never balanced the thermal comfort of the house. There is little that can be done to equalize temperatures between the two space types.

RESULTS - ENERGY

Heating was rarely required, and the actual use was about 7% of the predicted need. Cooling was more significant, but still only 70% of the predicted need. Primary energy was approximately 50% greater than predicted by the PHPP. Annual latent is estimated to be 15 kWh/m2/yr (compared to no quota). The total energy used by the mini-split for the 12-month test period was 1,342 kWh/a of which, approximately 1,271 kWh/a was cooling, and 71 kWh/a was used for heating.

There are a number of factors that contribute to the larger than expected primary energy number for the house:

- The addition of the stand alone dehumidifier in August 2011
- While the ERV is critical to performance, the measured performance (35%) is less than rated and suffered a few operational issues over the course of the study such as an extended period with an increasingly blocked intake duct
- The consequences of the house being a rental
- A irregular/inconsistent student lifestyle
- The occupants maintained a large electronics collection, including computers, video games, stereo equipment, an extra mini-fridge, projector

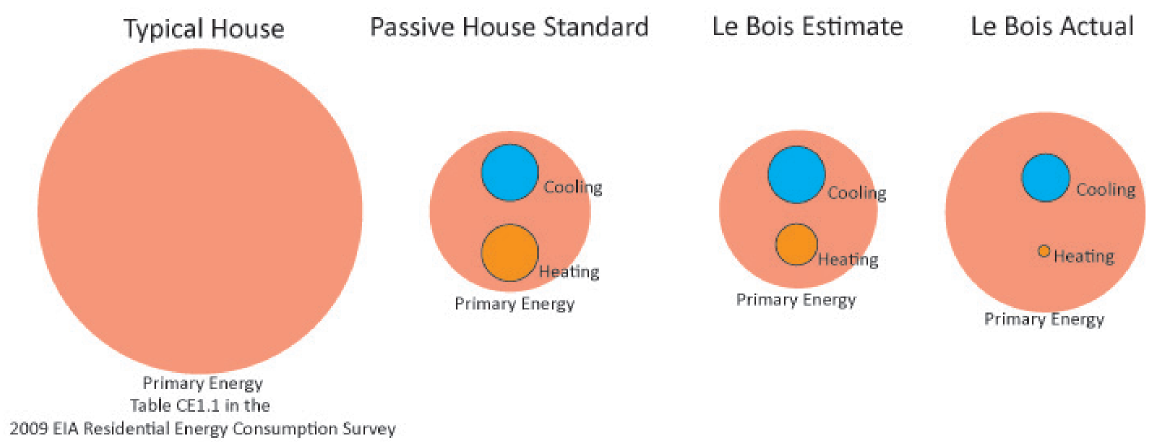

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Figure 3: Comparison of energy use between estimated, actual and benchmarks [image by C. Stelly].

and amplified musical instruments. [Going forward, this should probably be considered the norm and not an aberration.]

CONCLUSIONS

- The house exceeded the primary energy modeling by the PHPP for 12 months of data.
- The 12-month measured heating and cooling energy totals were below the PHPH model.
- The PHPP model may not realistically model the high cumulative latent loads induced by ventilation air in the Hot/Humid climate.
- Comfort was marginally maintained during the summer, but temperature uniformity between the open and private spaces was impossible.
- The next major modification to the data collection project will be a dedicated monitoring of the dehumidifier energy consumption separately from the ERV and the mini-split.
- Investigate improved comfort by delivering dehumidified air adjacent to mini-split head.
- Work with the PHIUS/PHPP software team to ensure latent loads are handled realistically
- More flexible and realistic energy requirements by setting a Total Source Energy and allowing each building to adapt this total, as appropriate for the climate, to heating/cooling/dehumidification.

VENTILATION AIR

The single greatest controllable factor in managing energy consumption when you have a high performance building, such as a Passive House or really any spray-foamed home in the humid South, is ventilation air. It is typically assumed that with super tight construction, such as Passive Houses, one has to compensate for their tightness with a robust delivery of fresh (outside) air. What typically follows during the shoulder seasons of fall and spring (and is extraordinarily difficult to efficiently manage) is partial load humidity issues that have given tight construction in the humid South such a stigma. So the conundrum of tight construction in the hot/humid climate zone can be characterized as build tight for efficiency but then compensate

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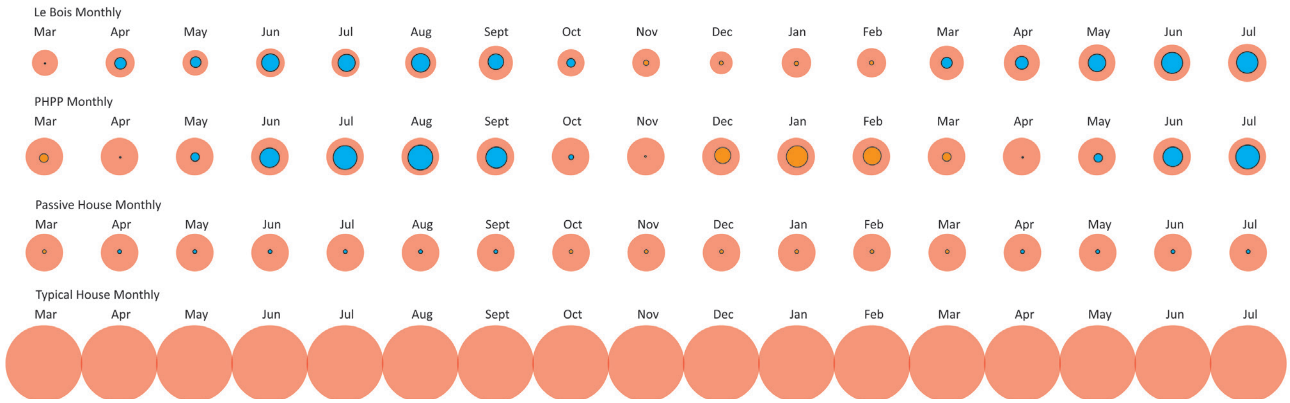

for the lack of infiltration (and fear of IAQ issues) with significant ventilation requirements. The IAQ concern that is the primary pivot for this argument is suspect but the energy penalty is not.

The shocking fact, if you follow Joe Lstebrick and the debate over this issue on blogs such as The Energy Vanguard, Green Building Advisor and The Energy Nerd[5], is that the very premise for this position, that older houses were significantly more leaky and that this allowed them to mange their ventilation needs through infiltration, is a myth. "We also know that millions of houses were constructed in the 1990s and 2000's that were between 2 and 5 air changes per house at 50 Pascals with no ventilation system and their air change rate are between .2 and .3 air changes per hours as tested by tracer gas work and that's consistent with houses tested in the '70s and '80s as well. The myth of the old leaky house is just a myth."[6] It quickly follows that if air changes per hour did not change relative to the increasing tightness of construction over the past 40 years then IAQ relative to ventilation air should not be no more of a concern now then it was then. And the conclusion is that perhaps we are over ventilating and paying a kind of ventilation tax in the process.

The tracer gas work he refers to is an empirical testing of built work and not the speculation of a theoretical modeling strategy. This leaves the current ventilation requirements under ASHRAE 62.2 2010 as likely too severe and causing a significant and unjustified energy penalty. The proposed changes to ASHRAE 62.2 2013 version will increase this already onerous requirement more. [7] The argument is based on indoor Air Quality. This argument is not borne out because the base case of the 'older leaky home' is not, in fact, the case. So if older homes and new, tightly sealed, high performance homes have comparable rates of air changes then current standards (and fears and habits) are giving a significant penalty to performance construction in humid environments without delivering benefit. Consequently, ventilation represents a primary opportunity in continuing to optimize the performance of residential construction in the hot/humid climate zones.

The process of commissioning the LeBois House became an accidental case-study of Joe Lstiburek's8 well reasoned belief that in the South we are over-ventilated. Our data collection did not look at IAQ relative to ventilation, which is the counterpoint to the over ventilated argument, but contaminates from building material in the LeBois house were carefully contained and the tightness of the house allows one to isolate an extremely high percentage of the ventilation air as being passing through the ERV and getting filtered to MERV 12 levels.

Figure 4: Monthly comparison of energy use between estimated, actual and benchmarks

[image by C. Stelly]

During the commissioning of the LeBois House inefficiencies that traced back to inadequate installation of the ERV were uncovered and we learned the dramatic energy consequences of ventilation air in a hot/humid climate.

During construction, and particularly during the install of our energy recovery ventilator (ERV), the setting knob was subtly broken (and unreported). The control knob had been pulled off without removing a set screw. The consequence was that when the control knob was depressed and a setting was dialed in (70-200 cfm) you could hear the motor rev up and down in accord but once you release the pressure on the knob it would default to its high setting and pump in 200 cfm of hot humid outside air. This is nearly triple the 70 cfm we needed to maintain and even more than we actually wanted.

Interestingly, the 200 cfm of outside air approximates some of the potential ASHRAE 62.2 2013 required ventilation numbers. [see the Martin Holliday footnote from the previous page] Before we identified the problem, we upsized the mini-split by 50% taking it from 1T to 1.5T and these extra 5000 btus of capacity had very little perceptible impact on the internal comfort levels. The bedrooms particularly, which were directly supplied by the ERV, had crossed outside of the comfort zone. If our exaggerated levels of ventilation air were the standard, which ASHRAE 62.2 2013 suggests, and we upsized the mini-split to handle them we would develop an exaggerated partial load humidity problem in the fall and spring when the min-split would not be necessary for the sensible load but the latent load would be large and difficult to otherwise manage. Part-load humidity problems are not really solvable in an efficient manner with available residential equipment. The best stand-alone dehumidifier's equivalent SEER is approximately 5.5, or 25% efficient and a typical high performance mini-split. The additional ventilation air adds significant extra loads to be managed and the available equipment to manage them are, comparably, energy hogs.

One of the basic insights of the Passive House strategy is the separation of the heating and cooling from the ventilation of the house. The most efficient system would have the conditioning come from a point source heat pump and the ventilation be a balanced system with recovery. This insight holds partially true for the humid South but to refine the system and optimize it for a humid climate requires the minimizing of the required ventilation air (cfm). This strategy will go a long we to capturing the possible benefits that the Passive House strategy offers to this climate zone. One solution outside of the regulatory framework would be to develop enthalpy optimizers for the residential market or allow ventilation air (cfm) to be regulated by occupancy or CO_2 sensors so flow rates can be reduced when no one is in the house.

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ENDNOTES

1. Crawley, Drury, Shanti Pless, Paul Torcellini. "Getting To Net Zero". NREL Jurnal aricle NREL/JA-550-46382 September 2009. <http://www.nrel.gov/docs/fy09osti/46382.pdf>.

2. Hawkin, Paul, A. Lovins, L.H.Lovins. 2008. *Natural Capitalism: Creating the Next Industrial Revolution*.Back Bay Books.p.100.

3. Harriman III, Lewis G., D. Plager, D. Kosar. "Dehumidification and Cooling Loads From Ventilation Air". ASHRAE Journal, November, 1997 pp 37 -45. http://www.interenergysoftware.com/downloads/BMVentCoolLoads.pdf.

4. Ibid, p.

5. Holladay, Martin. "How Much Fresh Air Does Your Home Need." Green Building Advisor [http://www.greenbuildingadvisor.com/blogs/dept/musings/how-much-fresh-air-does-your-home-need].

6. *Lstiburek, Joseph. "BSI-069: Unintended Consequences Suck." Building Science Insights[http://www.buildingscience.com/documents/insights/bsi069-unintended-consequences-suck/].*

7. Holladay "Until recently, the basic ventilation rate formula established by ASHRAE 62.2 back in 2003 — 7.5 cfm per person plus 1 cfm per 100 square feet — has remained unchanged. (The standard assumes that the number of occupants in a home equals the number of bedrooms plus one.) ___ However, the latest (2013) version of ASHRAE 62.2 includes a significant change in the decade-old ventilation formula. Under the new formula, high-performance homes will need to be ventilated at a higher rate, namely 7.5 cfm per person plus 3 cfm per 100 square feet. This means that for a tightly built 2,400-square-foot home with 3 bedrooms, the minimum airflow rate of the ventilation equipment has jumped 89%, from 54 cfm to 102 cfm."

8 Bailes, Allison. "Interview with Dr. Joe Lstiburek — The Ventilation Debate Continues". Energy Vanguard Blog. [http://www.energyvanguard.com/blog-building-science-HERS-BPI/bid/66004/Interview-with-Dr-Joe-Lstiburek-The-Ventilation-Debate-Continues]]