The Future of Housing: The Path to Net-Zero and Beyond

By Ted L. Clifton

Zero-EnergyPlans.com
Notes from William McDonnough: (Author of *Cradle to Cradle*)

Regulation is an indicator of design failure –
- Fix the design, no need for regulation!

What is our intention as a species?
- There is nothing in the Bill of Rights about a “right to pollute”!

The foundation of Human Rights –
- Every child born, no matter where, needs to be loved!
The Big Question -
• How do we love all children, of all species, for all time?

The big goal –
• Our goal is a delightfully diverse, safe, healthy and just world, with clean air, water, soil and power – economically, equitably, ecologically, and elegantly enjoyed!
Notes from William McDonnough: (Author of *Cradle to Cradle*)

- Humans need to be humble, especially Architects (& Designers) – after all, it took us five thousand years to put wheels on our luggage!

- Being less bad is not being good, it is still bad! Let’s strive for good! After all, trashing the planet is not our intention as a species! Let’s get the design right!
How “less bad” are your homes?

- Is a HERS rating of 41 good?
- Does everyone know what a HERS rating is? Home Energy Rating System
- HERS 100 is home built to the 2006 IECC
- HERS 0 is net-zero-energy home
- 2012 IECC would be about HERS 82, so a 41 would only be HALF AS BAD!
What if you bought all you energy at once?

HOW MUCH WOULD YOUR LAST 30 YEARS WORTH OF HOME ENERGY HAVE COST?

Total energy bill for 30 yrs. = $220,587.66 with no changes made, if paid over next 30 yrs., with average inflation on energy.

$8,550.93 in 1973
$28,996.20 in 1981
$77,040 if bought today

These figures are based on average energy used by 2,000 sf home in 2011. Your actual costs may vary, depending on the age, condition, heating fuel, and location of your home.
How much will your Future Energy Cost?

INFLATION IN ENERGY COSTS @ 6.33% / AVG. 2,000 SF HOME VS. CORE INFLATION AVG. LAST 30 YEARS (3.343%):

Total energy bill for 30 yrs. = $220,587.66 with no changes made

Total energy bill with actual inflation for 32 years = $345,150.48

Actual CPI Inflation

Actual Energy Inflation / 32 yr. period

$214/MO.

$569.92/mo. at avg. inflation / 30 yrs. leaves $779.78/mo. shortfall

$1,525.46/MO. (32 yrs.)
$1,434.64/MO. (31 yrs.)
$1,349.24/MO. (30 yrs.)

"Inflation Gap" just for last two years is over $20,000!

Actual Energy Inflation vs. Actual CPI Inflation leaves $169,665.12 shortfall over 30 yrs.
OK, so what can I do about it?

- Design & build better homes!
- Net-Zero Energy homes
- Positive NRG™ Homes

- But HOW????

- That is what this class is all about...
Course Objectives:

To learn how to design and build cost-effective net-zero-energy homes using:

- Building Orientation
- Simple Design
- Window Orientation
- Thermal Mass
- Tight Building Envelope
- Balanced Insulation Levels
Course Objectives (cont’d):

To learn how to design and build cost-effective net-zero-energy homes using:

- Balanced Ventilation
- Heat Pump Selection and Operation
- Water Heating Choices
- Efficient Appliances
- Efficient Lighting Systems
- Alternative Energy Sources
Who are you, and why are you here?

- Architects and Designers?
- Builders?
- Developers?
- Sub-Contractors? HVAC?
- Do-it Yourselfers?
- Policy-Makers?
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Chapter 1

Building Orientation
Where is South?

• Shadows from vertical objects will show true north at Local Apparent Noon (LAN)
• When is LAN?
• What is your Longitude? (123°w?)
• How many degrees does the sun move each hour? (15)
• Each minute? (1/4)

When is YOUR LAN?
Where Does the Sun Rise?

- In the Summer?
- In the Winter?
- In the Spring or Fall?
How High will the Sun Get?

• In the Summer?
• In the Winter?
• In the Spring or Fall?
• Where is the Tropic of Cancer?
How Do we Know this Stuff?

- The tropics are at 23° N & S
- Sun will be below the Azimuth by our Latitude (48°)

Winter sun will be 23° lower
Summer sun will be 23° higher
How do we Capitalize on this?

- Building Orientation
- Roof Height and Orientation
- Window Orientation
- Landscape Design & Orientation
- Must be Climate Specific!

We will look at each in turn…
How do we Optimize Building Orientation?

- Long side south if possible?
- Orient roof ridge east-west
- Locate rooms within the house to optimize daylighting during the hours of most activity in those rooms
- Move building location on lot to maximize (or minimize) solar exposure due to natural or man-made restrictions
How do we Optimize Window Orientation?

- Most windows facing South?
- East-facing windows will provide morning warmth (when it is most needed)
- Locate rooms within the house to optimize daylighting during the hours of most activity in those rooms
- Consider likely furniture arrangements, make sure windows are not wasted!
- Each Window should provide more than one function!
How do we Optimize Roof Height and Orientation?

- Largest face of roof should face South
- Eave height should get roof up above natural and man-made restrictions
- Keep plumbing vents and other impediments on the north side of the ridge line
- NO south-facing dormers (unless they are shed-style, and angled to support solar panels)
- Use T-shaped roof where main ridge cannot face south
How do we Optimize Roof Height and Orientation?

- **T-shaped roof:**
- **28’x48’ east-facing house has 42’ of roof facing South!**
How do we Optimize Landscaping Choices?
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Chapter 2

Simple Design
What is the Effect of Surface Area?

- Two-story vs. Single story
- Single story house of same size will have about 25% more surface area!
What is the Effect of Surface Area?

- More complex shape?
- Single story house of same size will have about 48.5% more surface area!
Why do we not want Surface Area?

- Surface area is where we lose Energy!
- Surface area is what costs you Money!
  - To build
  - To finish
  - To maintain
  - To dispose of at the end of its life-cycle

What is the real cost in Energy Loss?
What is the Real Cost of Surface Area?

- How much additional insulation would it take to make up a 25% increase in surface area?

- How about a 48.5% increase in surface area? Any guesses?
OK, so how do we make a cube look good??
OK, so how do we make a cube look good??
OK, so how do we make a cube look good??

- Add covered porch area
- Create outdoor covered living areas
- Use eyebrow roof over gable end first-floor windows:
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Chapter 3
Window Orientation
How much South-Facing Glass?

- ICC-700 recommends 7%-10% of floor area in South-Facing Glass, depending on Climate Zone
- ICC-700 recommends not more than 4% for East or West-Facing Glass
- One of our 2,408 sf Net-Zero homes has 208.5 sf (8.66%) of South-Facing Glass, and 85 sf (3.5%) of East-Facing Glass, and zero North or West-Facing Glass!
Why have East-Facing Glass?

- In most climates and seasons, homes will lose heat over night, and will need to be heated in the morning hours.
- East-facing glass can allow the sun to provide free solar energy to warm the house in the morning.
- Care must be taken not to over-heat the home in warmer climates or seasons.
What are the consequences of West-Facing Glazing?

- West-facing glass can over-heat the house in the afternoon, when the house is already warm from the heat of the day.
- The sun is lower in the sky in the late afternoon, so the energy penetrates the low-e glass more directly.
What are the consequences of North-Facing Glazing?

- No energy is gained from North-Facing Glazing
- Daylight gained must be reconciled against heat energy lost:
  - Calculate lighting energy needs
  - Balance lighting against 24/7/365 heat loss
- Can the area be lighted indirectly through other south-facing rooms in the house?
What are the consequences of North-Facing Glazing?

- Example 1, Light Cost:
  4 hours per day @ 23 watts = 92 w/day
  92 x 365 = 33,580 w, or 33.58 Kwh
  33.58 Kwh @ .11¢ per Kwh = $3.69/yr.

- Example 2, Heat Cost:
  3-0x4-0 window uses 165 btu/hr @ DDD (50 degree Δt) x 24 hrs x110 (5500 HDD)
  = 435,600 Btu/year = 127.66 Kwh
  127.66 Kwh @ .11¢ per Kwh = $14.04/yr.
Provide Shading:

- On East Side during late morning hours in Summer
- On South-facing during Late Spring, Summer, and Fall
- On all West-Facing

What can we do with glass options?
## What can we do with Glass Options?

<table>
<thead>
<tr>
<th>Product</th>
<th>IG Construction</th>
<th>Trans.</th>
<th>% Out</th>
<th>% In</th>
<th>SHGC</th>
<th>SC</th>
<th>RHG</th>
<th>Btu/hr/ft²/°F</th>
<th>Winter U-Value</th>
<th>Center of Glass R-Value</th>
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<tbody>
<tr>
<td>Two Pane LoE-179 #2</td>
<td>3.0C7/13.0/3.0</td>
<td>79</td>
<td>14</td>
<td>14</td>
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<td>0.75</td>
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<td>22</td>
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<td>139</td>
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<td>4.00</td>
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<td>16</td>
<td>20</td>
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<td>56</td>
<td>0.15</td>
<td>0.12</td>
<td>6.67</td>
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<td>46</td>
<td>0.13</td>
<td>0.11</td>
<td>7.69</td>
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Chapter 4
Thermal Mass
### How Important is Thermal Mass?

- Controlling the Day/Night temperature swing is the key to Energy Efficiency:

<table>
<thead>
<tr>
<th>Cubic volume of house</th>
<th>btu/cf/degree F</th>
<th>Btu/degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>10088</td>
<td>0.0183</td>
<td>184.6104</td>
</tr>
<tr>
<td>btuh on DDD</td>
<td>7800 (from CP Wksh)</td>
<td>42.2511408 Degrees/Hour heat loss</td>
</tr>
<tr>
<td>Btu/h/12 hours</td>
<td>93600</td>
<td>507.013689 Degrees/night heat loss</td>
</tr>
</tbody>
</table>

Note that the house would not REALLY lose hundreds of degrees in twelve hours, the number shown is merely a reflection of the number of Btus required to keep the home at the desired temperature for this amount of time at the Design Degree Temperature.

<table>
<thead>
<tr>
<th>square feet of 2nd floor</th>
<th>584 (concrete slab)</th>
</tr>
</thead>
<tbody>
<tr>
<td>thickness of 2nd floor</td>
<td>6</td>
</tr>
<tr>
<td>square feet of lower floor</td>
<td>544 (concrete slab)</td>
</tr>
<tr>
<td>thickness of lower floor</td>
<td>4</td>
</tr>
<tr>
<td>125</td>
<td>3,000</td>
</tr>
<tr>
<td>92.79167</td>
<td>1700</td>
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</table>

Enter Square feet of GWB
Enter Board Feet of Interior Lumber

<table>
<thead>
<tr>
<th>Adjusted volume of thermal mass</th>
<th>691.125</th>
<th>31.61</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Btu/cf/degree f Concrete)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Loss w/Thermal Mass:

<table>
<thead>
<tr>
<th>Btu/cf/degree F</th>
<th>Deg. F/Hr.</th>
<th>Deg. F/12 Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35404542</td>
<td>4.24854503</td>
<td></td>
</tr>
</tbody>
</table>
What will Thermal Mass really Save us?

- We can replace the lost Btus using Passive Solar Energy! Really? Yes, Really!
- Even without good window orientation, or a sunny day, a heat pump will be more efficient when running at warmer daytime temperatures.
- We will explore that further in the Heat Pump chapter below. (27%!)

How much Energy Can We Get From the Sun? Try CC-5:

<table>
<thead>
<tr>
<th>WEATHER DATA SUMMARY</th>
<th>LOCATION: Latitude/Longitude: Data Source:</th>
<th>Seattle Tacoma Intl A, WA, USA 47.47° North, 122.32° West, Time Zone from Greenwich -8 TMY3 727930 WMO Station Number, Elevation 400 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MONTHLY MEANS</strong></td>
<td><strong>JAN</strong></td>
<td><strong>FEB</strong></td>
</tr>
<tr>
<td>Global Horiz Radiation (Avg Hourly)</td>
<td>44</td>
<td>68</td>
</tr>
<tr>
<td>Direct Normal Radiation (Avg Hourly)</td>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>Diffuse Radiation (Avg Hourly)</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>Global Horiz Radiation (Max Hourly)</td>
<td>116</td>
<td>166</td>
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<tr>
<td>Direct Normal Radiation (Max Hourly)</td>
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<td>Diffuse Radiation (Max Hourly)</td>
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<tr>
<td>Global Horiz Radiation (Avg Daily Total)</td>
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<td>633</td>
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<td>Direct Normal Illumination (Avg Hourly)</td>
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<td>Dew Point Temperature (Avg Monthly)</td>
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<td>35</td>
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<td>Relative Humidity (Avg Monthly)</td>
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<td>Wind Direction (Avg Monthly)</td>
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<td>Wind Speed (Avg Monthly)</td>
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<td>8</td>
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<td>Snow Depth (Avg Monthly)</td>
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<td>44</td>
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<tr>
<td>Ground Temperature (Avg Monthly of 3 Depths)</td>
<td>48</td>
<td>44</td>
</tr>
</tbody>
</table>
How much Energy Can We Get From the Sun?

- The previous slide showed that Seattle gets up to 1,892 Btu per day per square foot of Direct Normal Radiation in the Summer.
- Seattle gets at least 340 Btu per day of Direct Normal Radiation even in the winter.
- Diffuse Radiation is less, but still at least 183 Btu/sf/day during the darkest Winter Month!

So how much is that, and what can we do with it?
How does that graph out?
Compare to Billings, Montana:
How much Energy Can We Get From the Sun? Let’s Calculate:

- Diffuse Radiation is less, but still at least 183 Btu/sf/day during the darkest Winter Month!
- If we have 200sf of South-Facing Glass, with an SHGC of .5, we would get 100 times 183, or 18,300 Btu on a cloudy winter day!
- That is about one hour worth of energy on the Design Degree Day for the house in our example
- On a Sunny Winter Day, we would gain about double that amount, 34,000 Btu.
Big whoop, one hour of Energy...

- Ah, but that is at the Design Degree Day, Based on an outside temperature of 19 degrees...
- What is the average outside temperature during that same cold winter month?

Let’s take another look at Climate Consultant 5:
What is our Average Winter Temperature?
What is our Average Winter Temperature?

- Looks like about 41 degrees in January…
- Only 57% of the way to the Design Degree Day!
- This means a sunny day would provide at least 3 1/2 hours of energy
- A cloudy day would provide 1 ¾ hours of energy…

This might not seem like much, but it adds up fast over time!
What is our Average Annual Temperature?

- Looks like about 52 degrees…
- Only 35% of the way to the Design Degree Day!
- Seattle’s Average Annual Direct Normal Radiation is just under 100 Btu/sf/hr
- Six hours of sun will provide 60Kbtu, or enough energy to heat the house for nine hours on the average day.
What Happens in the Summertime?

- Does the slab get too hot?
  - It can, in some climates
- Can we cool it off at night?
  - Yes, in most climates
- Where will the excess energy go?
  - Some will be transferred to air, and exhausted to the outside
  - Some can be transferred into the ground
  - Keep your thermal mass stable!
What can we do to optimize Thermal Mass?

- Keep all Thermal Mass completely within the Building Envelope.
- Add Thermal Mass even on second floors, by pouring a slab over your framed wood floor.
- Orient windows to provide direct access to your Thermal Mass.
- Use Thermal Mass walls or stairs to better capture energy from East or West-facing windows.
The Future of Housing: The Path to Net-Zero and Beyond

Chapter 5

Tight Envelope
What is the Effect of a Tight Building Envelope?

- How much energy is lost through convection?
  - Air contains .0183 Btu per cubic foot per degree (at sea level)
  - If your house is 1,000 sf, with an 8’ ceiling (as in our Cube House diagram earlier) you have 8,000 cubic feet of air to lose.
  - Let’s do the math: 8,000 \times 0.0183 = 146.4 Btu per degree of temperature difference
  - Our DDD is 50° Δt, 50 \times 146.4 = 7,320 Btu
What is the Effect of a Tight Building Envelope?

- How much energy is lost through convection?
  - Our DDD is $50^\circ \Delta t$, $50 \times 146.4 = 7,320$ Btu
  - At .6 ACH, you will lose 4,392 Btu/hr.
  - In a 24-hour day, that would be 105,408 Btu
  - At .35 ACH, you would lose 2,562 Btu/hr.
  - In a 24-hour day, that would be 61,488 Btu
  - At .1 ACH, you would only lose 17,560 Btu in a day. I like that better!
How does that compare to the Conductive Heat Loss for the same house?

- With 12% glazing, and a good wall assembly, the 1000 sf Two-Story design will use a total of 10,866 Btuh on the DDD including .6 ACH
- 4,392 Btuh are from air infiltration alone!
- If this is a 2-bedroom home, ASHRAE 62.2 only requires 32.5 cfm, or 1,784 Btuh
- How about we save the other 2,608 Btuh?
How much does this save us in a Year? Let’s do the math:

- 2,608 Btuh x 24 hours x 110 (HDD/DDDΔt) = 6,885,120 Btu per year
- If heating with 92% efficient Natural Gas at 80¢ per therm, this would save $59.87 per year.
- Remember, this is just for a tightening up a tiny 1,000 sf house!
- A 2,000 sf house would save twice as much, and a more complex house would save even more!
Walls as Filters? Not a good idea!

- Walls that “Breathe” trap pollens, mold and mildew spores, odors, steam and grease from cooking, and all other sorts of undesirable elements in the insulation layers.
- These can build up, and cause health problems, and degrade the structural integrity of the walls.
- Wall Cavities Must Be Tight!
Balanced Insulation
Why are we building houses this way?

- Consider a 10’x10’ room, with R-60 insulation on the lid.
- Then remove the insulation from a one-foot square area, what is the net R-value of the entire roof assembly?
Let’s try something...

- Start with any house for which you have an energy model (we will show one here using the WSU CP Worksheet)
- Skew your insulation levels so that you have very disparate levels in different areas, but so that they add up the same
  - For example, if you downgrade 1000 sf of walls from R-21 to R-11, upgrade the 1000 sf of roof from R-38 to R-49
What Happened? Original:

<table>
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<tr>
<th>Component Performance, R-3 Occupancies</th>
<th>Code Target Values</th>
<th>Proposed Design Values</th>
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<td><strong>Conditioned Floor Area</strong></td>
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<td><strong>Weather Station</strong></td>
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</table>

**Heating System Size**

- Ducts are located in unconditioned space.
- Equipment size over design load: 100%

<table>
<thead>
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**Component Performance Values**

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**Below Grade**

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</table>

**Target UA Total**

- Target UA Total: 295.2
- Target Credits from Chpt. 9: 1.0
- Proposed UA Total: 236.6
- Proposed Credits from Chpt. 9: 4.5

Qualifies
What Happened? Skewed:
The house uses 14% more energy!
Consider what Happens when we add windows:

- Remove 12 square feet of R-21 Wall
- Replace it with an R-3 Window
- What do you suppose just happened to the net-R-value of your R-21 Wall?
- Now do that about ten times!
  - Our Cube House just increased Btuh by 21%!
  - With U-.21 windows, only 14.6% increase!
- That is how we are building houses!
- We need to do better on our windows & doors!
If we use Better Windows, can we use More Glass?

- If we can save 1/3 of the energy loss by using better windows, we could add 33% more windows and get the same result!
- Could we add only those windows that will result in capturing the solar heat gains outlined above?
- Those are questions that must be answered individually for each project.
Balanced Insulation Levels, Summary: Heat goes to Cold!

- The closer all the insulation levels are to each other, the better the home will perform, relative to the cost and depth of the insulation.
Balanced Insulation Levels, Summary: Heat goes to Cold!

- The closer all the insulation levels are to each other, the better the home will perform, relative to the cost and depth of the insulation.
- Before considering adding even more attic insulation or crawl-space insulation, consider ways of adding more wall insulation, to help even out the insulation levels.
Balanced Insulation Levels, Summary: Heat goes to Cold!

- The closer all the insulation levels are to each other, the better the home will perform, relative to the cost and depth of the insulation.
- Before considering adding even more attic insulation or crawl-space insulation, consider ways of adding more wall insulation, to help even out the insulation levels.
- Use the Lowest U-value Windows and Doors you can find!
Balanced Insulation Levels, Summary: Heat goes to Cold!

- The closer all the insulation levels are to each other, the better the home will perform, relative to the cost and depth of the insulation.
- Before considering adding even more attic insulation or crawl-space insulation, consider ways of adding more wall insulation, to help even out the insulation levels.
- Use the Lowest U-value Windows and Doors you can find!
- Remember that every cost needs to be weighed against the cost of providing renewable energy!
The Future of Housing: The Path to Net-Zero and Beyond

Chapter 7
Balanced Ventilation
Balanced Ventilation, Why?

- You can’t really suck the spots off a leopard!
- Tight house will not allow air to come in through wall cavities
- Exhaust-only ventilation will not work at design values, and therefore will not provide adequate fresh air
- Cost of operation will be lower when balanced ventilation strategies are used
Balanced Ventilation, How?

- Commercial Kitchens are required to have balanced ventilation for the class-one hood system! Air in = Air out.
- Without make-up air, efficiency drops.
- Two smaller fans working in concert with each other will use less energy than one fan struggling by itself!
- Compare (2) FR100s, vs (1) FR160:
Balanced ventilation uses just 1/4 the energy of exhaust-only:

All dimensions in inches.
† Duct connections are 7/16" smaller than duct size.

**PERFORMANCE DATA**

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</table>

Performance shown is for installation type D - Ducted inlet, Ducted outlet. Speed (RPM) shown is nominal. Performance is based on actual speed of test. Performance ratings do not include the effects of appurtenances in the airstream.
Balanced ventilation uses 1/4 the energy of exhaust-only:

- Example:
  FR-100 uses 13w @ 0”wc, 137 cfm
  x 2 = 26w, moving 274 cfm of air

  FR-160 uses 106w @ .2”wc, 260 cfm!
What about Air Quality?

- Should our incoming air be filtered?
  - For pollens & other allergens?
  - For dust & dirt?
  - For molds & mildew?

Let’s look at how:

- Passive filters
- Active filters
What about Air Quality?

- In-line Filters:
  - Provide filtration
  - Do not provide balanced ventilation
What about Air Quality?

- Powered filters:
  - Provide filtration
  - Can provide balanced ventilation
Possible Electrical Schematic:

NOTES:
1. Make sure that fans you are using are compatible with speed controls. Panasonic fans cannot be used with this system.

2. HEPA filter CFM should be equal to or just above the combined CFM of the bath fans to achieve neutral or slightly positive pressure.

3. The HEPA filters and fans I am using are Fan-Tech brand. The bath fans are remote fans, drawing as little as 18-19W per fan. The 125 CFM fan uses 5" pipe, the 100 CFM fan uses 4". The remote fans are extremely quiet, and leave only a small penetration in the ceiling, looking much like a 4" or 5" recessed can trim. Check out www.elf.org/wholesale.

4. Locate the 3-way switch in the bathroom or other room served by the exhaust fan for convenience.

5. Locate the speed control in the area served by the HEPA filter, for best cooling and air handling control.

6. Other more automated controls could be used to adjust the speed control, but my experience has been that simple is best. My homeowners seem to like the manual controls of this system, no complicated buttons or manuals to read.
How about HRVs & ERVs?

- The more extreme your winter and summer temperatures, the more energy you will save with an HRV or ERV.
- What is the difference between HRV and ERV?
- Energy Recovery Ventilator (ERV) also re-captures moisture content.
- Heat Recovery Ventilator only re-captures a percentage of the sensible heat.
How much energy will an HRV recover?

- It depends on the efficiency of the unit:

- This cross-flow unit is rated at around 60%, depending on temperature and pressure
How much energy will an HRV recover?

- It depends on the efficiency of the unit:
- This counter-flow unit is rated at around 95%, depending on temperature and pressure
- What does that mean in real dollars?
How much energy will an HRV recover? Will it be worth the cost?

| Project Name: | Carlson House | Elect. cost/Kwh: | 0.11 |
| Location: | Street Address | Heat system HSPF | 15.4 |
| City: | Your City | Heat system COP | 4.51 |
| State: | Your State | Heating Degree Days | 5400 |
| ZIP: | | Avg. Ext. Temp: | 51 |
| | | ASHRAE 62.2 Req.(CFM) | 50 |

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Intended for comparison purposes only

| Fan Model: | Panasonic Whisper Green | Zehnder ComfoAir 200 |
| Fan Watts | 11 | HRV Watts | 143 |
| Fan CFM | 80 | HRV CFM | 118 |
| Recovery % | 95% | HRV cost: ** | $1,495.00 |
| Fan cost:* | $132.00 | |
| Fan Hrs/Day | 15 | HRV Hrs/Day | 10.1694195 |
| Fan Btuh/Yr lost | 9137556 | HRV Btuh/Yr. lost | 456877.8 |
| Fan Heat Kwh/Yr: | 2678.06448 <using HSPF> | HRV Heat Kwh/Yr: | 133.903224 |
| Heating system heat recovery Kwh: | 593.347792 | Heating system heat recovery Kwh: | 29.6673896 |
| Fan Total Kwh/Yr: | 653.57 | HRV Total Kwh/Yr: | 560.46 |
| Fan Total Cost/Yr: | $71.89 | HRV Total Cost/Yr: | $61.65 |
| Interest rate | 4.00% | 20-Yr Ammortization | ($110.00) |
| 20-Yr Ammortization: | ($9.71) | Total cost w/Ammort: | $171.66 |
| Total cost w/Ammort: | $81.61 | | |
Is there another way?

- Under-slab piping
- Cools incoming air during summer
- Warms incoming air during winter
- Must know soil temperatures!
- Works best with in-floor radiant systems!
And yet another way…

- Two opening windows, on opposite sides of the house, will allow for Balanced Ventilation
- Remember, warm air rises…
- Even without wind, the stack effect can cause sufficient air movement to ventilate a house, especially two and three stories
- Incorporate this idea into your window placement!
Ventilation Summary:

- Always balance large ventilation loads, especially in small, tight homes.
- Smaller venting loads can be exhaust-only, especially short-duration loads.
- Consider appropriate filtration for incoming air.
- Install controls that allow automatic operation, but allow user-adjustment.
- Keep it simple!
The Future of Housing: The Path to Net-Zero and Beyond

Chapter 8

Why Heat Pumps?
Why Heat Pumps?

- We can replace electricity with Wind, Solar, & Hydro
- Once Gas is used, it is GONE!
- When Gas is burned, it contributes to Climate Change
- A Heat Pump only moves heat from one place to another, does not create heat!
- Heat pumps have lower maintenance costs, and higher ultimate efficiency
Why Heat Pumps?

- Consider ONLY the efficiency factor:
  - Modern Gas Power Plants produce electricity at about 60% efficiency, delivered to the grid
  - They can be located right in the middle of town, so no line-losses
  - Operate a Heat Pump and see the net energy savings:
    - At 240% efficient x .6 = 144% net efficiency with use of gas, only requires HSPF of 8.2!
Why Heat Pumps?

• How efficient are Heat Pumps?
  ◦ Most newer units are 300% efficient, HSPF around 10.1
  ◦ This would be 180% net-efficiency with the gas used to make the electricity!
  ◦ A Ground Source Heat Pump can be up to 450% efficient, which would be 270% efficient with its use of gas!
  ◦ Air-source heat pumps are now available that will work down to -15°F at 200% efficiency!
Where will Air-source Heat Pumps NOT work?

- Consider Billings, Montana:
Where will Air-source Heat Pumps NOT work?

- Consider Billings, Montana:
  - Remember our section on Thermal Mass!
  - For overnight, store heat in the slab
  - Re-heat the home during the day using the air-source heat pump
  - The difference between the low (-9°F) and the average winter temperature (+26°F) is 35°F!
  - This represents a 44% savings in energy required to heat the home!
Where might Ground Source Heat Pumps have problems?

- Again, look at Billings, MT:
Where might Ground Source Heat Pumps have problems?

- Again, look at Billings, MT:
  - Ground temperature drops to near 32°F at 2 meter depth
  - Ground temperature at 4 meter depth is warm enough to operate safely
Where might Ground Source Heat Pumps have problems?

- Again, look at Billings, MT:
  - Ground temperature drops to near 32°F at 2 meter depth
  - Ground temperature at 4 meter depth is warm enough to operate safely

- Deep bore system may be preferred!

- Thermal Mass slabs will take several days, or even weeks to initially bring up to temperature, so take your time on start-up!
Where might GSHP be ideal?
Limitations on Air-Source Heat Pumps:

- Cold weather hard limits (-15°F)
- Reduced capacity at the lower end of the operating range
  - Requires careful sizing of unit to match peak demand
  - Could require back-up system

What can inverter-based units do for you?
Inverter-based Heat Pumps

- Ductless Mini-splits, and other newer heat pump designs now operate using DC motors
  - Can start slow, & ramp up to full load as needed
  - Can operate at part-load conditions at greater than rated efficiency
  - This is because they can operate at lower temperatures, using their larger, oversized surface areas
Heat with Heat, Cool with Air!

- Put your hand against your mouth, & puff softly… warm, isn’t it? 98.6˚ air!
- Now move your hand a few inches away, and blow hard… it feels cold! Still 98.6˚ air, but now it is moving
- Lesson: When warm air moves, it feels cold.
- Factor this into your HVAC plan
- Radiant heat will be more comfortable!
HVAC summary:

- Heat Pumps provide superior ultimate efficiency
- Augment Heat Pumps in colder climates, do not eliminate them!
- Use newer, inverter-based heat pumps when available
- Use Thermal Mass to allow your Air-Source Heat Pump to operate only during the day in colder climates
- Heat with heat, cool with air!
Chapter 9
Water Heating
How Important is Water Heating?

- Is usually the largest energy use, after space conditioning
- Can be the largest energy use, when the right measures are put into the building envelope, passive solar, thermal mass, etc.
- Water heating loads can be cut by more than 90%!
Water Heating, What are the Options?

- **Tank-type water heaters**
  - Electric (100% efficient, x.6 = 60% net use of gas)
  - Fossil Fuel (up to 95% efficient for condensing units)

- **On-demand water heaters**
  - Electric (same efficiency, no storage capacity)
  - Fossil Fuel (up to 98% efficient, no storage)

- **Heat Pump water heaters**
  - Up to 240% efficient (x .6 = 144% NU/Gas)
Water Heating, What are the Options, Cont’d

- GSHP Desuperheaters
  - Up to 450% efficient ($\times 0.6 = 270\%$ NU/Gas)
  - How about without a Desuperheater?
  - Desuperheaters only work when GSHP is heating the house
  - These two options prioritize the production of Domestic Hot Water:
Two GSHP/Domestic HW options:

GSHP OPTION #1
(AS WE DID IT WITH UNICHILLER IN BALLARD)

GSHP OPTION #2 (PREFERRED)
Water Heating, What are the Options, Cont’d

- GSHP Desuperheaters
  - Up to 450% efficient \((x \times 0.6 = 270\% \text{ NU/Gas})\)

- Solar hot water heaters
  - Require electricity to run pumps only
  - May not provide enough hot water during cold & rainy weather
  - Can be used in combination with other heating sources
  - Match very well with Ground Source Heat Pumps, and Air-to-Water Heat Pumps
Solar Water Heating Options?

- **Flat-plate collectors**
  - Work best in sunny climate

- **Evacuated-tube collectors**
  - Work best in cloudy climate

- **Closed-loop system**

- **Drain-back system**
  - Can shock Evacuated Tube system
Why, and where, to use a Tank...

- In cold climate, if tank is inside the conditioned building, residual heat is used by the building.
- In warm climate this is not desirable, it adds to the cooling loads.

What effect will a Heat Pump Water Heater have?
Why, and where, to use a Heat Pump Water Heater…

- In cold climate, if HPWH is inside the conditioned building, it will be robbing heat from the building…
- In warm climate this is desirable, it reduces the cooling loads!
- In a moderate climate, the HPWH can be placed in an attached garage. On average, the garage temperature will be warm enough to benefit the HPWH
Why, and where, to use an On-Demand Water Heater…

- In a cold climate, the On-Demand unit is only supreme when hot water use is irregular (as for vacation homes)
- In warm climate the On-Demand water heater will not contribute to the cooling loads
- On-Demand units can be located nearest the point of use
- They can be used as back-up to Solar Hot Water Heaters
Water Heating Summary:

- Water Heating is VERY climate specific!
- Water Heating can also be user-specific
- Calculate your loads, consult your climate, then specify your system!
- In a moderate or cold climate, residual heat is usually desirable, and can help offset space-heating loads
The Future of Housing: The Path to Net-Zero and Beyond

Chapter 10
Efficient Appliances
Define the Loads:

- In most Net-Zero-Ready homes, Cooking will be the largest remaining energy load!
- Clothes Dryers could be the next largest Appliance load
  - They not only create a lot of heat, they also suck conditioned air out of the house!
- The Refrigerator will likely come next
- The Dishwasher will use two to three times as much energy as the Clothes Washer
Get out the Hatchet!

- Start by chopping the largest loads
  - Induction Ranges are saving up to 60% of cooking loads!
- Then the next largest
  - Condensing clothes dryers re-circulate the same air, wringing the moisture out of it
  - Heat gets recovered, and re-used!
- Then tighten up on the smaller loads
  - Check the Energy Star stickers closely!
Check the EnergyGuides carefully:
Both are Energy Star!
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Appliance Efficiency Summary

- Small reductions in larger loads will have more impact!
- Ratchet down all loads as much as feasible
- Be on the watch for newer technology, such as Induction Ranges, Condensing Dryers… Remember the Microwave?
- Without spending any extra money, better energy efficiency numbers can be found
- Counter-top cooking appliances are more efficient than ranges or cook-tops!
The Future of Housing: The Path to Net-Zero and Beyond

Chapter 11
Efficient Lighting
Energy Efficient Lighting: It begins with the Design!

- Remember to light Surfaces, not Rooms!
  - Surfaces may be stationary, like counter tops
  - They can be portable, like a newspaper or book
  - Think about where these surfaces will be, and design for them!

- Design multi-purpose lighting systems
  - Task lighting can also provide general room illumination
  - Ambience lighting can also be used for general illumination
  - Fewer systems means fewer lights to be left on when not being used!
Also consider Lighting Controls:

- Dimmers can reduce loads when brightness is not required
- Specialty controls can light scenes instead of rooms
  - Can aid in reducing total connected load
  - Can provide dimming where full brightness is not needed
- Motion sensors or infrared detectors can shut lights off when not in use
What type of fixture should you use?

- Linear fluorescents are the most economical, but not often popular in homes.
- Compact fluorescent lamps are gaining in popularity and quality:
  - Select fixtures that use type A screw-in bulbs!
  - LEDs are only being made for this type of base!
- LEDs are improving in quality and price.
What is the difference, over time?

Light bulb cost/time

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<td>23</td>
<td>4</td>
<td>$0.1859</td>
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<td>23</td>
<td>4</td>
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<td>4</td>
<td>$0.2217</td>
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<td>4</td>
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<td>$85.81</td>
<td>$1,245.97</td>
<td>$959.40</td>
<td>$19.74</td>
<td>$286.57</td>
</tr>
</tbody>
</table>
How do I get my customers to accept CFLs?

- Select the right CFLs and LEDs!
  - Remember 2700° Kelvin Temperature
  - This is the best color range (warm white)
  - Select CFLs that are instant-on
  - Select dimmable CFLs where needed

- Use the LEDs in the highest use locations, they will provide the biggest benefit there!

- Just DO IT, they never need to know! <😊
What about Plug Loads?

- Education is the key to Consumer Awareness!
- Advise your customers on the selection process, so they can choose TVs and other large energy users based on energy loads
  - LED backlit LCD TVs use just a fraction of the energy of a similar-sized plasma TV, with similar clarity!
  - Install switches to turn off plugs at night
Lumens vs. Watts?

- Learn to select bulbs by the number of lumens they produce, not the number of watts they consume!

<table>
<thead>
<tr>
<th>Watts (energy)</th>
<th>Incandescent</th>
<th>CFL</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 w</td>
<td>2600 lm</td>
<td>32 - 35 w</td>
<td>25 - 28 w</td>
</tr>
<tr>
<td>100 w</td>
<td>1600 lm</td>
<td>23 - 26 w</td>
<td>16 - 20 w</td>
</tr>
<tr>
<td>75 w</td>
<td>1100 lm</td>
<td>18 - 22 w</td>
<td>+13 w</td>
</tr>
<tr>
<td>60 w</td>
<td>800 lm</td>
<td>13 - 15 w</td>
<td>8 - 12.5 w</td>
</tr>
<tr>
<td>40 w</td>
<td>450 lm</td>
<td>9 - 11 w</td>
<td>6 - 9 w</td>
</tr>
</tbody>
</table>

This chart shows the number of lumens produced by common incandescent bulbs. If you’re looking to buy a bulb that will give you the amount of light you used to get from a 60-watt bulb, you’ll now look for 800 lumens.
Energy Efficient Lighting Summary:

- Not all that shines brightly is gold!
- Light surfaces, not rooms
- Use CFLs for most applications
- Use LEDs for heavy-use areas
- Educate your customers
- Learn to select bulbs by the number of lumens they produce, not the number of watts they consume!
Chapter 12
Alternative Energy
What are your design tools?

- Climate Data (CC-5)
  - What time of year you get sun will help determine ideal roof pitch

- Web-based Solar Calculators or I-Phone Apps
  - Estimates annual production based on location, roof pitch and direction

- Local Installer
  - Will have more specialized tools for more accurate and specific assessment
Climate Consultant 5:
Climate Consultant 5:
Sharp Savings Estimator:
Calculate Energy Needs

- HERS rating will provide annual estimate of power usage
  - For heating & cooling
  - For water heating
  - For appliances
  - For lighting & plug loads
RemRate Energy Usage Report:

Be sure to deduct Service Charges from actual usage!
Match Energy Production to Needs:

- Use Web-based, Cell-phone App or Local Solar Installer’s Estimate for system sizing

- Explore electric car usage:
  - Chevy Volt will go 2.86 miles per Kwh
  - Nissan Leaf will go 3.45 miles per Kwh
  - Mitsubishi i-MIEV will go up to 3.33 miles per Kwh

A surplus of less than 3,000 Kwh per year could power a car for 10,000 miles!
How much is that worth?

- My Honda Civic gets 34.5 MPG avg.
  - At $3.85 per gallon, 10,000 miles costs me $1,115.94

- The Leaf gets 3.45 Miles/Kwh
  - If the 2,899 Kwh required to go 10,000 miles is worth the same as my gasoline, then it is worth $1,115.94, or 38.5¢ per Kwh!

- Average that out with the 7,000 Kwh of production that ran the house:
How much is that worth?

- $2,899 \times 38.5\,\text{¢} = $1,115.94$
- $7.000 \times 0.10\,\text{¢} = $700.00$
- Total value of Energy = $1,815.94$
- Value per Kwh = over $0.18\,\text{¢}$ per Kwh!
- This is in addition to any State or Federal incentives!
How about Wind Power?

- It depends on where you are!
  - Billings, Montana looked pretty good!
- Trees and tall buildings are Major impediments to successful wind power
  - Trees could make Western Washington pretty difficult!
- All renewable energy sources are Local!
- Consult with your Local Installer!
### How much does it cost to get to Net-Zero-Energy?

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation Insulation</td>
<td>4&quot; XPS foam</td>
<td>$1,250</td>
</tr>
<tr>
<td>SIPS Walls &amp; Roof</td>
<td>6.5&quot; walls, 10.25&quot; roof</td>
<td>$12,000</td>
</tr>
<tr>
<td>Air Sealing Labor</td>
<td>Saved 8 hrs labor w/SIPS</td>
<td>-$800</td>
</tr>
<tr>
<td>Heating System</td>
<td>Unico UniChiller in-floor Radiant</td>
<td>$10,000</td>
</tr>
<tr>
<td>Balanced Ventilation</td>
<td>FanTech HEPA Filter system</td>
<td>$1,000</td>
</tr>
<tr>
<td>Water Heating</td>
<td>Unichiller, extra tank w/coils, pump</td>
<td>$1,500</td>
</tr>
<tr>
<td>PV System</td>
<td>6.44 KW</td>
<td>$29,500</td>
</tr>
</tbody>
</table>

**Total:** (As-Built, to power house only) $54,450

**Less Federal Tax Credits:** $8,850

**Net Out of Pocket:** (net-zero home only) $45,600
How much does a new Positive NRG™ Home Cost? How fast does it Pay Off?

HOW ABOUT A FREE HOUSE?

CASH FLOW: $65K INVESTMENT IN NET-ZERO ENERGY, VS. INFLATION IN ENERGY COSTS @6.33%/AVG. 2,000 SF HOME

Total energy bill for 30 yrs. = $362,850 with Code minimum house, and 20 MPG car!

$349.80/MO. initial energy bill (including car)
$319.76/mo. bank pmt.
$268.11/mo. bank pmt.
$214.00/MO. initial energy bill without car

$2,205.45/MO. energy bill in 30 yrs.

$247,736 NET CASH SAVINGS INCLUDING CAR AFTER PAYING ALL LOAN COSTS!

$319.76/MO. (65K @ 4.25%/30 YRS) TOTAL OF PAYMENTS = $119,760

$416 "out of pocket" $1,416 recovered

$268.11/MO. (54.5K @ 4.25%/30 YRS) TOTAL OF PAYMENTS = $96,519

$110,114 NET SAVINGS W/O CAR

$1,345.25/MO. Energy Bill (house only)

$34,368.24 SAVINGS JUST IN NEXT TWO YEARS! (house only)

$56,334.24 SAVINGS JUST IN NEXT TWO YEARS! (including car)

WWW.Zero-EnergyPlans.com
107 S. Main St. Ste. G101
Coupeville, WA  98239
(360) 969-2363
Questions???

www.zero-energyplans.com
Ted L. Clifton