Efficiency Vermont BBD
BETTER BUILDINGS BY DESIGN

CONFERENCE THEME:
Trends in Cold Climate Construction

Using Cellulose in Superinsulated and Passive House Construction, Lessons Learned

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Using these techniques, we can:

- Construct simpler building assemblies that are familiar to people in the trades.
- Reduce the heating /cooling loads enough to allow shifting of costs from the mechanical systems to the building envelope.
- Do this in a thoughtful way. If projects are designed in this manner from the start, they can be completed for about the same cost as non-super insulated buildings.

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High Performance Buildings

	ICC 2012 Code Built	Super Insulation	Passive House*
Walls	R-20	R-40	R-60
Ceiling	R-49	R-80	R-90
Foundation**	R-15	R-30	R-60
Slab **	R-10	R-20	R-60
Windows***	R-3.1	R-7	R-10
Air Leakage @50Pa	3	1	0.6 (1)****
HERS Rating	55	30	20
Home Heating Index (Btu/Sqft / HDD)	4	1.5	0.5

*Notes: * Passive House R-values and air leakage numbers are site specific*
** *Foundation / Slab R-values are for under slab and for below grade wall areas*
****Window R-values are for entire unit including the frame*
*****PHI EnerPHit Retrofit Standards*

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Why Cellulose Insulation?

- All borate cellulose:
  - Thermal performance is stable over time
  - Resists insects
  - Is compatible with all other building materials
  - Improves building durability due the hygroscopic and anti-microbial properties
  - Is VOC compliant (NF & GF products)
  - Has a high recycled content, 85%
  - Low embodied energy and global warming potential

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Loose-fill or Dense Pack?

- Loose fill cellulose for open attics and scissor trusses.

  An approved ignition barrier over spray foam
- Dense pack cellulose for enclosed cavities:
  - is a code approved fire block
  - an excellent airflow and sound attenuator
  - a deterrent against pests
  - adds significant thermal mass to the building
  - dimensionally stable for the lifetime of the building

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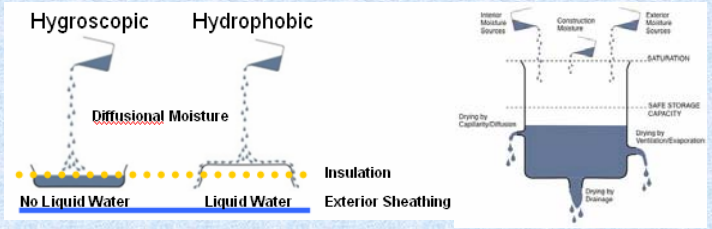
Hygroscopic v Hydrophobic

- Hygroscopic materials act as buffers that promote drying.
- Hydrophobic materials inhibit drying.



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Vapor

- In mixed heating and cooling climates:
  - Wintertime: vapor is driven to the exterior
  - Summertime: vapor is driven to the interior
- In above grade assemblies, vapor retarding/barrier materials will be on the “wrong” side of the building assembly for part of the year and allow moisture buildup behind them.
- The most durable buildings are those that can dry in either direction.
- Always use vapor barriers in below grade assemblies.

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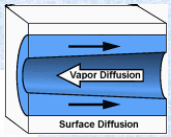
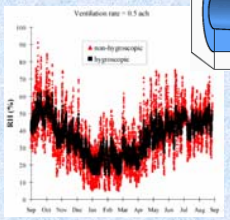
Hygroscopic Materials

- The hygroscopic properties of cellulose allow moisture buffering and redistribution which protects the insulation and adjacent materials.
- Cellulose can be used in buildings with appropriate RH levels:
  - Without vapor retarders or bariers
  - In building cavities with non-insulated sheathing
  - In unvented roof assemblies
- Helps to stabilize interior humidity levels.





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Moisture Testing Results

Assembly Number	Building Location	Test Date	Wall Orientation	Insulation Type(s)	Insulation Thickness	MC Interior Sheathing	MC Interior Cellulose	MC Mid Cellulose	MC Exterior Cellulose	MC Exterior Sheathing
1	Otego, NY	3/26/2014	N	FG	5.5"	7.9	FG	FG	FG	10.5
2	Northport, ME	3/28/2014	SSE	FG/Polyiso	3.5"/5.5"	6.6	FG	FG	FG	10.4
3	Williamstown, VT	3/16/2014	SW	DP Cell	13"	7.0	6.0	7.0	10.0	12.0
4	Williamstown, VT	3/16/2014	NE	DP Cell	5.5"	7.0	6.5	6.5	6.5	7.5
5	Shirley, MA	1/29/2013	N	DP Cell	11.25"	5.9	5.9	6.0	6.7	7.6
6	Shirley, MA	4/2/2014	N	DP Cell	11.25"	6.1	6.2	6.4	8.6	11.6
7	Wallsfield, VT	3/25/2013	N	DP Cell	12"	6.0	6.1	6.1	6.3	8.3
8	Wallsfield, VT	3/25/2013	E	DP Cell	12"	6.0	6.1	6.1	6.6	8.2
9	Norwich, VT	3/24/2014	S	DP Cell	12"	6.9	6.5	6.6	6.4	6.9
10	Norwich, VT	3/24/2014	N	DP Cell x 2	3.5"/8"	6.8	6.2	6.2	6.2	8.9
11	Norwich, VT	3/24/2014	E	DP Cell	12"	7.0	6.0	7.2	8.6	10.4
12	Norwich, VT	3/24/2014	S	DP Cell	12"	6.8	6.2	6.4	7.3	7.1
13	Norwich, VT	3/24/2014	S	DP Cell	12"	7.7	6.5	7.0	7.0	9.0
14	Norwich, VT	3/24/2014	W	DP Cell	12"	6.9	7.1	7.0	6.1	7.3

1: 1/2" drywall, 6 mil poly, 5.5" kraft faced fiberglass batt, 1/2" plywood sheathing, tar paper, wood clapboard
2: 1/2" drywall, 3.5" kraft faced fiberglass batt, 3/4" plywood, 5.5" recycled polyiso
3: 1/2" drywall, Insulweb, 13" dense pack cellulose, 5/8" plywood sheathing, tar paper, metal siding
4: 1/2" drywall, Insulweb, 5.5" dense pack cellulose, 1" board sheathing, tar paper, metal siding
5: 1/2" drywall, Insulweb, 11.25" dense pack cellulose, 1/2" plywood sheathing, Grace Ice & Water Shield, strapping, fiber cement siding
6: 1/2" drywall, Insulweb, 11.25" dense pack cellulose, 1/2" plywood sheathing, Grace Ice & Water Shield, strapping, fiber cement siding
7: 1/2" drywall, Insulweb, 12" dense pack cellulose, 1/2" Zip Wall OSB, straping, wood clapboard
8: 1/2" drywall, Insulweb, 12" dense pack cellulose, 1/2" Zip Wall OSB, straping, wood clapboard
9: 1/2" drywall, Insulweb, 12" dense pack cellulose, Proclima Mento Plus, straping, wood clapboard
10:1/2" drywall, Insulweb, 3.5" dense pack cellulose, 3/8" plywood, 8" dense pack cellulose, Proclima Mento Plus, straping, wood clapboard
11: 1" wood board, Insulweb, 12" dense pack cellulose, Tu-Tuff, concrete wall above grade
12: 1/2" drywall, Insulweb, 12" dense pack cellulose, Tu-Tuff, concrete wall above grade
13: 1/2" drywall, Insulweb, 12" dense pack cellulose, Tu-Tuff, concrete wall below grade
14: 1/2" drywall, Insulweb, 12" dense pack cellulose, Tu-Tuff, concrete wall below grade

This data indicates that the rate of drying is higher than the rate of wetting for all types of exterior sheathing when the assembly is insulated with dense pack cellulose.

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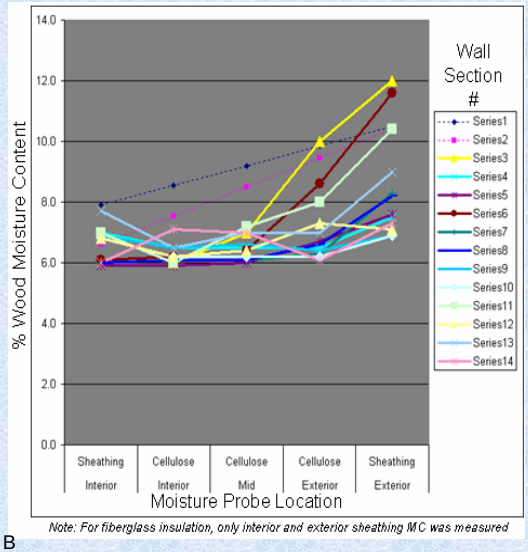
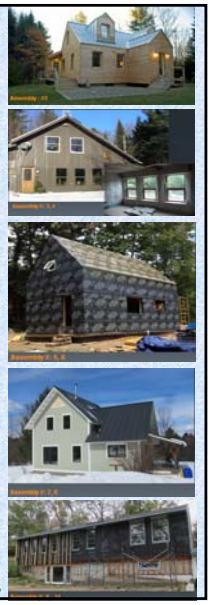


Note: For fiberglass insulation, only interior and exterior sheathing MC was measured



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Progressive Density

- The density of the cellulose needs to correspond to the thickness of the cavity being filled.

Dense Pack Cellulose (Walls or Enclosed Cavities)

(Coverage per 25 lb. Bag)

	R-Value	Cavity Depth (Inches)	*Coverage per Bag (Net SqFt)	Installed Density (lbs/cuft)
2 x 3	7	2	48.8	3.3
	9	2.5	38.1	3.3
2 x 4	11	3	29.9	3.3
	13	3.5	25.5	3.4
	15	4	22.2	3.4
2 x 6	16	4.5	19.8	3.4
	18	5	17.5	3.4
	20	5.5	15.8	3.4
	22	6	14.4	3.5
2 x 8	24	6.5	13.2	3.5
	26	7	12.2	3.6
	27	7.5	11.3	3.5
	29	8	10.6	3.5
	31	8.5	9.9	3.6
2 x 10	33	9	9.3	3.6
	35	9.5	8.8	3.6
	37	10	8.3	3.6
	38	10.5	7.8	3.6
2 x 12	40	11	7.4	3.7
	42	11.5	7.1	3.7
	44	12	6.7	3.7
	46	12.5	6.4	3.7
	47	13	6.2	3.8
	49	13.5	5.9	3.8
	51	14	5.7	3.8
	53	14.5	5.4	3.8
	55	15	5.2	3.8
	57	15.5	5.0	3.9
	59	16	4.8	3.9
	60	16.5	4.7	3.9
	62	17	4.5	3.9
	64	17.5	4.4	3.9
	66	18	4.2	4.0

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Cellulose Specifications

- *<u>Material</u>*
  - *National Fiber cellulose insulation shall contain an all borate fire retardant. Cellulose must comply with the CDPH/EHLB/Standard Method v1.1-2010 for Volatile Organic Compounds (VOC's) and conform to ASTM C-739 and ASTM C-1149 standards.*
- *<u>Installation</u>*
  - *Cellulose insulation must be installed by a certified National Fiber applicator in accordance with manufactures specifications.*
  - *In flat attics: Loose-fill cellulose to provide the rated R-value and depth at manufacturers settled density.*
  - *In enclosed framing: Dense pack cellulose to a minimum installed density of 3.5 lbs/cuft* using the tube insertion method.*
  - *Dry application in open wall framing: Dense pack cellulose behind Insulweb fabric to a minimum installed density of 3.5* lbs/cuft. Insulated areas to be rolled flat by installer after insulation.*

** Installed density will vary according to cavity depth, consult Expanded Bag Coverage Chart*

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Airflow Attenuation

- Super efficient buildings require a dedicated air barrier.
- No matter what type of air barrier is used, dense pack cellulose will improve the performance of the assembly.
- Examples:

  1. 6,831 sqft new building with a fluid applied air barrier on the exterior sheathing:

  Pre dense pack 1450 cfm@50Pa,

  post dense pack behind Insulweb 870 cfm@50Pa;

  40% cfm reduction

  2. 2,500 sqft new building with a interior air barrier membrane installed:

  671 cfm@50Pa pre dense pack,

  234 cfm@50 Pa post dense pack;

  65% reduction

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Super Insulated Buildings

- The goal is 1.0 ach@50 Pa for super insulated buildings and 0.6 ach@50 Pa for passive house buildings
- We have found that air sealing the building's exterior sheathing or using exterior air impermeable fabrics are the most cost effective methods for achieving an air tight envelope.

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When to Blower Door Test?

- Blower door test the building after the shell is weathered in (air tight), but just before the insulation work is started. This allows access to the framing and the air leaks.
- Use the back of your hand, an infrared camera, and/or fog machine to locate the air leaks.
- The most common air leak locations are the wall to foundation; wall to roof connections; and around windows and doors .

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Air Sealing Products

- Need to be flexible for long term durability.
- Silicone based caulks work well for sealing cracks.
- Non-expanding canned foam from a foam gun or gaskets work best for cracks up to one and a half inches. When using foam to seal around windows/doors, install in several small lifts to improve performance.
- Spray foam can be used to seal wider cracks, but should not be sprayed in continuous large areas (over six inches in width) since it is not flexible enough to move with the building. Remember, spray foam is a line of sight product. “If you can’t see it, you can’t seal it.”
- A new generation of acrylic adhesive air sealing tapes are gaining popularity (Pro Clima Tescon Vana, Siga Wigluv, 3M 8067 or ZipWall Tape).
- Fluid applied air barriers such as Tremco Exo-Air 220R or 230 are also effective.

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Air Sealing the Exterior Sheathing Connecting the “Dots”

- Air seal all connections:
  - All sheet to sheet seams of OSB or plywood
  - Around each corner
  - The wall to the foundation
  - The wall to the roof
  - Into each of the window and door openings
- The air barrier fabrics need this same attention to detail!
- Pay particular attention to air sealing between dissimilar materials (i.e. exterior sheathing to foundation with primer and super tape).
- Don’t mix and match products. They are usually not interchangeable.

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Air Sealing Existing Buildings

- A continuous/“perfect” air barrier is the goal.
- A discontinuous/”imperfect” (but good) air barrier is usually the reality.
- Exterior?
- Interior?
- In between?
- Transitions?

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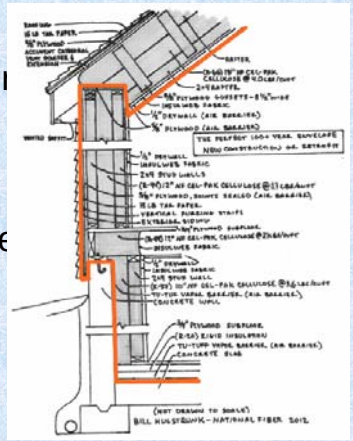
Locating Air Barriers For Superior Insulation Performance

- When using dense pack cellulose, the air barrier can be on either side of the assembly.
- The cellulose must be in direct contact with the continuous air barrier.



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Use an Interior Vapor Control Air Barrier Fabric if:

- You expect wintertime relative humidity levels will exceed 60% for significant periods of time during the winter months.
- For retrofits, if you are not going to be able to air seal the exterior sheathing of the building, or you cannot get the building below 1.0 ACH@50 Pa before the insulation is installed.
- This allows you to blower door test before installing the insulation and drywall in buildings with an interior air barrier.
- May decouple the hygric buffer of the cellulose from the interior.

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Cellulose Containment

- These fabrics allow you to see and/or feel the cellulose density behind them.
- Air Barriers: ProClima Intello Plus (interior) & Mento Plus (exterior), Siga Majpal 5 (interior) & Majvest (exterior), etc.
  - More expensive; the reinforced “plus” fabrics hold better with staples while the non-reinforced fabrics typically need to be strapped before dense packing.
  - Three inch air relief slits need to be cut into the fabric every four vertical feet on each edge of the cavity. These are sealed with the appropriate tape afterwards.
  - Air barrier fabrics tend to bulge and need to be strapped prior to insulating or rolled flat afterwards to allow for drywall installation.
- Air Permeable: Insulweb. Less expensive, translucent, does not bulge as much as the other fabrics.

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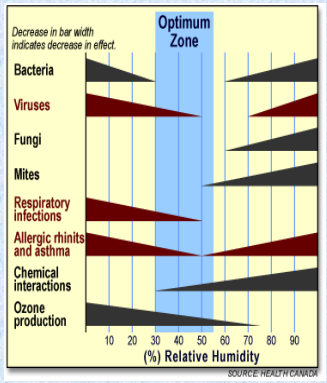
Moisture Concerns in Basements Retro-fits

- Bulk water: Manage it.
- Water vapor and wicking: Minimize it.
- Source control is critical.
- Do not neglect this even if it’s “too expensive”.



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Retro-fitting Basement Slabs

– Install a vapor barrier and insulation on top of the slab.

– Use multiple layers and stagger joints of high density EPS, Gutex, or Roxul ComfortBoard IS to achieve desired insulation value.

– Subfloor: 2 layers of 5/8 plywood or OSB with the joints staggered and screwed together with 1 ¼ inch deck screws.

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Retrofitting Vented Crawl Spaces

- Build down floor joists with plywood gussets with a 2 x 4 at the bottom (Larsen Truss).
- Staple Solitex Mento Plus or equivalent to the underside of the truss; air seal along the edges.
- Install strapping 16 inches on center perpendicular to the floor joists.
- Install dense pack cellulose.
- Cover ground with a durable vapor barrier and ballast if necessary.

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Foundations

- Foundation walls:
  - install a vapor barrier against the foundation (concrete/stone/etc.).
  - frame a 2 x 4 wall out from the foundation to the desired cavity depth.
  - dense pack the cavity to block thermal bridging through the footing.
- Moisture testing has demonstrated that the cellulose remains dry throughout the assembly.

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Band and Rim Joists

- If the exterior air sealing does not encapsulate this area; air seal the wood to wood joints with a good flexible caulk.
- Attach fabric to the top of the wall, staple the other end up to the subfloor and staple the sides to the floor joists making a pouch for the dense pack cellulose.

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Continuous or Separate Cavities?

- To establish bag counts for quality control purposes:
  - Wall cavities less than 12 inches deep, separate one wall from the next with Insulweb.
  - For cavities exceeding 12 inches deep, separate each bay with Insulweb.
  - Prefill cavities 50 – 75% , reset machine for dense pack and finish installing the cellulose with a two inch aluminum tube.
  - Concentrate on each of the cavity corners using a star pattern until you cannot easily push the tube back through.

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Walls: Innie or Outie?

- In new construction or retrofit, building a double wall to the inside can be more cost effective and easier for framing crews to understand.
  - Air seal exterior sheathing plane.
- When retrofitting buildings with large overhangs build outward with Larsen Trusses, I-joists, or parallel chord trusses (R-44 = 12”, R-60 = 16”)
  - If the original sheathing is exposed, you can air seal that, otherwise use an moisture permeable air barrier fabric on the exterior.
- Don’t forget the rain screen details: tar paper or Typar with vertical strapping or polypropylene mesh.

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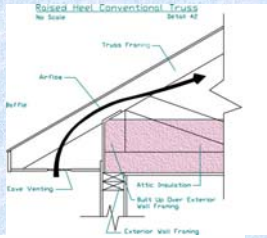
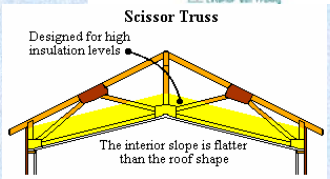
Flat Ceilings and Raised Heel Scissor Trusses

- Most cost effective insulation option.
- Install the drywall.
- Use flush mount light fixtures, or if you must, IC air tight fixtures.
- Air seal all penetrations.
- Install loose fill cellulose. (R-80 = 21.5”, R-100 = 26.5”)
- Attic space above the insulation must be vented.





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Cathedral Ceilings

- Size rafters for roof loads (use structural engineer) and then fatten down with plywood gussets and 2 x 4s (Larsen Truss); deep I-joists; or parallel cord trusses (R-60 = 16”, R-80 = 21.5”). Separate rafter bays with Insulweb.
- Install Insulweb (unvented) or air barrier fabric (vented) to underside and strap ceiling horizontally every 16 inches on center.
- Pre-fill the cavity. When dense packing; insert the tube perpendicular to roof deck every 16 inches for each rafter bay or with multiple passes of the hose to build the density both laterally and vertically.

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Unvented Roofs

- Unvented roofs work when the dense pack cellulose is installed to self supporting densities and is in direct contact with the underside of the roof sheathing.
- The air barrier can follow the exterior of the walls and the exterior of the roof. Sometimes the roof soffits are added on afterwards.
- Use tar paper or a moisture permeable roof underlayment with a perm rate of 20 or above.
- Light colored roofs can reduce summertime heat gain.
- Metal roofs are more reflective than asphalt shingles; Some colors are Energy Star rated.
- Installed density is critical, use an experienced installer.

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Vented Roofs

- Venting can be helpful by reducing some summertime solar heat gain
- For walls with an exterior air barrier, you will need to transition the barrier across the top of the walls to the interior to maintain continuity.
- Build down at least an inch and install moisture permeable venting baffles such as air impermeable fabrics or double wall cardboard supported every 8 inches along the center.
- Uninterrupted airflow from soffit up to ridge is a must.

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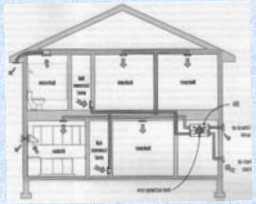
Mechanical Ventilation

- A ventilation system is critical, short and straight duct runs are best for performance and cost.
- Use parallel cord trusses between floors to run HRV/ERV distribution system.
- Use separate bathroom fans and kitchen range hoods for source control of odor and moisture removal.



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Our Top 40+ List

1. It costs less when you plan ahead
2. Incremental performance improvements rarely lead to cost improvements
3. Model your building before you building it
4. You are not building high performance buildings unless you test them
5. Leading edge can sometimes mean bleeding edge
6. Use materials and methods contractors are familiar with
7. Materials are only as good as the installers who install them
8. Keep it simple, more is not necessarily better, only more expensive
9. Under-insulated slabs and foundations allow for heat loss and discomfort
10. Foam free basements and slabs, Roxul has the technology
11. Use vapor barriers below grade in contact with foundation and slab
12. Avoid semi-conditioned areas, is it inside or outside?
13. In the wintertime, building assemblies like to dry to the exterior, this vapor drive reverses direction in the summer
14. Avoid vapor barriers and materials that act like vapor barriers above grade
15. Hygroscopic materials like cellulose insulation are more forgiving to water vapor and in most above grade applications do not require a vapor retarder/barrier
16. Source moisture control is key in tight buildings
17. Make ventilation a priority and not an after thought
18. Use parallel cord trusses between floors for running your mechanical systems
19. Meet your air tightness goal before installing your insulation
20. Dense pack cellulose is not an air barrier, but is a good airflow attenuator
21. Focus your air sealing attention to connections between materials, especially dissimilar ones
22. Choose where your air barrier will be and focus all of your efforts on it, dense pack only needs an air barrier on one side of the building assembly
23. Air sealing the joints of your exterior sheathing or using an exterior air barrier fabric is the easiest way to achieve passive house 0.6 ach@50Pa or better
24. Deeper building assemblies require denser cellulose to remain self supporting
25. Larson truss is useful for fattening down rafters and building walls outward (also I-joists)
26. Wood heat can be tricky in tight homes, use stoves with direct air intakes, hardwired w/ battery backup CO and smoke detectors are mandatory
27. Partially filled exterior building cavities are highways for bad things; smoke, fire, rodents, insects, air, odor, moisture, sound, etc…
28. Spray foam is not magic, if the man in the spacesuit can't see it, than they can't seal it
29. Long term air tightness is all about flexibility, when buildings move, rigid air barriers break
30. Don't use the term hot or cold roofs, on a sunny day an unvented roof will typically be colder than a vented roof
31. Raised heel scissor trusses make economical high performance vaulted ceilings
32. For really deep attic insulation, create an attic access from the exterior
33. Attic areas above an insulated attic floor need to be vented or connected with the outdoors
34. For vented roofs, avoid plastic soffit baffles, use double wall cardboard or moisture permeable fabrics instead
35. Unvented roof assemblies with dense pack cellulose only work when the cellulose is in direct contact with the exterior sheathing
36. Radiant barriers only are effective for summertime heat rejection, not wintertime heat containment
37. In regions with low wintertime average sun hours, choose higher performance windows over those with high SHGC
38. Good quality work costs more; the lowest bid usually results in lowest quality work!
39. Reduce thermal bridging with double studs, Larsen Trusses, I-joists and interior basement insulation
40. Convection can seriously undermine the performance of batts, and board insulation systems
41. Cellulose quality control includes bag counts and blowing behind fabric where you can feel the density behind them, 3.5 lbs/cuft (firm mattress), 4.0 lbs/cuft (almost hard)
42. If your mechanical system is too complex for your local fuel company too fix, it is too complex!
43. If your systems require significant human intervention to operate, either automate it or eliminate it (i.e. movable insulation)
44. In homes with knee walls, like cape's, insulating the roof slope is more effective than trying to insulate the knee wall and knee wall floor
45. Use only "all borate" cellulose insulation

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Questions? Comments? Feedback?

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