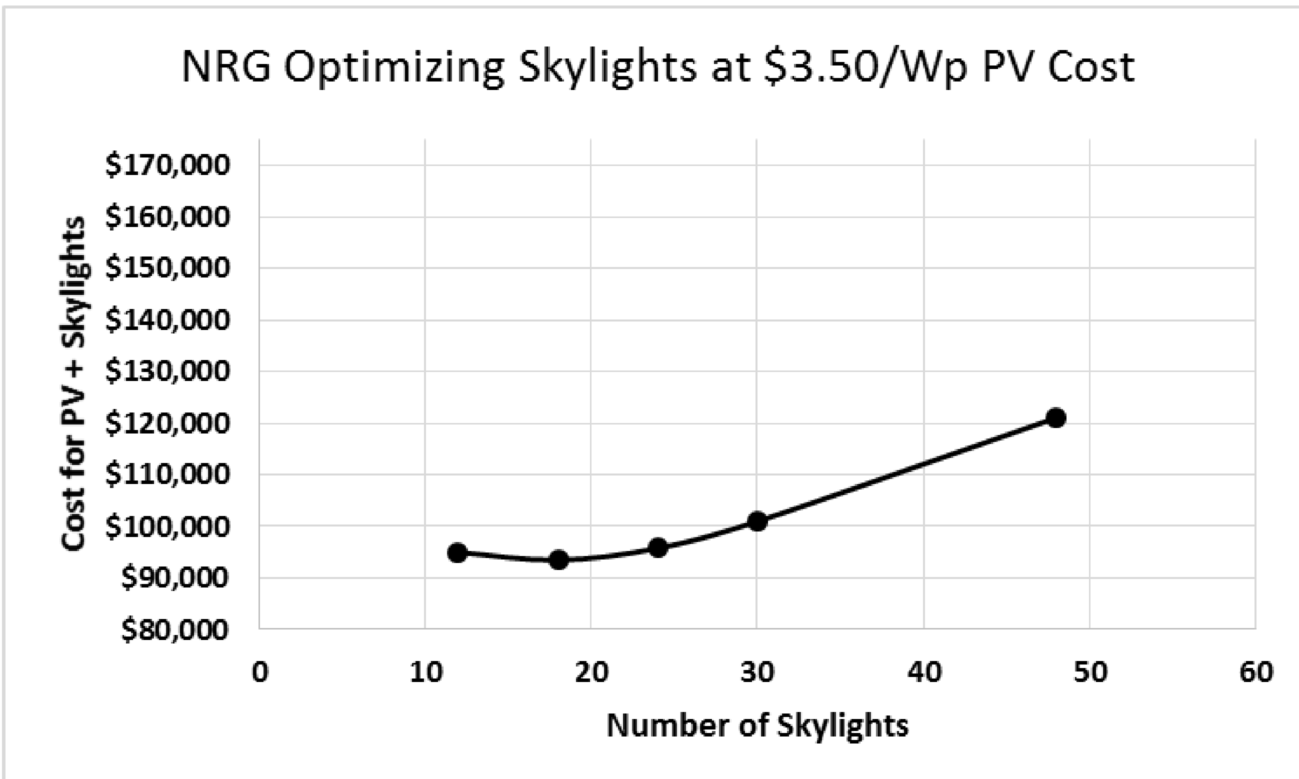
Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

NRG Warehouse/manufacturing area:

Meet lighting load with PV at minimum cost



What's the right amount of attic insulation?

Is it worth the cost to go from R55 roof to R80 for long term affordability?

	560	load kWh saved by going to R80 roof over R55
	243	energy kWh sved
$	**1,400**	cost of PV's to accomplish this
$	6.00	$/Wp for PV
	2.30	COP
	1.05	kWh/yr-Wp
$	**2,528**	cost for additional insulation
		PV is in this case cheaper so do not install additional insulation

What’s the right amount of wall insulation?

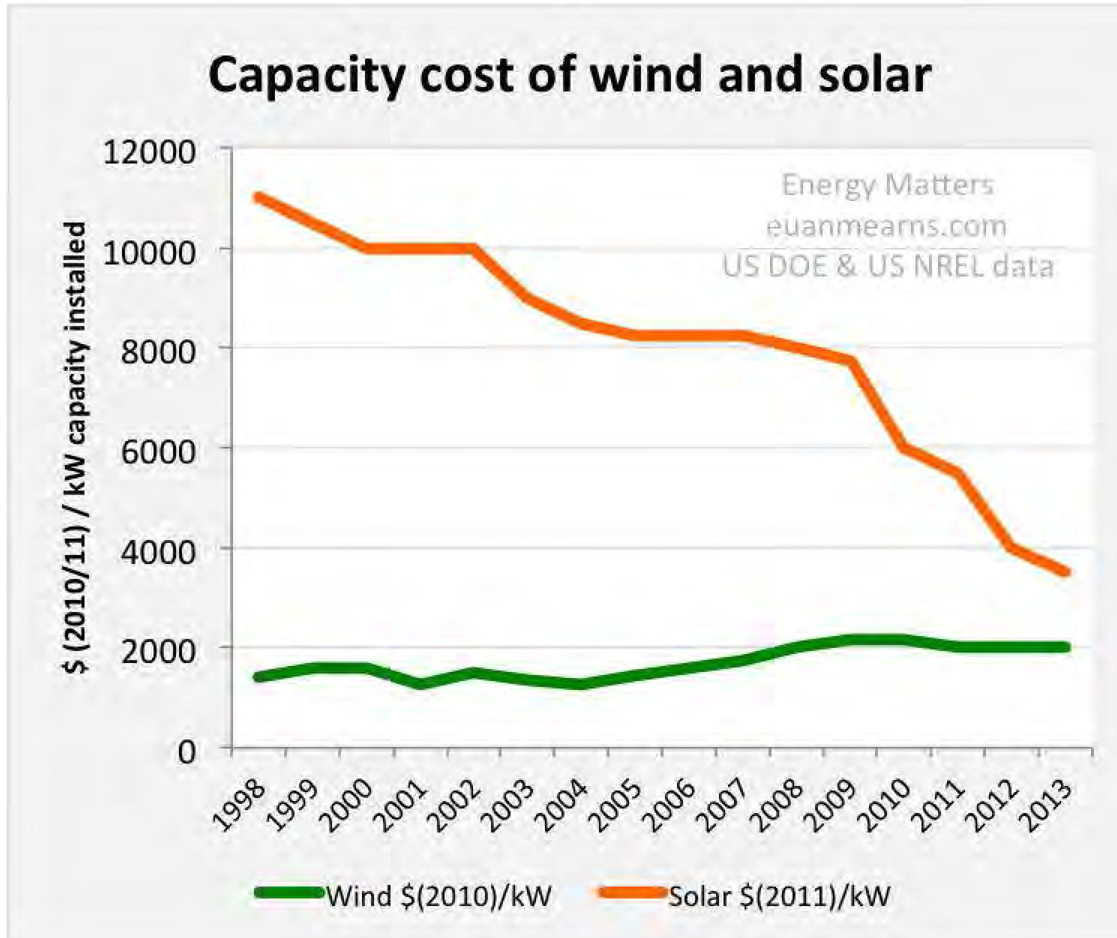
Is it worth the cost to go from 2" to 4" ext. wall foam for long term affordability?

	3,246	load kWh saved by going to R40 walls over R27, run 7
	1,411	energy kWh saved by going to R40 walls over R27 with HP
$	**8,100**	cost of PV's to accomplish this
$	6.00	$/Wp for PV
	2.30	COP
	1.05	kWh/yr-Wp
$	**7,717**	cost for 2 additional inches of foam
		Insulation is less costly in this case, so install added insulation

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

With PV costs going down, where to stop with efficiency??



With PV costs going down, where to stop with efficiency??

- Reduced heating distribution (down to point source in residential)
- Resiliency
- Comfort

Is there a rule of thumb???

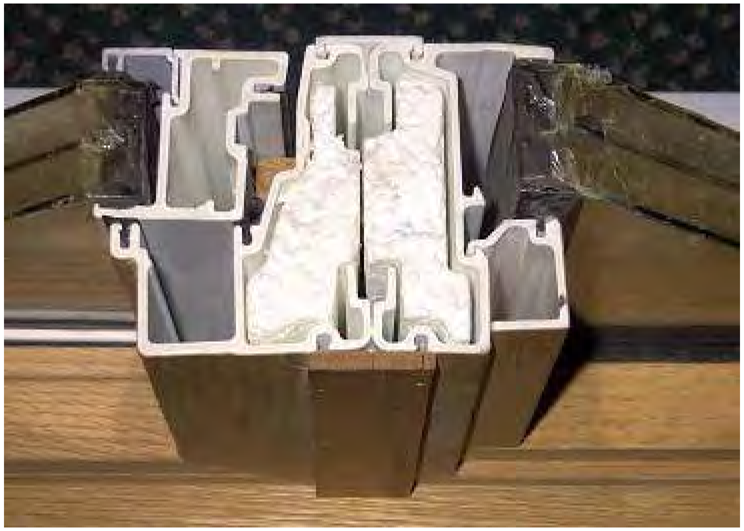
- 0.1 / 5 / 20 / 40 / 60
- Recover energy

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

Is there a rule of thumb???

- <0.1 cfm50/sq.ft. of building shell max. air leakage rate
- R-5 windows
- R-20 earth contact
- R-40 walls
- R-60 roof

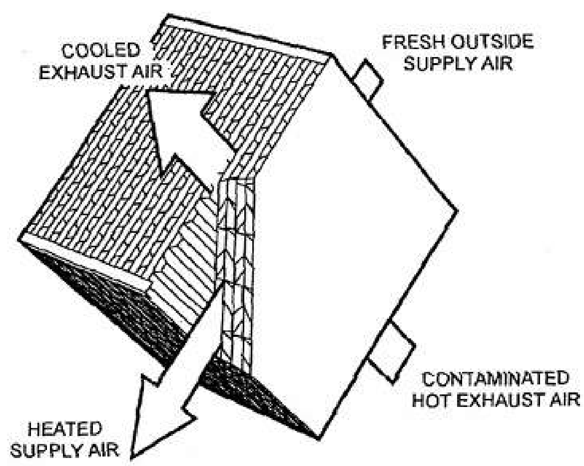


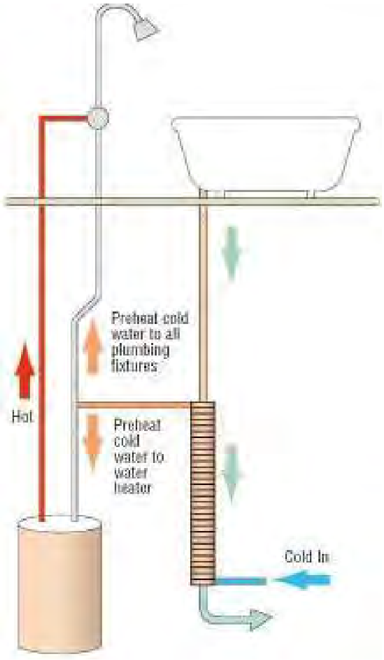
Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

Is there a rule of thumb???

- Recover energy
  - Ventilation
  - Drainwater
  - Simultaneous heating/cooling





When to use rule of thumb?

- Rule of thumb good for smaller projects and smaller offices
  - Residential, Multifamily, Office and Commercial up to about 20k or 30k sq. ft.
- Where don't need to meet a numeric energy goal such as net zero
- Where internal loads are not significant
- Where there is no 900 pound gorilla

When to model?

- To meet a numeric energy goal such as a particular EUI or net zero
- Where there are large internal gains/loads
  - E.g., a kitchen hood, or refrigeration in a store
- Larger buildings – more complex model
  - (E-Quest, Energy Plus, HAP)
- Daylighting
- During "Value Engineering" – modeling can turn cost cutting into actual value engineering
  - How do we come as close to owner's goals as possible within budget?

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

What to model with?

- Smaller, simpler buildings
    - Spreadsheet UA models
        - Marc Rosenbaum's net zero course
        - Heat Load Estimator 170302.xlsx
    - Energy-10 (not supported)
        - With post processing spreadsheet

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

What to model with?

- Larger buildings and/or large internal gains/loads
  - E.g., a kitchen hood, or refrigeration in a store
  - more complex models: E-Quest, Energy Plus, HAP, TRACE
  - Custom spreadsheets (ventilation, refrigeration, refrigeration heat recovery, ASHP performance)
  - Daylighting
    - Physical models
    - Sketchup for shadows
    - Radiance
    - Skycalc

Who to run the models?

- E-10 and spreadsheet models can be learned easily, with some aptitude and effort
- More complex models need to be run by someone who does it frequently enough to know all the model quirks.
- ***ALL MODELS HAVE QUIRKS***

Critical factors for success in modeling

- Realize that models are not reality: your mileage will vary. *+/- 20% is a REALLY GOOD result!*
- Reasonable inputs
  - Thermostat settings, occupancy times, internal gains, air leakage rates can all have big effects

Critical factors for success in modeling

- ***Develop your sense of smell, so you can give results the smell test: DO RESULTS MAKE SENSE?***
  - Best way: track your projects actual usage over time.
  - Track modeled against actual.
  - Reconcile to actual weather for skin dominated loads

Critical factors for success in modeling

Peer review is critical!

- Errors easy to overlook
- Modelers can be good modelers but know very little about building performance
- Knowing what dials and levers to twiddle
- Review inputs carefully
- Check how results smell
  - Use simple parameters first; e.g.:
    - EUI (kBtu/sq.ft.-yr)
    - sq.ft. per ton of cooling capacity
    - Watts/sq.ft. lighting

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

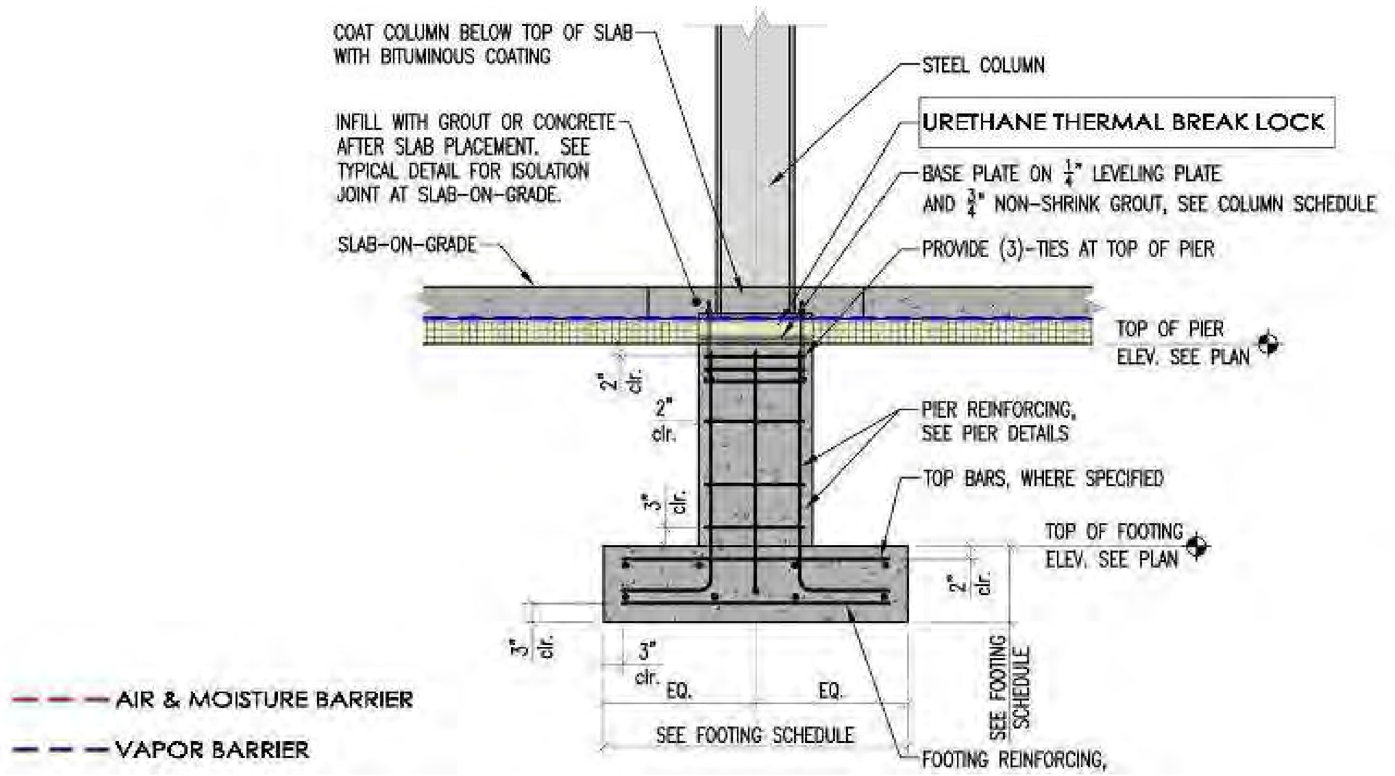
Develop/review plans and specs for consistency with the environmental goals and objectives

- *Who: Design team job to do first cut; Review and revise with Owner*
- *When: DD and CD*

Step 7 – Minimize Energy Loads

Establish EUI, Target Building Loads, Focus on Envelope Loads

Develop/review plans and specs for consistency with the environmental goals and objectives



Develop/review plans and specs – air leakage

SECTION 07220

AIR BARRIERS

PART 1 - GENERAL

1.1 SUMMARY

AIntroduction

1. **This section is incorporated into these specifications to minimize air leakage to insure adequate thermal performance, comfort, and avoid moisture problems in the building envelope.**

Develop/review plans and specs – air leakage

SECTION 07220

3. Intent: This section of the Specification is intended to define the ***quantitative and qualitative requirements*** for the products, materials, and workmanship for the air barrier system of the thermal envelope of this building. The intent of the design is for the building to perform in accordance with the following requirements:

a. The Vermont Fire and Building Safety Code.

b***. The building envelope will incorporate a continuous air barrier system***

Develop/review plans and specs – air leakage

SECTION 07220

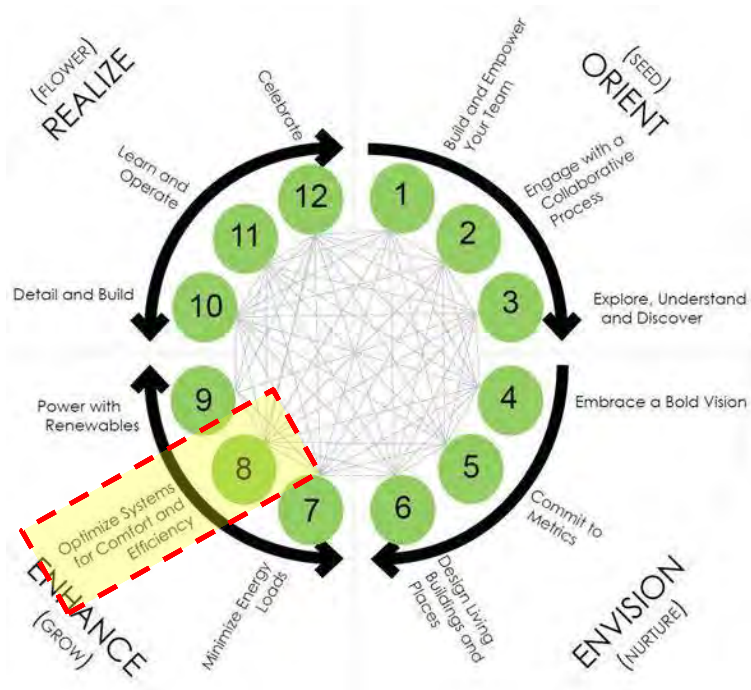
A. Compliance Testing:

Air Leakage and Air Sealing Testing – General: Air leakage of the building envelope shall be subject to field tests conducted by Owner's testing agent…

Minimum Air tightness Specification: The ***building shall achieve a maximum air leakage rate of*** 0.10 cfm per square foot of shell area at 50 PA pressure differential from the inside to the outside (15 cfm50/100 square feet of exterior shell). Exterior shell area shall exclude slab on grade area, but not below grade walls.

ENHANCE

- Step 8 - Optimize Systems
  1. Right Size System
  2. Simplify Systems
  3. Minimize Distribution
  4. Separate Ventilation Air from Heating Air



Step 8 - Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

System Selection Matrix

Heating
Cooling
Domestic Hot Water
Ventilation
Energy source, for annual net-zero performance
Category of Net Zero
Advantages
Disadvantages
Installed Cost, Mechanicals
Installed Cost, Photovoltaics
Total Installed Cost
First Year Operating Cost

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

SYSTEM SELECTION MATRIX		**Assumptions**		
		0.1 / 5 / 20 / 40 / 60 envelope		
	Air Source Heat Pump (VRV ASHP) - air delivery	**Ground Source Heat Pump (GSHP) - radiant delivery**	**Ground Source Heat Pump (GSHP) - air delivery**	**Biomass boiler ground-water cooling - radiant delivery**
Heating	ASHP ducted or wall mounted delivery	Radiant floor/ceiling	Ducted, many HP's in building	Radiant
Cooling	ASHP ducted delivery	Radiant floor/ceiling	Ducted, many HP's in building	Radiant
Domestic Hot Water	Solar+electric backup or HPWH or resistance	Solar+electric backup or HPWH or resistance	Solar+electric backup or HPWH or resistance	Solar hot water, boiler backup
Ventilation	Energy Recovery Ventilation, dedicated outside air ducting, variable control boxes on supply and return	Energy Recovery Ventilation, dedicated outside air ducting, variable control boxes on supply and return, control humidity via ventilation	Energy Recovery Ventilation, may combines supply ducting, variable control boxes on supply and return	Energy Recovery Ventilation, dedicated outside air ducting, variable control boxes on supply and return, control humidity via ventilation

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

System Selection Matrix

	Air Source Heat Pump (VRV ASHP) -	**Ground Source Heat Pump (GSHP) -**	**Ground Source Heat Pump (GSHP) -**	**Biomass boiler ground-water cooling - radiant**
Energy source, for annual net-zero performance	PV to power ASHP, hot water backup and plug loads	PV to power GSHP, hot water backup and plug loads	PV to power GSHP, hot water backup and plug loads	PV to power cooling and plug loads; wood pellets for thermal energy
Category of Net Zero	On-building/on-site (1 or 2)	On-building/on-site (1 or 2)	On-building/on-site (1 or 2)	On-building/on-site/off site (3)

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

System Selection Matrix

	Air Source Heat Pump (VRV ASHP) - air delivery	**Ground Source Heat Pump (GSHP) - radiant delivery**	**Ground Source Heat Pump (GSHP) - air delivery**	**Biomass boiler ground-water cooling - radiant delivery**
Advantages	Can be completely powered with renewable electricity; Simpler, less costly than ground source, can share heat between zones	Can be completely powered with renewable electricity; highest efficiency, lowest utility peak load, fewest PV's for heat load; less refrigerant in use	Can be completely powered with renewable electricity; highest efficiency, lowest utility peak load, fewest PV's for heat load, shares heat between zones	Less expensive first cost; ***VERY*** high efficiency cooling; very stable, comfortable temperatures
Disadvantages	Ground mounted condenser; more PV's may require more ground mounted equiopment; cold weather uncertainty; Large refrigerant quantity	More expensive; requires several trades to coordinate installation; requires boring several deep wells or buried slinky, requires hard floor if radiant is in slab	More expensive; requires several trades to coordinate installation; requires boring several deep wells or buried slinky, Noise from individual heat pumps	On-going fuel costs; system maintenance required; commodity fuel; Requires hard floor if radiant is in slab; Requires location to dump water

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

System Selection Matrix

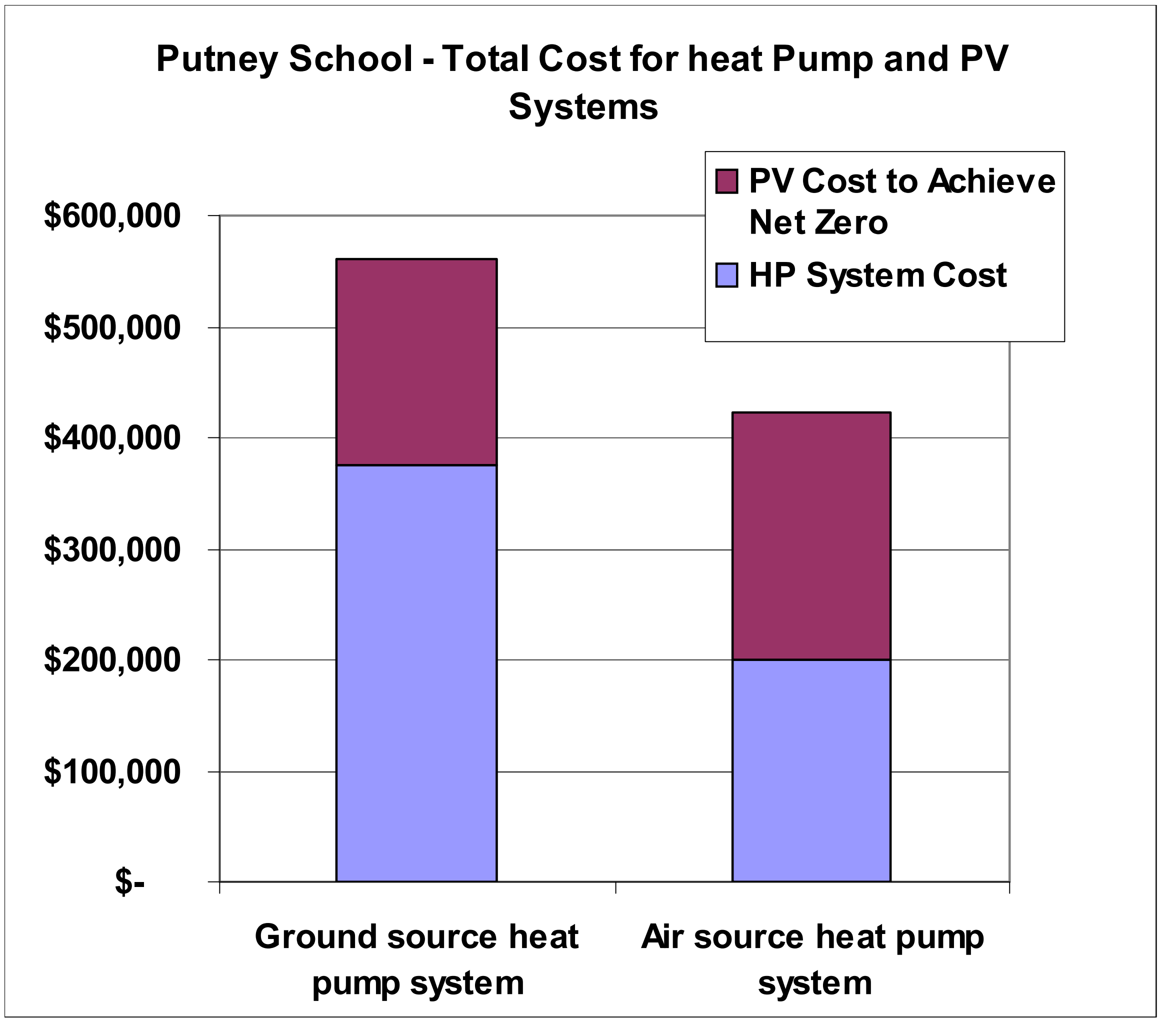
	Air Source Heat Pump (VRV	Ground Source Heat Pump	Ground Source Heat Pump	Biomass boiler ground-water
Installed Cost, Mechanicals				
Installed Cost, Photovoltaics				
Total Installed Cost				
First Year Operating Cost				

Include Cost of Renewable Energy System

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

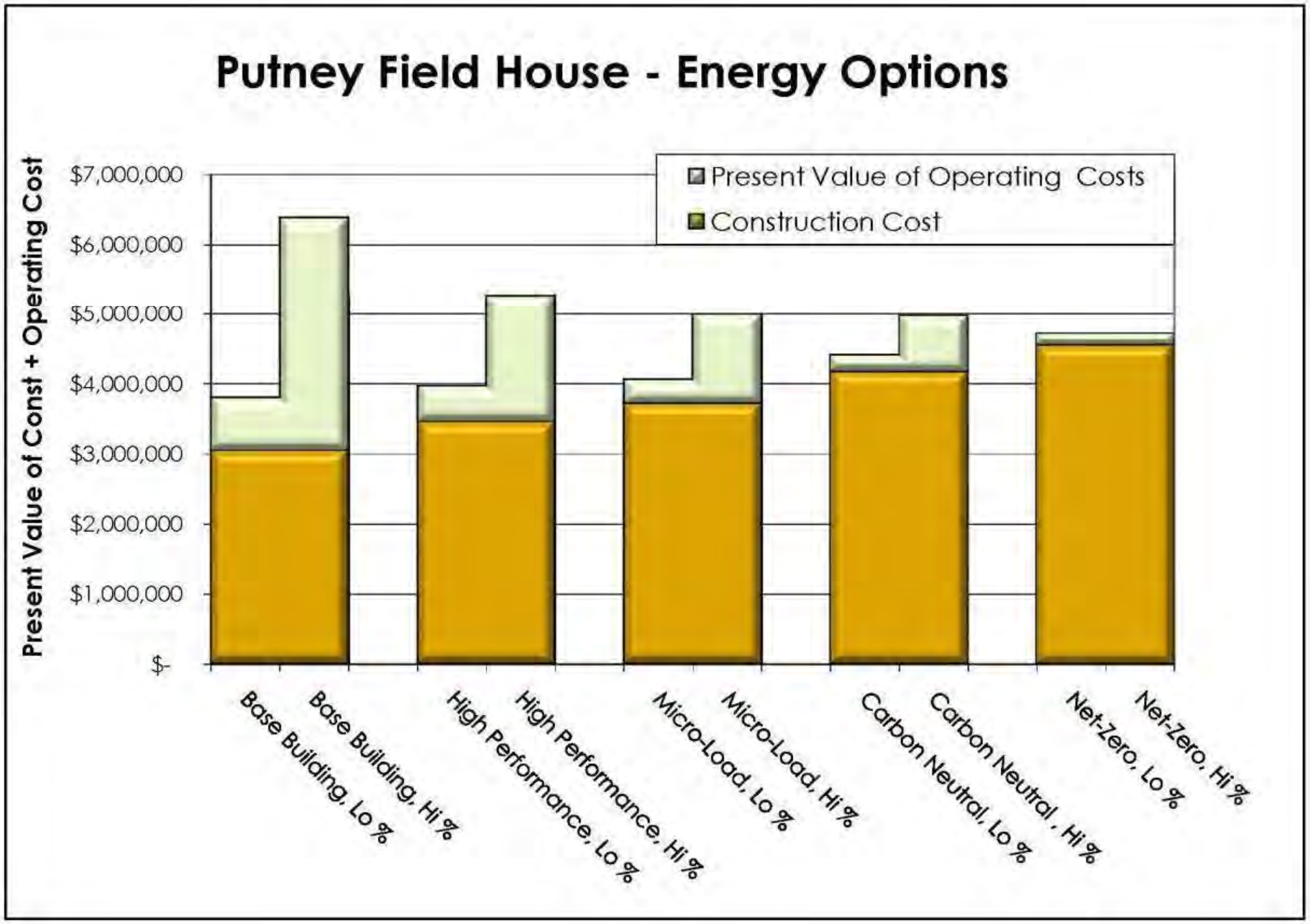
Total Heat/cool/PV Cost



Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

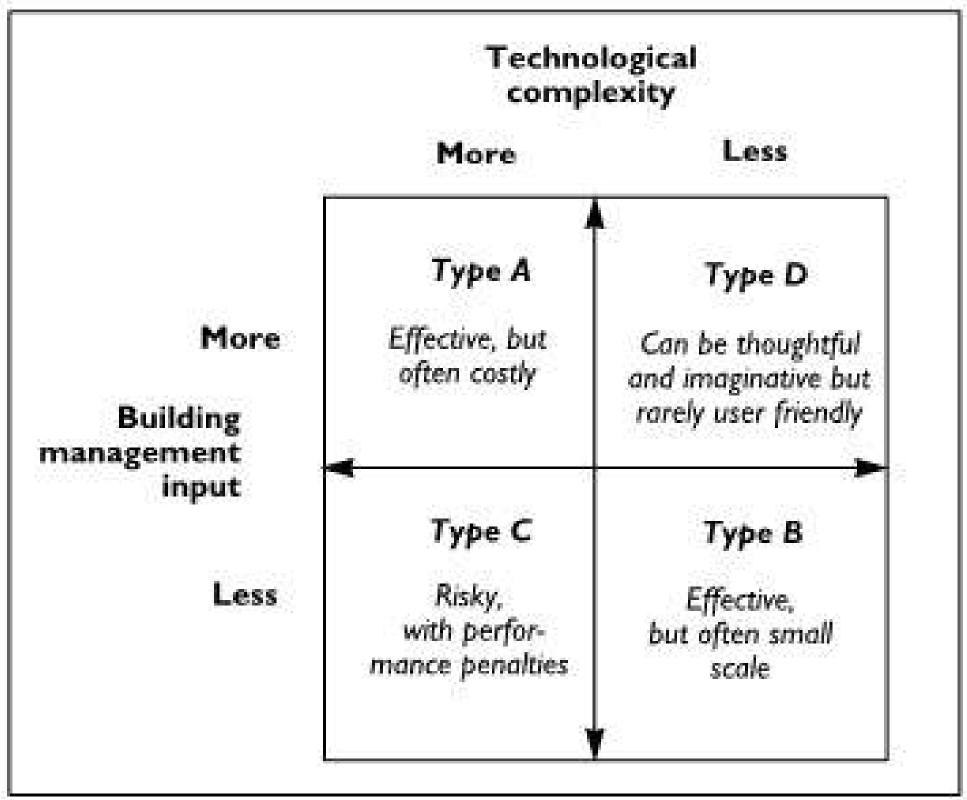
Field House Energy Analysis



Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

Match complexity to owners' ability to manage!
(Avoid the complexity trap)



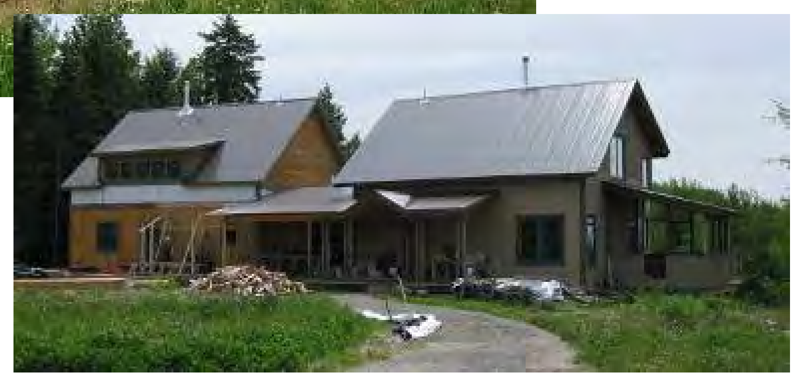
FINAL REPORT 4: Strategic conclusions **William Bordass,1999, UK, PROBE Study**

Step 8 – Optimize Systems

Right Size, Simplify, Minimize Distribution, Separate Ventilation from Heating

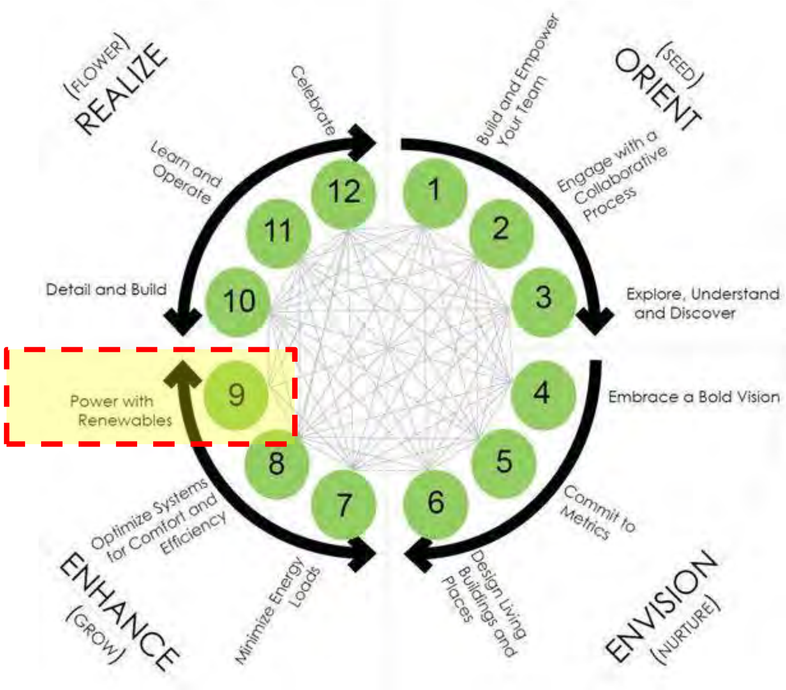
The complexity trap

The job is not done when there is nothing left to add; it is done when there is nothing left to take away.



ENHANCE

- Step 9-Power with Renewables
    1. Right Size System
    2. Evaluate Renewable Options
    3. Consider Cost, Operation, Maintenance & Funding
    4. Explore On-site Renewables and Off-site Power Purchase Options



Step 9 – Power with Renewables

Right Size, Evaluate Options, Consider Cost, Explore On and Off-site options

- Daylighting
- Passive solar/sun tempering ***where appropriate***
  - *Offices, schools often NOT appropriate*
  - *Lower occupancy spaces and residential usually appropriate*

Step 9 – Power with Renewables

Right Size, Evaluate Options, Consider Cost, Explore On and Off-site options

NREL Net Zero Energy Building Categories:

1. Use RE sources available within the building footprint
2. Use RE sources available at the building site
3. Use RE sources available off site to generate energy on site
4. ~~Purchase recently added off-site RE sources, as certified from Green-E (2009) or other equivalent REC programs.~~

Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options
Shanti Pless and Paul Torcellini; Technical Report NREL/TP-550-44586 June 2010

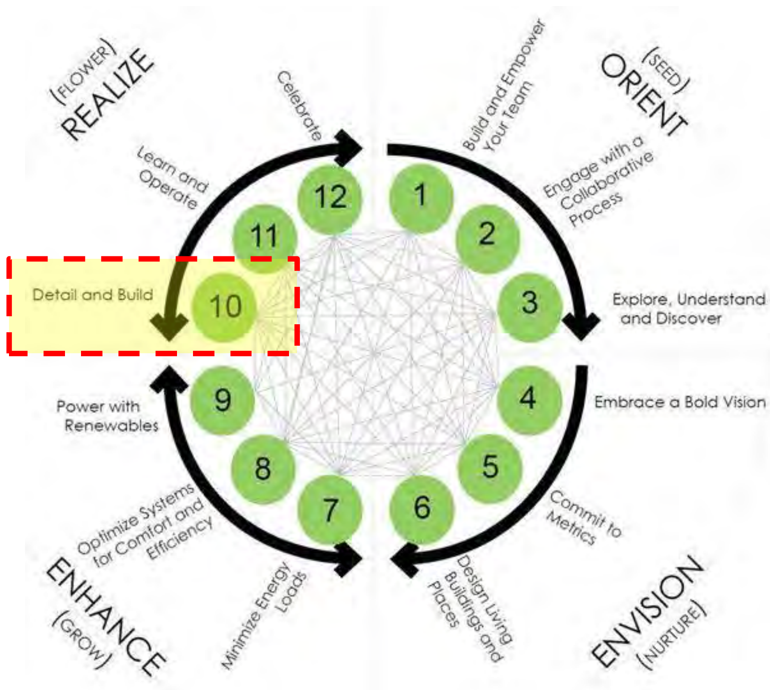
Step 9 – Power with Renewables

Right Size, Evaluate Options, Consider Cost, Explore On and Off-site options

- PV's most cost-effective renewable source of on-site electricity
- Biomass ***may*** be least first-cost thermal energy source

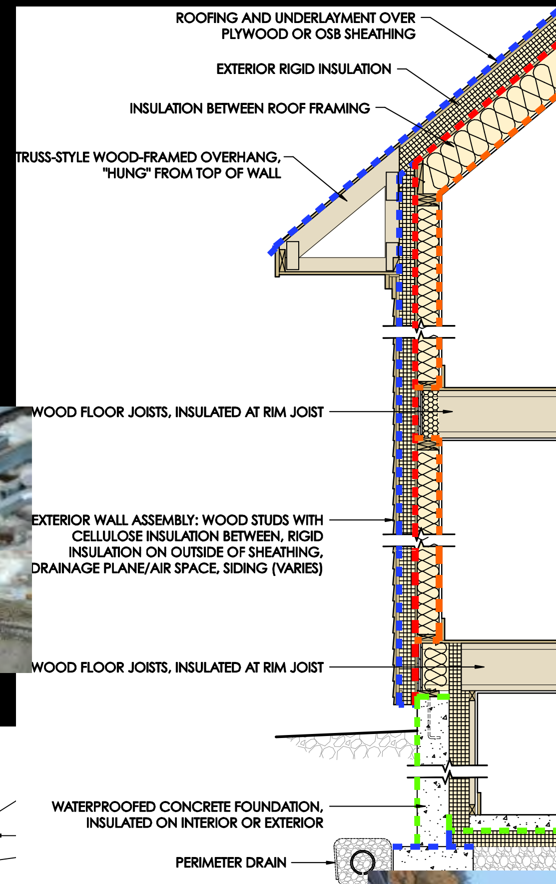
REALIZE

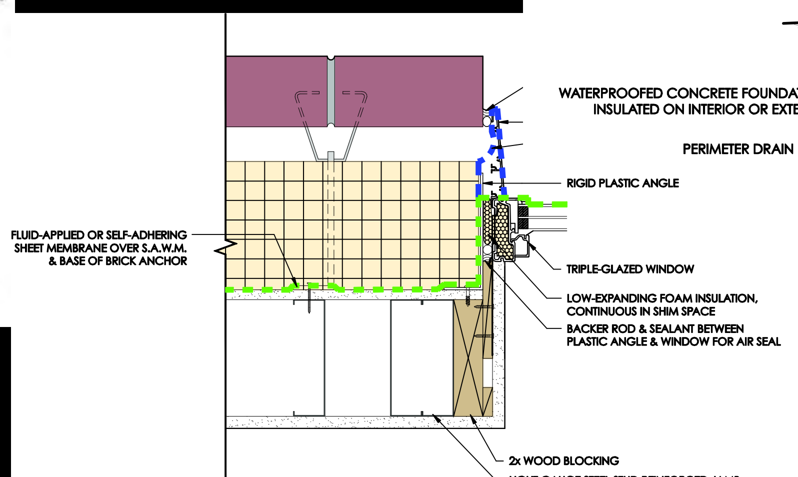
- Step 10 - Detail & Build
    1. Documentation for Success
    2. Building with Care, Commitment and Teamwork
    3. Confirming Performance through Inspection, Testing, Commissioning & Initial Monitoring



Step 10 - Detail & Build

Documentation for Success





Step 10 - Detail & Build

Building with Care, Commitment & Teamwork

Step 10 - Detail & Build

Confirming Performance – Inspection, Testing & Commissioning
Monitoring

The Putney School Net Zero Fieldhouse

- Net Zero since 2011
- Financial paradigm shift
- Enclosure/ASHP/PV Strategy

- SF: 16,800
- EUI: 9 kBtu/sf-yr (actual)
  11 kBtu/sf-yr (modeled)
- EUI with renewables: 0 kBtu/sf-yr
- LEED Cert: Platinum