Integrating Systems for Green Design

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www.buildingscience.com

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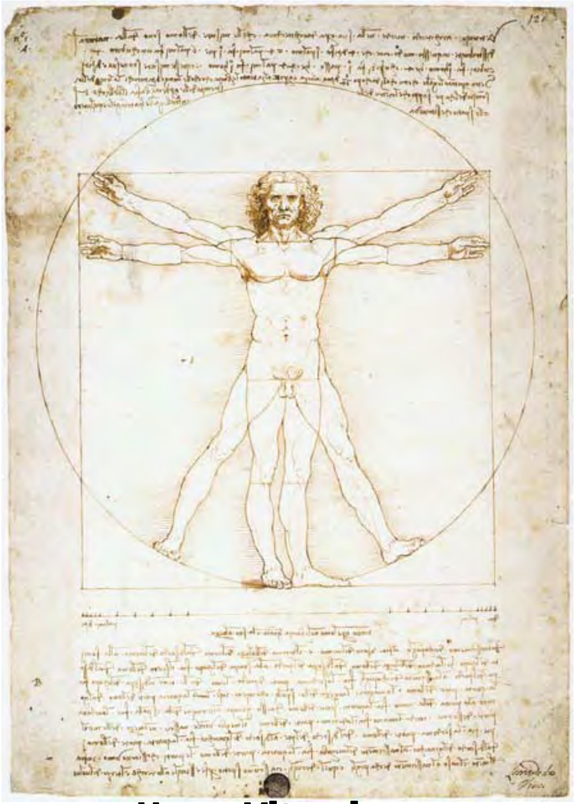
What makes good building design?

Firmness, commodity, and delight?

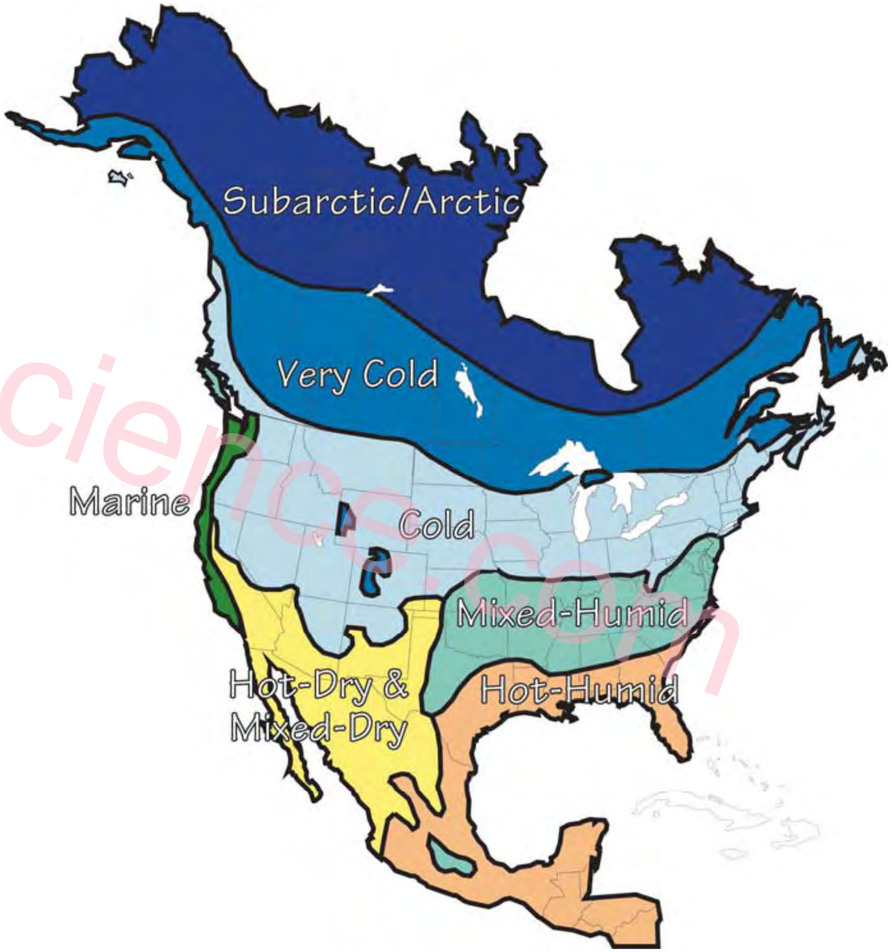
"Well building hath three conditions: firmness, commodity, and delight." This quote is taken from Sir Henry Wotton's version of 1624, and is a plain and accurate translation of the passage in Vitruvius



Homo Vitruvianus
By Leonardo da Vinci

Vitruvius also said,

"These are properly designed, when due regard is had to the country and climate in which they are erected. For the method of building which is suited to Egypt would be very improper in Spain, and that in use in Pontus would be absurd at Rome: so in other parts of the world a style suitable to one climate, would be very unsuitable to another: for one part of the world is under the sun's course, another is distant from it, and another, between the two, is temperate".



Green Building

Minimize Need for Energy, Water and Materials

↓

Satisfy Need with Least Disruption.
Reduce, Reuse, Recycle
Managed Resource Extraction and Processing

Durability

The effects of building development on the environment are at the most basic level about **durability**. Building a house or community is really about the durability of people (health, safety and well being of people), the durability of buildings (the useful service life of a building is typically limited by its durability), and the durability of the planet (the well being of the local and global environment). **Durability** is really another way of expressing the concept of **sustainability** to the building community.

Goals

- Create buildings that ensure a healthy environment for its occupants
- Deliver building that are durable (life expectancy of 100 years with only minimal replacement of parts needed) thereby reducing future waste and depletion of natural resources
- Deliver buildings that have low total energy consumption during their lifetime. They must have low operating energy since operating energy accounts for 70-to-90% of the total energy consumption

Operating Energy +
Embodied Energy +
Decommissioning Energy +

Total Energy

Priorities

People (personal environment) → **Buildings** (indoor environment) → **Environment** (exterior environment)

Short-Term Concerns → **Mid-Term Concerns** → **Long-Term Concerns**

Local Concerns → **Regional Concerns** → **Global Concerns**

Integrating Systems for (green) building design

Leak-free thermally efficient enclosure systems

- Intentional openings for exhaust of pollutants
- Intentional openings for outside air intake
- Control of materials intentionally brought into building

Right-sized integrated mechanical systems

- Efficient distribution of conditioned air
- Efficient removal of pollutants
  - Efficient filtration
  - Efficient introduction of outside air for dilution

Budget = Form
(dictates choices for enclosure design)

- Structure
- Foundation type
- Roof design
- Cladding type
- Energy collection systems

Budget = Sophistication (dictates choices for mechanical systems)

- Mechanical equipment efficiency, motors, burning fuels, moving air
- Ability to clean, distribute, recover energy, dehumidify
- Collecting and using site generated energy

System Integration

Improvements in the enclosure (+)

Downsize the mechanical equipment (-)

=

Better Performance, lower energy bills

Type of Occupancy dictates choices for enclosure & mechanical systems

- Comfort of Occupants
- Indoor Air Quality
- Energy Efficiency

Comfort, indoor air quality, energy efficiency, durability all require…

- Leak-free buildings with high R-value enclosures
- Source control of pollutants
- Heated or cooled air delivered in consistent manner to occupied space
- Outside air change with mixing

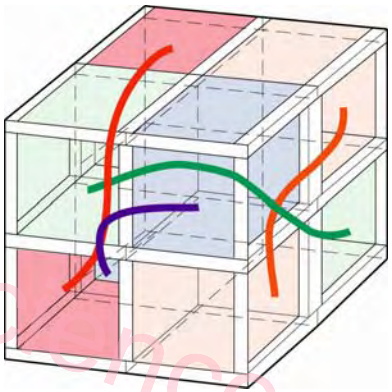
Provide a Durability Plan

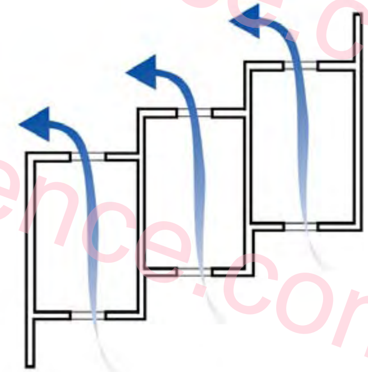
- ✓ Foundation moisture control strategies
- ✓ Wall moisture control strategies
- ✓ Roof moisture control strategies
- ✓ Interior “wet” rooms moisture control strategies
- ✓ Mechanical systems moisture control strategies

In order to control the air

Enclose the air

- An enclosure is constructed
- This enclosure provides closure for all six sides of the cube
- Openings in the enclosure should be intentional
  - Doors, Windows, Exhaust vents, Outside Air Intake





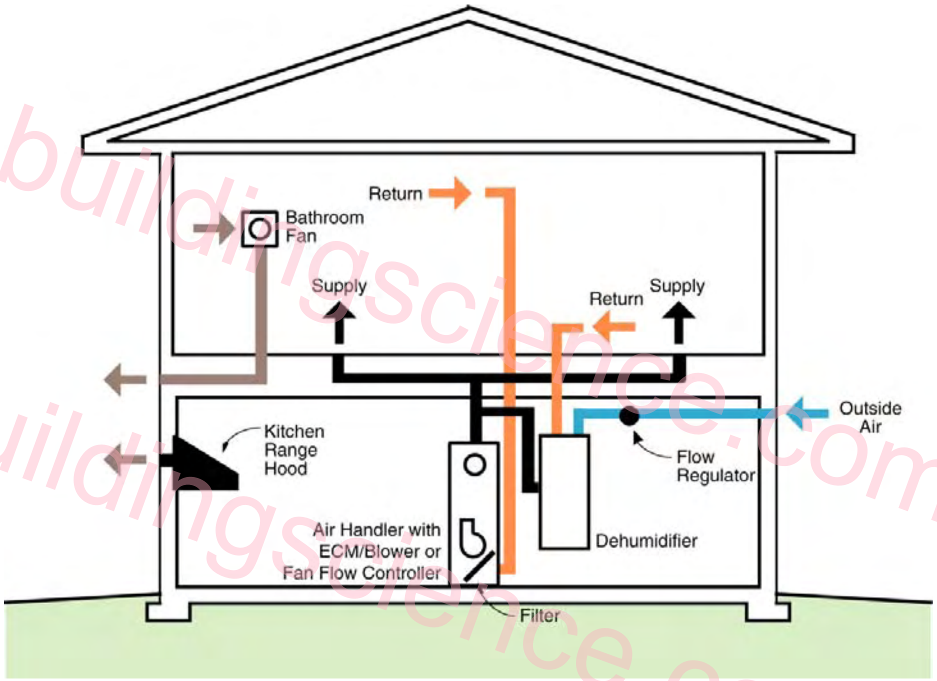
Staggering rooms or using wing walls increases ventilation through rooms oriented north to south

Establish Enclosure Tightness

- Same metric everywhere
  - What metric?
- Not too tight, not too leaky, just right (depends on ventilation system choice
  - Trial and error
- Between 2 and 3 ach@ 50 Pa
  - Leakier than the Canadian R-2000
  - Tighter than the typical American home
  - Achievable- Over 100,000 built to this standard under this program

Air brought into the the home can be

- Heated
- Cooled
- Humidified
- Dehumidified
- Cleaned, Filtered
- Distributed, Mixed



Energy is spent in the process

According to ASHRAE 62.2

- The same amount everywhere, every climate
- Big houses need more air than smaller houses
- Selecting materials does not affect the rates under current thinking
  - This will change as we learn more in the future
- We assume the enclosure are equally leaky everywhere regardless of age

DOWLING RESIDENCE
January 6, 2004

Bringing in Outside Air Can Be Expensive in Terms of Energy

- **We do not want to bring in more than we need**
- **If we build a perfectly tight enclosure and eliminate uncontrolled air leakage,the above is possible**



Fan Recycling Application

Activates the central system fan for a selectable ON time if it has been inactive for a selectable OFF time

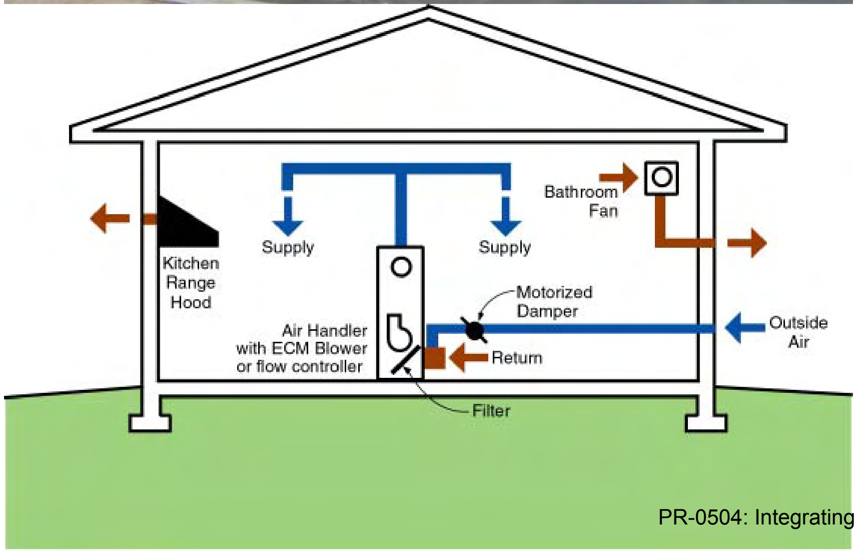
- Improved comfort control by periodic mixing
- Improved indoor air quality by periodic full distribution of ventilation air

Control of Moisture Pollutant

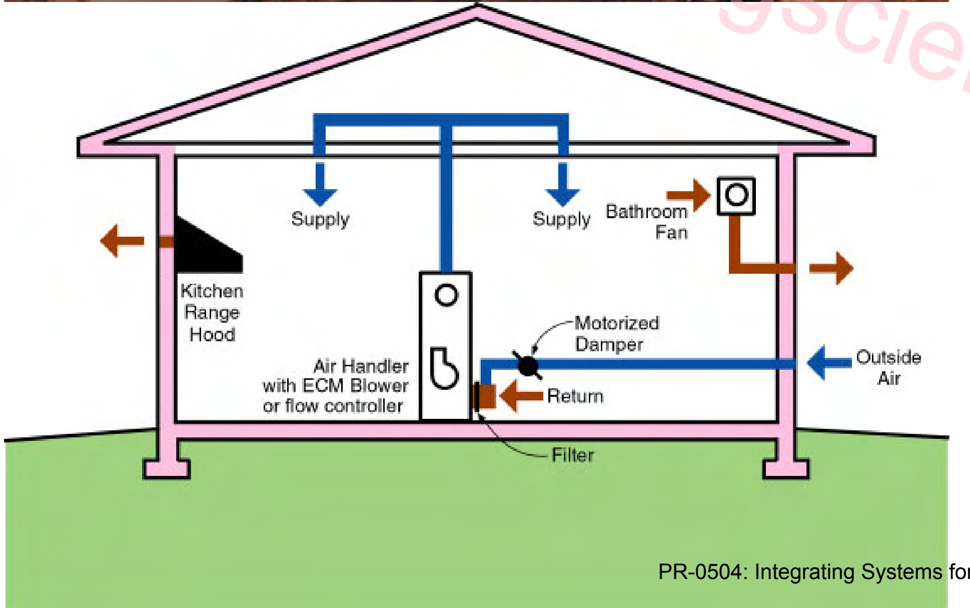
- **In cold climates, it is interior moisture generation**
  - **Air change with dryer outside air**

- **In hot humid climates, it is exterior moisture**
  - **Dehumidification through cooling or dedicated dehumidifiers**

Ducts in Conditioned Space - Mixed Dry Climate



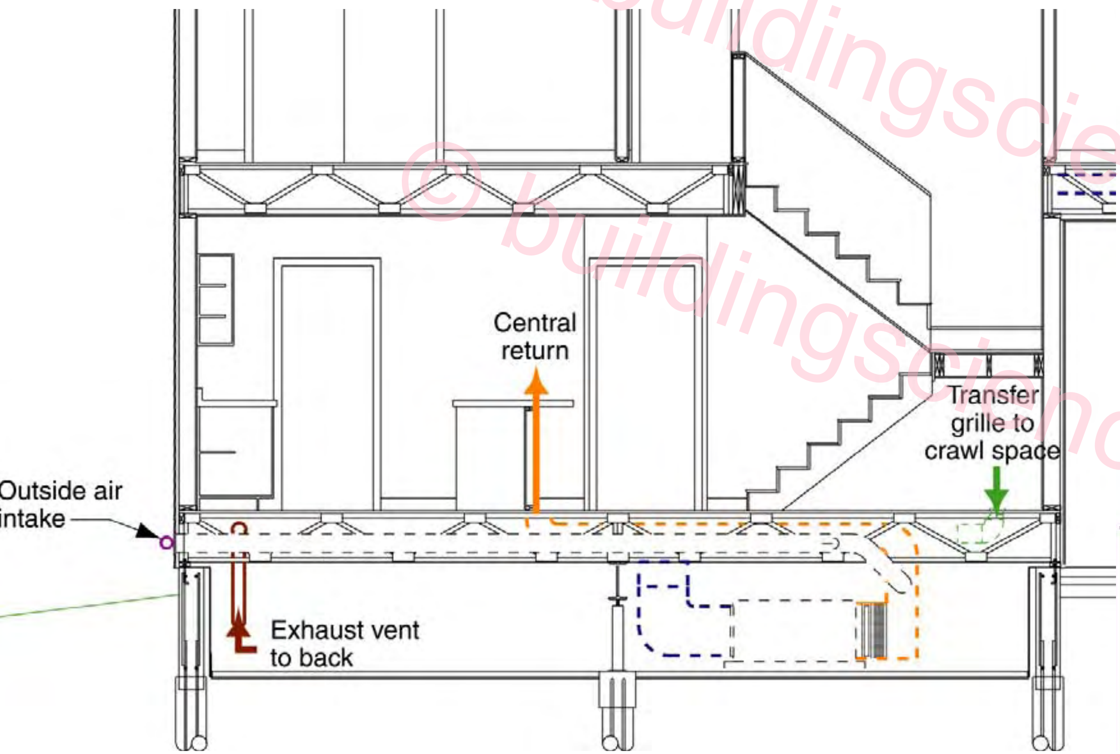
Ducts in Conditioned Space - Hot Dry Climate

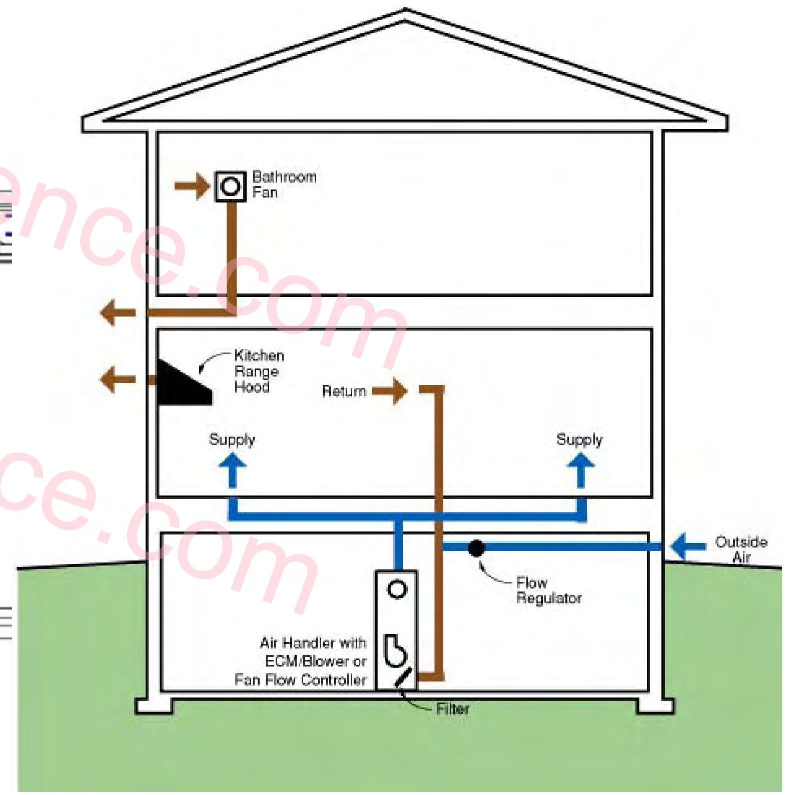


Cold Climate - Ohio

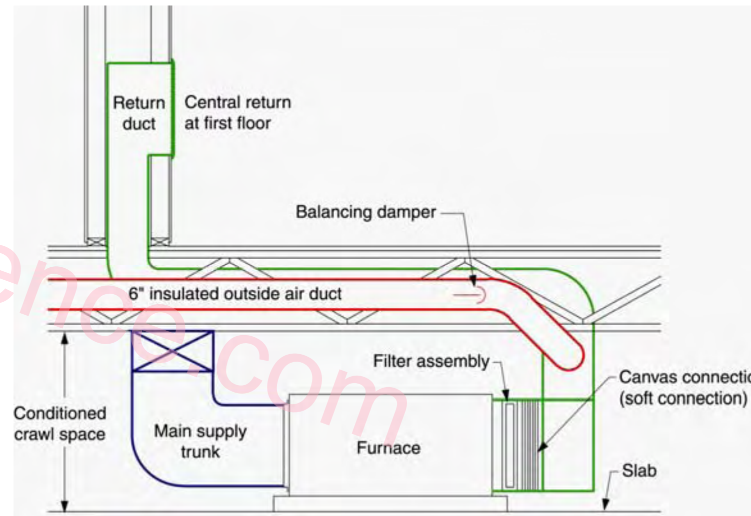
Cold Climate - Ohio

Cold Climate Integration





Cold Climate Integration



Cold Climate - Cleveland, Ohio

Cold - Details

Cold - Details

Energy Efficiency

Thermally Efficient Assemblies

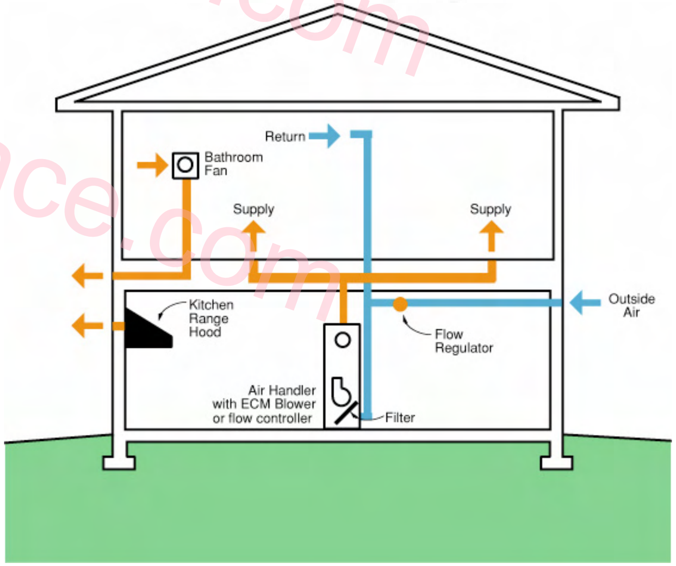
- **Structure only where needed**
- **Insulating sheathing**
- **Blown insulations that fill the entire void**

Cold Climate - Details

Energy Efficiency - Ventilation

Plan for ventilation:

- Air tight houses need controlled air change
- ERV's can deliver savings, but watch out for their electricity consumption
- Central Fan integrated system among the simplest

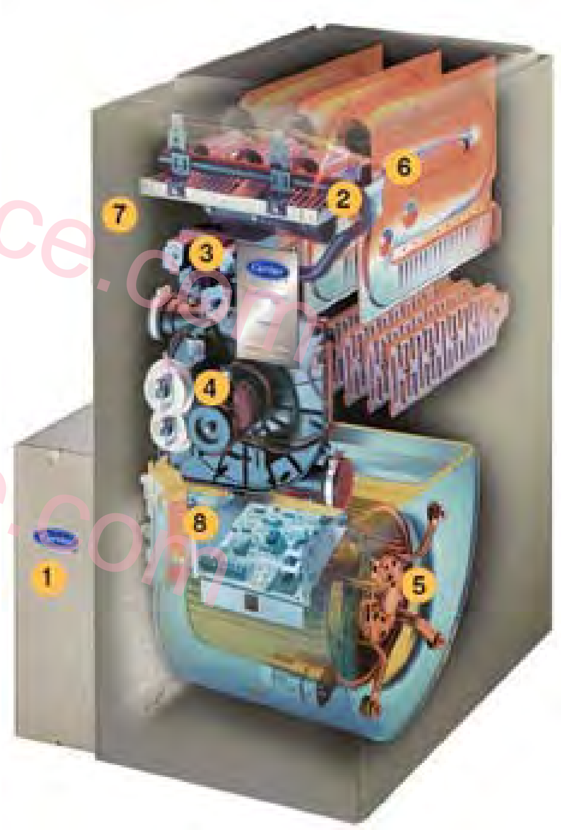


Cold Climate - Carbondale, Colorado

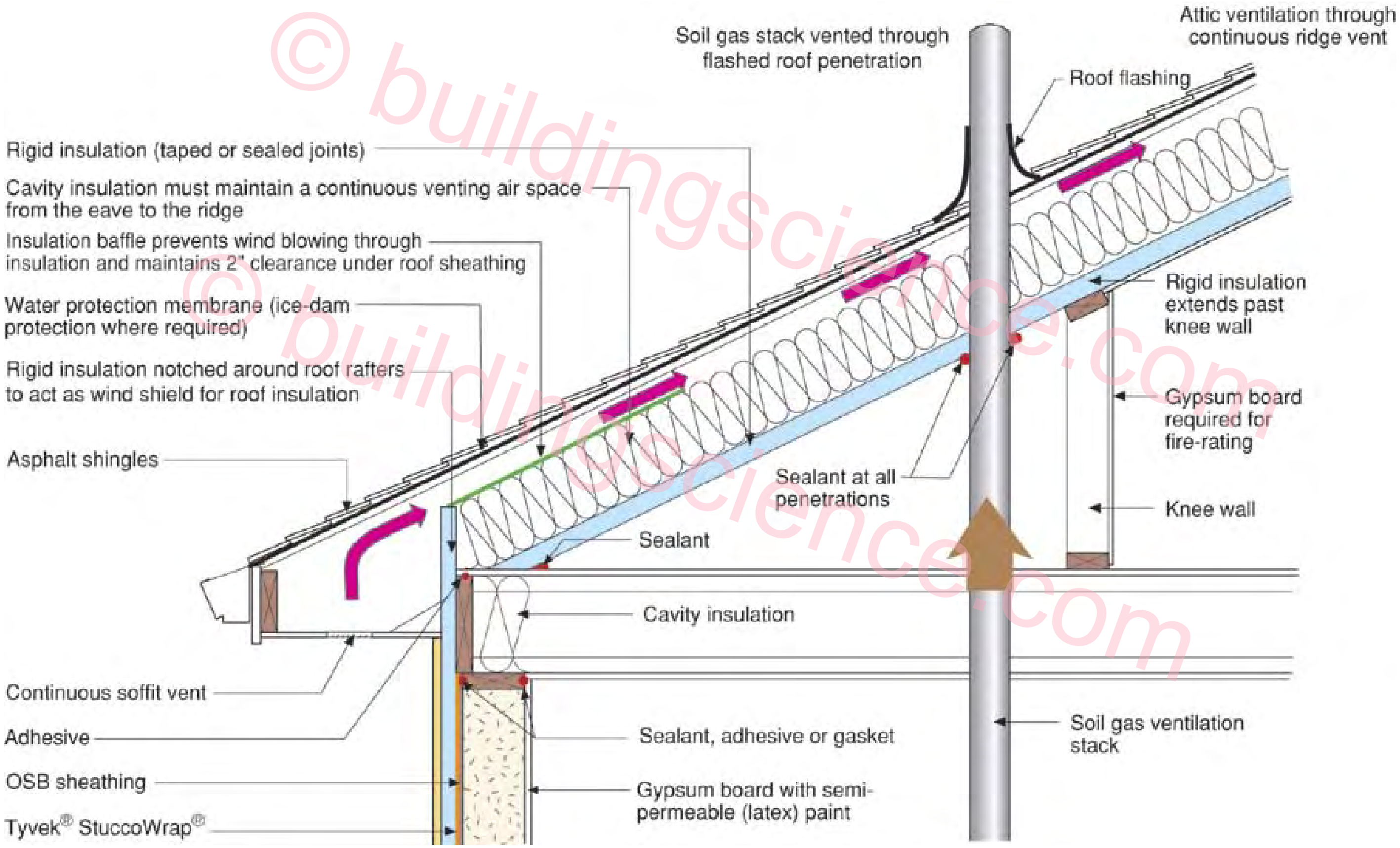
Energy Efficiency
Heating/Cooling - Gas/Electric

Condensing furnaces yield efficiencies over 90% AFUE

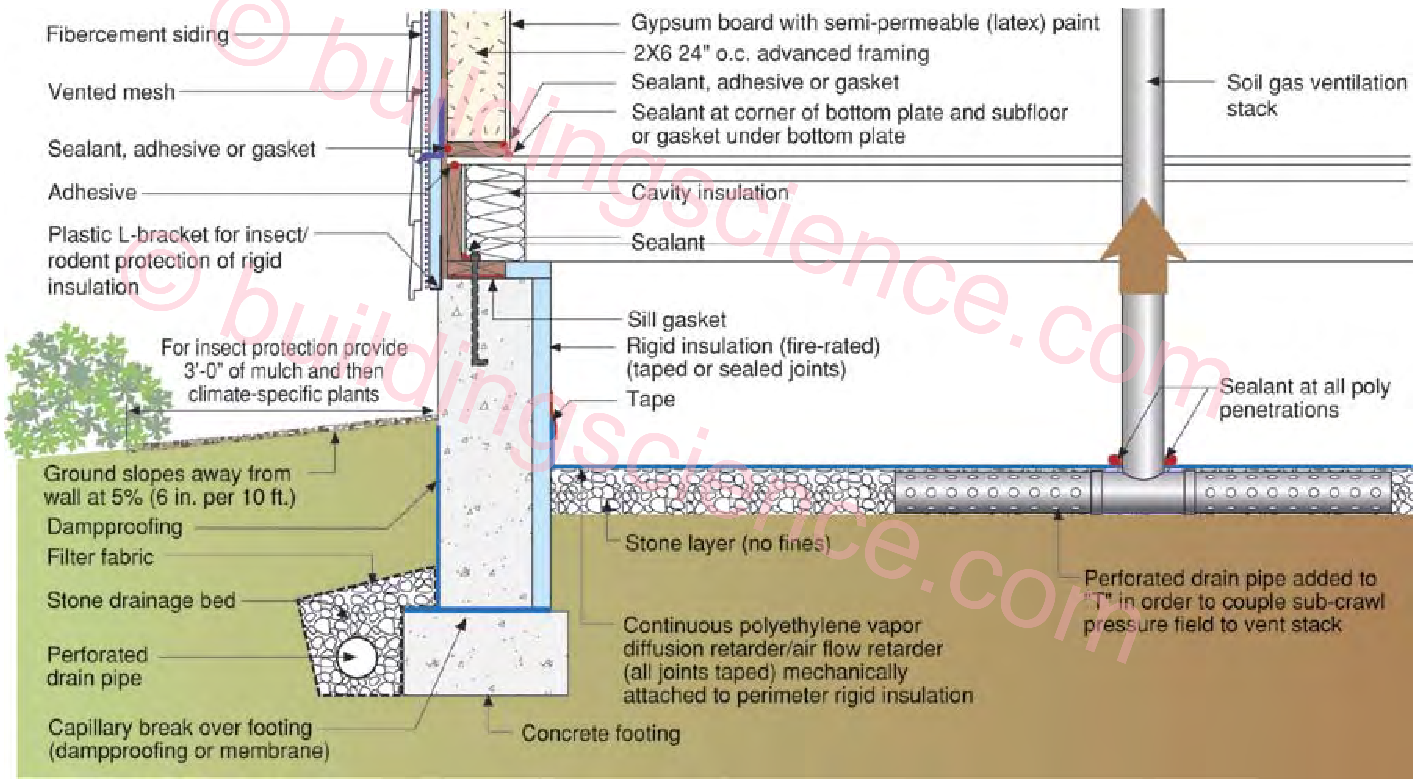
- Typically sealed combustion
- Ducted system facilitates installation of ventilation system
- Get ECM motors
- Use High SEER AC units



Very Cold - Details



Very Cold - Details



Very Cold - Details

Energy Efficiency
Hot Water - Gas, Tankless

- Tankless hot water heater eliminates standby losses
- Efficiencies in ~83% range – a ~30% increase in hot water efficiency over gas tanks
- Locate hot water heater central to fixtures to create short piping runs
- Put piping in walls, not ground

Cold Climate - Details

Cold Climate DAS Construction, Cleveland EcoVillage, OH

Building America
Toward Zero Energy Homes - Cleveland

Cleveland EcoVillage Townhouses

Project Highlights (1666 sf House)

Building Enclosure	R-19 2x6 24 oc + R-5 walls R-38 vented attic Low E windows (U-0.36, SHGC-0.45) R-10: 2" XPS on basement walls R-8 2" EPS under entire slab BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	90%+ AFUE Sealed-Combustion Furnace 12 SEER Air Conditioner Split System 0.59 EF Power-Direct Vent Water Heater Fan cycler ventilation system
Solar Site Collection	3.8 kW Peak PV system

Energy Performance

	MMBtu/yr
Heating	38.6
Cooling	5.4
Hot water	21.4
Light/Appl	n/c
Sub-total	65.4
Solar PV Collection	-13.5
Total Predicted Use	51.9
MEC 95 Predicted Use	130.8
% Savings vs MEC 95	60%

Building America

DAS Construction, Cleveland EcoVillage, OH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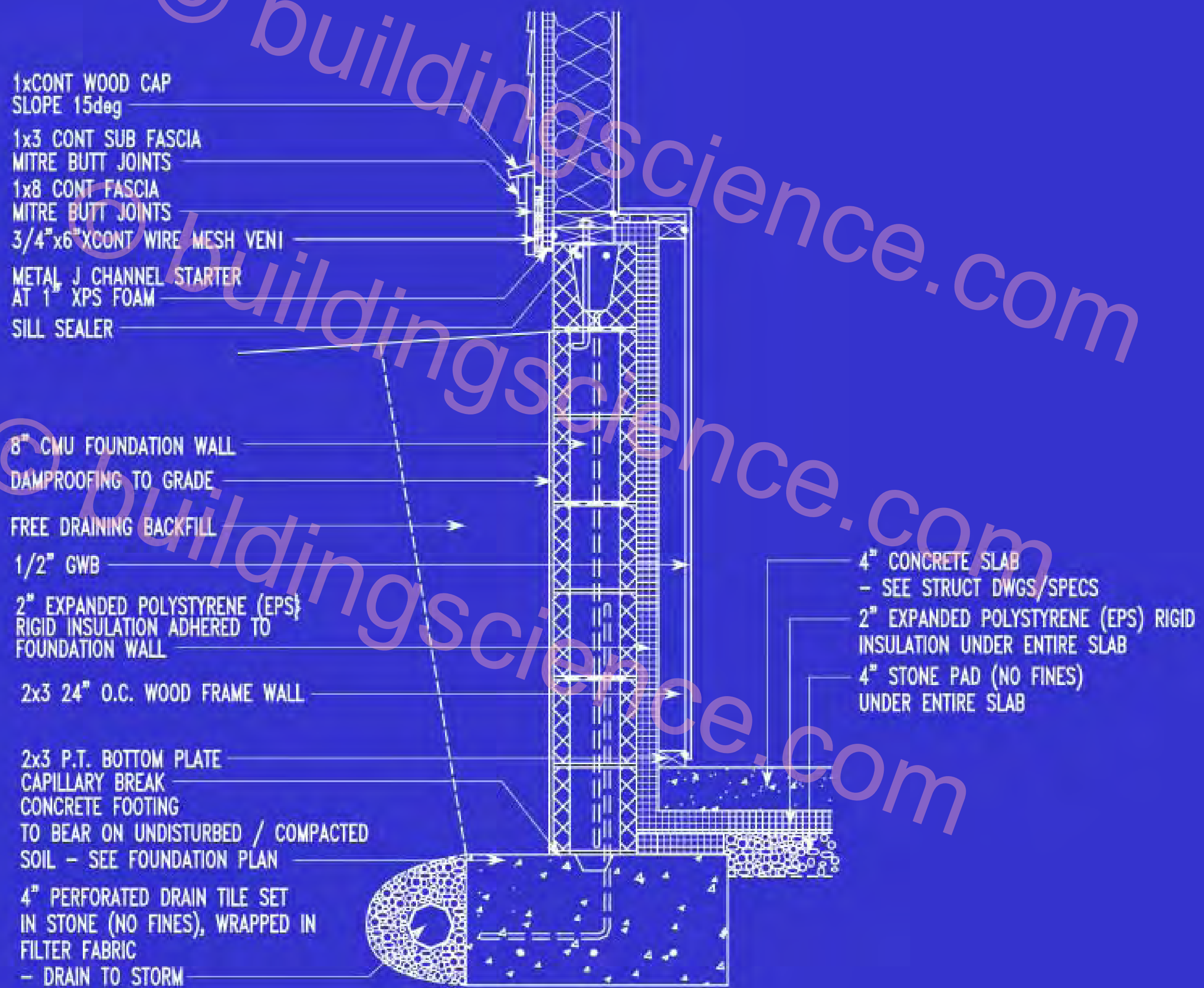
Foundation Detail

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Division 6: Wood - FSC-certified, focus on engineered wood products/efficient framing

Building America

DAS Construction, Cleveland EcoVillage, OH


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Cold Climate - Loveland, Colorado - McStain Site Generated Energy - Heat , Hot Water

Building America
Toward Zero Energy Home Projects

McStain Enterprises Discovery House (Boulder, CO)

Project Highlights (2512 sf House)

Building Enclosure	Walls: 2x6 24 oc R-19 + R-4 insul. shth. R-44 blown cellulose at ceiling Solar Low E windows (U-0.35, SHGC-0.34) Insulated foundation (R-11 wall, R-6 floor) BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	High Efficiency (92% AFUE, 20 EER) Combo system ASHRAE 62.2 ventilation by HRV Flourescent lighting
Solar Site Collection	96 sf drain back SHW system Integrated with heating system

Energy Performance

	MMBtu/yr
Heating	100.2
Cooling	0.7
Hot water	31.0
Light/Appl	55.2
Sub-total	187.1
Solar SHW Collection	-27.2
Total Predicted Use	159.9
Benchmark Predicted Use	283.0
% Savings vs BA Benchmark	44%

Site Generated Energy - Heat , Hot Water

Enclosure Design

Enclosure Design

Cold Climate - Carbondale, Colorado
Novy Architects - Fenton Construction

Building America
Toward Zero Energy Home Projects

CORE/Fenton Construction: Blue Creek Ranch: Next Generation Homestead Houses

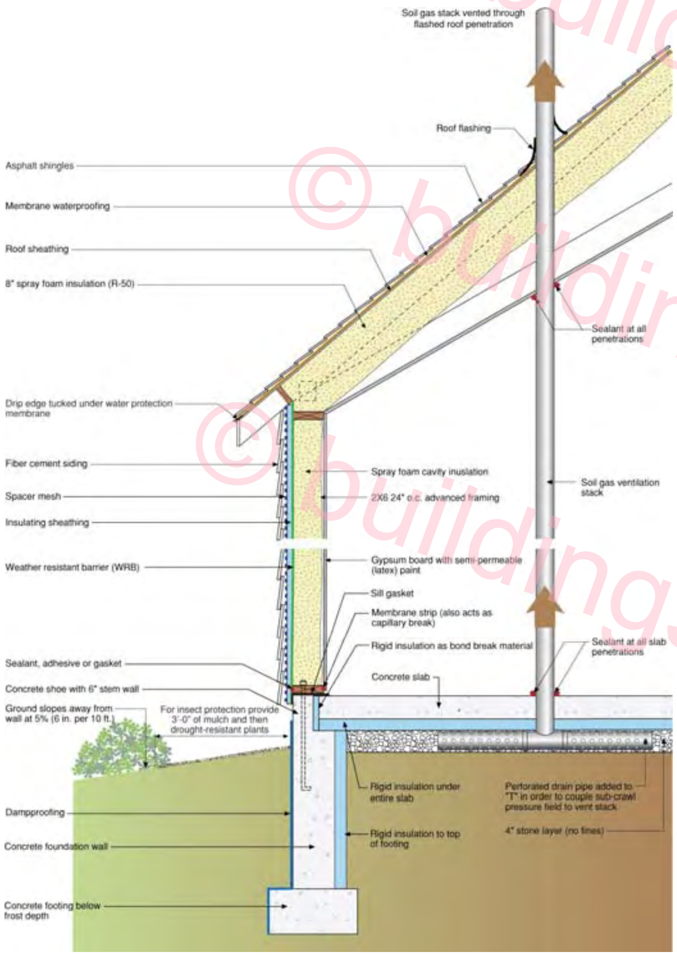
Project Highlights (1256 sf House)

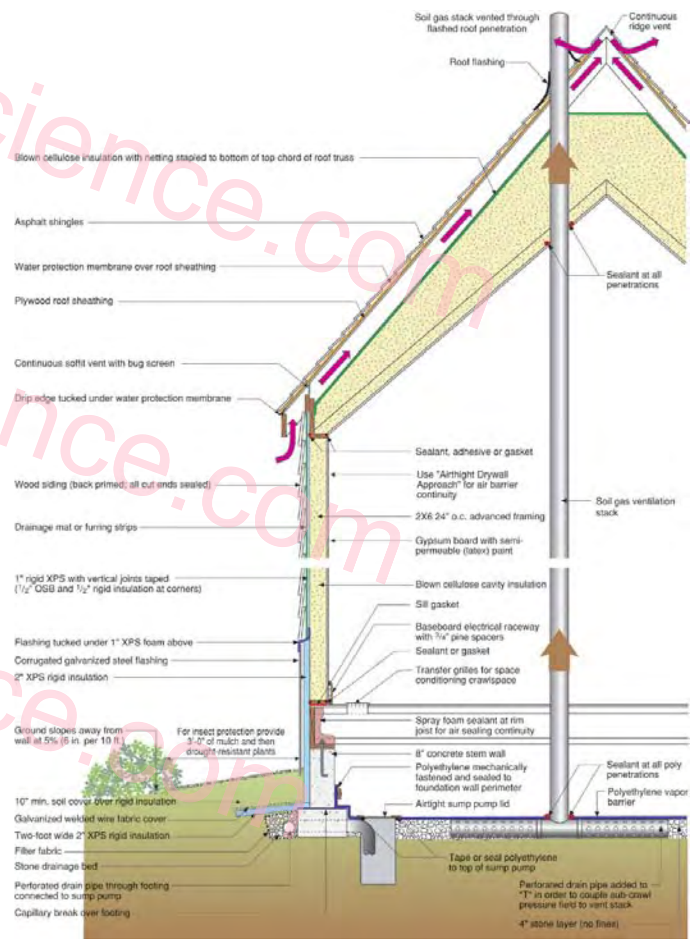
Building Enclosure	R-19 2x6 24 oc OVE w. damp-spray cellulose R-56 blown cellulose (14" minimum) Low E windows (U-0.36, SHGC-0.48) Conditioned Crawl (R-10) BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	High Efficiency (92% AFUE) Condensing Boiler Integrated DHW / SHW / space heating system ASHRAE 62.2 ventilation by HRV Flourescent lighting
Solar Site Collection	52 sf glycol solar thermal system 1.68 kW Peak PV system

Energy Performance

	MMBtu/yr
Heating	66.8
Cooling	0.0
Hot water	28.0
Light/Appl	44.6
Sub-total	139.4
Solar PV Collection	-21.8
Solar SHW Collection	-22.8
Total Predicted Use	94.7
Benchmark Predicted Use	173.0
% Savings vs BA Benchmark	45%

Integration





Mixed Humid Climate - Barley Phieffer Design - Anderson Sargent Homes - Dallas

Building America
Zero Energy Home Projects- Dallas

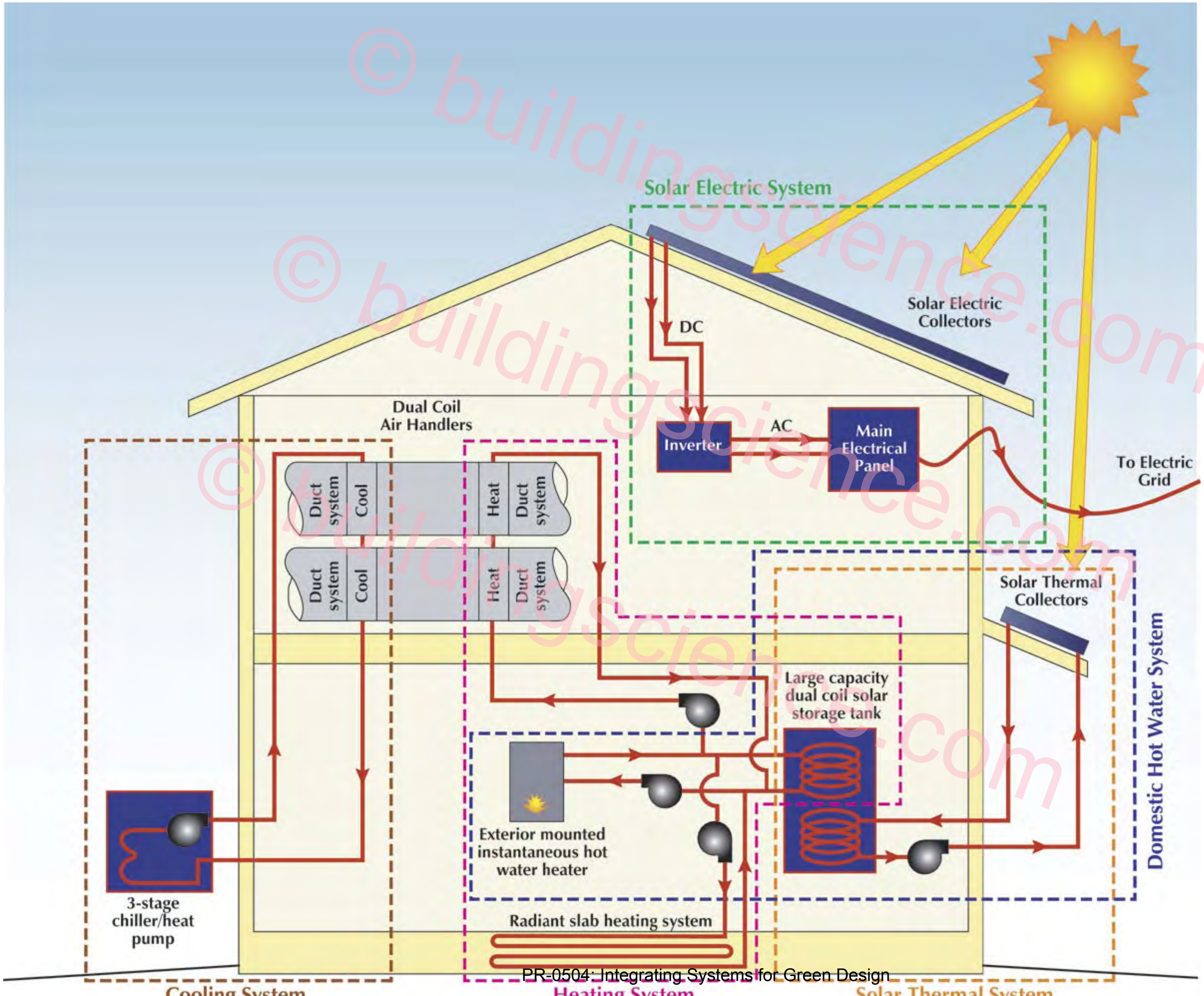
Anderson Sargent Homes: Dallas Parade of Homes

Project Highlights (3814 sf House)

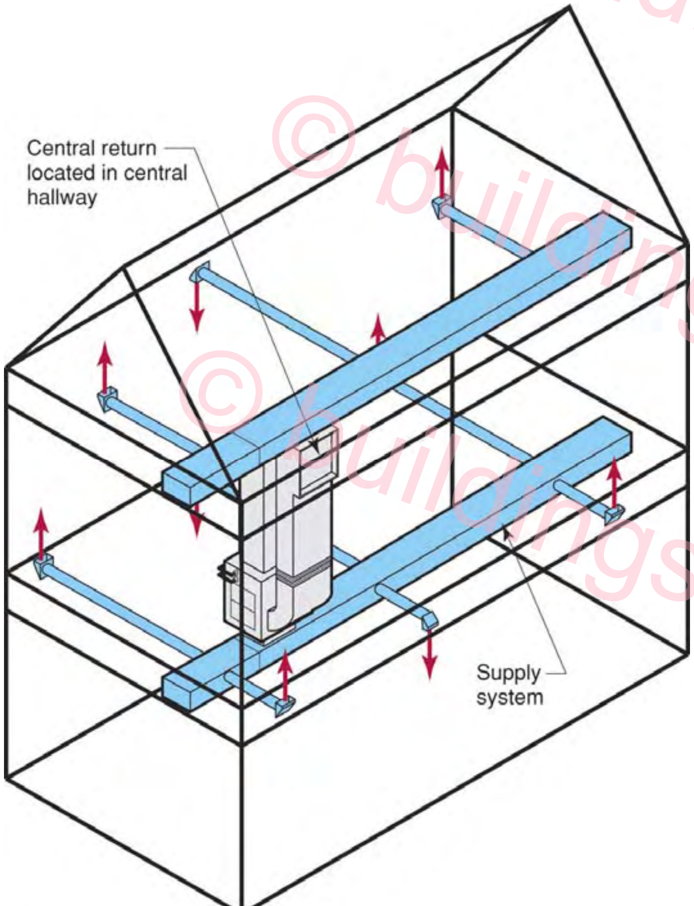
Building Enclosure	Durisol walls (R-14) Spray foam unvented attic (R-30) Solar Low E windows (U-0.38, SHGC-0.29) Insulated Radiant Slab (R-5) BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	High Efficiency (9 HSPF, 13 SEER) Chilled Water Heat Pump Tankless HWH back-up (0.82EF) ASHRAE 62.2 ventilation Flourescent lighting
Solar Site Collection	64 sf SHW system 8.12 kW Peak PV system

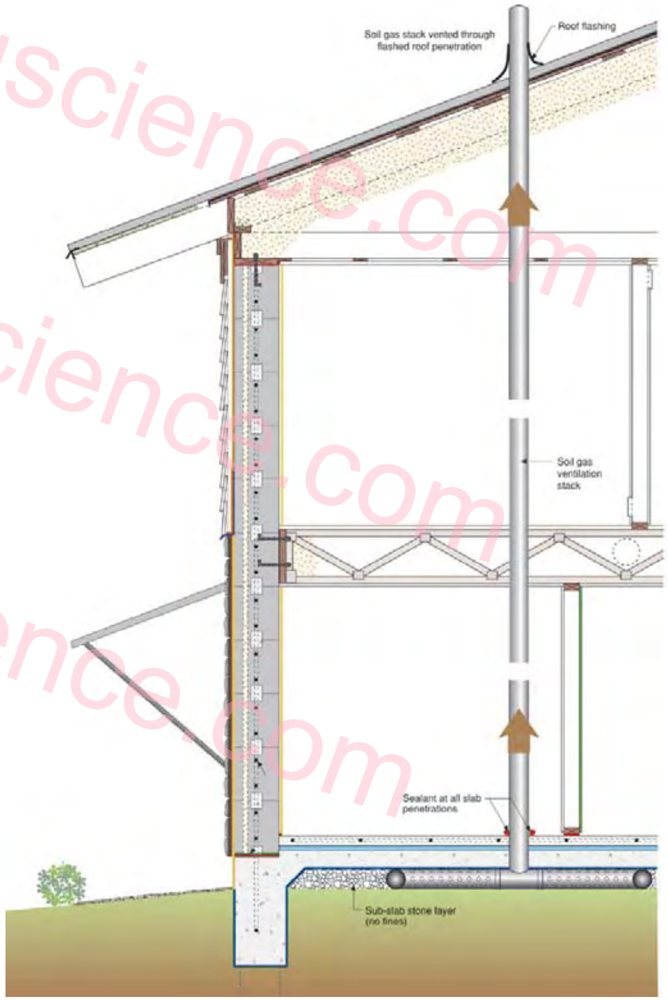
Energy Performance

	MMBtu/yr
Heating	17.4
Cooling	18.2
Hot water	19.8
Light/Appl	66.5
Sub-total	121.8
Solar PV Collection	-82.5
Solar SHW Collection	-11.8
Total Predicted Use	27.5
Benchmark Predicted Use	329.0
% Savings vs BA Benchmark	92%


Solar Electric System
DC
Solar Electric Collectors
Dual Coil Air Handlers
Inverter
AC
Main Electrical Panel
To Electric Grid
Duct system
Cool
Heat
Duct system
Duct system
Cool
Heat
Duct system
Solar Thermal Collectors
Domestic Hot Water System
Large capacity dual coil solar storage tank
Exterior mounted instantaneous hot water heater
3-stage chiller/heat pump
Radiant slab heating system
Cooling System
Heating System
Solar Thermal System

Integration





Mixed Humid Climate - Ideal Homes, - Oklahoma

Building America
Zero Energy Home Projects - Oklahoma

Ideal Homes, OKC, OK

Project Highlights (1644 sf House)

Building Enclosure	Walls: 2x6 24 oc R-19 + R-3 insul. shth. R-38 blown cellulose at ceiling Radiant barrier roof sheathing Solar Low E windows (U-0.39, SHGC-0.31) Insulated Slab edge (R-3) BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	High Efficiency (4 COP, 20 EER) Ground Source Heat Pump Tankless HWH (0.82EF) ASHRAE 62.2 ventilation by ERV Flourescent lighting
Solar Site Collection	5.3 kW Peak PV system

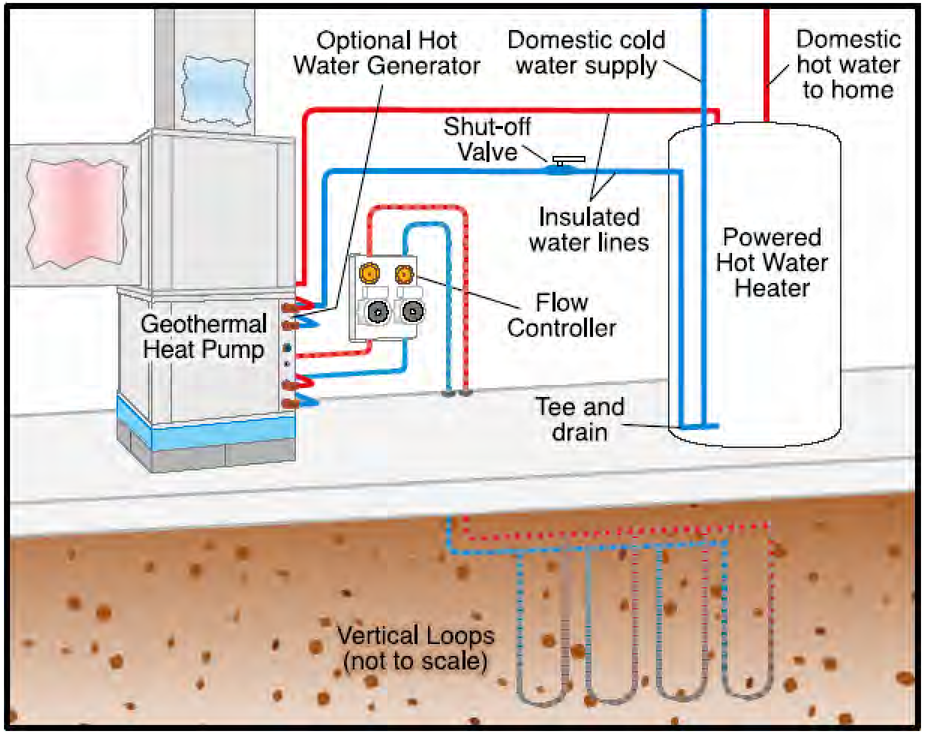
Energy Performance

	MMBtu/yr
Heating	26.8
Cooling	11.6
Hot water	14.5
Light/Appl	54.5
Sub-total	107.4
Solar PV Collection	-82.5
Total Predicted Use	24.9
Benchmark Predicted Use	230.0
% Savings vs BA Benchmark	89%

Energy Efficiency
Heating/Cooling - Electric

High efficiency ground source heat pump (GSHP)

- Moves heat to & from the ground, instead of burning stuff
- Year 'round heating and cooling at high efficiency
- No combustion risks
- Option of de-superheater hot water system



Hot Humid Climate - South Georgia

Building America
Toward Zero Energy Homes- South Georgia

GA DNR Admin Building SIPS Cottage (Fargo, GA)

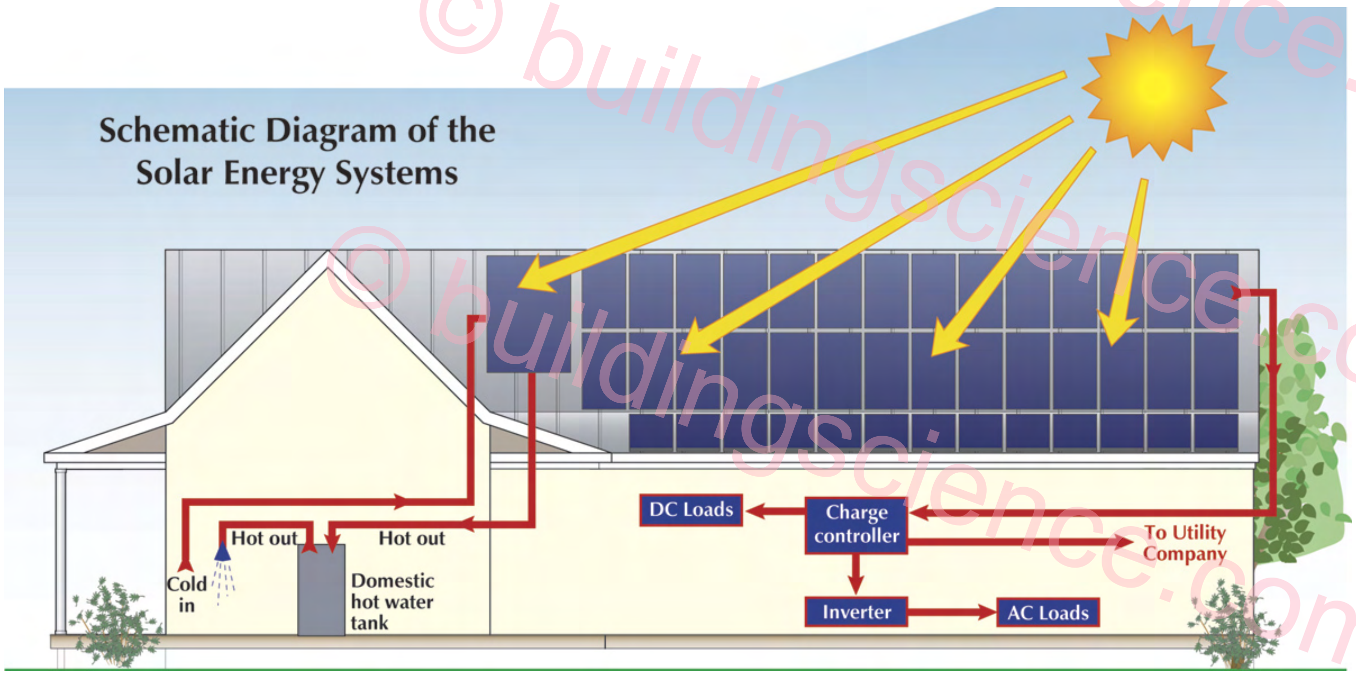
Project Highlights (1880 sf House)

Building Enclosure	SIPS walls (R-23) & roof (R-38) Solar Low E windows (U-0.33, SHGC-0.33) Conditioned Insulated (R-8) crawl BSC BA Airtightness (2.5 ins/100 sf)
Mechanical	High Efficiency (9 HSPF, 13 SEER) Air Source Heat Pump Marathon Electric HWH (0.94EF) Stand alone dehumidifier ASHRAE 62.2 ventilation Flourescent lighting
Solar Site Collection	2.9 kW Peak PV system

Energy Performance

	MMBtu/yr
Heating	16.5
Cooling	26.9
Hot water	16.7
Light/Appl	50.6
Sub-total	110.7
Solar PV Collection	-48.9
Total Predicted Use	61.8
Benchmark Predicted Use	180.0
% Savings vs BA Benchmark	66%

Site Generated Energy - Integration

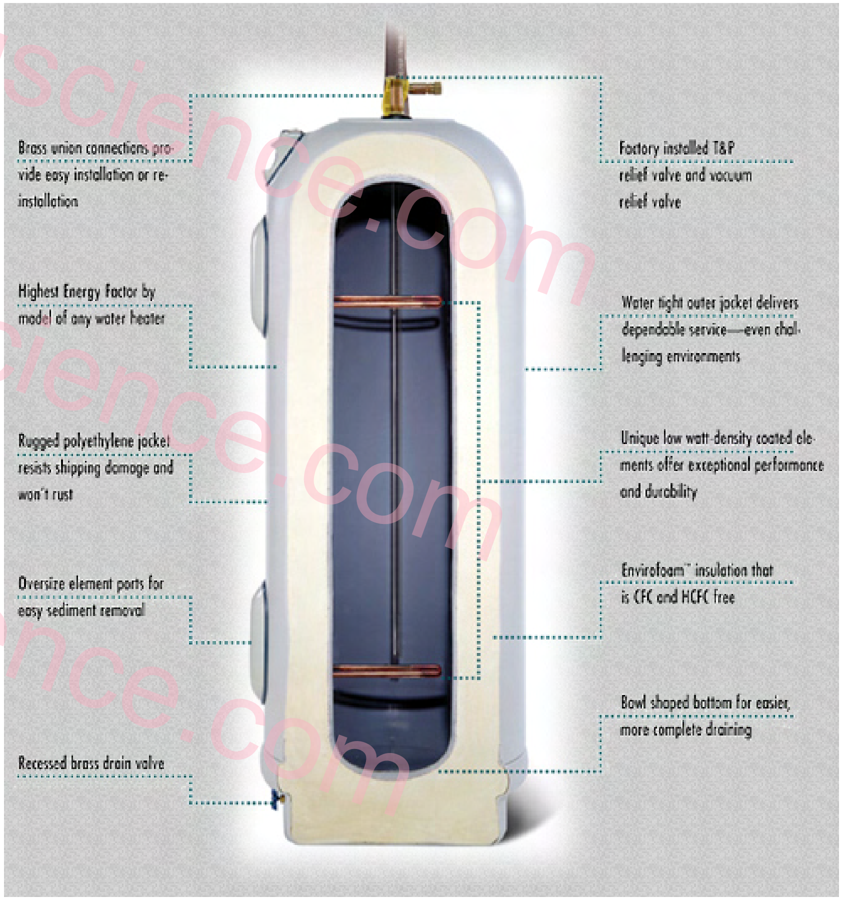


- **PV** - back-up batteries or grid connection
- **Solar water** - passive system drawn down with demand
- **Passive Solar Gain -** awnings to protect from overheating

Energy Efficiency - Hot Water, Electric

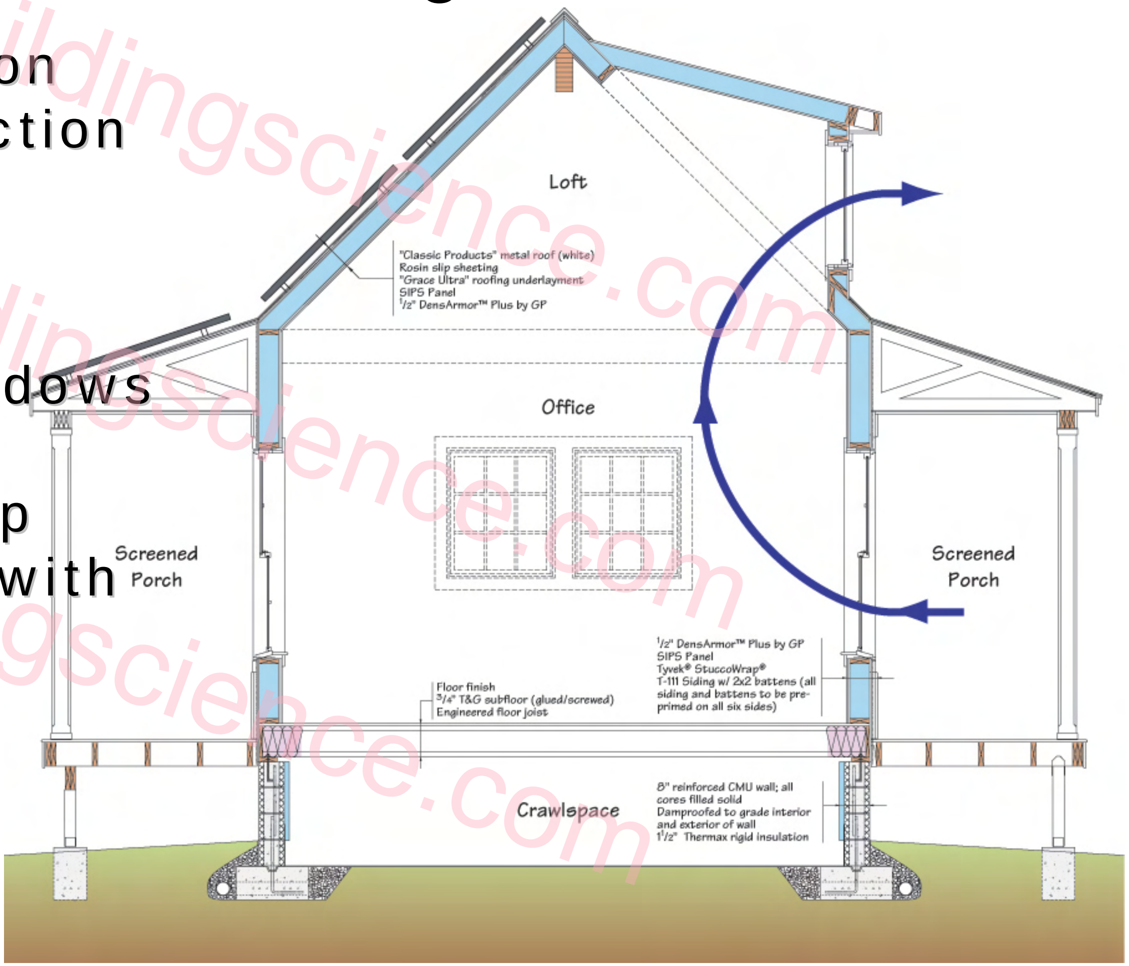
Electric resistance

- High efficiencies available, up to 94%
- However, it's more expensive than gas
- Simple installation
- No combustion risks



Building Shell: Strategies Used

- High levels of insulation and leak free construction
- Reflective roofing
- High performance windows
- High Ceilings and Deep wrap around porches with strategically placed windows to promote natural ventilation



Ductwork in Conditioned Crawlspace