Integrating Systems for Green Design

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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.
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 | + |

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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
(ddictates 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
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 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
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

PR-0504: Integrating Systems for Green Design
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

Rigid insulation (taped or sealed joints)
Cavity insulation must maintain a continuous venting air space from the eave to the ridge
Insulation batts prevent wind blowing through insulation and maintain 2” clearance under roof sheathing
Water protection membrane (ice-dam protection where required)
Rigid insulation notched around roof rafters to act as wind shield for roof insulation

Asphalt shingles

Continuous soffit vent
Adhesive
OSB sheathing
Tyvek® StuccoWrap®

Sealant at all penetrations

Cavity insulation

Sealant, adhesive or gasket
Gypsum board with semi-permeable (latex) paint

Soil gas ventilation stack

Soil gas stack vented through flashed roof penetration
Attic ventilation through continuous ridge vent

Roof flashing
Gypsum board required for fire-rating
Knee wall

PR-0504: Integrating Systems for Green Design
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
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

<table>
<thead>
<tr>
<th></th>
<th>MMBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>38.6</td>
</tr>
<tr>
<td>Cooling</td>
<td>5.4</td>
</tr>
<tr>
<td>Hot water</td>
<td>21.4</td>
</tr>
<tr>
<td>Light/Appl</td>
<td>n/c</td>
</tr>
<tr>
<td>Sub-total</td>
<td>65.4</td>
</tr>
<tr>
<td>Solar PV Collection</td>
<td>-13.5</td>
</tr>
<tr>
<td>Total Predicted Use</td>
<td>51.9</td>
</tr>
<tr>
<td>MEC 95 Predicted Use</td>
<td>130.8</td>
</tr>
</tbody>
</table>

% Savings vs MEC 95
- 60%
Building America
DAS Construction, Cleveland EcoVillage, OH
Foundation Detail

- 1x CONT WOOD CAP
  - SLOPE 15deg
- 1x3 CONT SUB FASCIA
  - MITRE BUTT JOINTS
- 1x8 CONT FASCIA
  - MITRE BUTT JOINTS
- 3/4"x6" CONT WIRE MESH VENI
- METAL J CHANNEL STARTER AT 1" XPS FOAM
- SILL SEALER

- 8" CMU FOUNDATION WALL
  - DAMPROOFING TO GRADE
  - FREE DRAINING BACKFILL
- 1/2" GWB
- 2" EXPANDED POLYSTYRENE (EPS)
  - RIGID INSULATION ADHERED TO FOUNDATION WALL
- 2x3 24° O.C. WOOD FRAME WALL
- 2x3 P.T. BOTTOM PLATE
  - CAPILLARY BREAK
  - CONCRETE FOOTING
  - TO BEAR ON UNDISTURBED / COMPACTED SOIL - SEE FOUNDATION PLAN
- 4" PERFORATED DRAIN TILE SET IN STONE (NO FINES), WRAPPED IN FILTER FABRIC
  - DRAIN TO STORM

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PR-0504: Integrating Systems for Green Design
Division 6: Wood - FSC-certified, focus on engineered wood products/efficient framing
Building America

DAS Construction, Cleveland EcoVillage, OH
Cold Climate - Loveland, Colorado - McStain
Site Generated Energy - Heat, Hot Water
### McStain Enterprises Discovery House (Boulder, CO)

#### Project Highlights (2512 sf House)

<table>
<thead>
<tr>
<th>Building Enclosure</th>
<th>Energy Performance (MMBtu/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>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)</td>
<td>Heating: 100.2</td>
</tr>
<tr>
<td></td>
<td>Cooling: 0.7</td>
</tr>
<tr>
<td></td>
<td>Hot water: 31.0</td>
</tr>
<tr>
<td></td>
<td>Light/Appl: 55.2</td>
</tr>
<tr>
<td></td>
<td>Sub-total: 187.1</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Solar SHW Collection: -27.2</td>
</tr>
<tr>
<td>High Efficiency (92% AFUE, 20 EER) Combo system ASHRAE 62.2 ventilation by HRV Flourescent lighting</td>
<td>Total Predicted Use: 159.9</td>
</tr>
<tr>
<td>Solar Site Collection</td>
<td>Benchmark Predicted Use: 283.0</td>
</tr>
<tr>
<td>96 sf drain back SHW system Integrated with heating system</td>
<td>% Savings vs BA Benchmark: 44%</td>
</tr>
</tbody>
</table>
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)**

<table>
<thead>
<tr>
<th>Building Enclosure</th>
<th>Energy Performance MMBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-19 2x6 24 oc OVE w. damp-spray cellulose</td>
<td>Heating 66.8</td>
</tr>
<tr>
<td>R-56 blown cellulose (14&quot; minimum)</td>
<td>Cooling 0.0</td>
</tr>
<tr>
<td>Low E windows (U-0.36, SHGC-0.48)</td>
<td>Hot water 28.0</td>
</tr>
<tr>
<td>Conditioned Crawl (R-10)</td>
<td>Light/Appl 44.6</td>
</tr>
<tr>
<td>BSC BA Airtightness (2.5 ins/100 sf)</td>
<td>Sub-total 139.4</td>
</tr>
</tbody>
</table>

| Mechanical | |
| High Efficiency (92% AFUE) | Solar PV Collection -21.8 |
| Condensing Boiler | Solar SHW Collection -22.8 |
| Integrated DHW / SHW / space heating system | Total Predicted Use 94.7 |
| ASHRAE 62.2 ventilation by HRV | Benchmark Predicted Use 173.0 |
| Fluorescent lighting | % Savings vs BA Benchmark 45% |

**Solar Site Collection**

- 52 sf glycol solar thermal system
- 1.68 kW Peak PV system
Integration

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Mixed Humid Climate - Barley Phieffer Design - Anderson Sargent Homes - Dallas
# Anderson Sargent Homes: Dallas Parade of Homes

## Project Highlights (3814 sf House)

<table>
<thead>
<tr>
<th>Building Enclosure</th>
<th>Energy Performance MMBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durisol walls (R-14)</td>
<td></td>
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<tr>
<td>Spray foam unvented attic (R-30)</td>
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<tr>
<td>Solar Low E windows (U-0.38, SHGC-0.29)</td>
<td>Heating 17.4</td>
</tr>
<tr>
<td>Insulated Radiant Slab (R-5)</td>
<td>Cooling 18.2</td>
</tr>
<tr>
<td>BSC BA Airtightness (2.5 ins/100 sf)</td>
<td>Hot water 19.8</td>
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<tr>
<td></td>
<td>Light/Appl 66.5</td>
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<tr>
<td></td>
<td>Sub-total 121.8</td>
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<table>
<thead>
<tr>
<th>Mechanical</th>
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</tr>
</thead>
<tbody>
<tr>
<td>High Efficiency (9 HSPF, 13 SEER)</td>
<td>Solar PV Collection -82.5</td>
</tr>
<tr>
<td>Chilled Water Heat Pump</td>
<td>Solar SHW Collection -11.8</td>
</tr>
<tr>
<td>Tankless HWH back-up (0.82EF)</td>
<td>Total Predicted Use 27.5</td>
</tr>
<tr>
<td>ASHRAE 62.2 ventilation</td>
<td></td>
</tr>
<tr>
<td>Flourescent lighting</td>
<td>Benchmark Predicted Use 329.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar Site Collection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>64 sf SHW system</td>
<td></td>
</tr>
<tr>
<td>8.12 kW Peak PV system</td>
<td>% Savings vs BA Benchmark</td>
</tr>
<tr>
<td></td>
<td>92%</td>
</tr>
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**Building America**

**Zero Energy Home Projects - Dallas**

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**Building Science Consortium**

PR-0504: Integrating Systems for Green Design
PR-0504: Integrating Systems for Green Design
Integration
Mixed Humid Climate - Ideal Homes, - 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)

Energy Performance MMBtu/yr

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>MMBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>26.8</td>
</tr>
<tr>
<td>Cooling</td>
<td>11.6</td>
</tr>
<tr>
<td>Hot water</td>
<td>14.5</td>
</tr>
<tr>
<td>Light/Appl</td>
<td>54.5</td>
</tr>
<tr>
<td>Sub-total</td>
<td>107.4</td>
</tr>
<tr>
<td>Solar PV Collection</td>
<td>-82.5</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Building Enclosure</th>
<th>Energy Performance MMBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIPS walls (R-23) &amp; roof (R-38)</td>
<td>Heating: 16.5</td>
</tr>
<tr>
<td>Solar Low E windows (U-0.33, SHGC-0.33)</td>
<td>Cooling: 26.9</td>
</tr>
<tr>
<td>Conditioned Insulated (R-8) crawl</td>
<td>Hot water: 16.7</td>
</tr>
<tr>
<td>BSC BA Airtightness (2.5 ins/100 sf)</td>
<td>Light/Appl: 50.6</td>
</tr>
<tr>
<td>Sub-total</td>
<td>110.7</td>
</tr>
</tbody>
</table>

| Mechanical | |
| High Efficiency (9 HSPF, 13 SEER) | Solar PV Collection: -48.9 |
| Air Source Heat Pump | Total Predicted Use: 61.8 |
| Marathon Electric HWH (0.94EF) | Benchmark Predicted Use: 180.0 |
| Stand alone dehumidifier | |
| ASHRAE 62.2 ventilation | |
| Flourescent lighting | |

| Solar Site Collection | |
| 2.9 kW Peak PV system | |

% 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