


## Building for Energy Efficiency – Part 1

Understanding the House as a System

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Building Science Corporation  
[www.buildingscience.com](http://www.buildingscience.com)

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## Objectives for this session . . .

1. Introduce the Building America Research Program
2. Explain the “House as a System” approach (Part 1)
3. Explain Advanced Framing (Part 2)

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## Why build energy efficient homes?

**Consumers:**

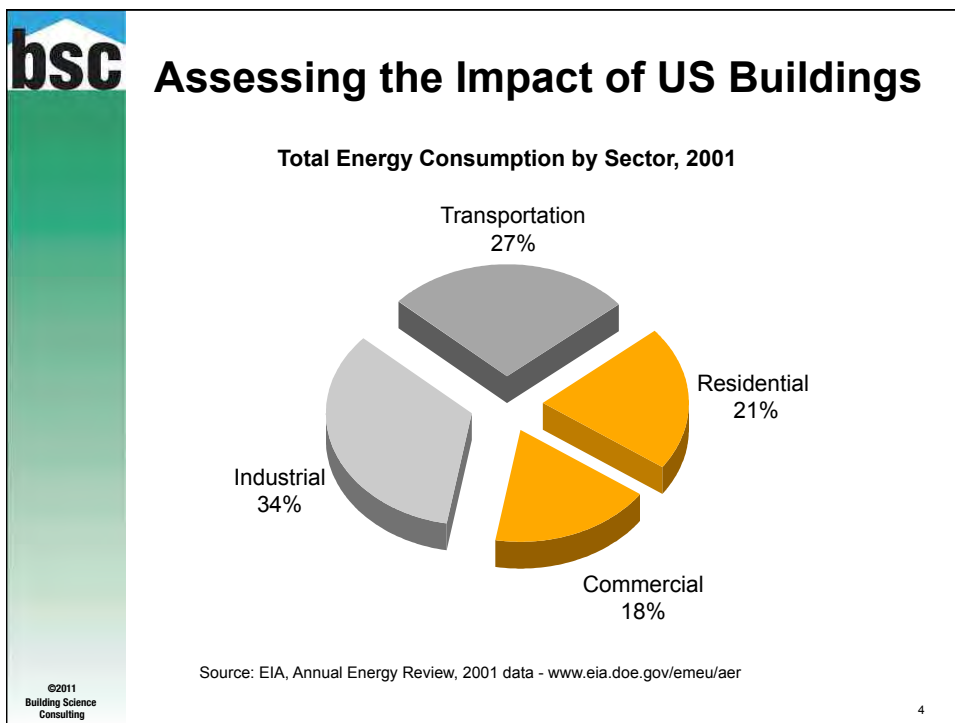
- Lower energy bills and maintenance costs
- More money for things other than energy
- Healthier, more comfortable, more durable homes

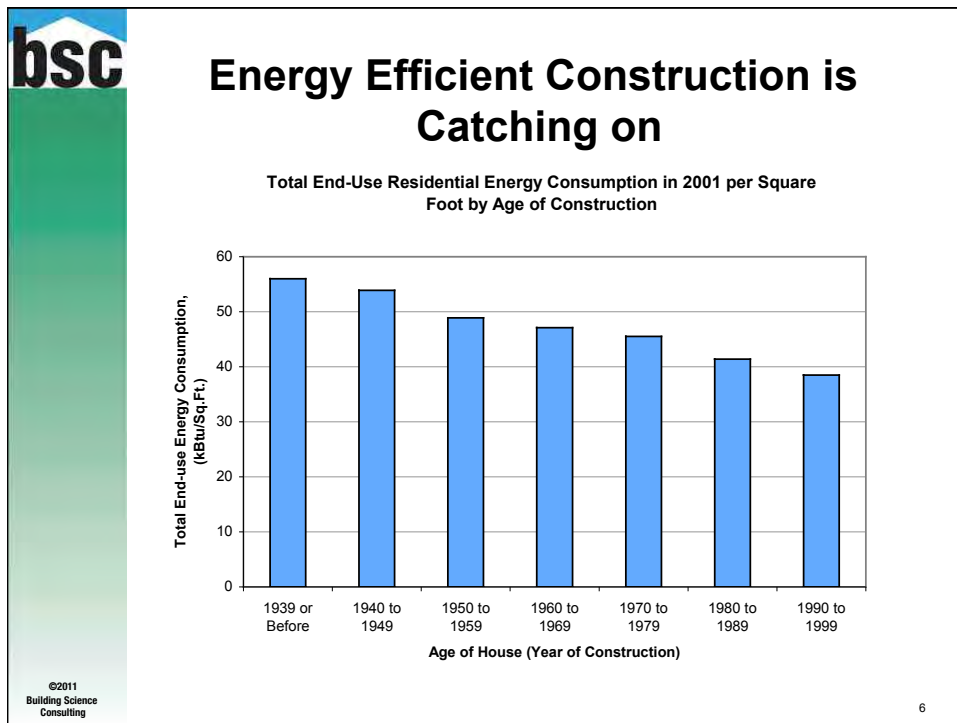
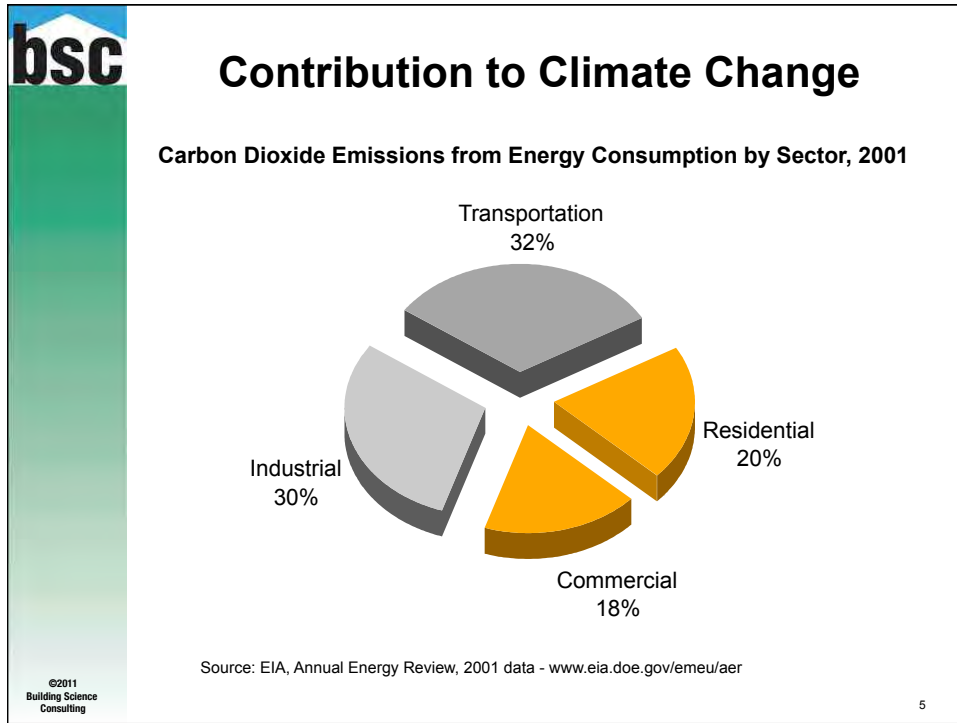
**The nation:**

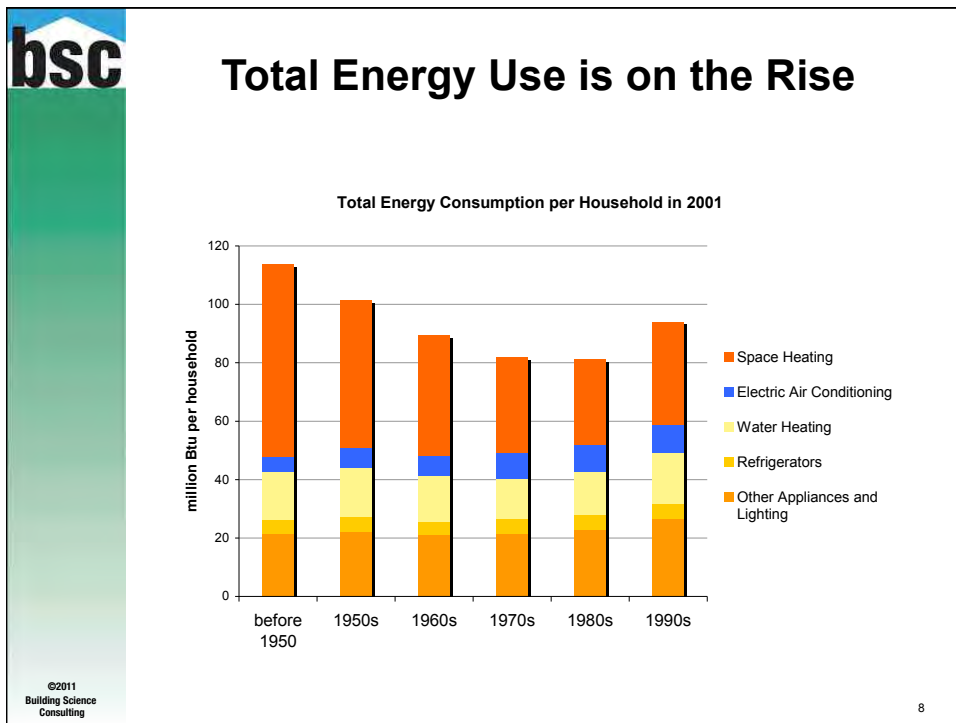
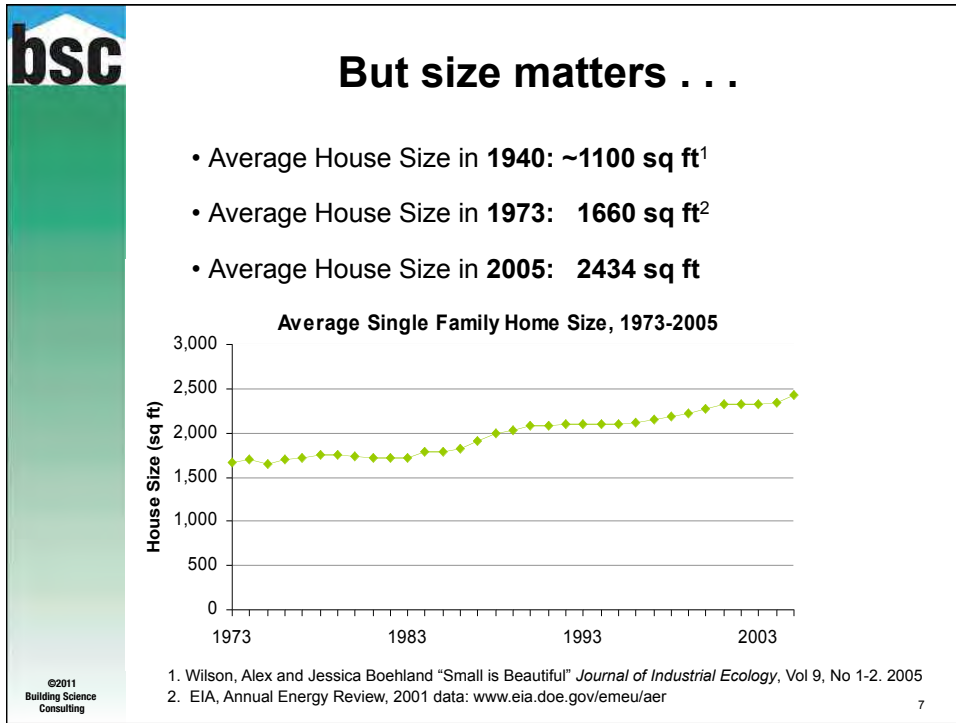
- Wise use of resources through energy savings
- Greater energy security through the use of domestic resources
- A healthier environment through reduced emissions
- Increased use of onsite power and renewable energy systems


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## Building America

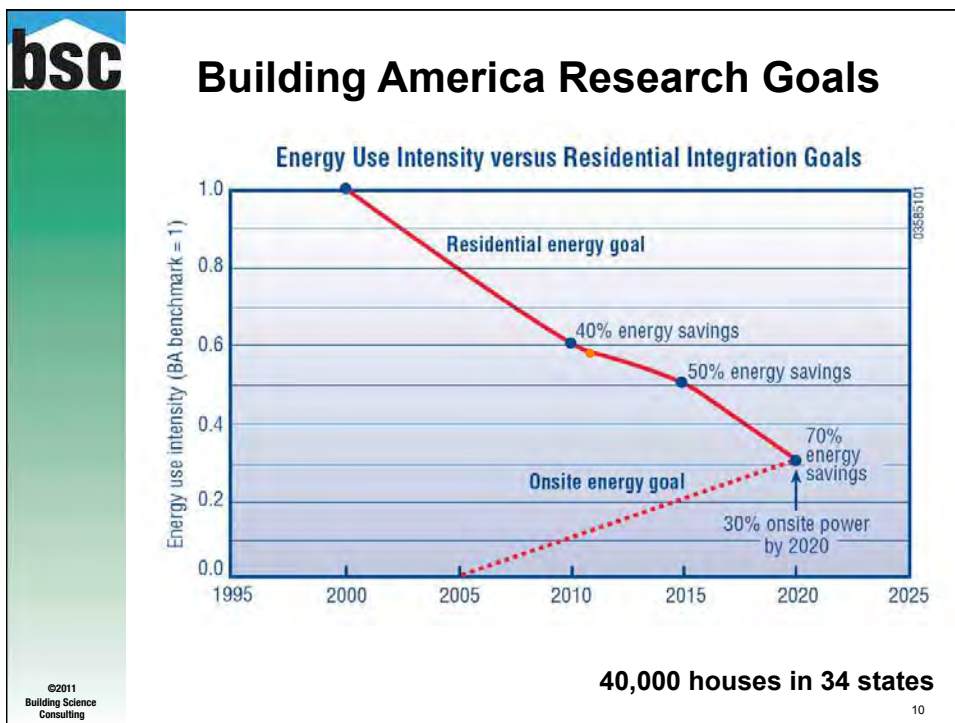


The U.S. Department of Energy's Building America Program is reengineering the American home for energy efficiency and affordability. Building America works with the residential building industry to develop and implement innovative building processes and technologies – innovations that save builders and homeowners millions of dollars in construction and energy costs. This industry-led, cost-shared partnership program uses a systems engineering approach to reduce energy use, utility bills, construction time, and construction waste.

For more information, visit our website at:  
[www.buildingamerica.gov](http://www.buildingamerica.gov)




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**bsc** **Overview of the Design approach**

Our approach follows three general steps:

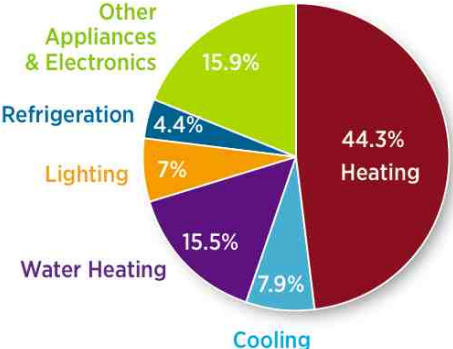
-  Step 1: Reduce Enclosure Energy Use
-  Step 2: Reduce Mechanical System Energy Use
-  Step 3: Add Site Generated Energy

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**bsc** **Background – Energy Use in the Home**


2005 Typical Residential On-Site Energy Consumption End Uses in the Western United States



End Use	Percentage
Heating	44.3%
Other Appliances & Electronics	15.9%
Water Heating	15.5%
Cooling	7.9%
Lighting	7%
Refrigeration	4.4%

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## Systems Engineered for Zero Cost


Energy-Efficiency Feature	Added Cost, per Home, Over Builder's Conventional Practice
Double-wall construction	\$2,500
R-50 attic insulation	\$300
R-40 floor insulation	\$540
Triple-pane windows	\$3,000
Solar water heating system	\$9,750
Heating system	(\$5,000)
Ventilation system	\$450
100% CFL	\$114
ENERGY STAR appliances	\$190
<b>Total</b>	<b>\$11,844</b>
Annual cost (when incorporated into a 30-year loan at 7% interest)	\$1,050
Annual utility bill savings	\$2,192
<b>Net Annual Cash Flow to Homeowner</b>	<b>\$1,142</b>

**Conclusion: These energy-efficiency improvements are actually money makers for the owner of this home.**

Cost estimates were provided by the builder. A 10% markup is assumed; incentives and rebates are not considered. .  
AFUE = annual fuel utilization efficiency, CFL = compact fluorescent lamp, EF=energy factor

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## Looking long-term . . .

End Use	Annual Electric Energy (Site)			Annual Gas Energy (Site)			Annual Utility Bill Reduction vs Benchmark
	Benchmark	Builder Standard Practice (Optional)	Prototype House	Benchmark	Builder Standard Practice (Optional)	Prototype House	
	(kWh/yr)	(kWh/yr)	(kWh/yr)	(therms/yr)	(therms/yr)	(therms/yr)	
Space Heating	1847.5		594	2142.5		778	\$2,533
Space Cooling	2763		1389				\$261
DHW	0		0	291		152	\$238
Lighting	3463		1626				\$349
Appliances and CFLs	6642		6292	0		0	\$67
Ventilation	13.5		15				(\$0)
<b>Total Usage</b>	<b>14529</b>	<b>0</b>	<b>9916</b>	<b>2433.5</b>	<b>0</b>	<b>930</b>	<b>\$3,447</b>
Site Generation							\$0
<b>Net Energy Use</b>	<b>14529</b>	<b>0</b>	<b>9916</b>	<b>2433.5</b>	<b>0</b>	<b>930</b>	<b>\$3,447</b>
Added Annual Mortgage Cost w/o Site Gen.							\$2,055
Net Cash Flow to Consumer w/o Site Gen.							\$1,392
Added Annual Mortgage Cost with Site Gen.							\$2,055
Net Cash Flow to Consumer with Site Gen.							<b>\$1,392</b>

- Balance initial investment with long-term savings
- Add technology in a cost-effective manner

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## Overview of the Design approach

Top ten elements in the design of high performance homes:

1. Design for comfort with as little added energy as possible
2. Built tight
3. Ventilate
4. Use more insulation
5. Provide for durability by controlling moisture
6. Design a roof that is sloped to the south
7. Use the most efficient equipment the project can afford
8. Use efficient lighting, appliances and match to occupant needs
9. Reduce energy use 40-70% before adding onsite energy generation
10. Commission mechanical and onsite energy systems

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## Overview of the Design approach


Top ten elements in the design of high performance homes:

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**1. Design for comfort with as little added energy as possible**

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**Start with the building itself**

- 1. Siting** (choice of building site or position on it)
  - exposure to wind and rain
  - micro-climate: trees for shading, wind-blocks
- 2. Orientation**
  - windows south, “service” rooms north
  - positioning and size of windows and doors
- 3. Building form**
  - external features: overhangs, breezeways, porches
  - building size and shape


- **At each step there are opportunities to reduce the energy that the building will use**
- **These changes decisions can't be made later**

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## Breezeways and Porches



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This slide features the BSC logo in the top left corner. The main title is "Breezeways and Porches". The central image shows a large, white, two-story house with a prominent front porch. The porch has a green metal roof that extends over the entrance area. The house is set on a large green lawn. In the bottom left corner, there is a copyright notice for 2011 Building Science Consulting. The page number 19 is located in the bottom right corner.

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## Overhangs




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This slide features the BSC logo in the top left corner. The main title is "Overhangs". The central image shows a blue house with a prominent front porch. The porch has a large overhang that extends over the entrance area. The house is set on a lawn with a sidewalk leading to the porch. In the bottom left corner, there is a copyright notice for 2011 Building Science Consulting. The page number 20 is located in the bottom right corner.

**bsc** House size and form – Unvented Roof




**Plan 'A'**  
30' x 30'  
2 Stories  
8:12 roof

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**bsc** House size and form – Unvented Roof



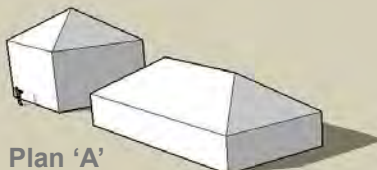
**Plan 'A'**  
30' x 30'  
2 Stories  
8:12 roof

**Floor Area** 1800 sq ft  
**Surface Area** 4142 sq ft

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**bsc** House size and form – Unvented Roof



**Plan 'A'**  
30' x 30'  
2 Stories  
8:12 roof


**Plan 'B'**  
30' x 60'  
1 Story  
8:12 roof

<b>Floor Area</b>	1800 sq ft
<b>Surface Area</b>	4142 sq ft

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**bsc** House size and form – Unvented Roof



**Plan 'A'**  
30' x 30'  
2 Stories  
8:12 roof

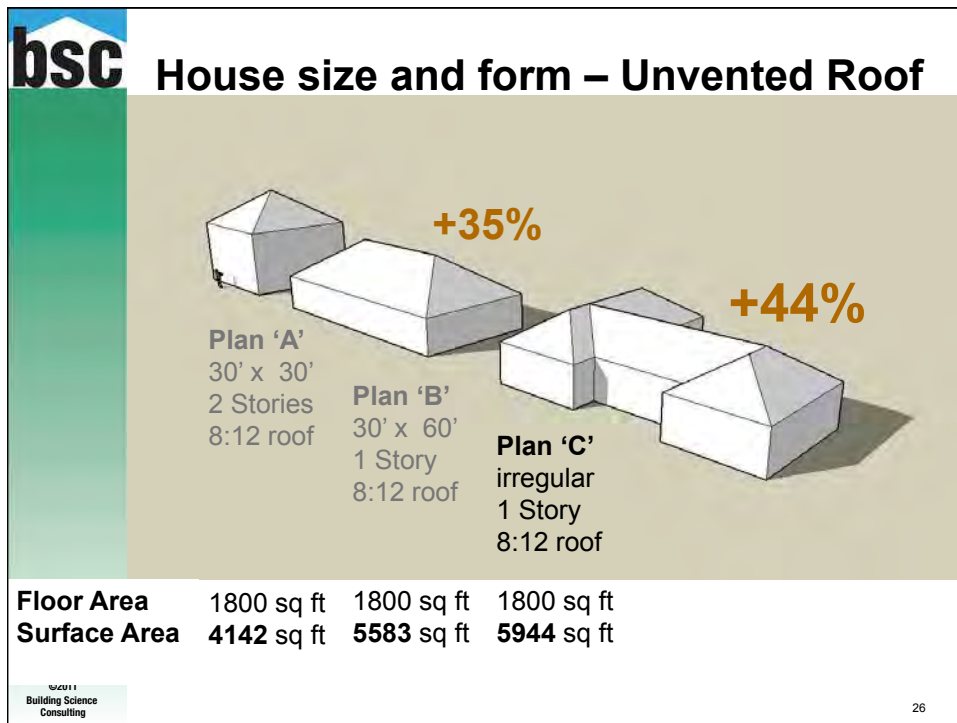
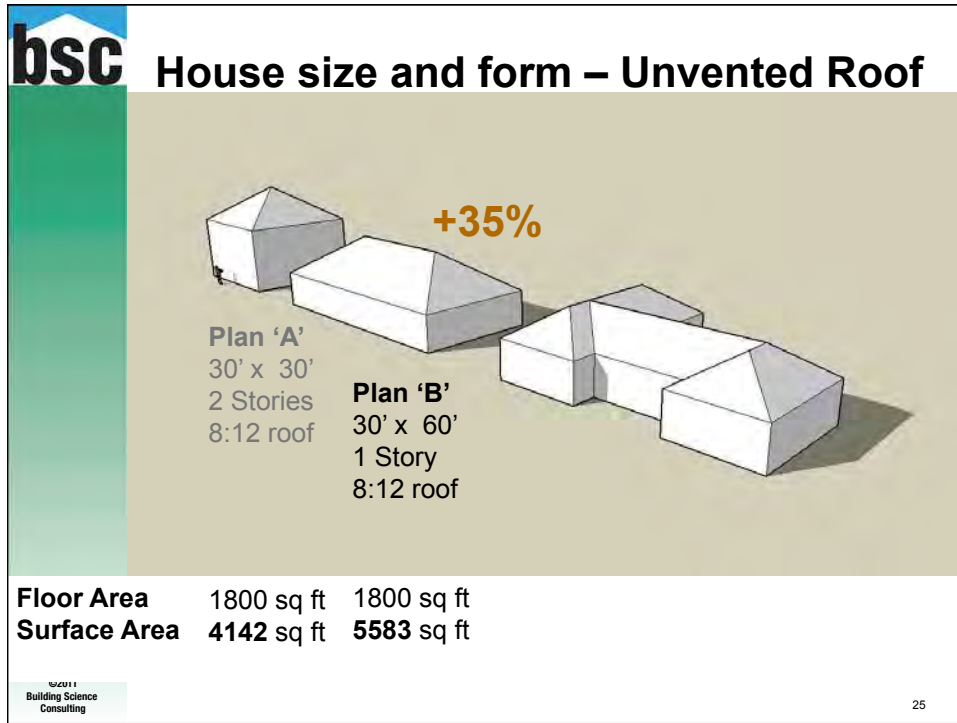
**Plan 'B'**  
30' x 60'  
1 Story  
8:12 roof

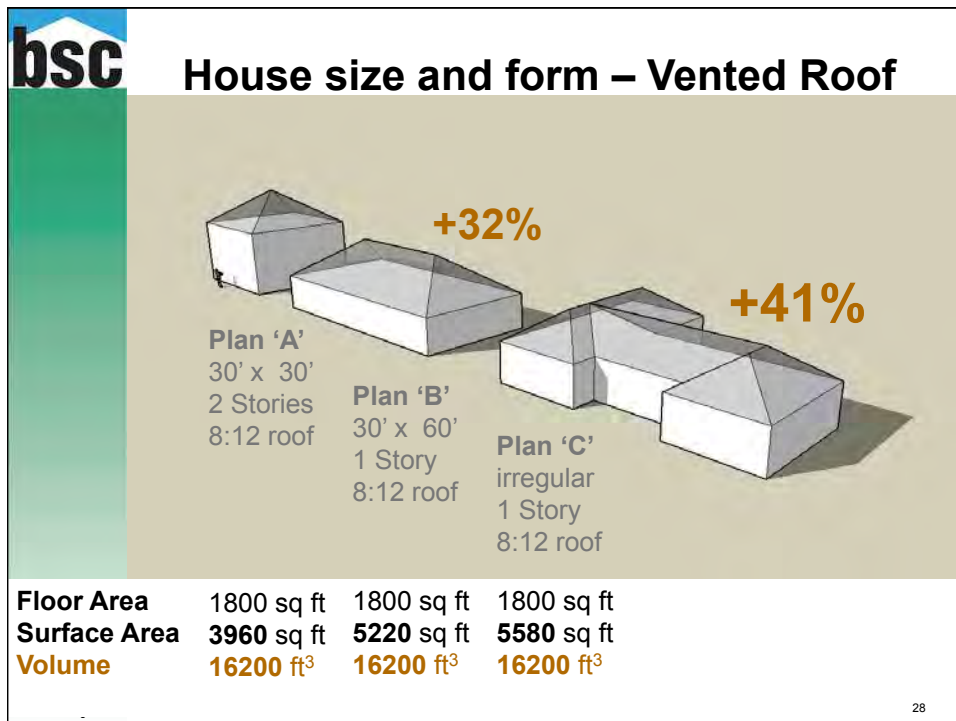
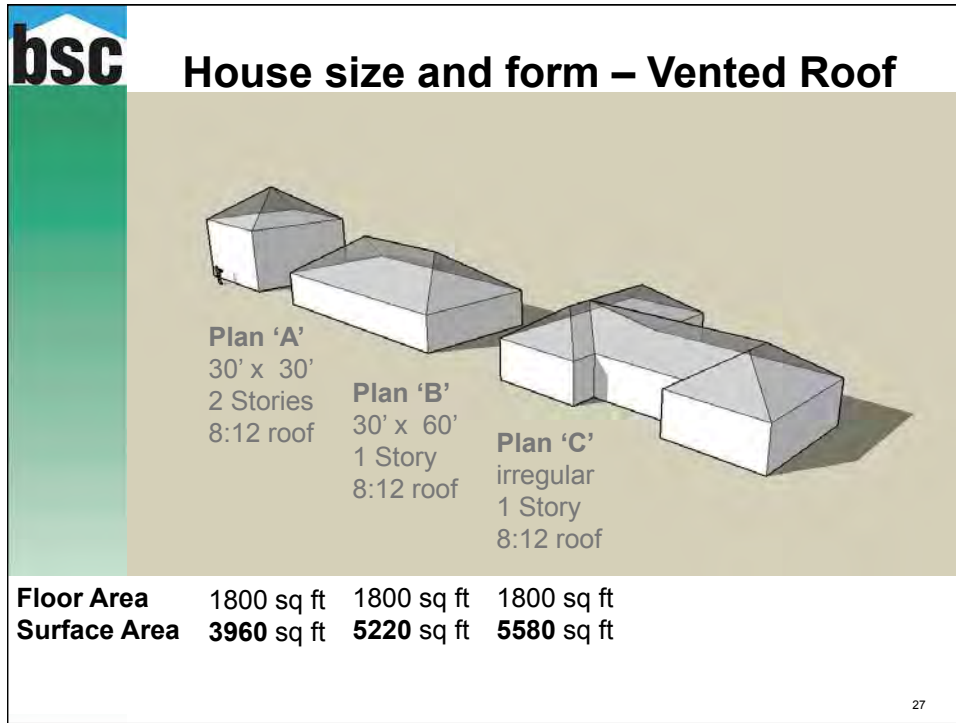
**+35%**

<b>Floor Area</b>	1800 sq ft	1800 sq ft
<b>Surface Area</b>	4142 sq ft	5583 sq ft

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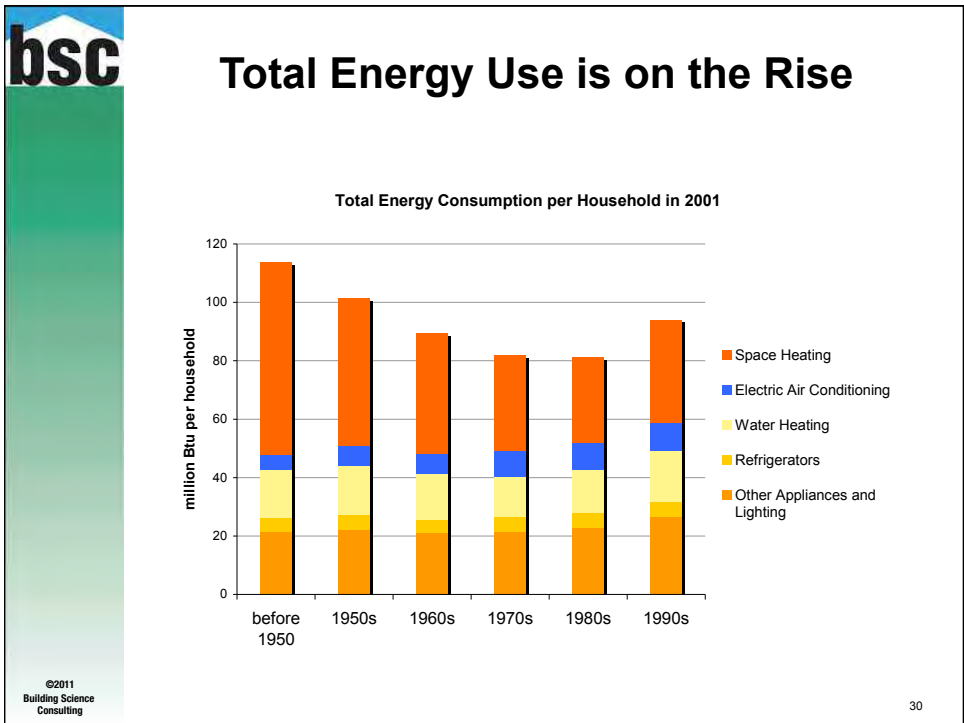


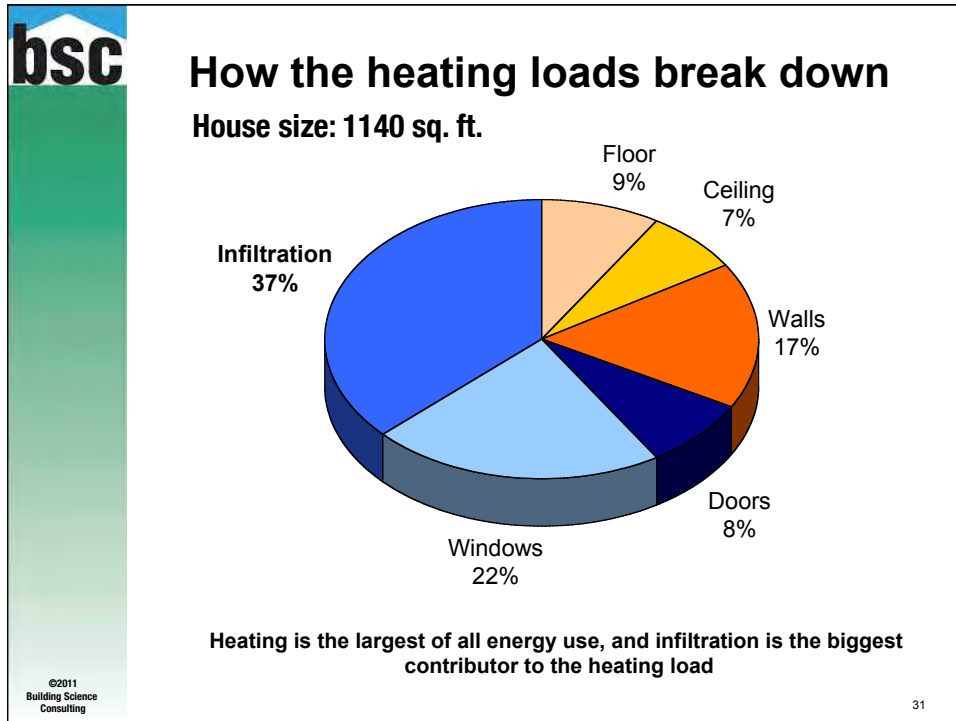
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## 2. Build tight

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## Why airtight buildings?

**Reasons to control airflow:**

- Energy - Heat loss/gain
- Durability - Air leakage condensation
- Occupant health - Pollution and odors
- Occupant comfort - Drafts, noise

**Do this using an “AIR BARRIER SYSTEM”**

- Many materials are air impermeable, most systems are not

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**Interior Air Flow Retarder Using Drywall and Framing**

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1" HD spray foam

4 1/2" cellulose or spray fiberglass

1" XPS insulating sheathing

2x6 frame wall

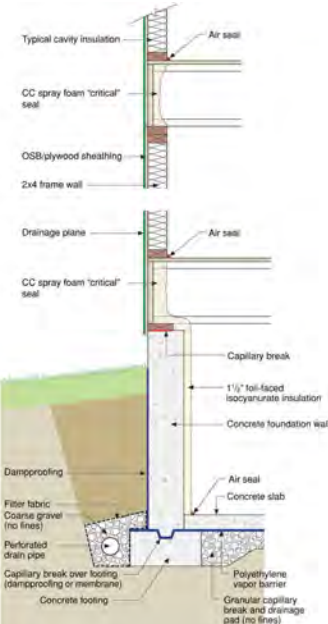

Drainage plane

Air seal

Air seal

34

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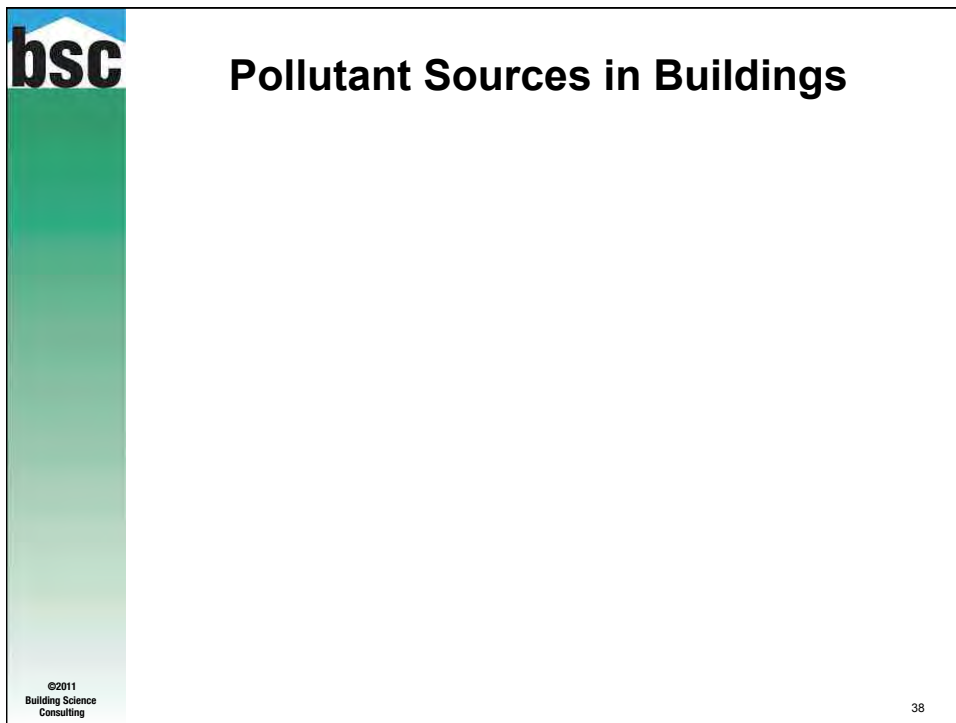
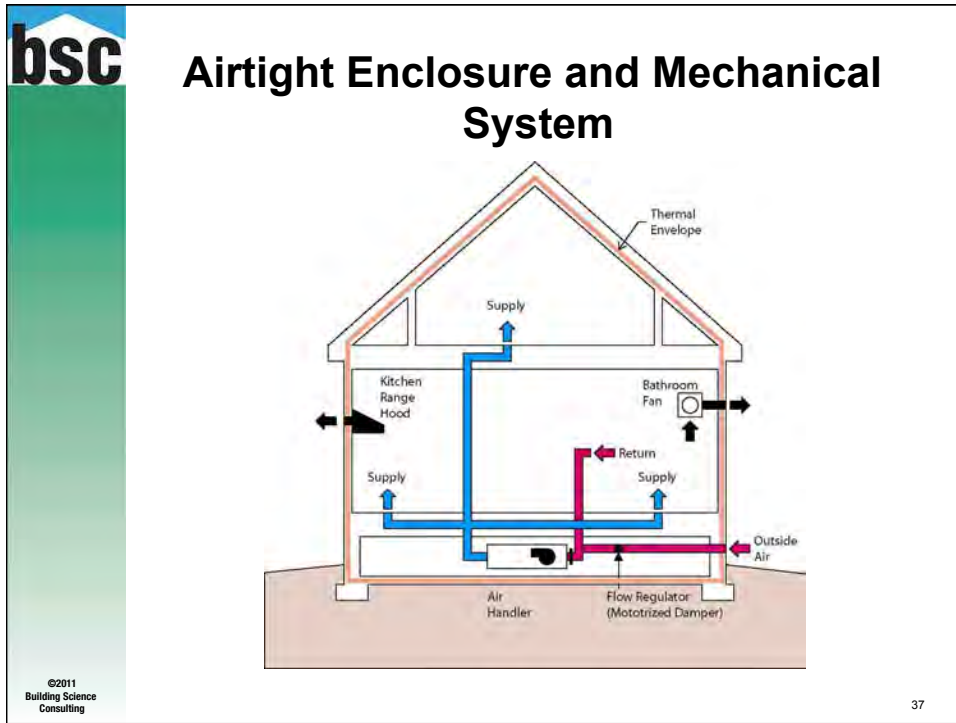
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### 3. Ventilate

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**bsc** **Inadvertent Depressurization**

Leaky air handling unit and supply ducts

Air handling unit

Supply

Return

Supply

Depressurized conditioned space inducing infiltration

Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

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**bsc** **Tight Ductwork and Sealed Combustion**

A.O. Smith EnergySaver

ENERGYGUIDE

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## 4. Use more insulation

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## It's not just how much you use . . .

2x6 Framed Wall

simple R-value through studspace

clear wall R-value

thermal bridging heat flow

siding sheathing batt + framing drywall

warm interior

cold exterior

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**bsc** **Surface temperature and condensation**

Thermal Bridging Causes Surface Condensation

The diagram illustrates a room with various areas where condensation occurs. Orange arrows point to the corners, window frames, and behind furniture, indicating where heat is lost and air is trapped. A separate cross-section shows an exterior closet with condensation on the interior wall.

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**bsc** **Eliminating thermal bridging**

2x4 with Exterior Insulation

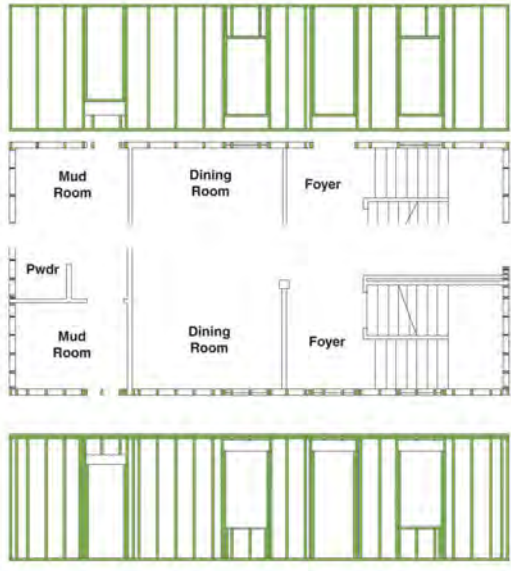
The diagram compares two wall construction methods. On the left, a simple studspace shows heat loss through the studs. On the right, a clear wall with exterior insulation shows that the R-value is the same as nominal. A window opening is also shown with a cross-section of the framing and insulation.

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## Advanced Wall Framing



**Wall 1 (2x6 24"o.c.)**

Plate	36'-0"	2
Stud	8'-0"	20
Jack	7'-9 1/4"	6
Jack 2	6'-8 1/2"	2
Cripple 2	1'-2 1/4"	2
Cripple 3	2'-1"	3


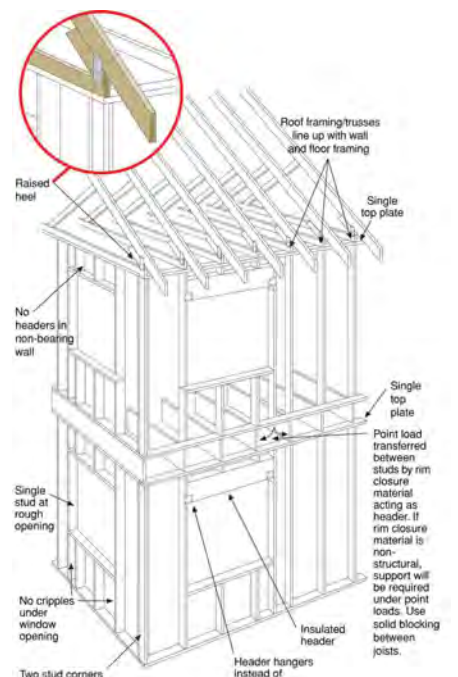
Gross wall area 327 ft<sup>2</sup>  
 Window area 74 ft<sup>2</sup>  
 Opaque area 45.17 ft<sup>2</sup>  
 Cavity area 207.83 ft<sup>2</sup>

**Wall 1 (2x6 16"o.c.)**

Plate	36'-0"	3
Stud	8'-8 1/2"	29
Jack	7'-8 1/2"	6
Jack 2	6'-8 1/2"	2
Cripple 1	0'-2 1/4"	6
Cripple 2	1'-2 1/4"	2
Cripple 3	2'-1"	8

Gross wall area 327 ft<sup>2</sup>  
 Window area 74 ft<sup>2</sup>  
 Opaque area 65.60 ft<sup>2</sup>  
 Cavity area 181.40 ft<sup>2</sup>

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Roof framing/trusses line up with wall and floor framing

Single top plate

Point load transferred between studs by rim closure material acting as header. If rim closure material is non-structural, support will be required under point loads. Use solid blocking between joists.

Insulated header

Header hangers instead of jack studs

Single stud at rough opening

No cripples under window opening

Two stud corners


No headers in non-bearing wall

Raised heel

Single top plate

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**5. Provide for durability by controlling moisture**

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**Why control moisture?**

1. Our efforts to save energy and reduce the flow of heat through building assemblies have **reduced drying potentials** and, therefore, increased the importance of controlling moisture flow through building assemblies.
2. Building **materials last longer** when their faces are exposed to similar or equal temperature and humidity.
3. Three things destroy materials in general and wood in particular: **water, heat, and ultraviolet radiation**. Of these three, water is the most important by an order of magnitude.

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## How to control moisture?

In moisture control, the priority is **liquid water first**, particularly when it comes in the forms of rain and groundwater. In these forms it is referred to as “bulk” water.

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## How to control moisture?

Following are **air-transported vapor** and then **diffusive vapor**, all other things being equal.

4x8 sheet of gypsum board  
Interior at 70° F and 40% RH

1/3 quart of water

4x8 sheet of gypsum board with a 1 in<sup>2</sup> hole  
Interior at 70° F and 40% RH

30 quarts of water

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## Remember:

It's always a question of **quantities** and **rates**, of wetting and drying, and the tolerance of materials (individually and in combination) for each and all of the above.

- When the rate of wetting exceeds the rate of drying, **accumulation** occurs.
- When the quantity of accumulated moisture exceeds the storage capacity of the material or assembly, **problems** occur.
- The storage capacity of a material or assembly depends on **time, temperature**, and the **material** itself.


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**bsc** Fungal growth = bad “green” building



58



**6. Design a roof that is sloped to the south**

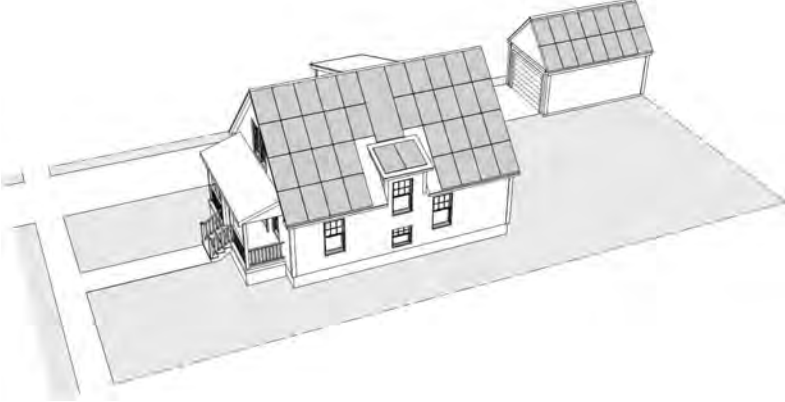


60

A slide with a white background and a green vertical bar on the left side. The 'bsc' logo is in the top-left corner. The main text is '6. Design a roof that is sloped to the south' in bold black font. In the bottom-left corner, there is a copyright notice: '©2011 Building Science Consulting'. In the bottom-right corner, there is the page number '60'.

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## Plan to use the available solar resource



These two roofs total about 900 sq.ft. of south sloping roof and can accommodate about a 9 kW PV system and 40 sq. ft. of SHW panels . . . but the roof needs to face the right direction!




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## But the loads must be minimized first

Recall the three general steps:

-  Step 1: Reduce Enclosure Energy Use
-  Step 2: Reduce Mechanical System Energy Use
-  Step 3: Add Site Generated Energy

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**bsc** **Roof area is a future resource**

A photograph of a two-story house with a green metal roof. Several solar panels are mounted on the roof. The house has a large window and a stone pillar. The scene is set outdoors with trees and a clear sky.

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## On-site Renewable Energy

The slide contains three schematic diagrams of on-site renewable energy systems. The top diagram is a 'GSHP Schematic' showing a house with a ground-source heat pump system. It includes a 'Ground Loop' with 'Vertical Boreholes' and a 'Heat Exchanger' connected to the house's 'HVAC System'. The middle diagram is a 'Solar Hot Water Schematic' showing a house with solar panels on the roof. It includes a 'Solar Collector', 'Water Storage Tank', and 'Distribution System' connected to the house's 'Water Heating System'. The bottom diagram is a 'Photovoltaic Schematic' showing a house with solar panels on the roof. It includes a 'Solar Panel Array', 'Inverter', and 'Electrical System' connected to the house's 'Electrical System'.

GSHP Schematic

Solar Hot Water Schematic

Photovoltaic Schematic

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## Summary of the Design approach

Top ten elements in the design of high performance homes:

1. Design for comfort with as little added energy as possible
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## Resources

Building Science Corporation  
**Designs that Work – Cold Climate Case Study**  
*find this at:*  
[www.buildingscience.com/dtw](http://www.buildingscience.com/dtw)

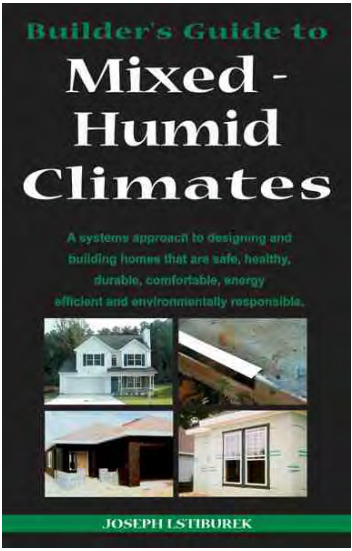
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## Resources

Building Science Corporation  
**Builder's Guide to Cold Climates**  
*find this at:*  
[www.buildingsciencepress.com](http://www.buildingsciencepress.com)



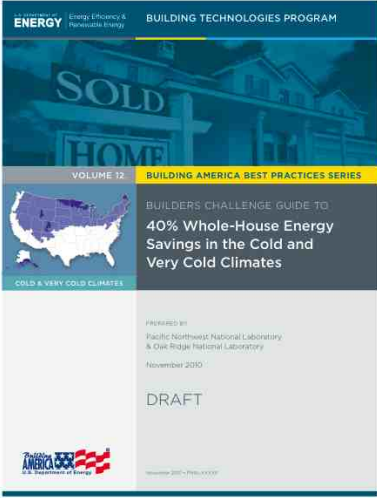
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## Resources

Building America  
**Cold Climate Best Practices Guide**  
*find this at:*  
[www.buildingamerica.gov](http://www.buildingamerica.gov)  
(look for "publications")



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## Questions?

**Contact us:**

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