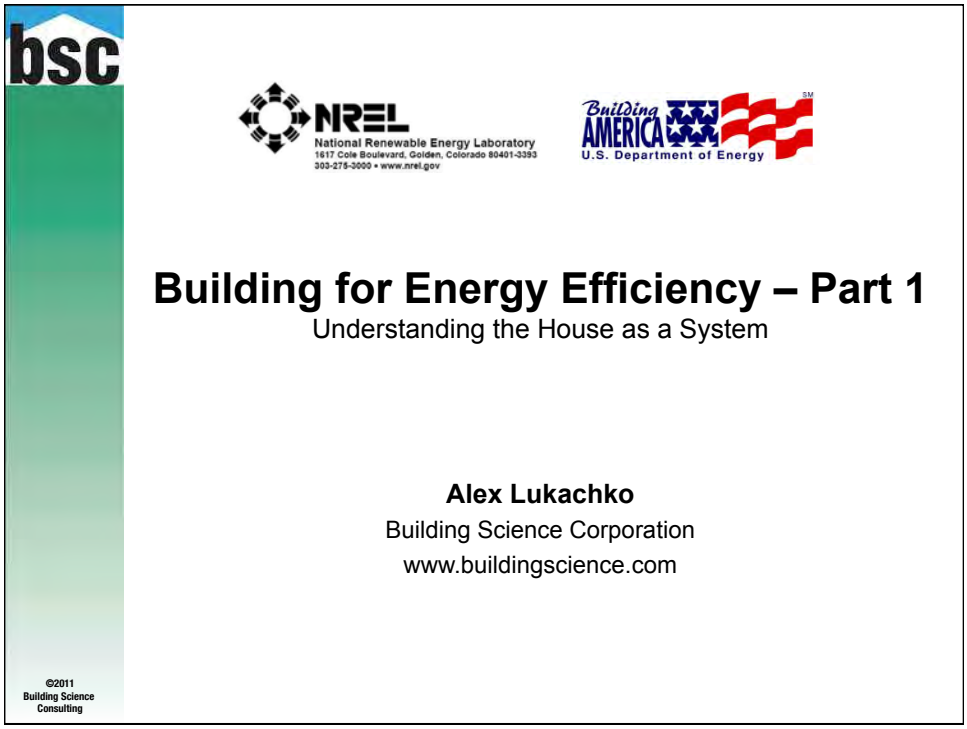
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NREL
National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov
Building AMERICA
U.S. Department of Energy
Building for Energy Efficiency – Part 1
Understanding the House as a System
Alex Lukachko
Building Science Corporation
www.buildingscience.com
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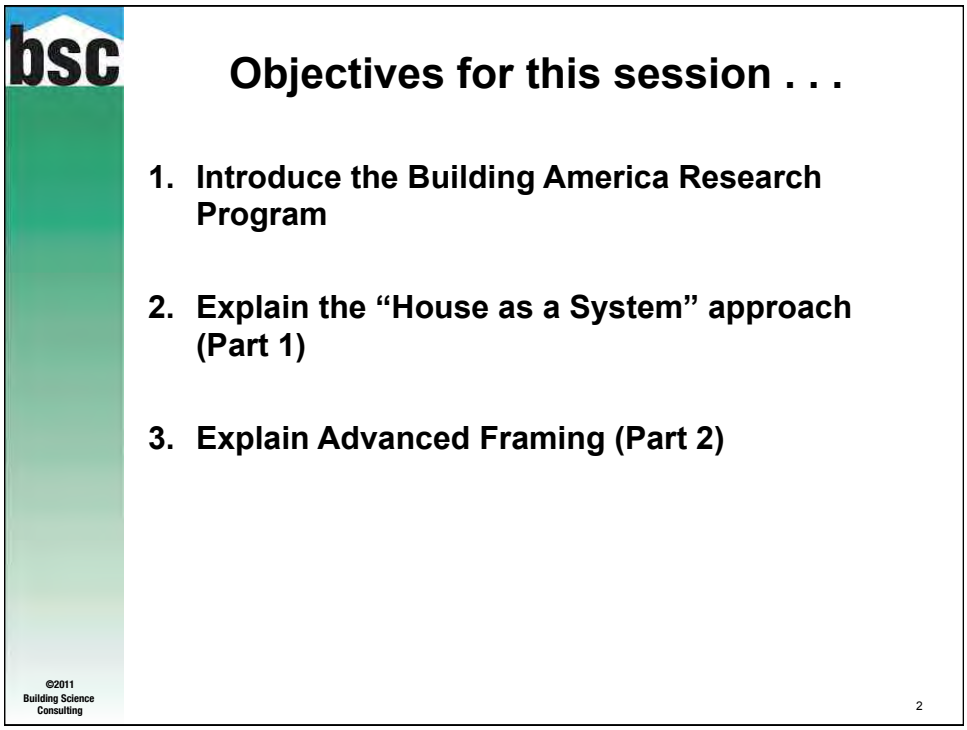
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Objectives for this session . . .
1. Introduce the Building America Research Program
2. Explain the "House as a System" approach (Part 1)
3. Explain Advanced Framing (Part 2)
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2

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

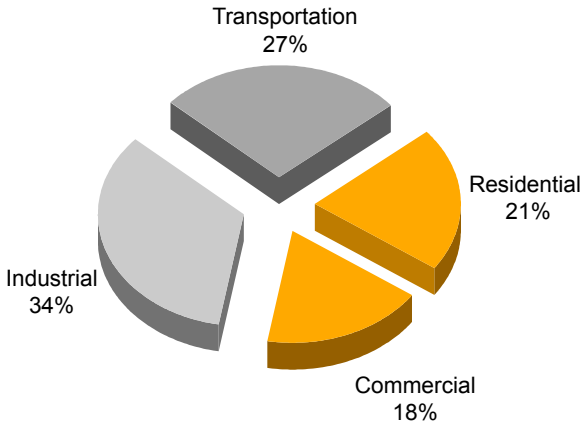
The nation:

- 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

3

Assessing the Impact of US Buildings

Total Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data - www.eia.doe.gov/emeu/aer

4

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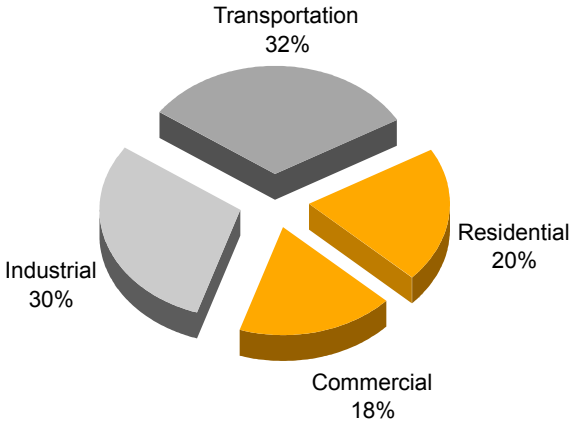
Contribution to Climate Change

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data - www.eia.doe.gov/emeu/aer

5

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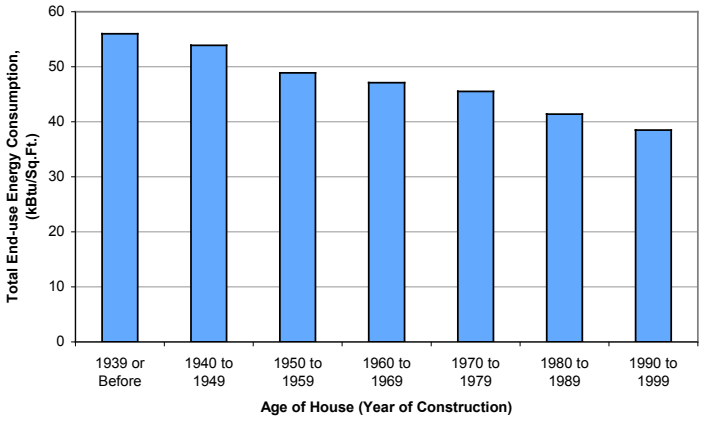
Energy Efficient Construction is Catching on

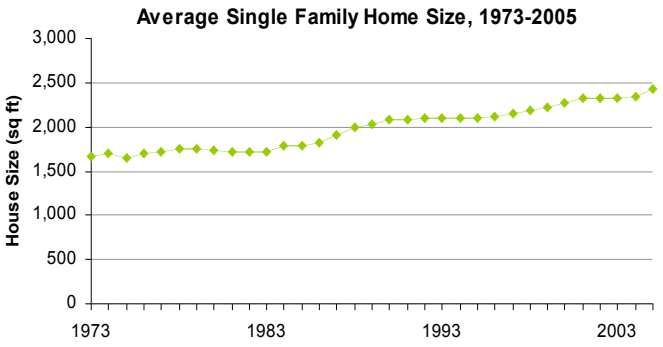
Total End-Use Residential Energy Consumption in 2001 per Square Foot by Age of Construction



6

But size matters . . .

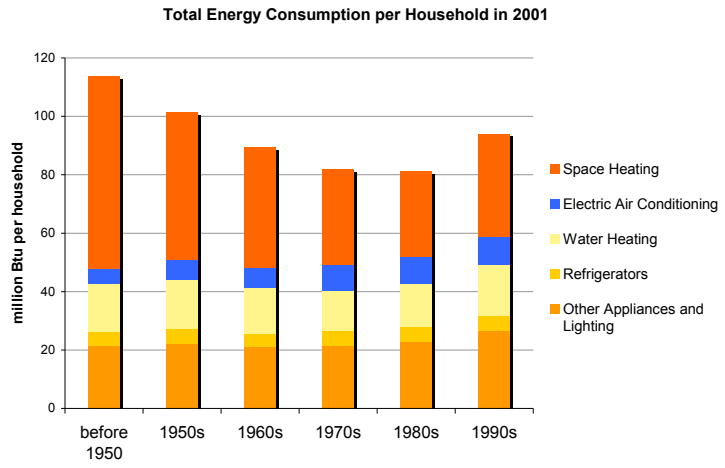
- Average House Size in **1940: ~1100 sq ft**[1]
- Average House Size in **1973: 1660 sq ft**[2]
- Average House Size in **2005: 2434 sq ft**



1. Wilson, Alex and Jessica Boehland "Small is Beautiful" *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

7

Total Energy Use is on the Rise



8

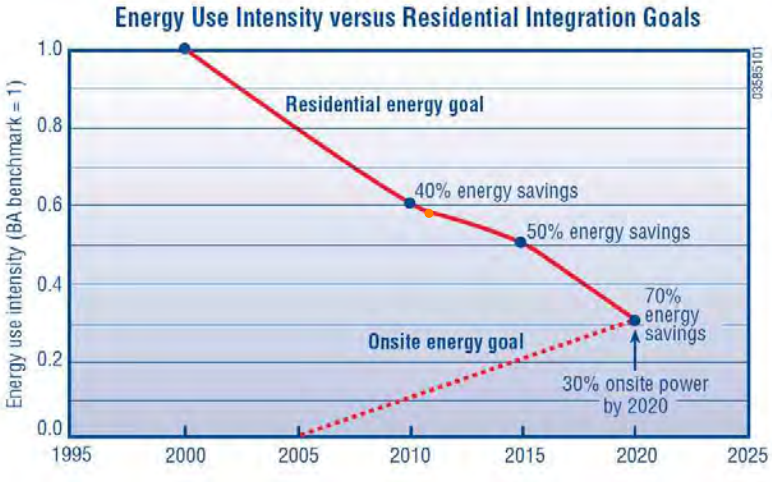
Building America

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

9

Building America Research Goals

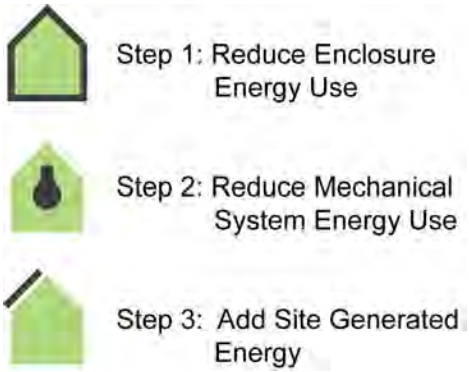


40,000 houses in 34 states

10

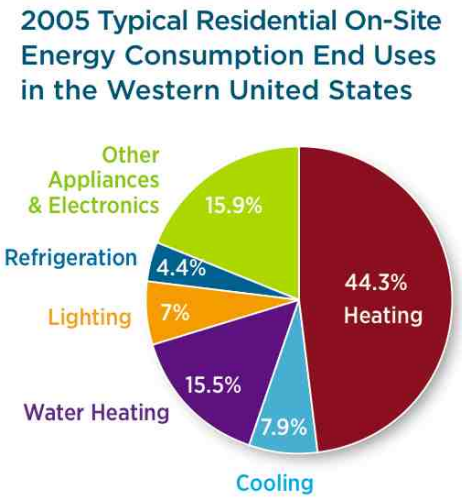
Overview of the Design approach

Our approach follows three general steps:



11

Background – Energy Use in the Home



12

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
Total	**$11,844**
Annual cost (when incorporated into a 30-year loan at 7% interest)	$1,050
Annual utility bill savings	$2,192
Net Annual Cash Flow to Homeowner	**$1,142**
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 . . .

	Annual Electric Energy (Site)			Annual Gas Energy (Site)			
End Use	Benchmark (kWh/yr)	Builder Standard Practice (Optional) (kWh/yr)	Prototype House (kWh/yr)	Benchmark (therms/yr)	Builder Standard Practice (Optional) (therms/yr)	Prototype House (therms/yr)	Annual Utility Bill Reduction vs Benchmark ($/yr)
Space Heating	1647.5		594	2142.5		778	$2,533
Space Cooling	2763		1389				$261
DHW	0		0	291		152	$218
Lighting	3463		1626				$349
Appliances and MELs	6642		6292	0		0	$87
Ventilation	13.5		15				($0)
Total Usage	**14529**	**0**	**9916**	**2433.5**	**0**	**930**	**$3,447**
Site Generation							$0
Net Energy Use	**14529**	**0**	**9916**	**2433.5**	**0**	**930**	**$3,447**
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.							**$1,392**

- **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

15

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

17

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**

18

Breezeways and Porches

19

Overhangs

20

House size and form – Unvented Roof

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

21

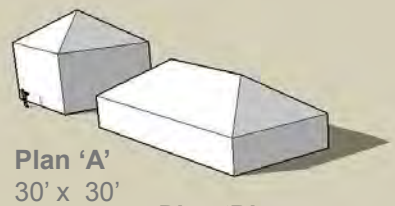
House size and form – Unvented Roof

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

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

22

House size and form – Unvented Roof



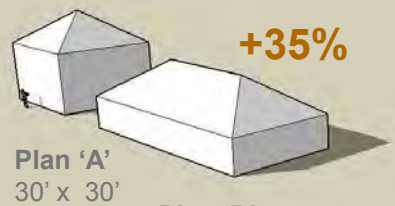
Plan 'A'
30' x 30'
2 Stories
8:12 roof

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

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

23

House size and form – Unvented Roof



+35%

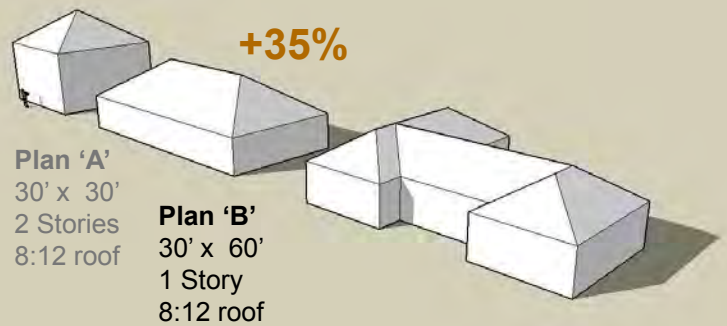
Plan 'A'
30' x 30'
2 Stories
8:12 roof

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

Floor Area	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft

24

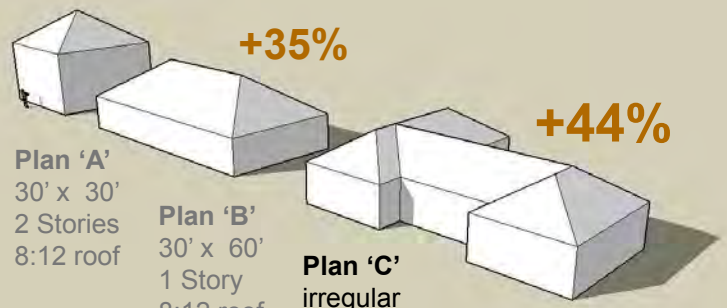
House size and form – Unvented Roof



Floor Area	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft

25

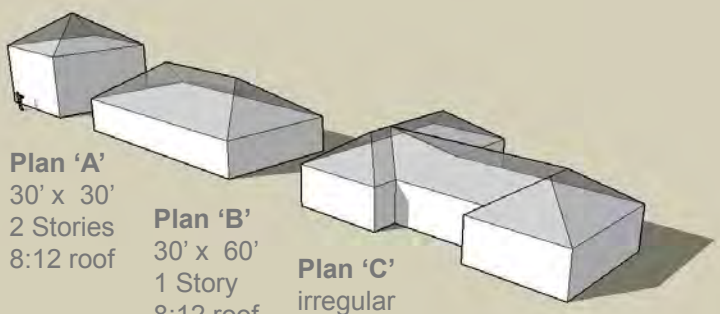
House size and form – Unvented Roof



Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft	**5944** sq ft

26

House size and form – Vented Roof



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

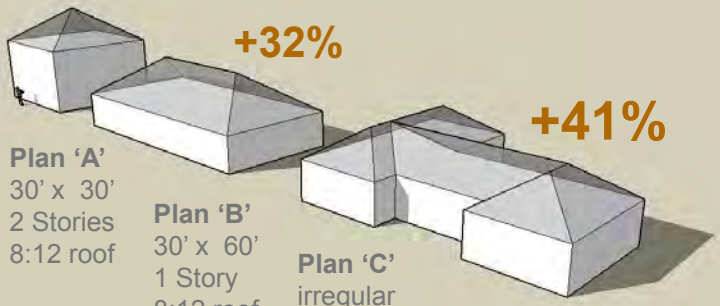
Plan 'B'
30' x 60'
1 Story
8:12 roof

Plan 'C'
irregular
1 Story
8:12 roof

Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**3960** sq ft	**5220** sq ft	**5580** sq ft

27

House size and form – Vented Roof



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

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

Plan 'C'
irregular
1 Story
8:12 roof

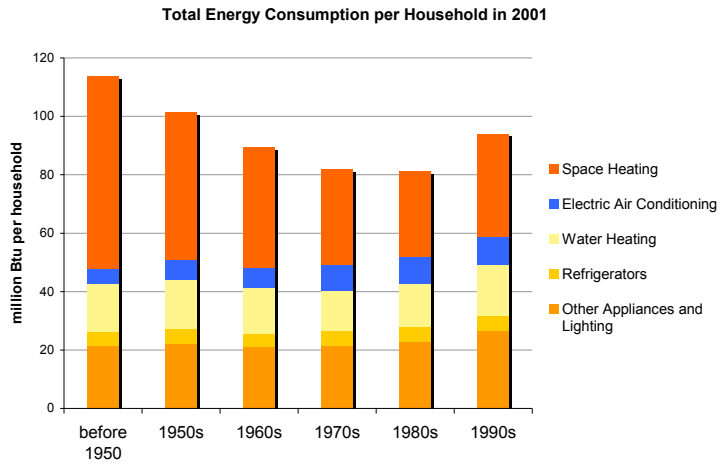
Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**3960** sq ft	**5220** sq ft	**5580** sq ft
Volume	**16200** ft^3	**16200** ft^3	**16200** ft^3

28

2. Build tight

29

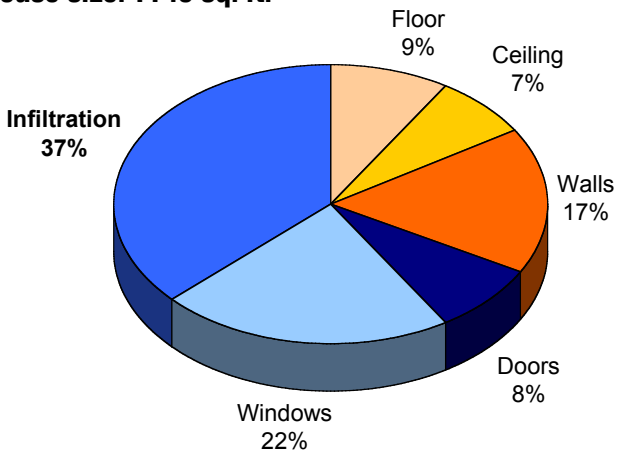
Total Energy Use is on the Rise



30

How the heating loads break down

House size: 1140 sq. ft.



Heating is the largest of all energy use, and infiltration is the biggest contributor to the heating load

31

Why airtight buildings?

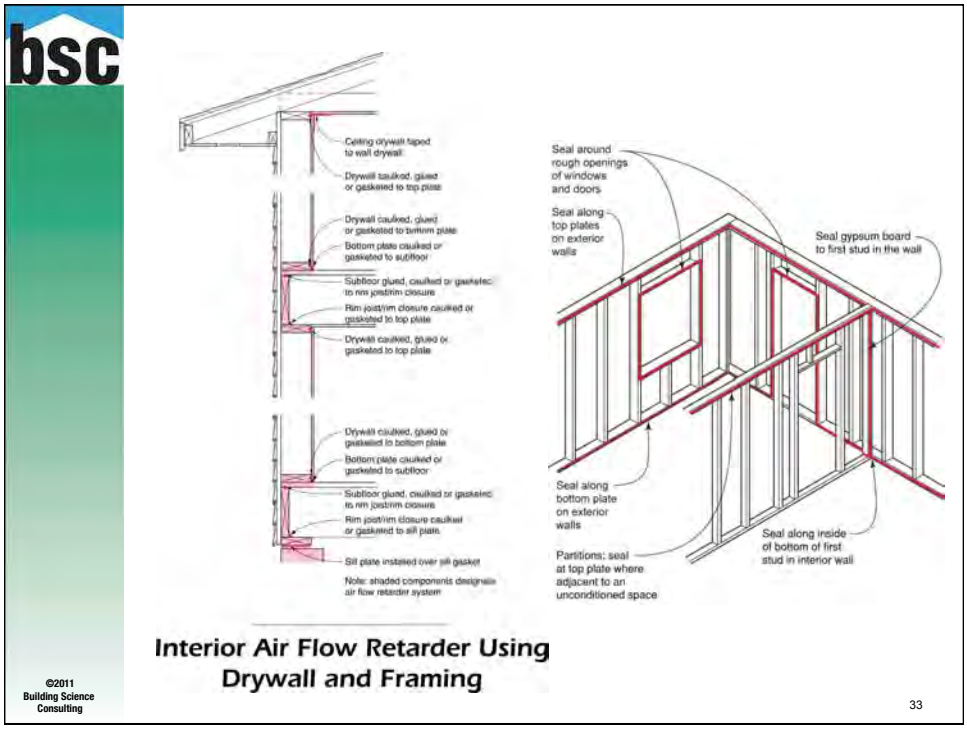
Reasons to control airflow:

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

Do this using an "AIR BARRIER SYSTEM"

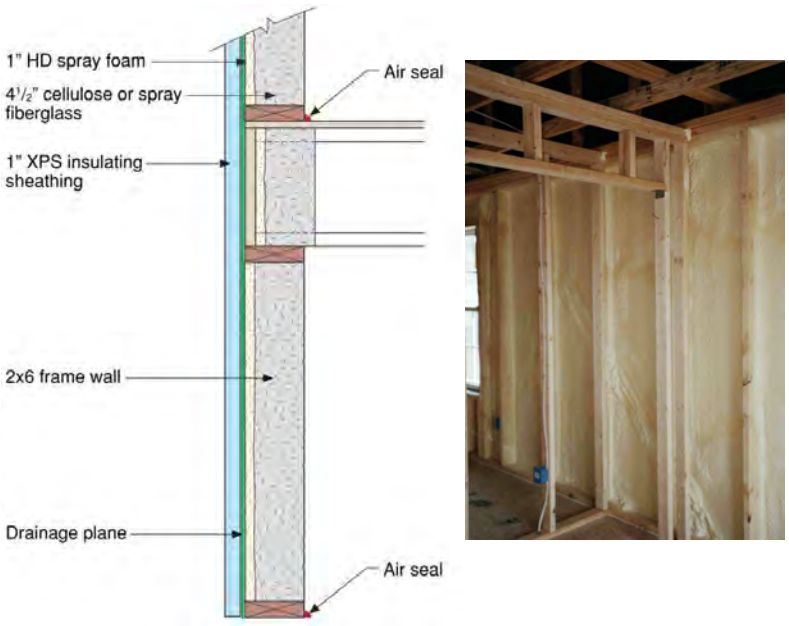
- Many materials are air impermeable, most systems are not

32



Interior Air Flow Retarder Using Drywall and Framing

33



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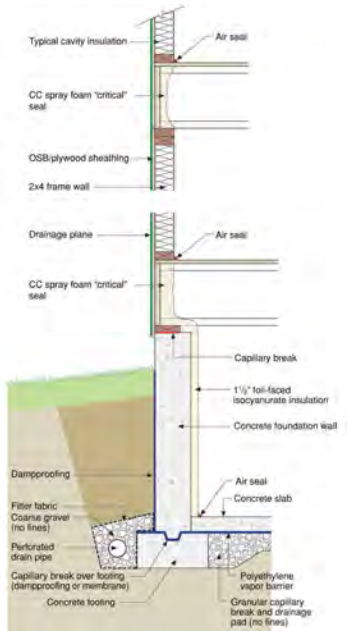
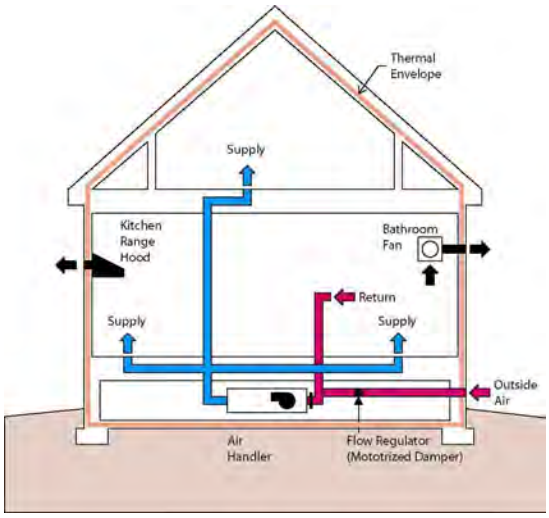


35

3. Ventilate

36

Airtight Enclosure and Mechanical System



37

Pollutant Sources in Buildings

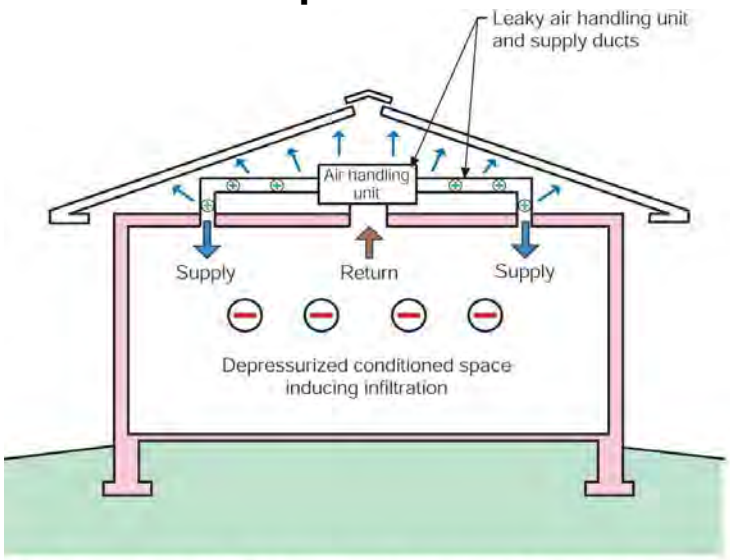
38

Where should you put the holes?

Outside Air Intake

Direct vented to outside

Inadvertent Depressurization



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

43

Tight Ductwork and Sealed Combustion

44

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4. Use more insulation

45

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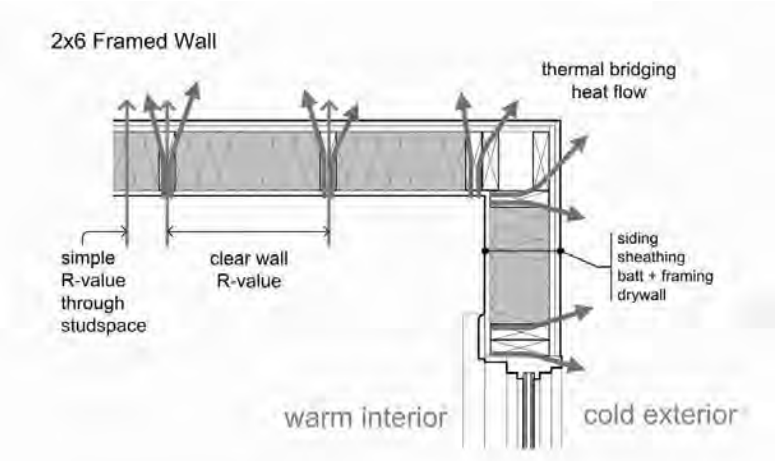
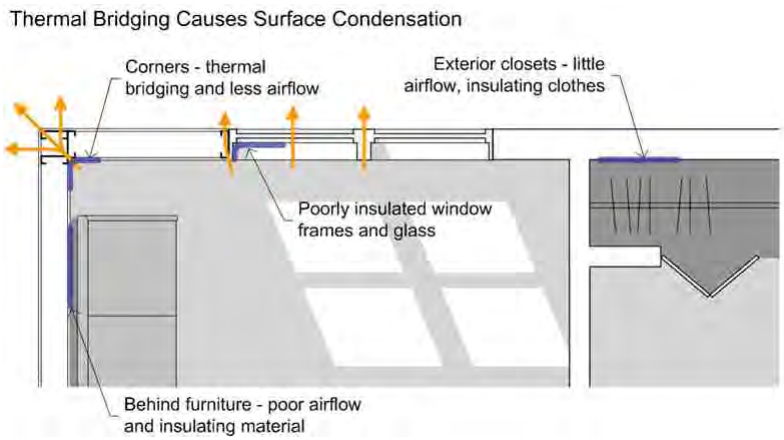
It's not just how much you use . . .



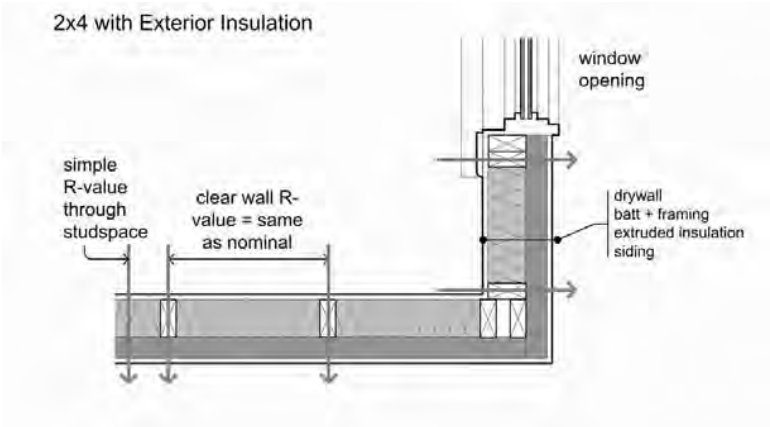
46

Surface temperature and condensation



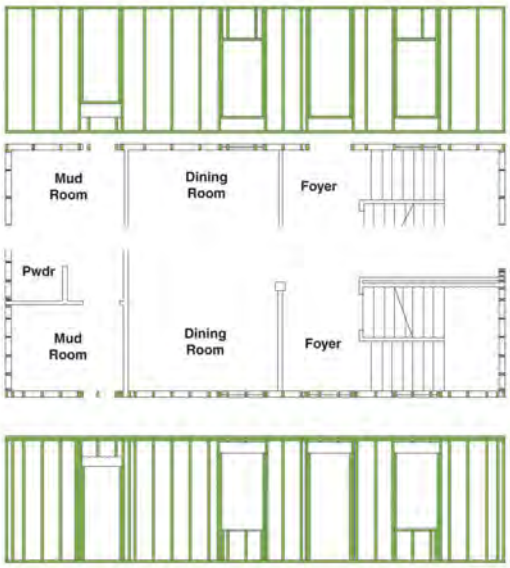
47

Eliminating thermal bridging



48

Advanced Wall Framing



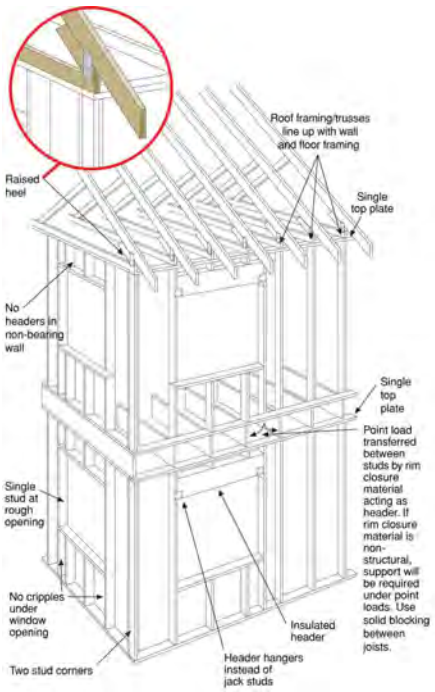
Wall 1 (2x6 24"o.c.)

Plate	36'-0"	2
Stud	8'-0"	20
Jack	7'-9¼"	6
Jack 2	6'-8½"	2
Cripple 2	1'-2¾"	2
Cripple 3	2'-1"	3
Gross wall area		327 ft²
Window area		74 ft²
Opaque area		45.17 ft²
Cavity area		207.83 ft²

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

Plate	36'-0"	3
Stud	8'-8½"	29
Jack	7'-8½"	6
Jack 2	6'-8½"	2
Cripple 1	0'-2¾"	6
Cripple 2	1'-2¾"	2
Cripple 3	2'-1"	8
Gross wall area		327 ft²
Window area		74 ft²
Opaque area		65.60 ft²
Cavity area		181.40 ft²

49



50


R-19
R-19
R-19

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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.

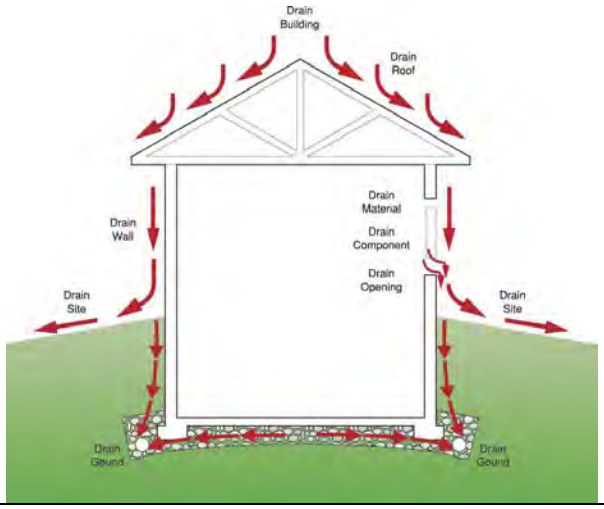
2. Building **materials last longer** when their faces are exposed to similar or equal temperature and humidity.

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.

54

How to control moisture?

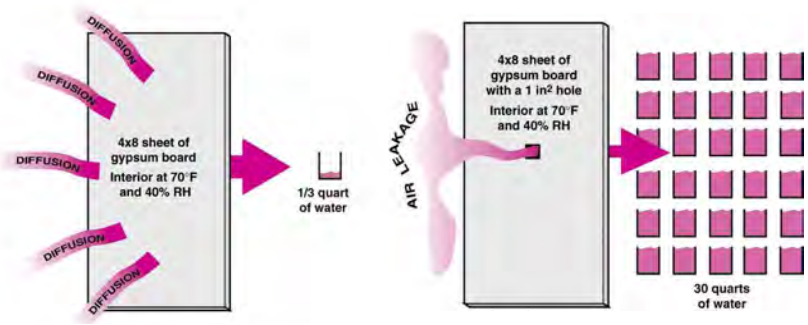
In moisture control, the priority is **liquid water first**, particularly when it comes in the forms of rain and groundwater. In these forms it is referred to as “bulk” water.



55

How to control moisture?

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



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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.

57

Fungal growth = bad "green" building

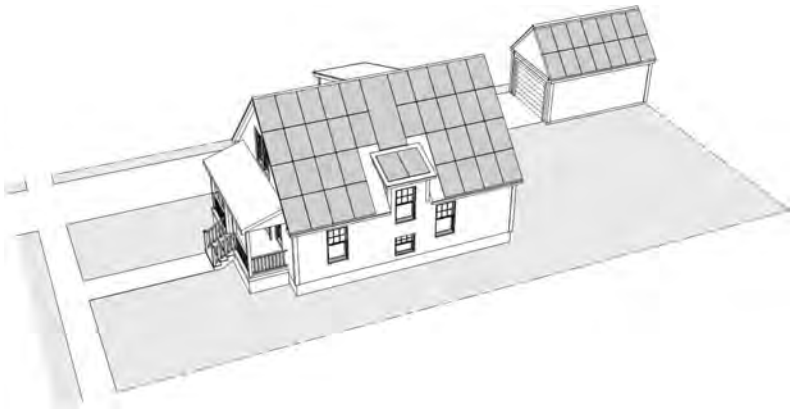
58

59

6. Design a roof that is sloped to the south

60

Plan to use the available solar resource

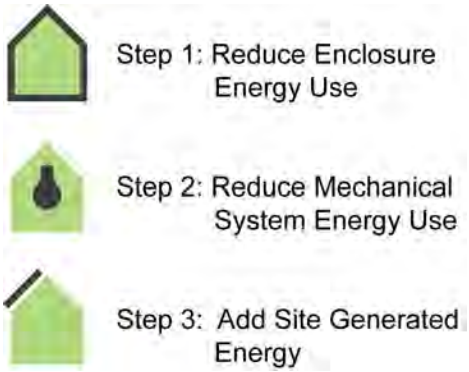


These two roofs total about 900 sq.ft. of south sloping roof and can accommodate about a 9 kW PV system and 40 sq. ft. of SHW panels . . . but the roof needs to face the right direction!

61

But the loads must be minimized first

Recall the three general steps:



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Roof area is a future resource

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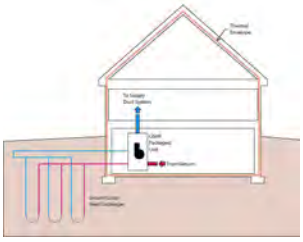
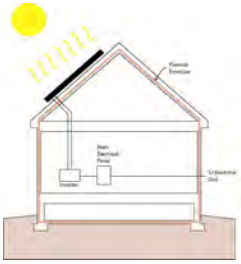
On-site Renewable Energy



GSHP Schematic

Solar Hot Water Schematic



Photovoltaic Schematic

65

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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
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

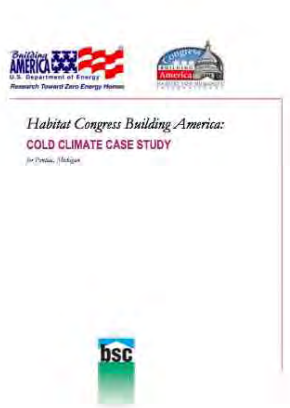
Resources

Building Science Corporation

Designs that Work – Cold Climate Case Study

find this at:

www.buildingscience.com/dtw



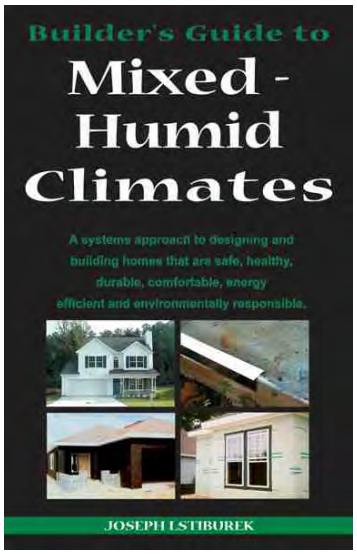
Resources

Building Science Corporation

Builder's Guide to Cold Climates

find this at:

www.buildingsciencepress.com



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Resources

Building America

Cold Climate Best Practices Guide

find this at:

www.buildingamerica.gov

(look for "publications")

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Questions?

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