Beyond Weatherization: Deep Energy Retrofits for the Real World

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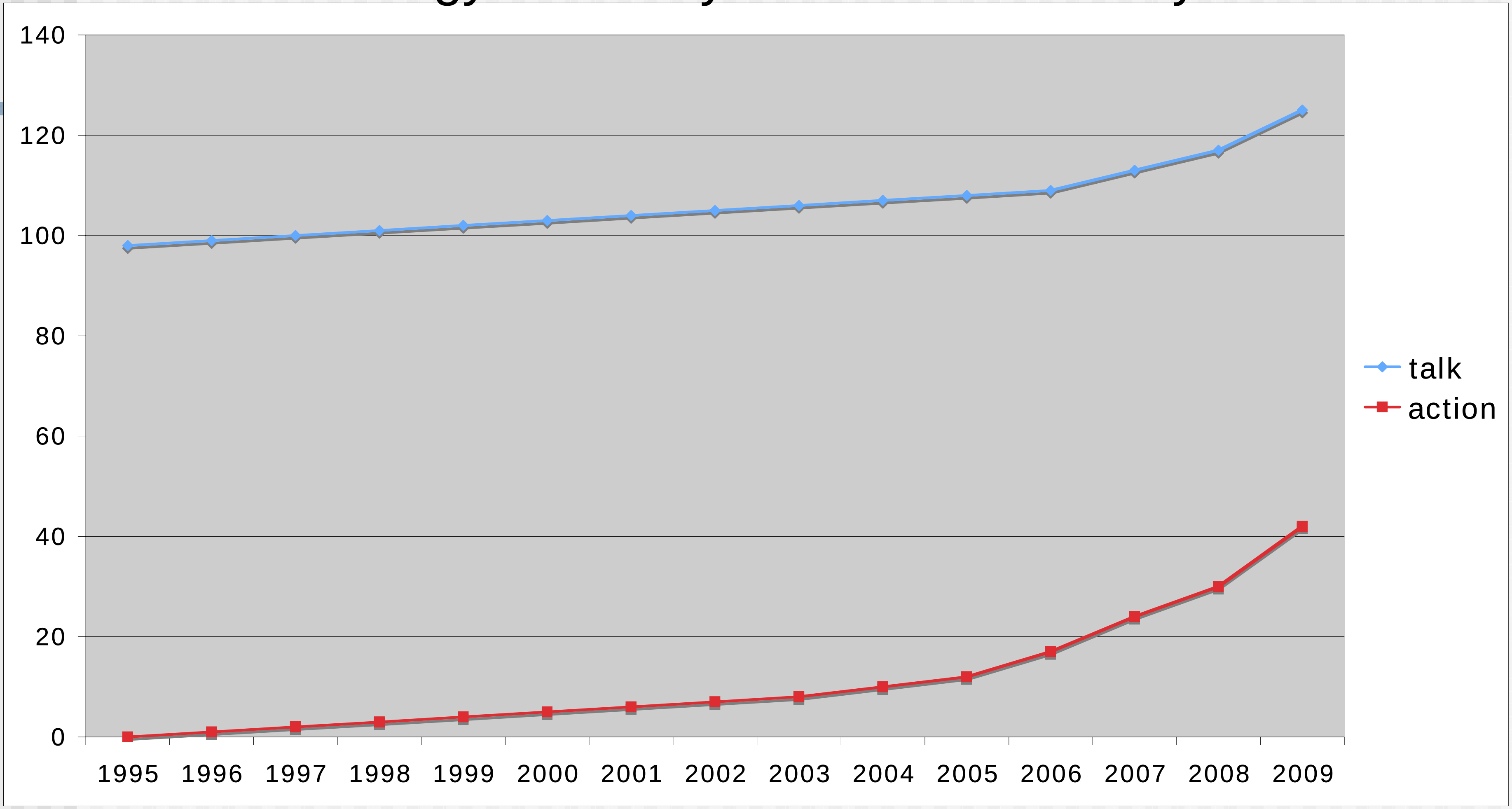
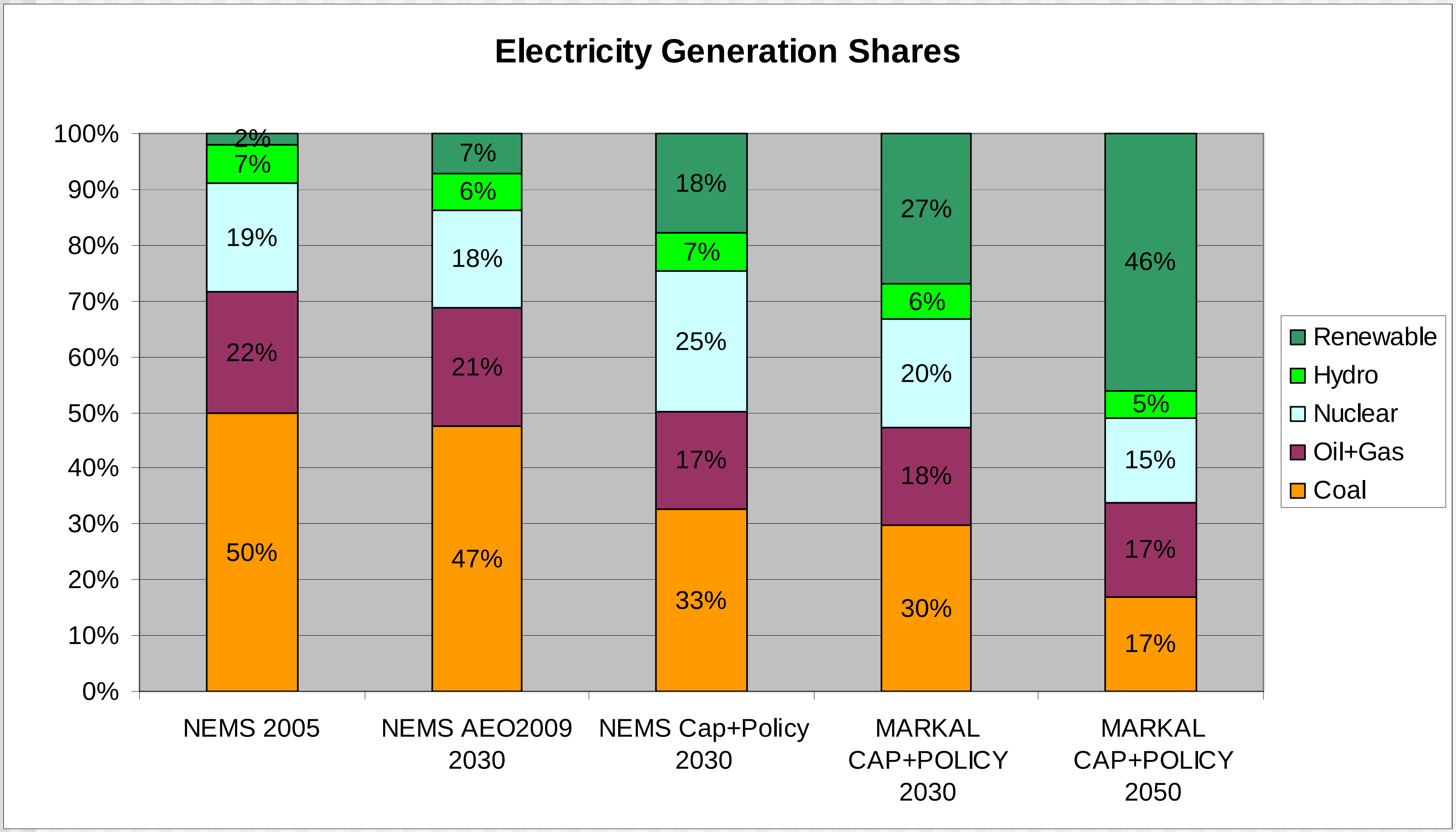
Paul's energy-efficiency career: Trend analysis



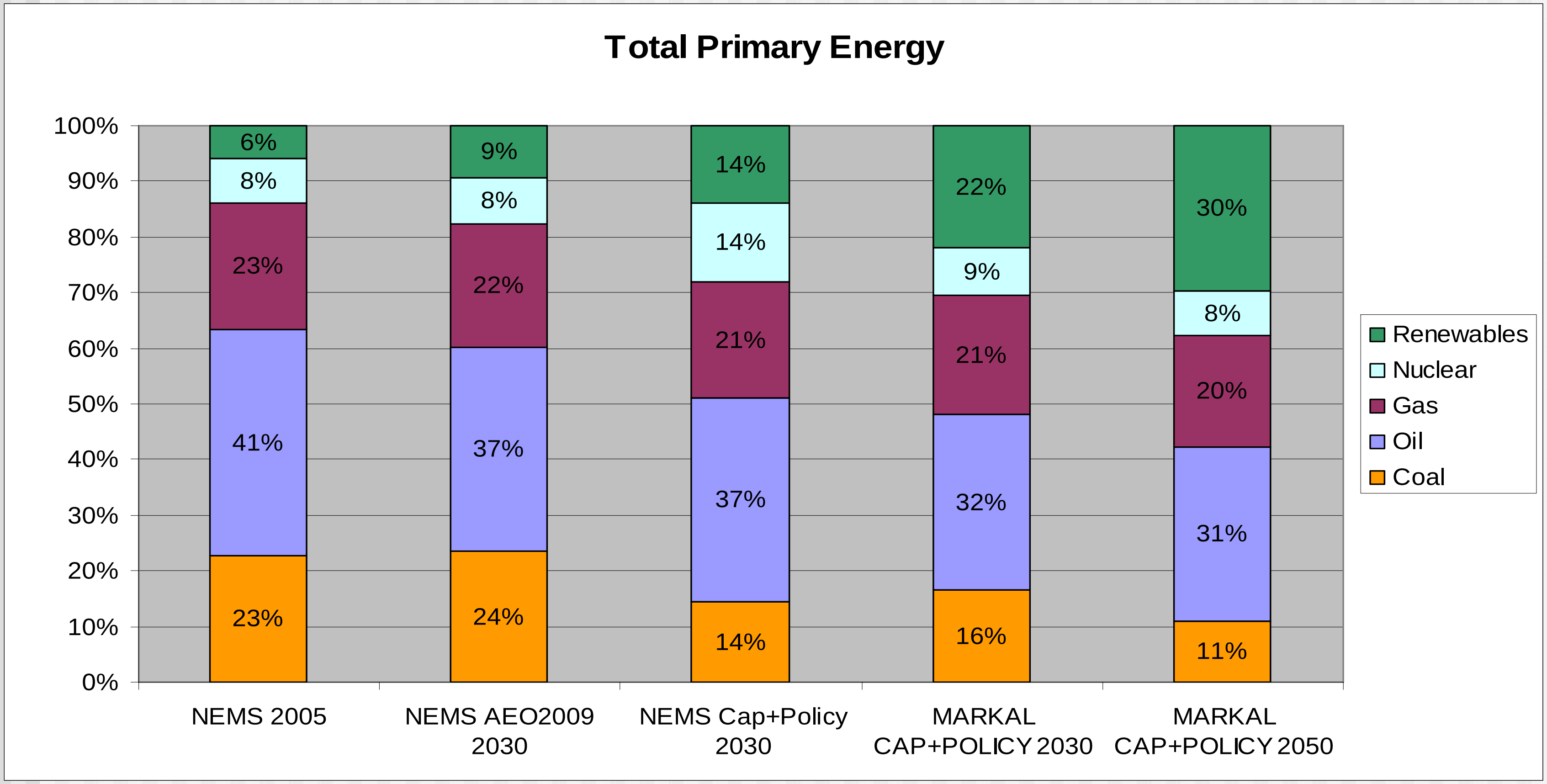
Key thoughts

- “Green building” is impossible—it’s a distraction.
- The more time & energy we spend on standard weatherization work (10% to 20% reductions), the longer it will take to reach our goal of 80% greenhouse gas reductions by 2050.
- Deep Energy Retrofits present many more “real world” challenges than just how to apply ever-thicker insulation to a wall.
- Our most useful tool would be an energy budget (national, state, household) that we can figure out the most cost-effective way to reach—the best route to a a radical transformation of how we think about buildings.

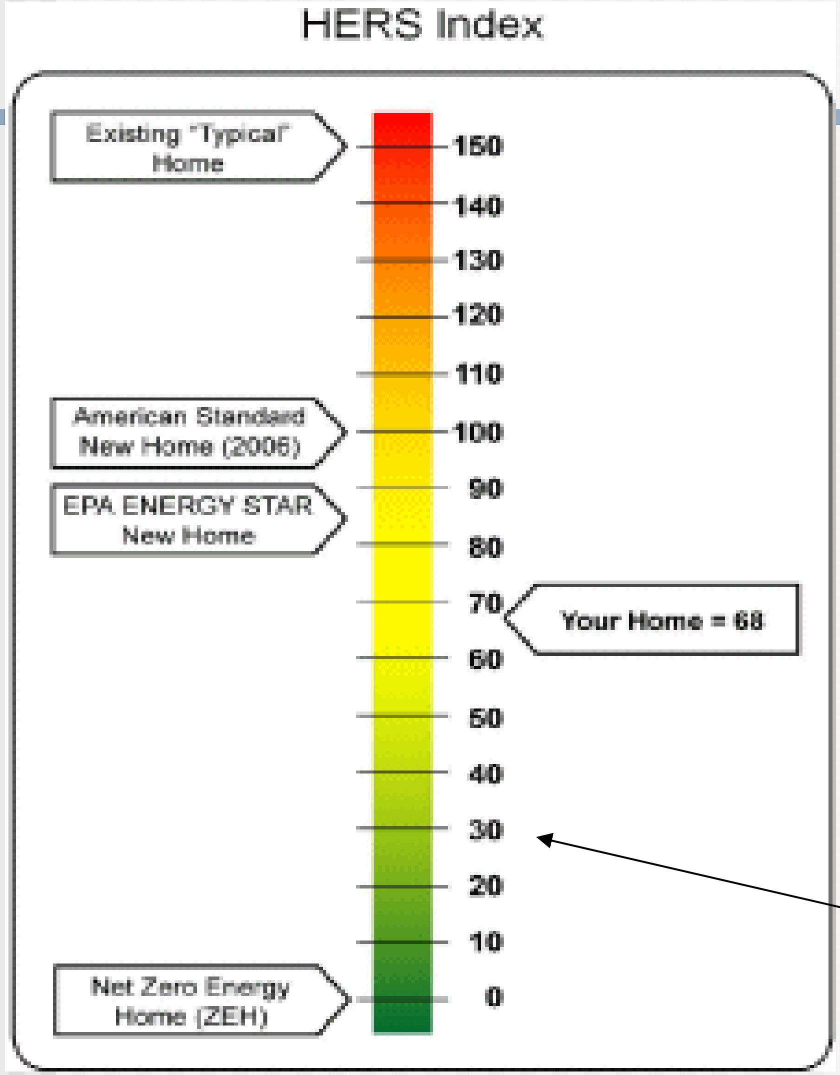
Anticipated energy sources



Anticipated energy sources



HERS scores, for perspective



- 100 = same energy use as House built to 2004 IECC (International Energy Conservation Code)
- 150 = 50% more energy use than house built to code
- 75 = approximate lower limit with conventional high-quality weatherization and high-efficiency HVAC
- To achieve 80% greenhouse gas reduction by 2050, average HERS will need to be about 30

Deep Energy Retrofits: background on metrics & measures

- Asset rating
  - HERS index
  - Passive House "budget"
- Per-house operational rating
  - Btu/sf/yr
- Combined asset and operational rating
  - Thousand Home Challenge
- Per-person operational rating
  - Btu/sf/yr/occupant
  - 2000-Watt Society
- All solutions will need to include:
  - Intense use of currently available materials and techniques
  - Technological breakthroughs
  - End-user buy-in
  - Reliable use of clear targets and score-keeping methods

GRT and Cape Ann Energy Network--Getting Started in Green Building for Contractors

Date: 4/4/2009 10:00 am - 1:00 pm

Location: Universalist Unitarian Church, 10 Church St, Gloucester, MA, 01930

Cost: $10

Join the growing ranks of residential contractors and developers who have recognized and embraced green building as the new "business as usual" in the home building and renovation realm.

This 4 hour workshop covers the fundamental principles of green design and construction and the practical application of those principles in a project. While the primary emphasis of the program is on the rehabilitation & remodeling of existing housing stock, the majority of the material covered can be applied to new construction as well. After a detailed examination of energy conservation measures, the cornerstone of green building, the program will address sustainable landscape design, design for durability, water conservation products & methods, sustainable materials, and indoor environmental quality considerations. The discussion will also include practical considerations in project planning and approvals, maintaining good indoor air quality while a project unfolds, effective construction waste management and site protection. In addition to the nuts & bolts of implementing green building strategies, the development of an effective marketing message, green building economics and helping clients to identify funding sources will also be discussed.

Ways the architecture & construction industry thinks about “green” building:

1. I’ll define “green” to match pretty much what I’m already doing, so I don’t have to think too hard.
2. I’ll define “green” in a way that allows clients to get exactly what they wanted anyway, and feel that they’re doing something important.
3. I’ll define “green” in a way that means I have to say “no” to a lot of things that people want me to do.

Q: What is a good definition of “greenwashing”?

A: Any answer except #3.

“Green” costs very little more than standard construction…

So what does “green” really mean?

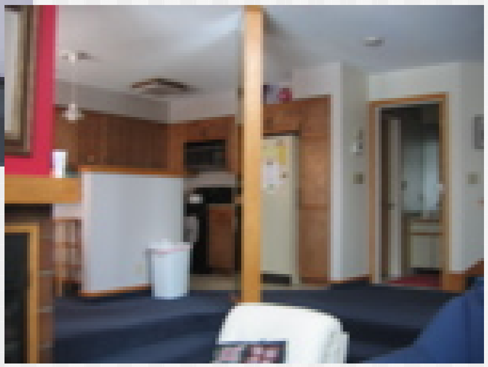
Per capita energy consumption:

Bangladesh	300 watts
India	1,000 watts
China	1,500 watts
Western Europe	6,000 watts
United States	*12,000 watts*
Goal for global sustainability	2,000 watts

Case study #1:

What I did on my ski vacation

How to retrofit this?



Lesson:

Deep energy retrofits need not always be about truckloads of insulation.

Think more broadly:
Deep energy *reductions.*

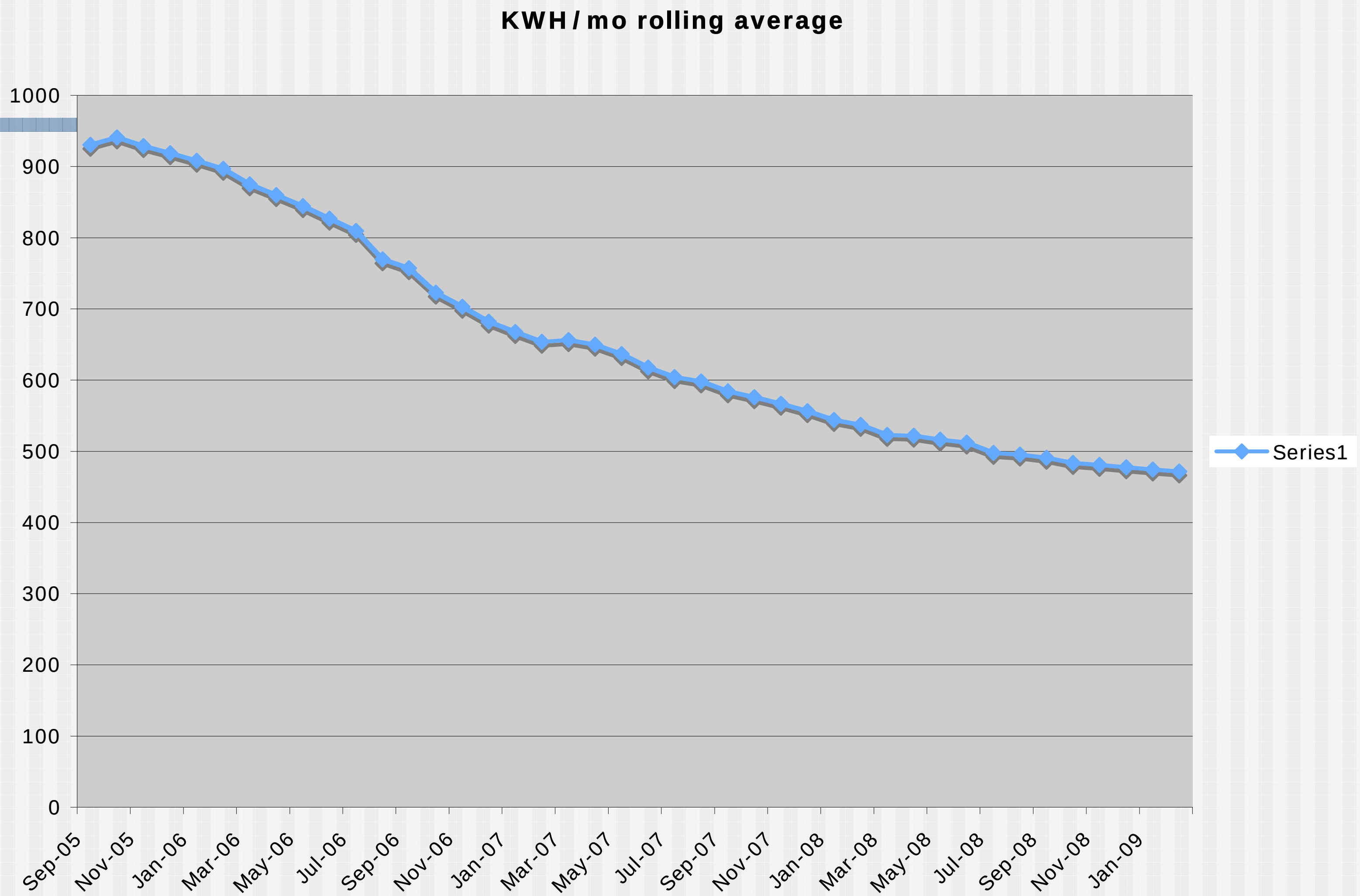
Case study #2:

My home renovation

My energy strategy: “Do some stuff and see where it gets me.”

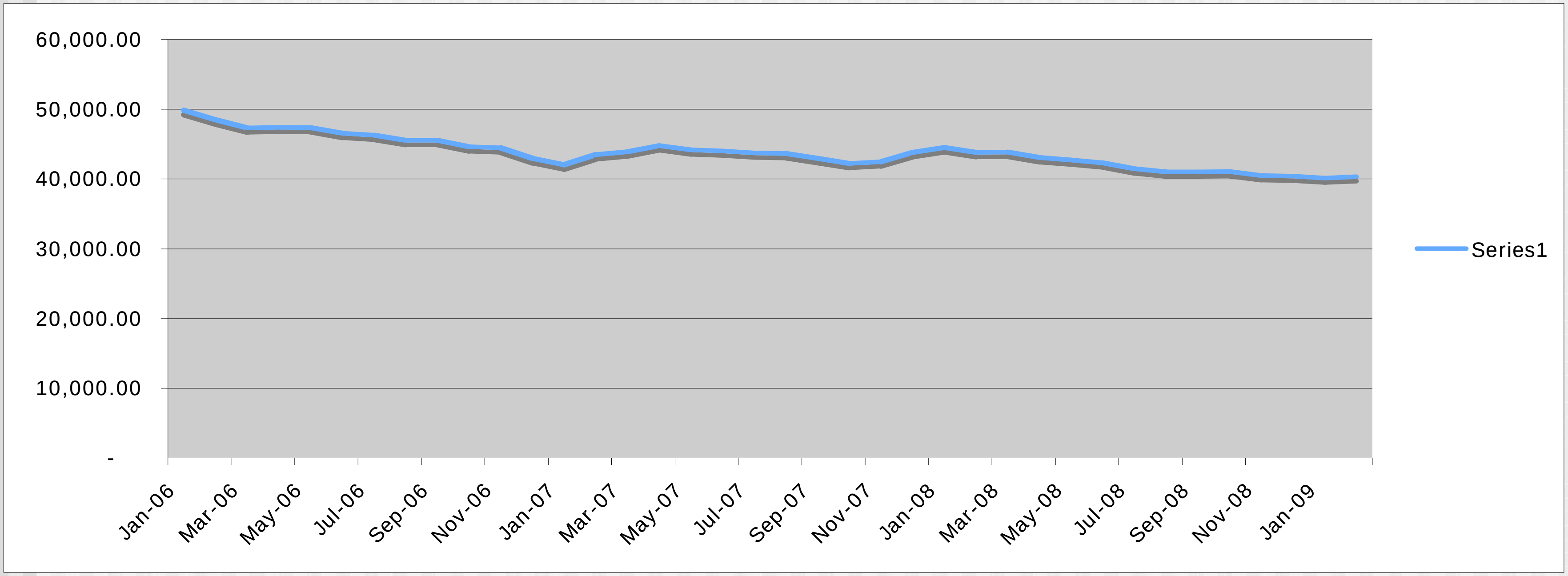
Answer: “Not far enough.”

Behavior changes have helped some…



Electricity usage only

But it’s easier to change occupant behavior than building envelope behavior…



Total energy usage: electricity + gas

Lesson:

You have one chance every 30-40 years
to get a building envelope right.

Don’t blow it.

Case study #3

Byggmeister Does a Big Project

Energy strategies

- Added 1500 sq. ft.; total is now 6000 sq. ft. (for a family of 5)
- Upgraded service from 100 to 400 amps
- Installed brick veneer to maximize difficulty of exterior insulation retrofit at a later date (won’t need to: we used Icynene!)
- Saved about 500 watt/hours by not running blower door to test envelope prior to drywall installation
- Consulted with renowned building scientist to make sure we got the exterior drainage right; did not talk to him about energy usage—and he did not ask

What sort of 50% Deep Energy Retrofit (DER) could we do with this house at this point?

1. DER based on asset rating, #1: Do a super-insulated exterior retrofit to reduce HERS index from 85 to 42. Cost: About $400,000.
2. DER based on asset rating, #2: Buy the house next door, tear it down, and cover the 12,000 sq. ft. lot with PV to reduce HERS index from 85 to 42. Cost: About $1 million.
3. DER based on per-house operational rating: Reduce Btu/sf/yr from 60K to 30K through occupant behaviors, such as leaving all the lights off almost all the time and keeping the thermostat at 55° in the winter and camping in the yard in the summer. Cost: The marriage.
4. DER based on per-occupant operational rating: Invite 6 recently homeless people to live with you in the house; per-person Btu/sf/yr is cut by 50%, from 12K to 6K. Cost: Priceless.

Lessons:

Every now and then, step back and think about whether we’re paying attention to the right things.

Case study #4

Byggmeister draws a line in the sand
and *doesn’t* do a big project

Current draft insulation standards for Byggmeister projects (our “line in the sand”)

- For Boston climate (5600 HDD), once “master plan” is complete, the house will have:
  - R-10 basement floor
  - R-20 basement walls
  - R-40 above-grade walls
  - R-60 roofs
  - U-0.20 windows
  - ACH@50 < 2
  - High-efficiency air-to-air heat pump, HRV

I lost the job…

- There were multiple factors, but some primary ones included:
  - I could not come close to justifying the cost of the added insulation in terms of financial payback, especially since homeowners had a 5- to 10-year timeframe in the house.
  - My sales skills were not adequate to the task of selling the improved energy performance on ethical & environmental grounds.

Lessons

1. Much of our nation's climate policy for the next 30-40 years is being determined by the sales skills of remodeling contractors.
2. Many if not most deep energy retrofits will likely not be economically justifiable until the price we pay for energy reflects the true costs of consuming that energy. Until that time, though, *all* building efficiency investment decisions will be based on fundamentally flawed information.
3. Using payback as the determining criterion in an efficiency investment assures that our buildings will always lag 30-40 years behind our energy needs—30-40 years being the time difference between our ability to predict energy costs and the service life of major building components.
4. We *have* to get a much clearer idea of what our overall goal is, *and of what that goal means at a building-by-building level*.

An open letter to President Obama

Dear Mr. President,

Please help us out. Tell us at what level our total residential energy consumption needs to be to meet our national priorities, and we will figure out how to get the nation there as cost-effectively and as quickly as we can. Until then, we're all just making it up as we go along.

Sincerely,
Your friends in the residential building community

Case study #5

In which we start to work out an incremental retrofit strategy

Jamaica Plain carriage house

- Pre-project HERS index = 184
- HERS index after phase one = 85
  - Closed-cell foam in stud bays
  - 25” of cellulose in ceiling
  - Spray foam on basement walls
  - Some new windows
  - High-efficiency kitchen appliances
- Next steps:
  - Exterior foam
  - Much better windows
  - Better mechanicals
  - PV?
  - Eventual HERS index of 0?

Possible incremental strategy for Deep Energy Retrofits

- Deal with health & safety issues first
- Add exhaust-only ventilation as short-term strategy
- Do the roof (R-60)
- Do the basement (walls = R-20, floor = R-10)
- Do the above-grade walls (R-40)
- Replace the windows (R-5)
- Remove chimney; re-engineer HVAC
- *Measure and monitor every step of the way—incremental improvements can cause as many problems as they solve*
- *And don't expect any dramatic improvements until you're done*

Comparing benchmarks

Boston climate (5600 HDD); 2400 sq. ft. home; #s are approximate	Btu/sf/yr	HERS index	percent reduction
avg existing home	70,000	130	0%
7th edition code house	54,000	100	23%
Energy Star	46,000	85	34%
Best case with 2x4 walls, no solar	40,000	75	43%
Best case with ext. insulation, R-3.5 windows, no solar	27,000	50	61%
Best case with ext. insulation, R-5.0 windows, no solar	22,000	40	69%
Thousand Home Challenge	15,000	28	79%
Passive House (does not credit for solar)	13,000	24	81%
Net Zero	0	0	100%

Note: In addition to extra insulation, steady improvements in air-sealing and, ultimately, a really good HRV are required to reach higher levels of performance noted

Note also that occupant behavior looms larger as the goals get more aggressive

Case study #6

Foam insulation for retrofits:
pros, cons, alternatives

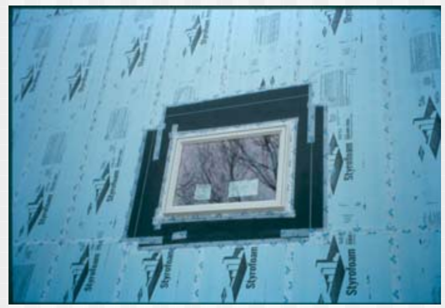
Basement foam

- 1870 North Cambridge home
- Closed-cell foam on floor and walls
- Thin concrete slab on floor; spray mortar on walls
- Seems to be very robust (after 5 years)

before

after

Wayland project:
rigid foam as exterior insulation



Wayland project—8 years later

Cladding takes on a lot of water, but wall cavities are dry

Somerville project

Somerville project

Note: existing cladding stays in place

Somerville project

Somerville project

Insulation retrofit—plan view of wall detail

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Insulation retrofit—basement detail

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Insulation retrofit—foundation sill, window details

QuickTime™ and a
TIFF (Uncompressed) decompressor
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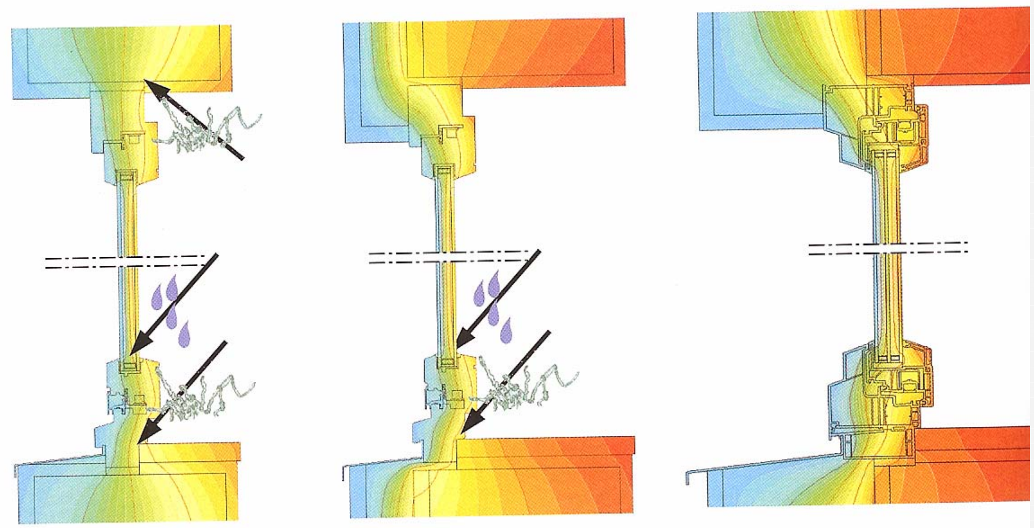
Thermal bridging at windows



ungedämmt	konventionell	hocheffizient
$U_{W,Ein}$ = 1,70 W/(m²K)	$U_{W,Ein}$ = 1,51 W/(m²K)	$U_{W,Ein}$ = 0,85 W/(m²K)
Ψ_o = 0,07 W/(m²K)	Ψ_o = -0,015 W/(m²K)	Ψ_o = -0,012 W/(m²K)
Ψ_u = 0,07 W/(m²K)	Ψ_u = 0,058 W/(m²K)	Ψ_u = 0,051 W/(m²K)
$\vartheta_{min,o}$ = 10,9°C W/(m²K)	$\vartheta_{min,o}$ = 13,6°C W/(m²K)	$\vartheta_{min,o}$ = 15,8°C W/(m²K
$\vartheta_{min,u}$ = 9,4°C W/(m²K)	$\vartheta_{min,u}$ = 9,7°C W/(m²K)	$\vartheta_{min,u}$ = 15,1°C W/(m²K

Abb. 26: Fenstereinbausituationen

Get friendly with moisture meters and data loggers

Try not to rely just on spray foams

Melted wire insulation from over-heating closed-cell foam

3.2 Surface Burning Characteristics:

When tested in accordance with ASTM E 84, at a thickness of 5.5 inches (140 mm) and a nominal density of 0.5 pcf (8 kg/m³), the Icynene Insulation System® has a flame spread index of 25 or less and a smoke-developed index of 450 or less.

Salespeople don't read their own literature

Really thoughtless foam installation

Test all installations before drywall

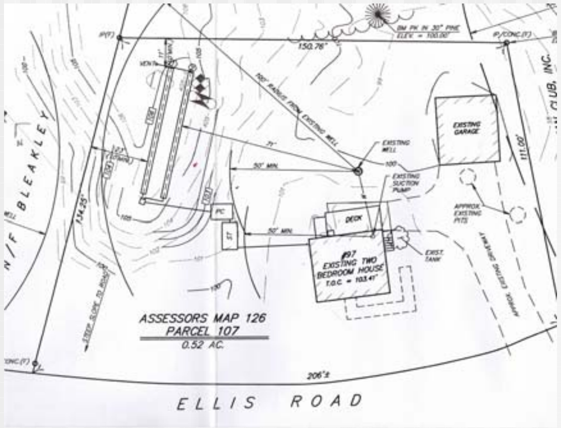
Comparing insulations

Type	Energy (MJ/kg)	Carbon (kg CO_2/kg)	Density (kg/m^3)
cellulose	.94 - 3.3	-	43
fiberglass	28.00	1.35	12
spray foam	72.10	3.00	30

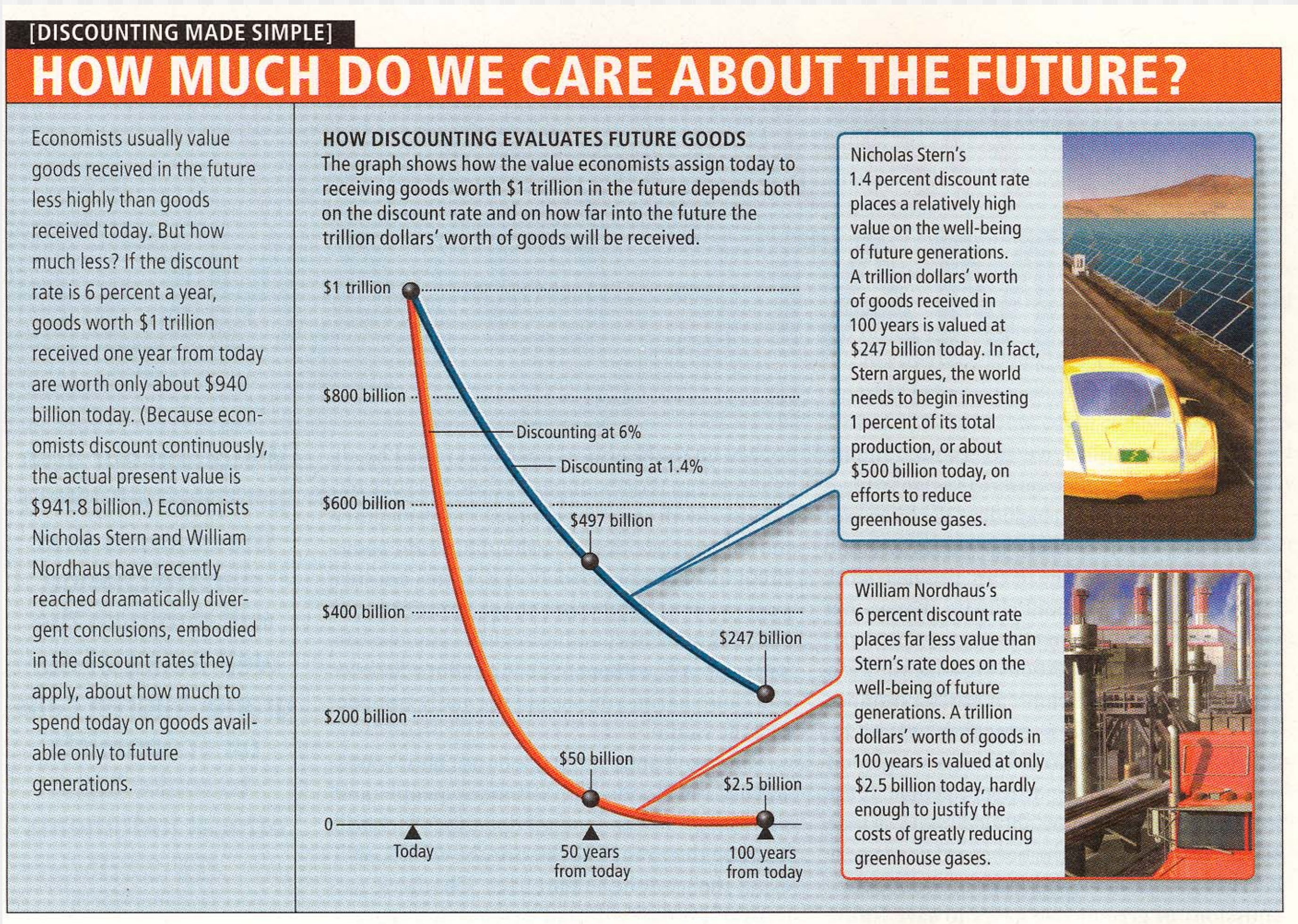
1 MJ = .28 kWh

Source: http://www.greenspec.co.uk/html/materials/embodied_energy.html

The next frontier…Passive House retrofit with almost all cellulose?



How much to invest in buildings now, for what future return?



[DISCOUNTING MADE SIMPLE]

HOW MUCH DO WE CARE ABOUT THE FUTURE?

Economists usually value goods received in the future less highly than goods received today. But how much less? If the discount rate is 6 percent a year, goods worth $1 trillion received one year from today are worth only about $940 billion today. (Because economists discount continuously, the actual present value is $941.8 billion.) Economists Nicholas Stern and William Nordhaus have recently reached dramatically divergent conclusions, embodied in the discount rates they apply, about how much to spend today on goods available only to future generations.

HOW DISCOUNTING EVALUATES FUTURE GOODS

The graph shows how the value economists assign today to receiving goods worth $1 trillion in the future depends both on the discount rate and on how far into the future the trillion dollars' worth of goods will be received.

Nicholas Stern's 1.4 percent discount rate places a relatively high value on the well-being of future generations. A trillion dollars' worth of goods received in 100 years is valued at $247 billion today. In fact, Stern argues, the world needs to begin investing 1 percent of its total production, or about $500 billion today, on efforts to reduce greenhouse gases.

William Nordhaus's 6 percent discount rate places far less value than Stern's rate does on the well-being of future generations. A trillion dollars' worth of goods in 100 years is valued at only $2.5 billion today, hardly enough to justify the costs of greatly reducing greenhouse gases.

Scientific American, June 2008

Where are the biggest opportunities for substantial reductions with existing homes?

“Green jobs training” for 20% reductions, or for 80% reductions?

Superinsulation economics

- Most cost-effective:
  - As part of new construction (*when will we ever figure this out?*)
  - As part of an addition
  - When you're re-siding
  - When you're re-roofing
- Least cost-effective
  - As a stand-alone project

The challenge:

How can we make it easier and less expensive?

Stewardship of existing buildings

- “Green building” needs to mean that *buildings will be as few, as small, and as efficient as possible*
- Which means we need to make *best use of what we have* before building new
- Which means we builders and architects need to start to view ourselves as analogous to enlightened farmers and foresters…

Last word

Woe to you who add house to house and join field to field till no space is left and you live alone in the land. The LORD Almighty has declared in my hearing: "Surely the great houses will become desolate, the fine mansions left without occupants." (Isaiah 5:8-9)