Deep Energy Retrofit Performance and Guidance
Lessons from a Cold-Climate DER Pilot Program

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What is Deep Energy Retrofit?

- Retrofit to *high performance*
  - Durability
  - Comfort
  - Indoor air quality
  - Aesthetics
  - Amenity
  - Energy
- Existing building ➔ Zero Net Energy Ready

How does "all of this" support zero net-energy ready homes?

How does zero net-energy ready homes support "all of this"?

"All of this" = significant energy use reductions in the residential sector

Deep Energy Retrofit is a path to ZNE

- What are the barriers?
  - Benefits are not understood
  - Methods are not understood
  - Costs are not understood

Barriers to Deep Energy Retrofit

- Benefits are not understood
  - Why do we do this?
  - Energy is what we focus on
    - energy use
    - airtightness
  - Other benefits ~~may be~~ are more valuable

Barriers to Deep Energy Retrofit

Methods are not understood

- Different from high performance new construction?
  - Constraints
    - Framing
    - Foundation already back-filled
    - Furniture and people inside
  - Stakes are higher
  - Value proposition more certain: unified incentives

➢ General methods and lessons

MASS SAVE DEEP ENERGY RETROFIT BUILDER GUIDE

https://www1.nationalgridus.com/DeepEnergyRetrofit-MA-RES

http://www.buildingscience.com/documents/guides-and-manuals

Barriers to Deep Energy Retrofit

- Costs are not understood
  - Costs less to build new?
  - Cost for what?

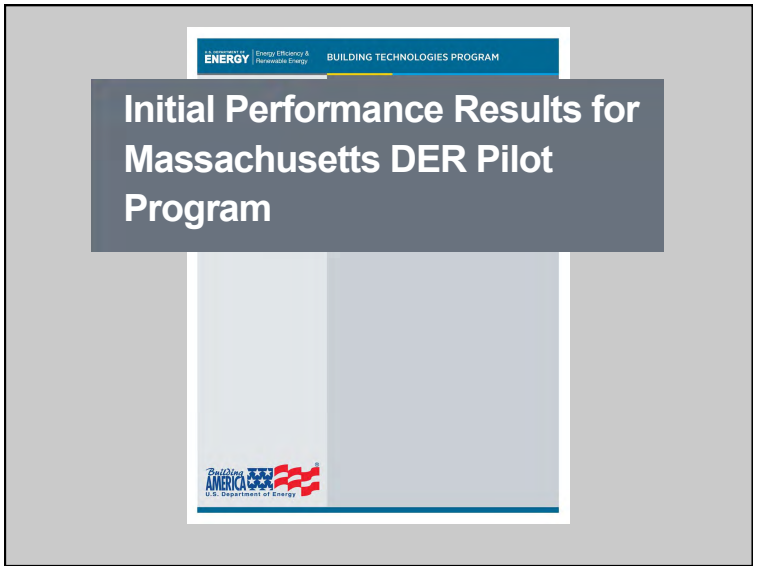
➢ DER project and measure costs

DER Performance and Guidance

Where do we get our information?

National Grid Deep Energy Retrofit Pilot

- Started in 2009, closed end of 2012
- Ambitions enclosure performance targets
- Ventilation measures, HVAC incentives
- Significant incentives!
  - Single family base: $35-$42K, 3 family $72K
- Application, field verification, testing, utility bills
- 42 projects completed, 62 housing units
- Analysis completed for first 13 projects



DER Performance and Guidance

Enclosure performance targets:

- R 5, 10, 20, 40, 60
- 0.1 cfm50 / s.f. enclosure

DER Performance and Guidance

Enclosure performance targets:

- R 5 window,
- R10 slab,
- R20 foundation wall,
- R40 frame wall,
- R60 attic/roof
- 0.1 cfm50 / s.f. enclosure

DER Performance and Guidance

Performance parameters:

- Water control
- Airflow control
- Vapor control
- Thermal control

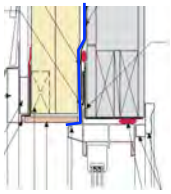
DER Performance and Guidance

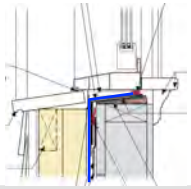
R-5 Windows

- Triple-glazed, low-e
- Flashing a big deal
- Approaches:
  - Innie
  - Outie
    - Metal strap ties
    - Picture frame

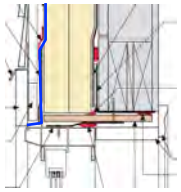
DER Performance and Guidance

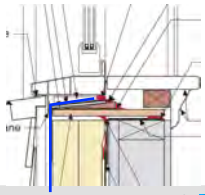
Innie





Outie





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Window over strapping:

a hard habit to break, leads to water and air control problems

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- Window over strapping

DER Performance and Guidance

- Mock-up makes perfect

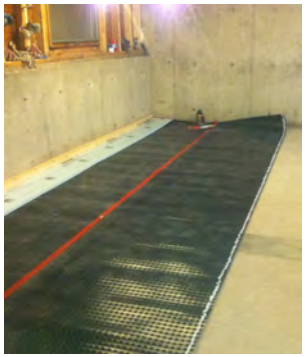
DER Performance and Guidance

R-10 Slab

- Make it so that stuff can be in the basement
  - Provision for drainage
  - Water, air, vapor, thermal control
- Approaches:
  - Over existing
  - New slab
  - Some didn't

DER Performance and Guidance

- Basement slab treatment



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- Basement slab treatment


DER Performance and Guidance

Basement slab treatment

- ~$6/sf average whole measure cost for insulation over the slab
- Insulation under the slab costs less but the whole measure unit cost is higher
- Unit cost for over the slab ≅ basement ceiling unit cost

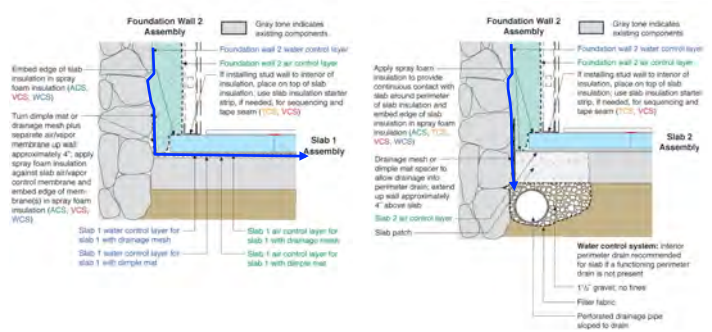
DER Performance and Guidance

R-20 Foundation Walls

- Approaches:
  - ccSPF + paint ~ $8/sf
  - ccSPF w/ stud wall ~ $8.90/sf
  - Rigid board w/ or w/o stud wall ~ $4.50/sf
  - Exterior? (one)

DER Performance and Guidance

Basement slab treatment – water control connection



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- Issues at top of foundation wall: moisture risk related to airflow control


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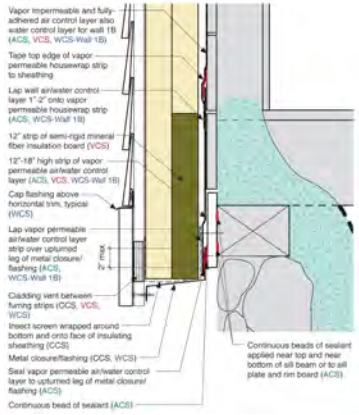

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- Issues at top of foundation wall: diffusion drying and redistribution response to capillary risk


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R-40 Frame Walls

- 2 layers polyisocyanurate, outer layer foil-faced
- Others:
- 1 ccSPF interior
- 1 ccSPF cavity plus rigid ext
- 1 ocSPF cavity plus rigid ext
- 1 exterior ccSPF plus rigid
- 1 mineral fiber exterior

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R-40 Frame Walls

- Costs for exterior insulation vary widely
  - From < $5/sf to > $19/sf incremental cost
  - Repeat contractors > $15/sf
  - Mean $11.50/sf
- ccSPF interior
  - $6.60/sf (1 instance)

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R-40 Frame Walls: why approach from outside?

- Water management
- Water management
- Air control
- People and stuff

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Why approach from exterior?

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Why approach from exterior?

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Why approach from exterior?

Why approach from exterior?

- Drainage remediation

Siding removed to remediate flashing

Head flashing at new window

Drainage plane remediation at base of wall

Why approach from exterior?

Why approach from exterior?

Why approach from exterior?

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R-60 Roof

- Unvented
  - Rigid over deck and fibrous in cavities
    cost increment: ~$10 – $18/sf, avg $13.40/sf
  - Thick ccSPF underside of deck
    cost increment: $9.40 - $14.40/sf, avg $11.05/sf
- Vented
  - Vented attic $14/sf energy-related
  - Mixed vented/unvented $10.25/sf

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National Grid DER Pilot Performance

What energy performance do these DER homes achieve?

- Utility bill data collected
- Reduction?
- Achievement? (with respect to benchmark)
- What do outliers tell us?

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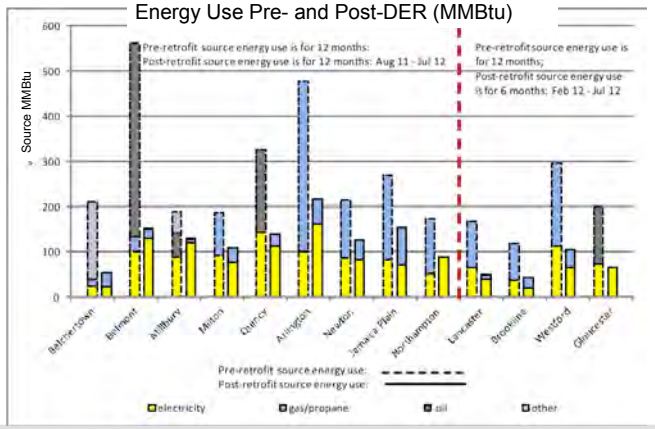

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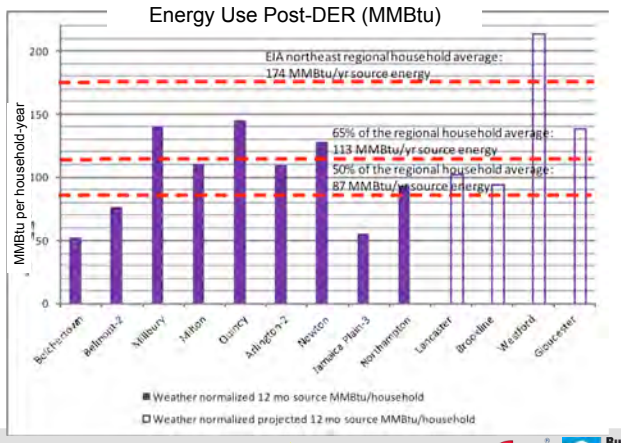

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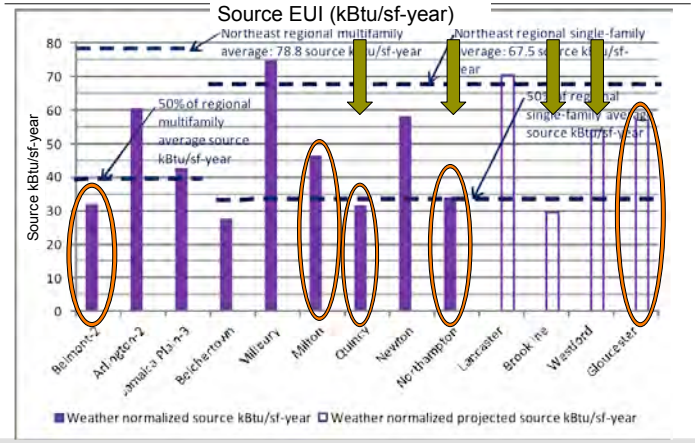

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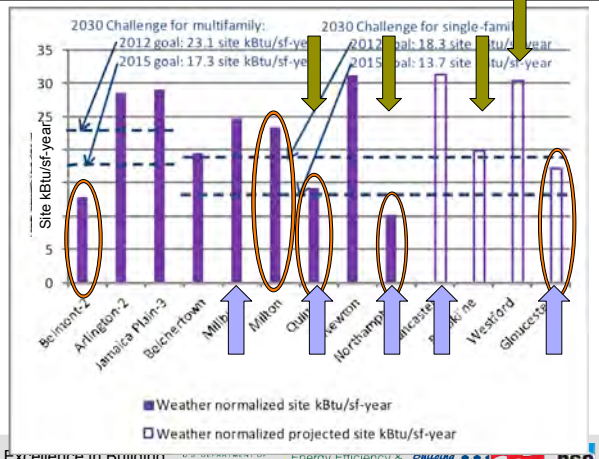

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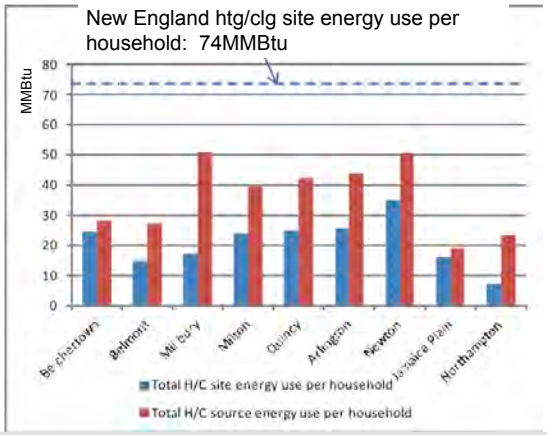

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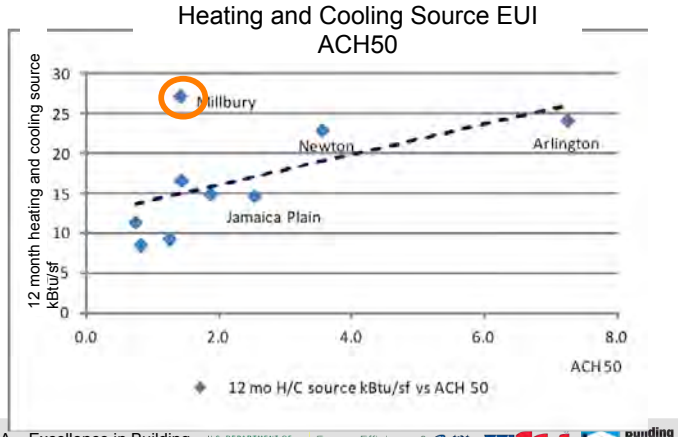

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The following appears possible:

- 50% of regional source energy use / household
- 50% of regional source EUI (possible for average size homes)
  - More difficult for smaller homes
  - Slightly more difficult for electrically heated homes
- ~15 kBtu/sf heating and cooling energy use (source energy, climate zone 5)

National Grid DER Pilot Performance

Other things we learned:

- Occupant behavior matters (duh)
- System commissioning is important (catch major equipment malfunctions)
- Air tightness matters (but no advantage seen for projects below 1.5 ACH50)
- Slab insulation does not appear to impact heating/ cooling energy use (lost amidst other variables)

National Grid DER Pilot Performance

How airtight are these DER homes?

- Pre- and post-retrofit measurements
- Reduction
- Achievement (with respect to benchmark)
- What are the impact of various approaches?
- What do outliers tell us?

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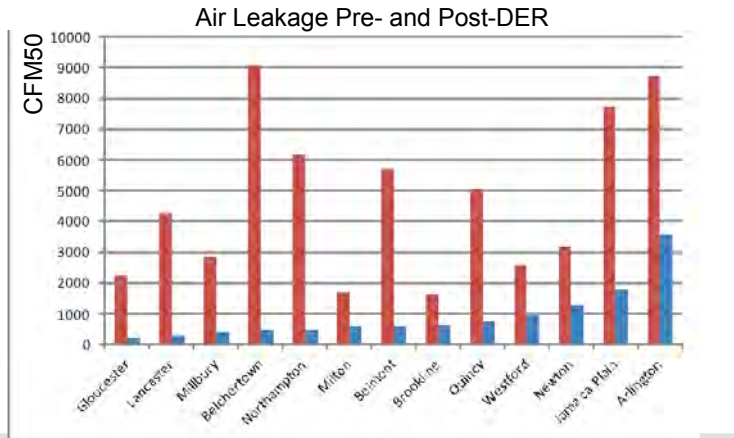

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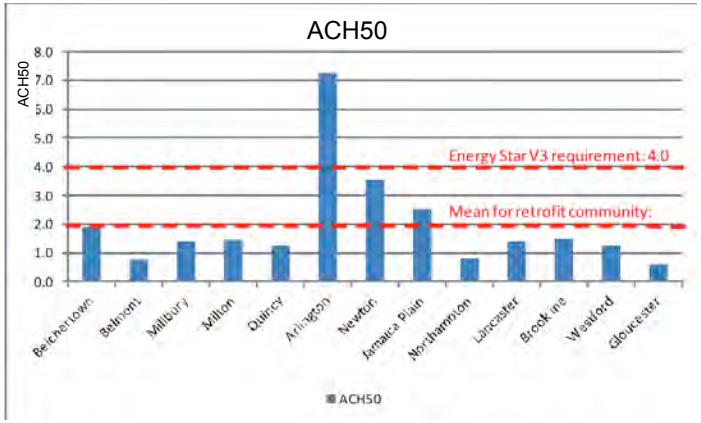

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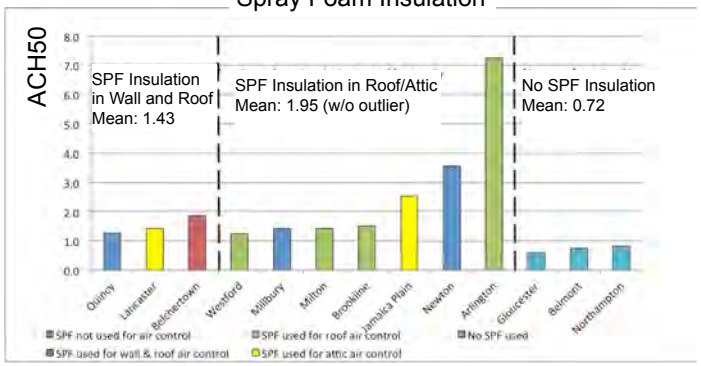
Spray Foam Insulation



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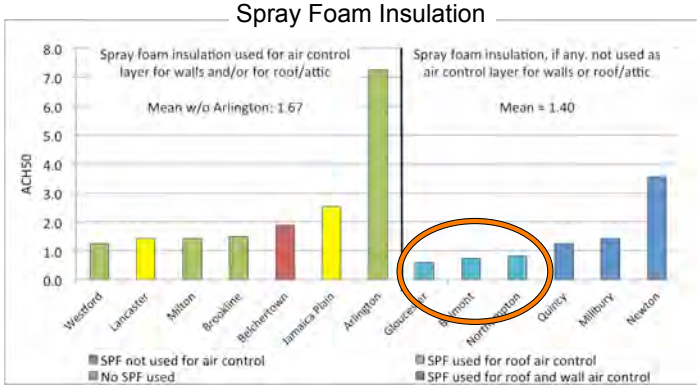
Spray Foam Insulation



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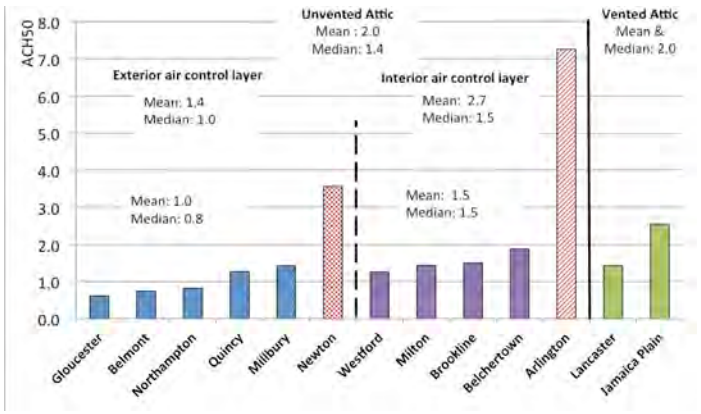

Chainsaw roof: why, why not, how?

- Continuity of air and thermal control
- Sometimes not accommodated by structure

Chainsaw Retrofit

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Chainsaw Retrofit

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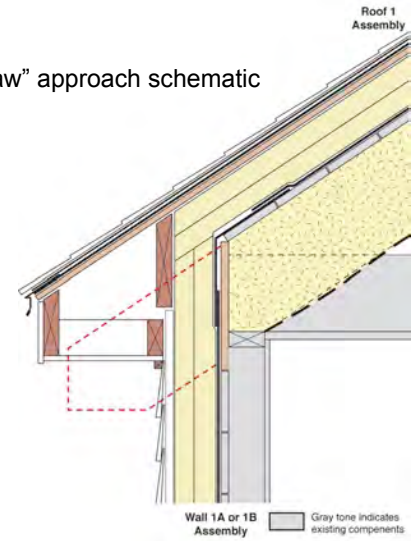
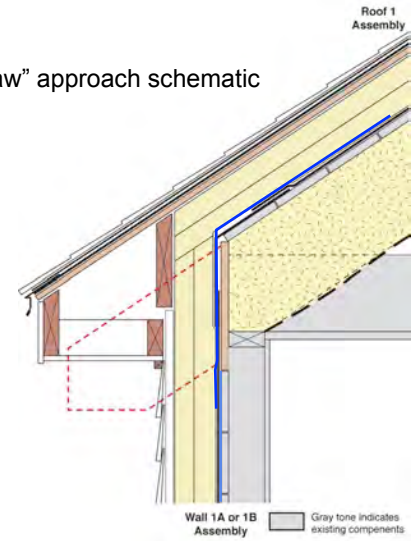
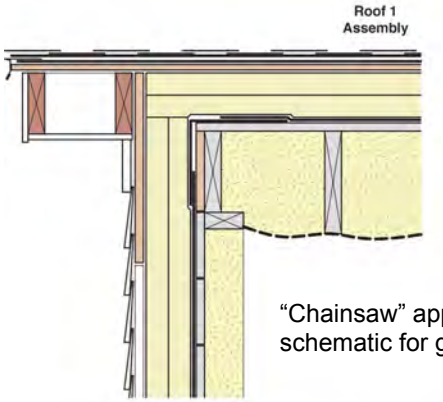
“Chainsaw” approach schematic



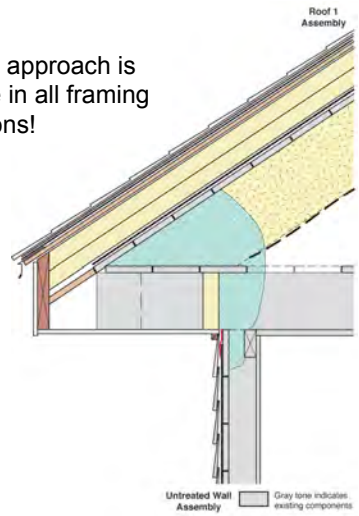
“Chainsaw” approach schematic





“Chainsaw” approach schematic for gable/rake

“Chainsaw” approach is not feasible in all framing configurations!



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Chainsaw Retrofit

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Chainsaw retrofit

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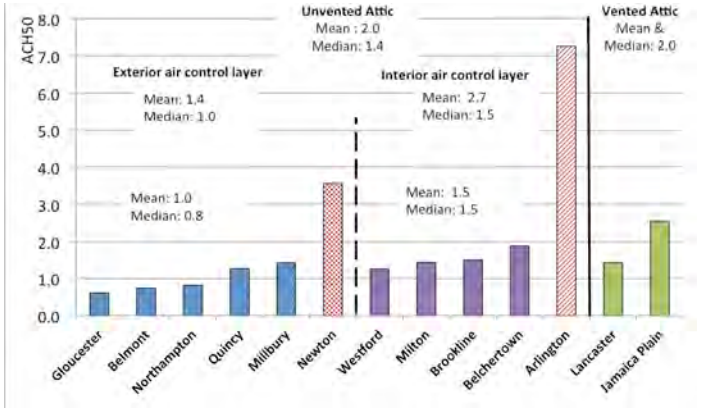

Continuity of Control at Porch Roof and Deck

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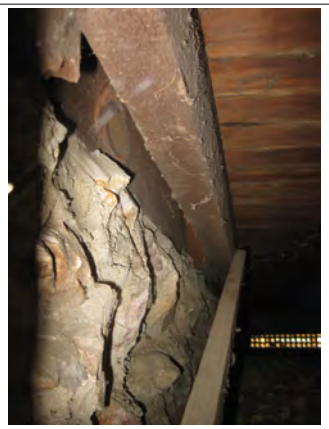

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Continuity of Control at Porch Roof and Deck

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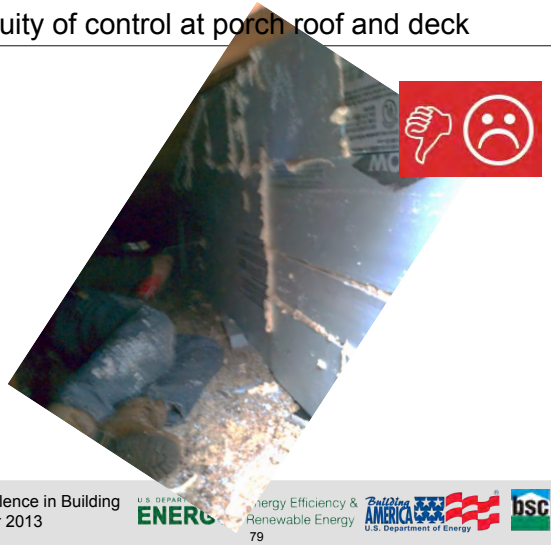
Continuity of control at porch roof and deck



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Continuity of control at porch roof and deck

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Continuity of control at porch roof and deck

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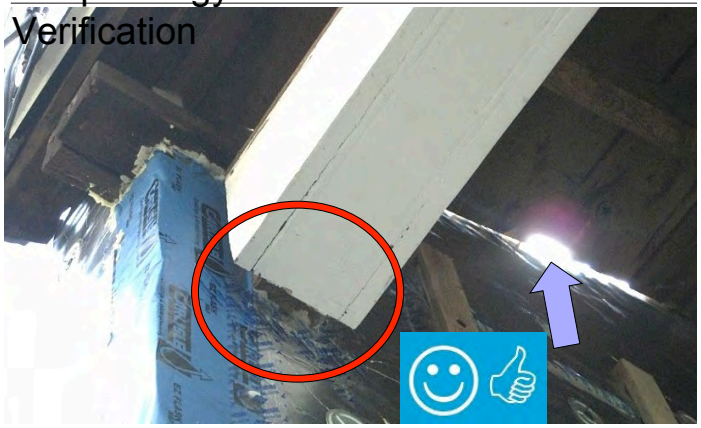
Deep Energy Retrofit Measures Verification



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Continuity of control at porch roof and deck

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Continuity of control at porch roof and deck

Continuity of control at porch roof and deck

- Built up siding detail over exterior insulation and control layers

Continuity of control at porch roof and deck

Continuity of control at porch roof and deck

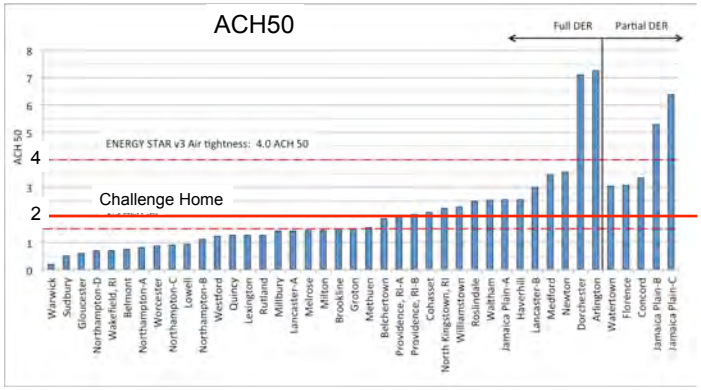
- Dormer built over exterior insulation and control layers

National Grid DER Pilot Performance

Airtightness, what do we think we know?

- If we detach the porch decks/roofs and include attic we can get to Challenge Home airtightness
- Below 1 ACH50 is possible
- Basements are inside and should be explicitly included
- Exterior air control has an edge over interior spray foam air control
- Unvented attic has edge over vented attic

National Grid Pilot Performance – full set



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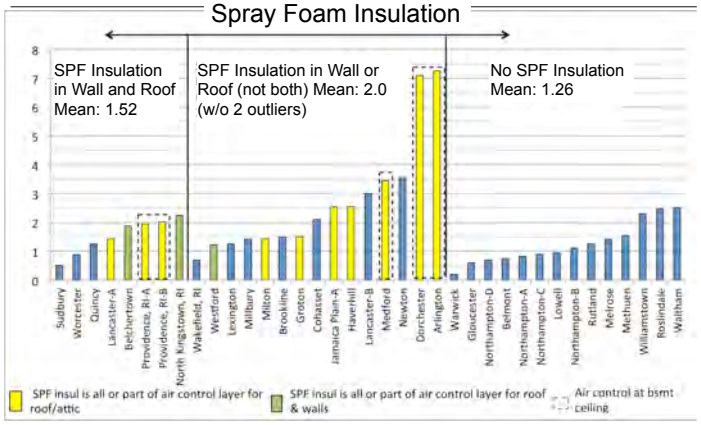

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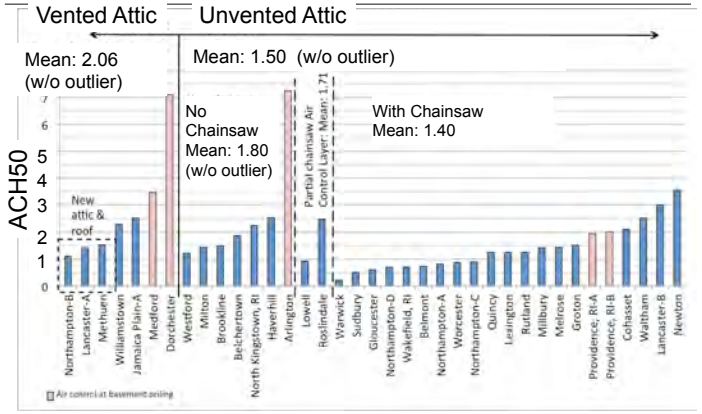
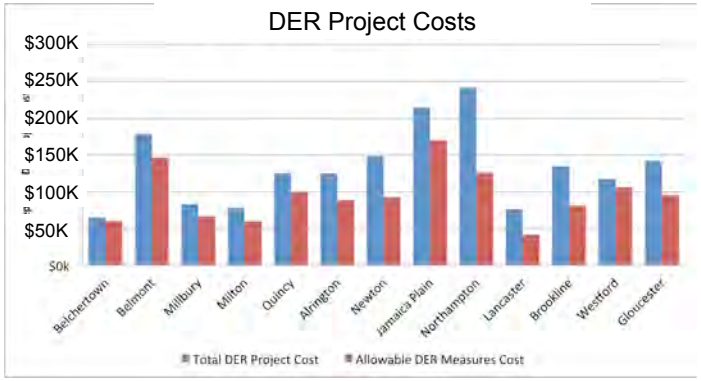


National Grid DER Pilot – Cost Data

- How much does it cost?
  - A lot
- Why do people do it?
  - Many reasons, energy savings among them

National Grid DER Pilot – Cost Data



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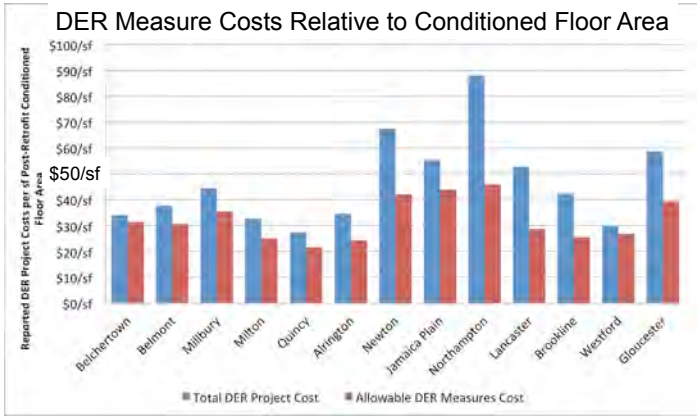

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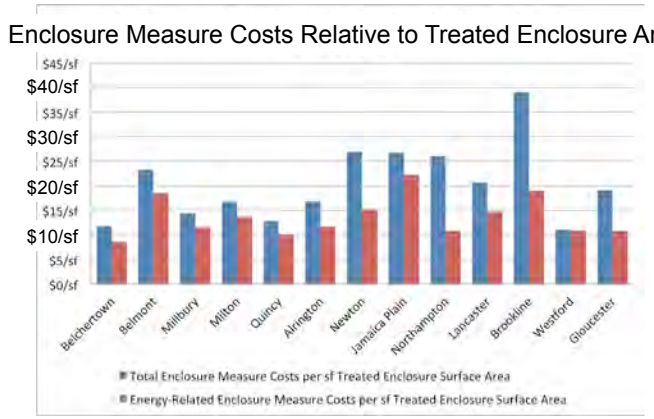

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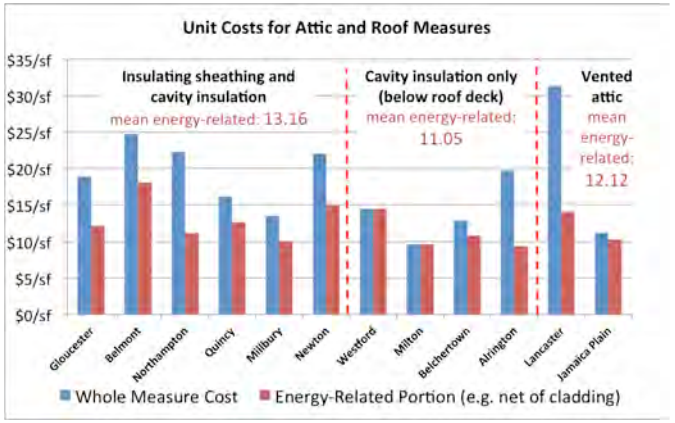
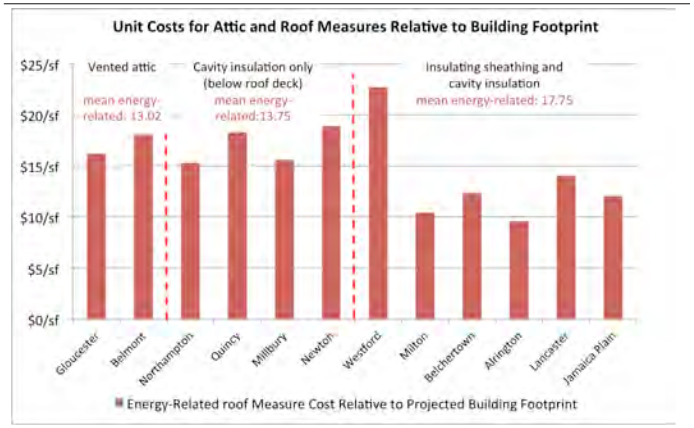
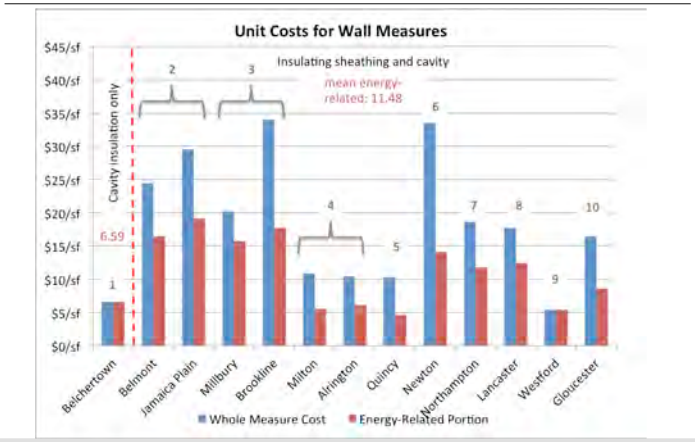


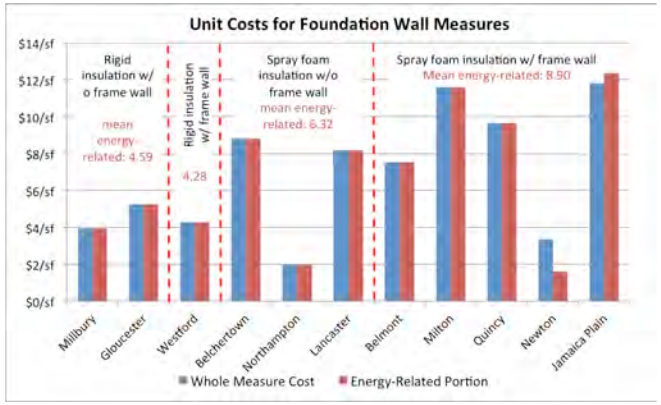
National Grid DER Pilot – Cost Data



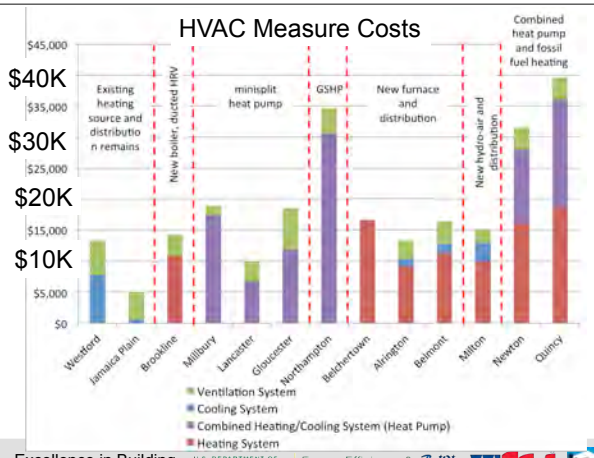
National Grid DER Pilot – Cost Data



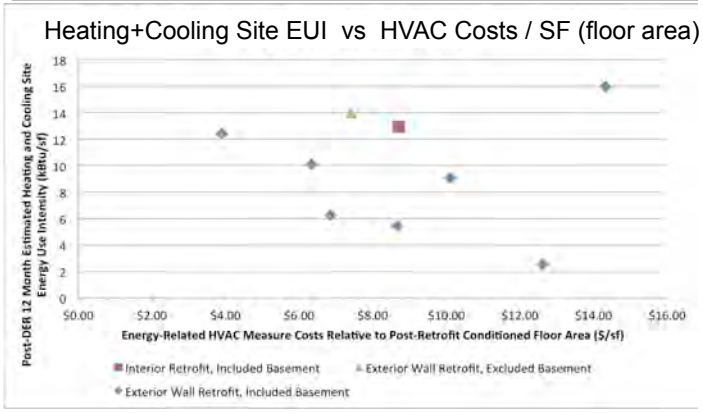
National Grid DER Pilot – Cost Data



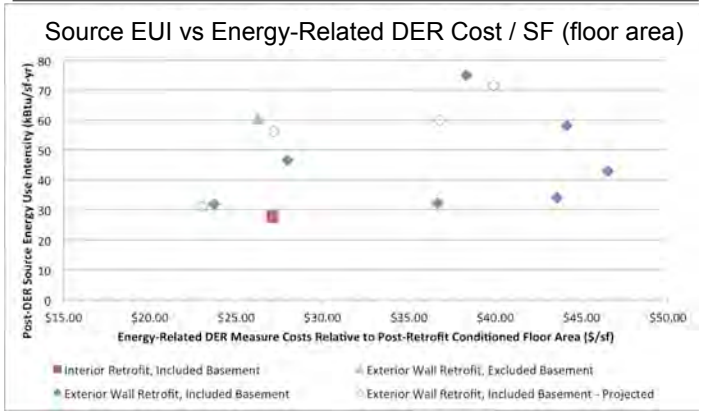
National Grid DER Pilot – Cost Data



National Grid DER Pilot – Cost Data



National Grid DER Pilot – Cost Data

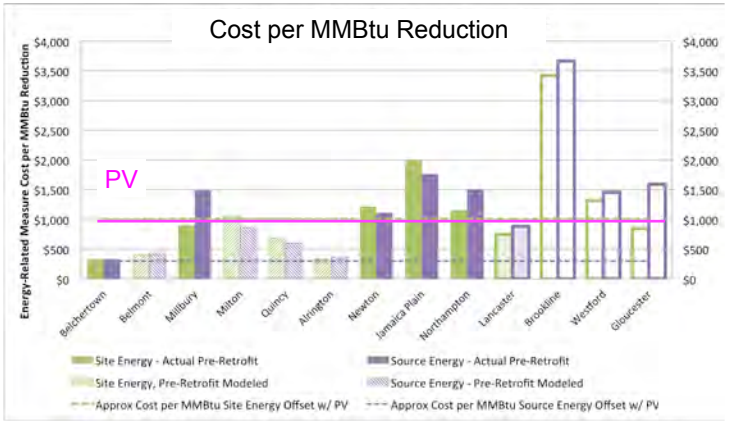


National Grid DER Pilot – Cost Data

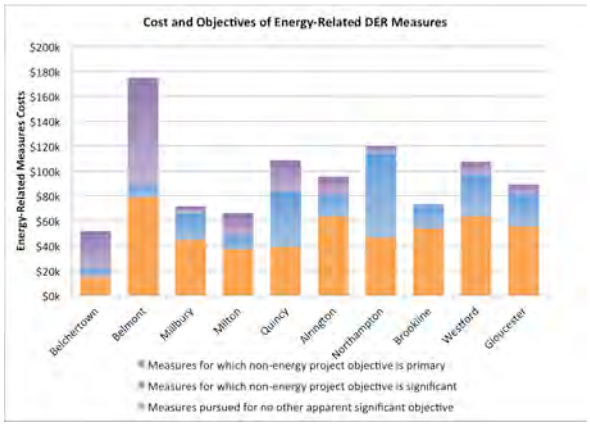
DER costs, what do we think we know?

- Costs vary widely, it is not cheap
- Comprehensive DER: ~$50K to ~$180K
- Comprehensive DER cost/sf conditioned area: average ~$40/sf, (range ~$25/sf to $80+/sf)
- Incremental cost for enclosure retrofit: average ~$13.50/ssf (range ~$8.50/ssf to ~$22/ssf)
- Within the cost variation, there does not appear to be correlation between cost and performance

National Grid DER Pilot – Cost Data



National Grid DER Pilot – Cost Data



National Grid DER Pilot – Cost Data

Should we DER or PV?

- PV might have more source energy reduction

But! Can your PV do this?

- Create usable conditioned space
- Improve comfort
- Make a stinky damp basement dry and fresh
- Increase building durability
- Eliminate ice dams
- Improve appearance of the building…

National Grid DER Pilot Performance

Lessons:

- Make it easy (simplify geometry of the enclosure)
- Give the enclosure an outside chance
- Keep HVAC simple (HVAC, focus on V)
- Basements (and crawlspaces) are *in*
- Spray foam is not a silver bullet
- If it's new and unfamiliar, don't mock it! Mock it up!

National Grid DER Pilot Performance

How does "all of this" support zero net-energy ready homes?

DER is a path to ZNE ready homes

Future for DER:

- Value-add for regular renovation activity
- Builder/developer not at center of process
- Details and guides
- Broader material options
- Techniques for foundations

Example DER Project – Before

Example DER Project – After

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Example DER Project's Neighbor

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Discovered During Exterior Retrofit

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Discovered During Exterior Retrofit

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