What is Deep Energy Retrofit?

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

Deep Energy Retrofit is a path to ZNE

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

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
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 more valuable

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

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

Barriers to Deep Energy Retrofit

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

- DER project and measure costs

MASS SAVE
DEEP ENERGY
RETROFIT BUILDER
GUIDE


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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

Enclosure performance targets:

- R 5, 10, 20, 40, 60
- 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

Window over strapping:
a hard habit to break, leads to water and air control problems
DER Performance and Guidance

- 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
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

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

DER Performance and Guidance

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

DER Performance and Guidance

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
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)

R-40 Frame Walls: why approach from outside?

- Water management
- Water management
- Air control
- People and stuff
Why approach from exterior?

- Drainage remediation

- Head flashing at new window

- Siding removed to remediate flashing

- Drainage plane remediation at base of wall
Why approach from exterior?

DER Performance and Guidance

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
What energy performance do these DER homes achieve?

- Utility bill data collected
- Reduction?
- Achievement? (with respect to benchmark)
- What do outliers tell us?
National Grid DER Pilot Performance

New England htg/clg site energy use per household: 74MMBtu

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?
National Grid DER Pilot Performance

Spray Foam Insulation

- SPF Insulation in Wall and Roof: Mean = 1.43
- SPF Insulation in Roof/Attic: Mean = 1.95 (w/o outlier)
- No SPF Insulation: Mean = 0.72

National Grid DER Pilot Performance

Spray Foam Insulation

- SPF not used for air control
- SPF used for roof air control
- SPF used for wall/roof air control
- SPF used for attic air control
- No SPF used

Chainsaw roof: why, why not, how?

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

Chainsaw Retrofit

Chainsaw Retrofit

Chainsaw Retrofit
"Chainsaw" approach schematic for gable/rake

"Chainsaw" approach schematic

"Chainsaw" approach is not feasible in all framing configurations!
Chainsaw Retrofit

Chainsaw Retrofit

Chainsaw retrofit

Chainsaw retrofit
Continuity of Control at Porch Roof and Deck
Continuity of control at porch roof and deck
Deep Energy Retrofit Measures
Verification

Continuity of control at porch roof and deck

Continuity of control at porch roof and deck
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

Challenge Home

National Grid Pilot Performance – full set

Spray Foam Insulation

ACH50

SPF Insulation in Wall and Roof
Mean: 1.52
(SPf Insulation in Wall or Roof (not both) Mean: 2.0 (w/o 2 outliers))

No SPF Insulation
Mean: 1.26
National Grid Pilot Performance – full set

Vented Attic
Mean: 2.06 (w/o outlier)

Unvented Attic
Mean: 1.50 (w/o outlier)

No Chainsaw
Mean: 1.80 (w/o outlier)

With Chainsaw
Mean: 1.40

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

- DER Project Costs
- DER Measure Costs Relative to Conditioned Floor Area
National Grid DER Pilot – Cost Data

Enclosure Measure Costs Relative to Treated Enclosure Area

- Total Enclosure Measure Costs per 1000 Enclosures Surface Area
- Energy-Related Enclosure Measure Cost per 1000 Treated Enclosure Surface Area

Unit Costs for Attic and Roof Measures Relative to Building Footprint

- Vented attic: mean energy related: 13.16
- Cavity insulation only: mean energy related: 11.05
- Insulating sheathing and cavity insulation: mean energy related: 12.12

National Grid DER Pilot – Cost Data

Unit Costs for Wall Measures

- Insulating sheathing and cavity: mean energy related: 11.48
National Grid DER Pilot – Cost Data

Unit Costs for Foundation Wall Measures

HVAC Measure Costs

Heating+Cooling Site EUI vs HVAC Costs / SF (floor area)

Source EUI vs Energy-Related DER Cost / SF (floor area)
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

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

Example DER Project’s Neighbor

Discovered During Exterior Retrofit

Discovered During Exterior Retrofit