Deep Energy Retrofit Pilot Lessons Learned – Technical Perspective

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Learning Objectives

- Sample of DER lessons learned from the NGrid pilot concerning
  - Water management
  - (Air flow control)
  - (Mechanical systems)
- What measures or approaches allowed pilot projects to succeed
- What key guidance was offered to these projects through the pilot

DER Lessons Learned

Retrofit is *hard*!

- Doing DER right is not simple, quick, or cheap
- Challenges not found in new construction
- Scale and breadth of potential improvement is rewarding

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DER Topics

- Water management
- Air flow control
- Thermal control
- ~~Mechanical systems~~

DER Themes

- Retrofit changes things
- High performance is different
  - Less margin of error
  - Standard practice/products may not fit

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DER Challenge – Water Management

- Effective water management must take precedence over ~~insulation~~ all other enclosure measures

- Crucial to performance:
  - Air quality
  - Durability
  - Thermal performance
  - Pest control

DER Challenge – Water Management

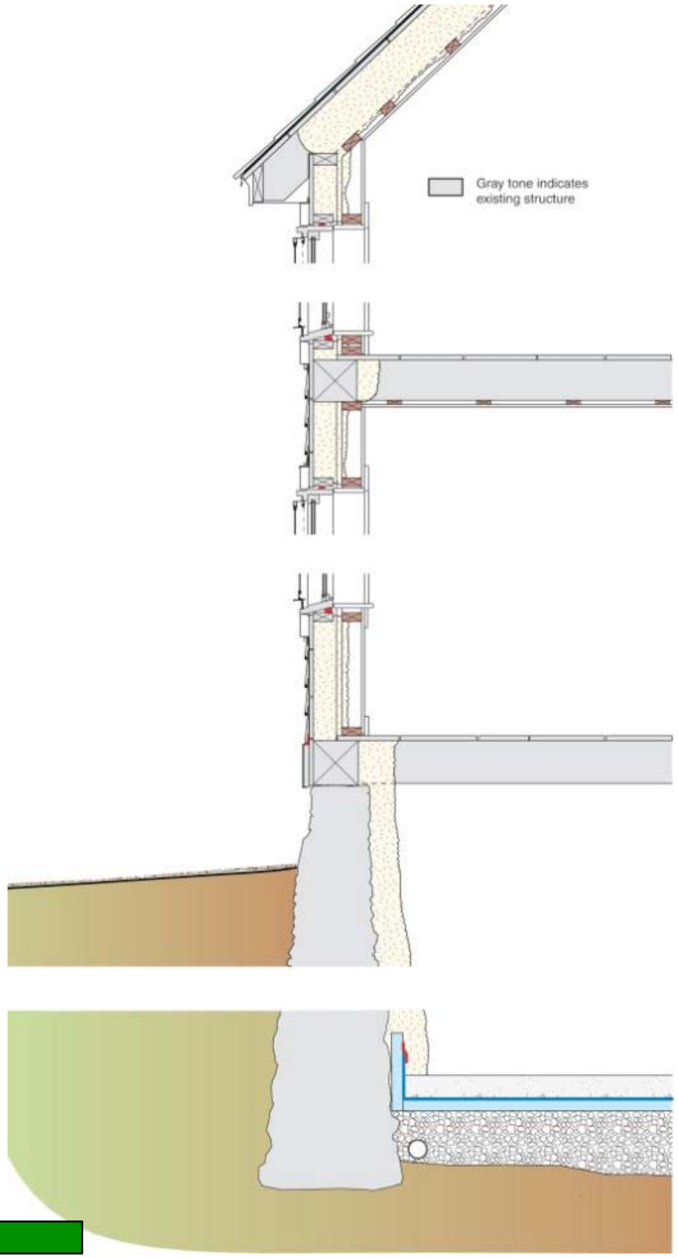
Why is effective water management especially significant to high performance retrofit?

- Low efficiency buildings can (sometimes) get away with more
- Assemblies with higher thermal resistance tend to have lower drying potential

Be aware of change:

- Perturbing a system proven to work

DER Challenge – Water Management



1760's Cape

Changing the system: super-insulation to the inside

- New stud wall framing to interior
- Medium density SPF in cavities

Clark residence pre-retrofit

DER Challenge – Water Management

Recent window replacement with no flashing or air sealing

Existing replacement windows installed without flashing

DER Challenge – Water Management

Changing the system: super-insulation to the inside

- Recommended pulling and properly flashing all windows
- Project agreed to retro-flashing
- Inspection of critical details revealed problems

Existing window trim - head

Existing replacement windows installed without flashing

Existing window trim - sill

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DER Challenge – Water Management

Inspection of critical details revealed problems

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DER Challenge – Water Management

Inspection of critical details revealed problems

DER Challenge – Water Management

Inspection of critical details revealed problems – damage observed

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DER Challenge – Water Management

Changing the system: super-insulation to the inside

- Drainage remediation

Head flashing at new window

Siding removed to remediate flashing

Drainage plane remediation at base of wall

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DER Challenge – Water Management

Changing the system:
super-insulation to the inside

- Builder ended up removing and replacing ~80% of siding ***in December*** to remediate drainage issues
- This was not in the plan

Siding removed to remediate flashing

Lesson Learned:

Plan on drainage plane remediation!

DER Challenge – Airflow Control

Why do we care about air flow control?

- A very important driver of energy use
- Often related to moisture management issues

Be aware of change

- Reduces (accidental) dilution of contaminants
- When reducing dilution, need to have better source control

DER Challenge – Airflow Control

Wet and funky basements:

Sometimes the problem gets worse if we try to distance ourselves from it.

- Insulating between the house and basement/crawlspace tends to make that space colder and wetter
- Wood structure exposed to basement/ crawlspace is at greater risk

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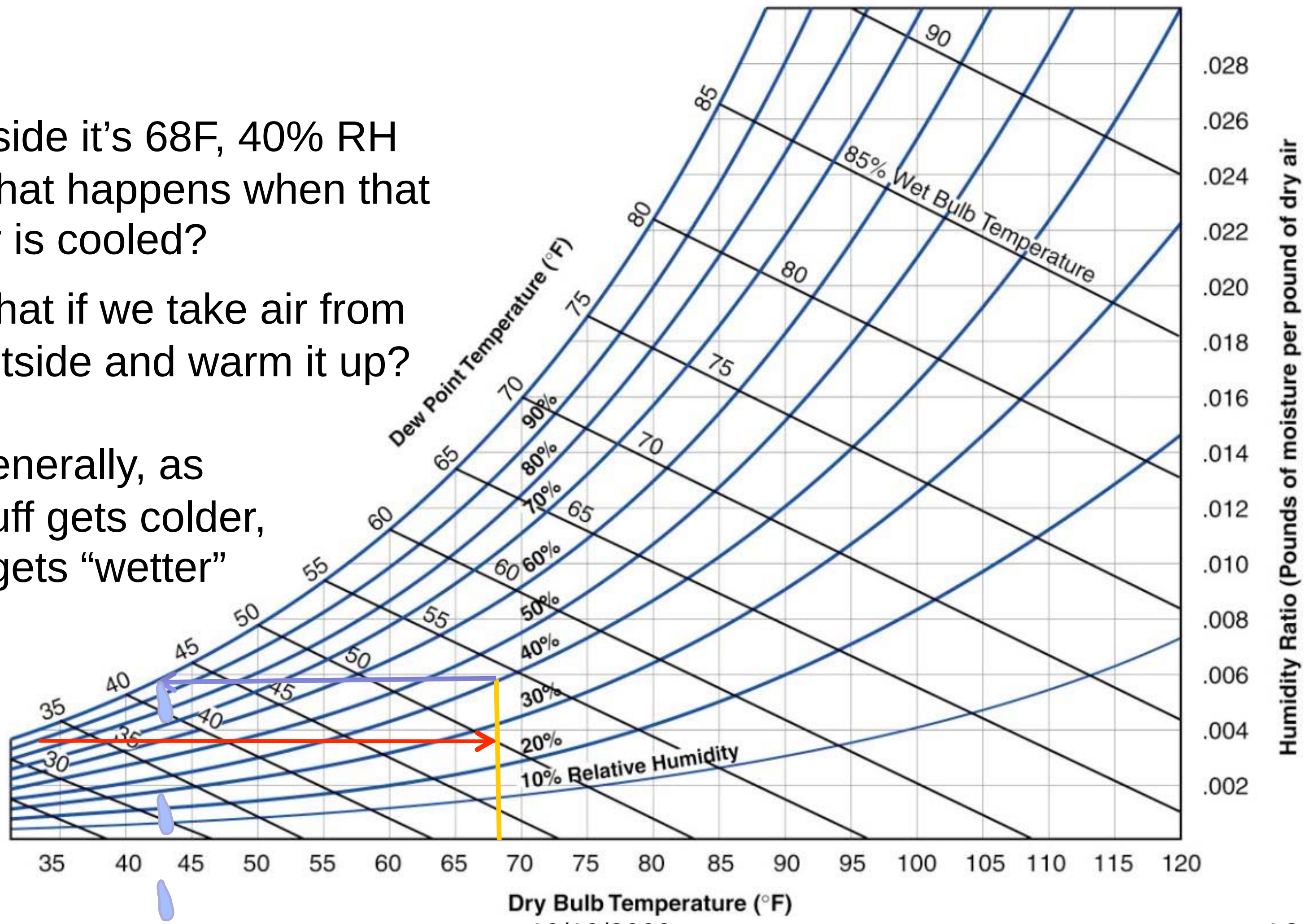
Colder tends to be wetter (in terms of relative humidity)

Inside it’s 68F, 40% RH
What happens when that air is cooled?

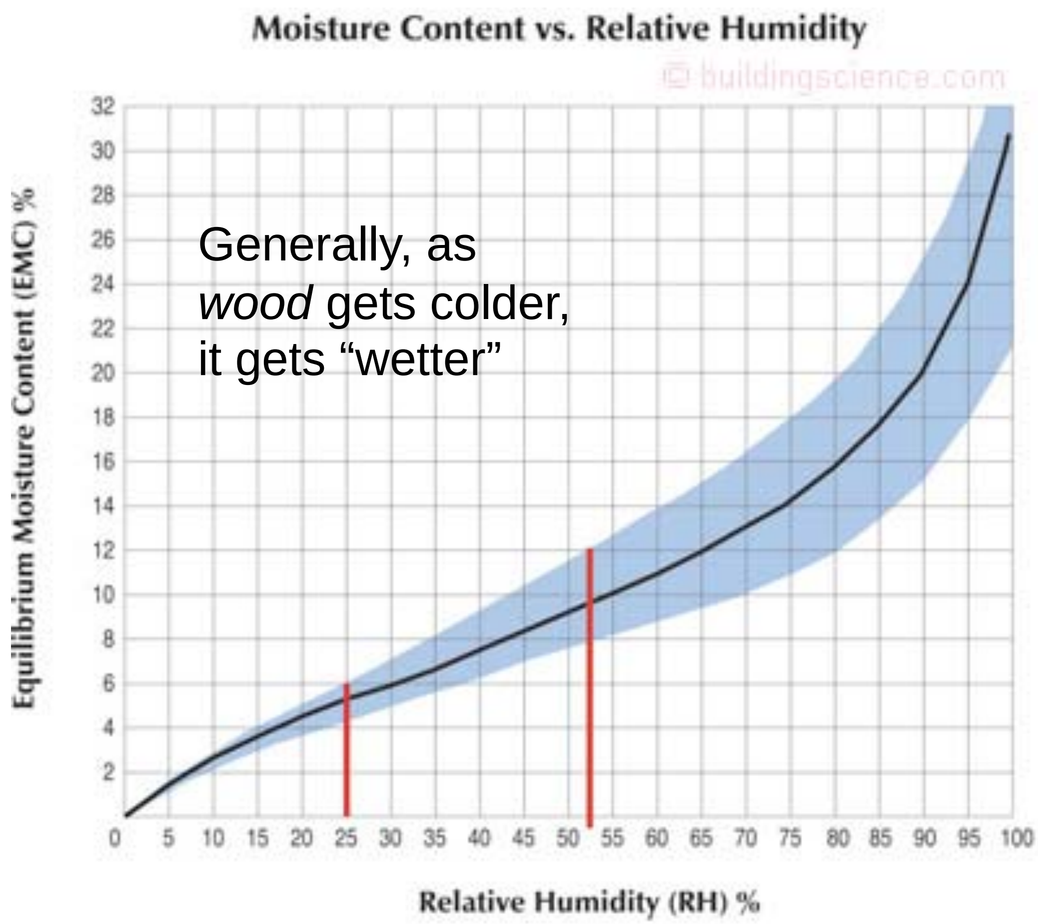
What if we take air from outside and warm it up?

Generally, as stuff gets colder, it gets “wetter”



Wood cares about *relative* humidity

Generally, as
wood gets colder,
it gets "wetter"



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DER Challenge – Airflow Control

- It is very difficult to actually separate the basement air from the rest of the building
- Attempted isolation of basement can be a two-fold performance compromise
  - Communication with basement remains – bad air
  - Mechanicals not in conditioned space – efficiency losses, bad air

Example DER – 19c Farmhouse

Pre-Retrofit Conditions:

- Attached greenhouse, kitchen and harvest rooms
- Largely uninsulated
- Stream running through cellar

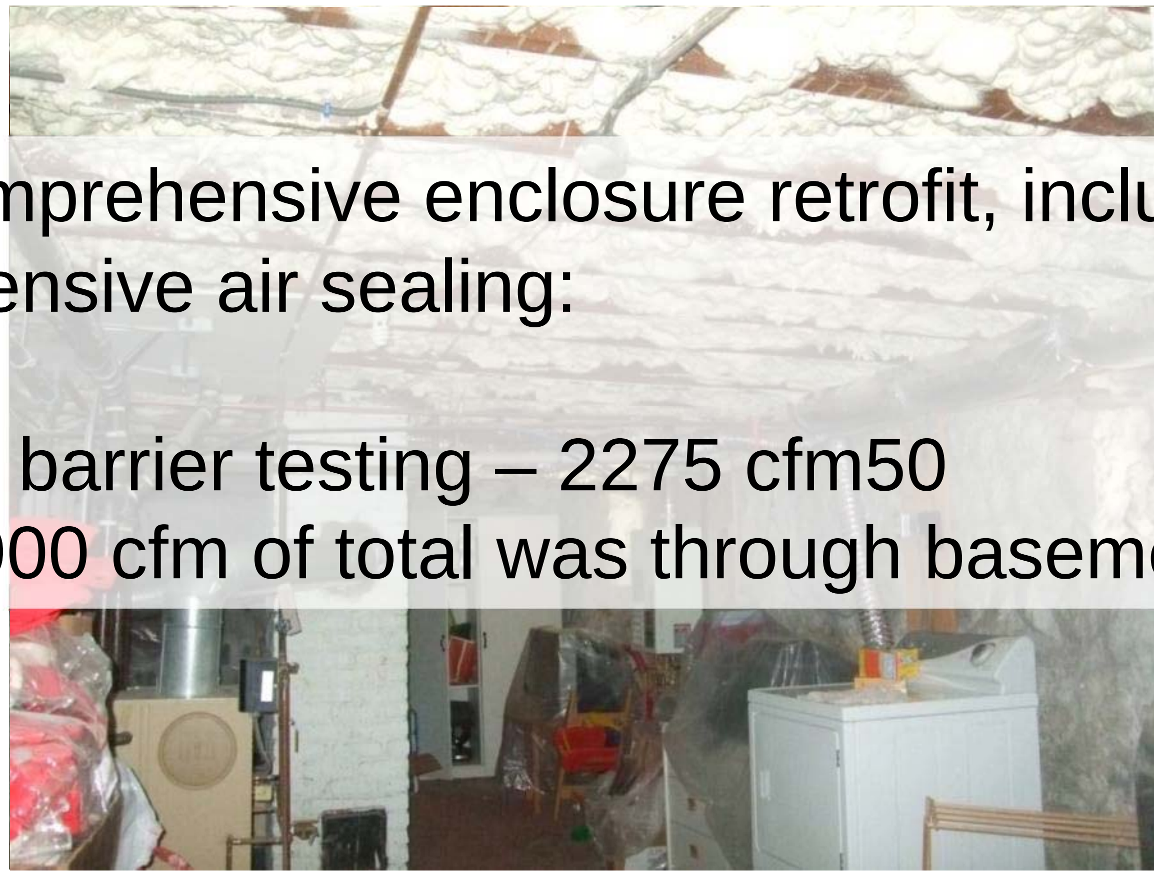
Red House Farm pre-retrofit

DER project plan:

- Isolate greenhouse and harvest kitchen from original structure
- Trench and pipe stream beneath new insulated slab
- High-R enclosure: exterior insulating sheathing, cavity cellulose, windows, storms
- Extend thermal enclosure to basement to protect structure
- Ground-source heat pump, solar thermal, PV, ERV

DER Challenge – Airflow Control

Isolating the Basement – past experience



Comprehensive enclosure retrofit, including extensive air sealing:

•Air barrier testing – 2275 cfm50
~900 cfm of total was through basement

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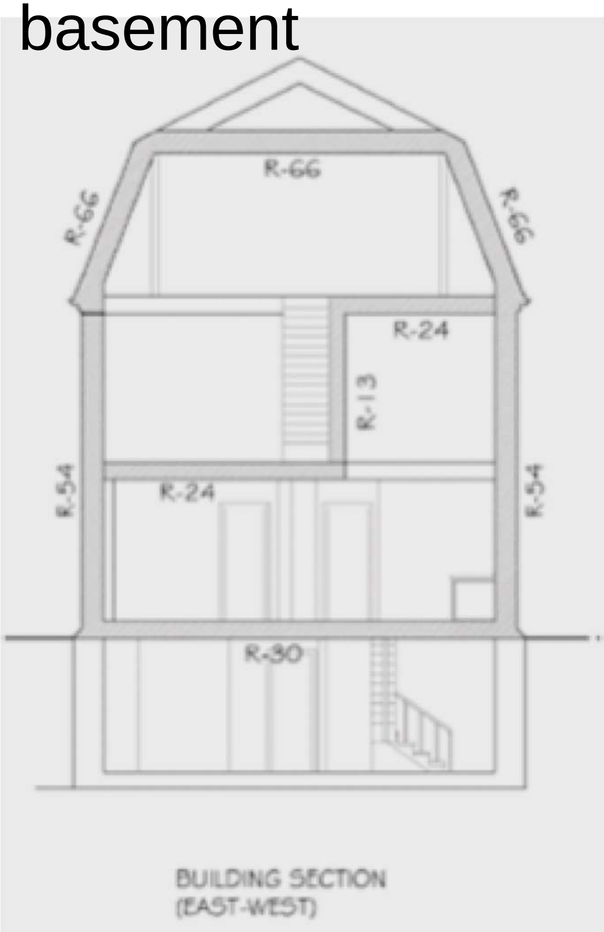
DER Challenge – Airflow Control

- Project proposed separating basement from conditioned space
- Air control and thermal control to be at floor over basement



24-26 Princeton Street, Medford

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DER Challenge – Airflow Control

A Bold New Approach to Basement Separation:

- Sheet good air control material over subfloor
- Enclose floor framing within the thermal control layer
- Expose and seal bottom plates of partition walls
- Spray foam at perimeter

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DER Challenge – Airflow Control

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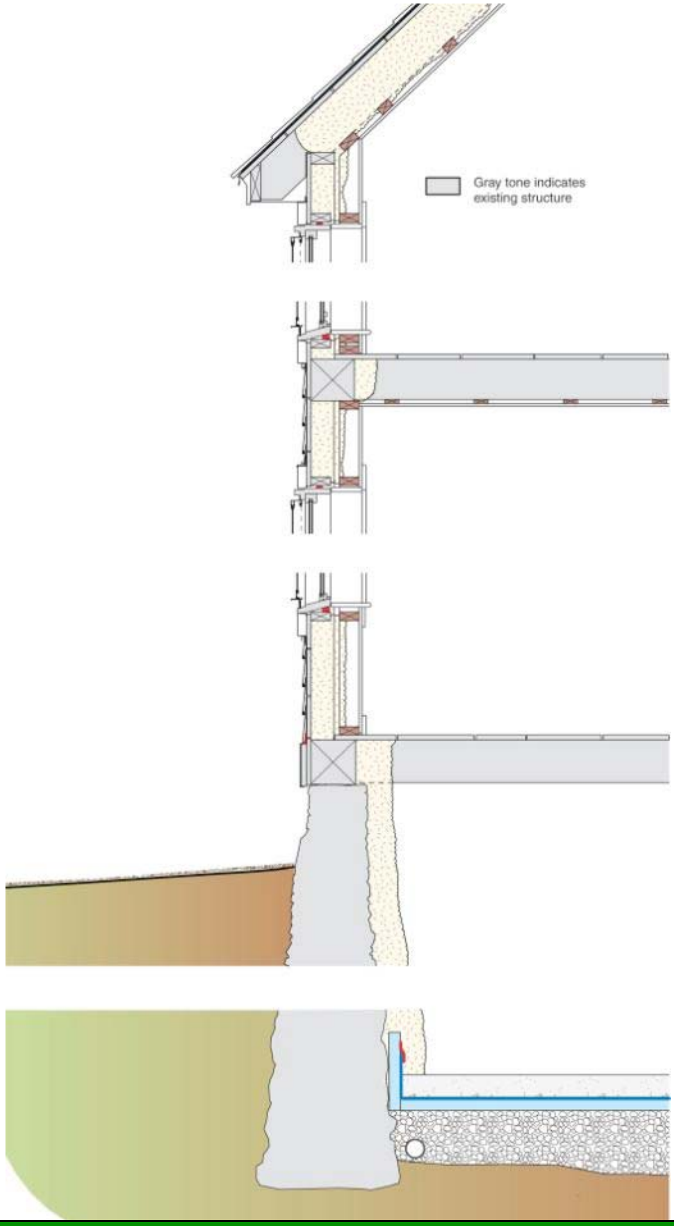
DER Challenge – Airflow Control



Interior cavity insulation approach:

- Double wall
- Thick insulation

Clark residence pre-retrofit

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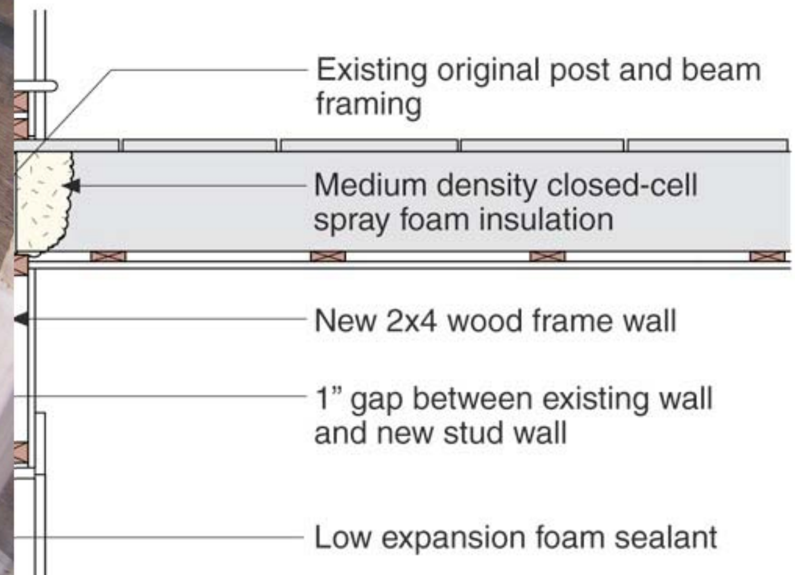
DER Challenge – Airflow Control

Gap between double wall framing:

- Allows continuous control layer
- Minimize framing joints projecting through control layer

low-E, wood-framed windows



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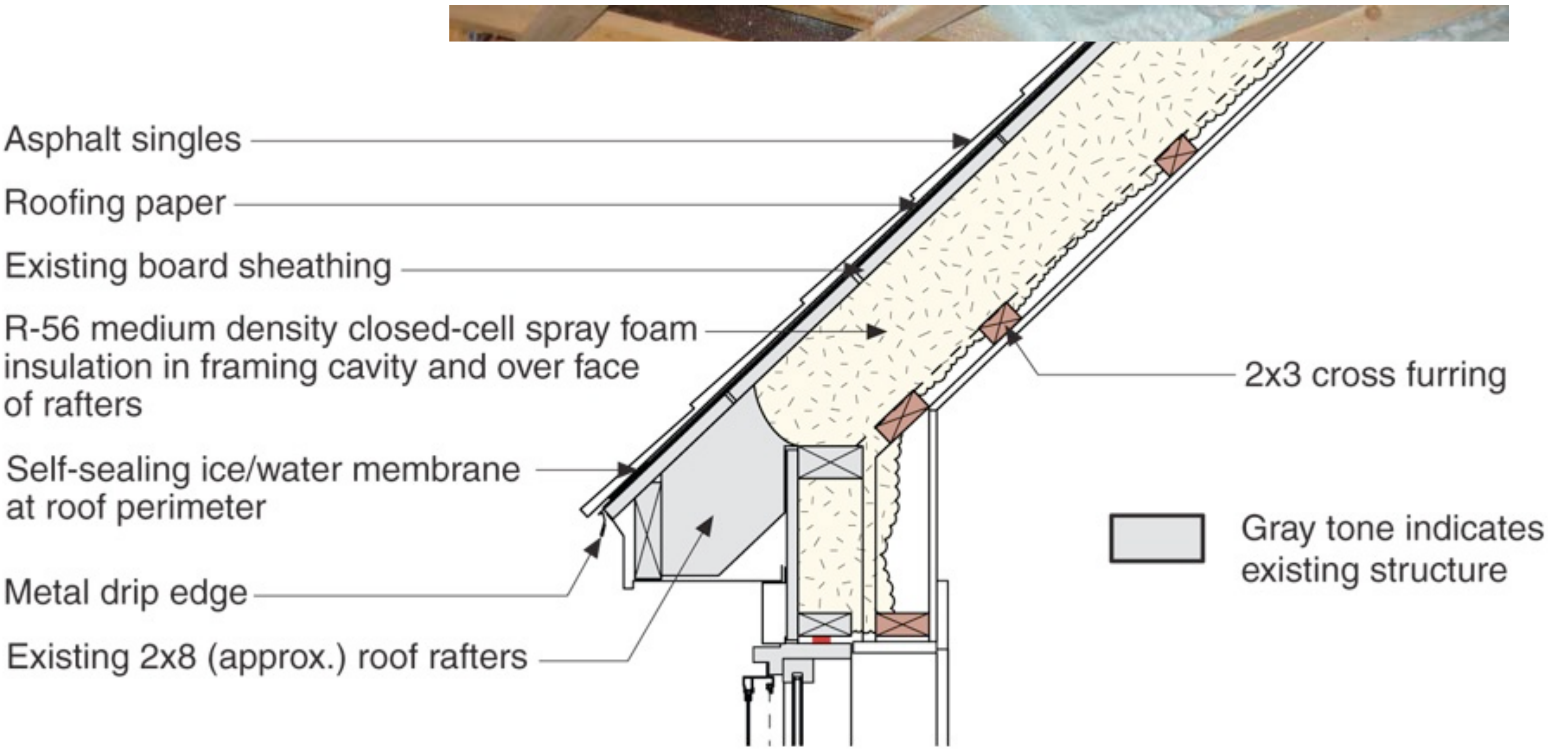
DER Challenge – Airflow Control

Air control layer covers framing:

- Allows continuous control layer
- Minimize framing joints projecting through control layer



DER Challenge – Airflow Control

Attic air sealing

- attic sealed
- ducts entirely within conditioned space

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DER Challenge – Water, Air, Thermal, etc. control

- Condition of basement very important
- Pre-retrofit, standing (flowing) water in basement

Retrofit Plan:

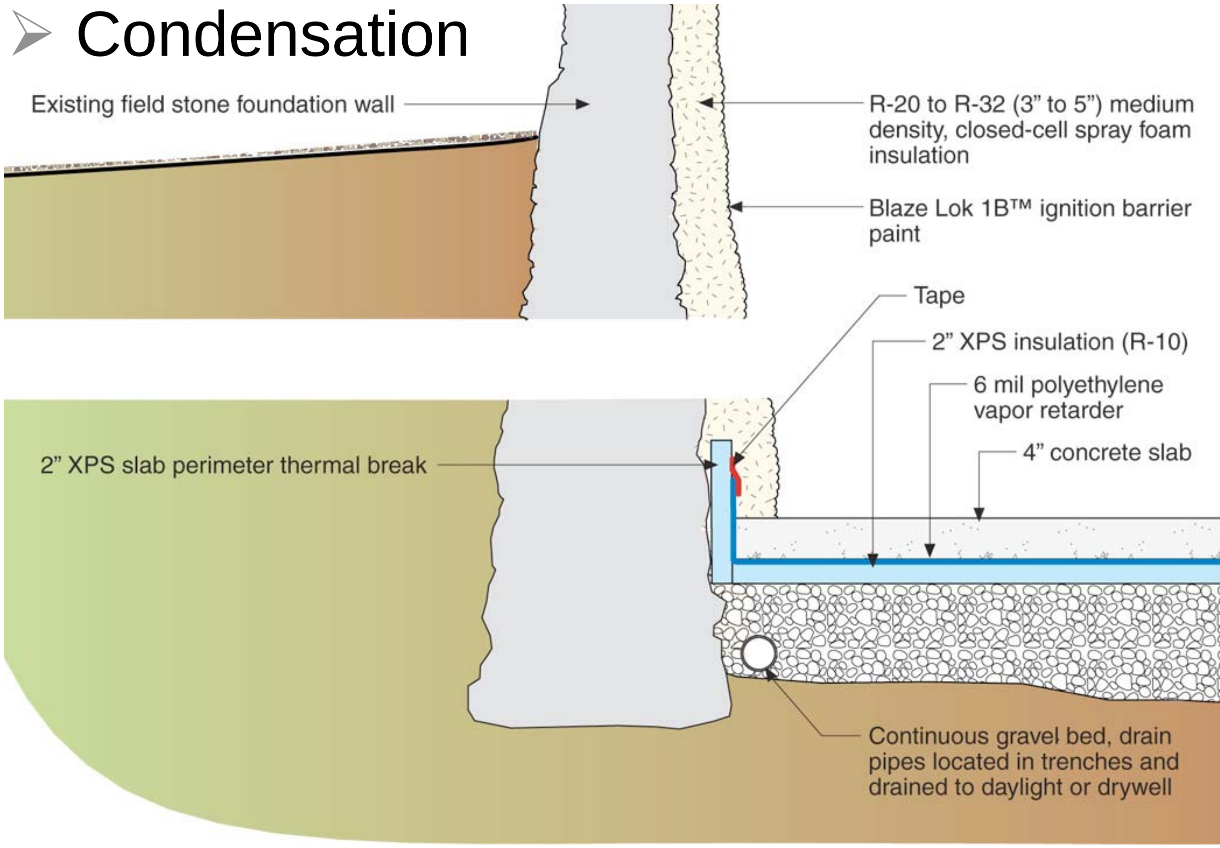
- Trenches, drain pipe to daylight, gravel
- 6 mil poly
- More gravel
- SPF on walls

DER project guidance:

- Insulation
- Concrete slab
- Poly in contact with concrete
- 12” high XPS at slab perimeter

DER Challenge – Water, Air, Thermal, etc. control

- Bulk water
- Capillary transfer
- Condensation
- Convective transfer
- Difusion



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Time check

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DER Challenge – Windows

So, you don't want to replace your windows…

- Windows fairly new
- Already at Double, Low-E
- Essential to character of the building

Existing window trim - head

Existing replacement windows installed without flashing

Existing window trim - sill

DER Challenge – Windows

Improving existing windows

- Evaluated window quilts and exterior storm windows
  - Window quilts claim R3.5 - R5 performance
  - Storm windows available with low-e
- Found exterior storm windows to offer least interior window condensation risk
- *But* there still high condensation risk for storm window surface

Clark residence exterior

DER Challenge – Windows

Storm windows

- Composite performance in range of R4 – R5 over double low-e windows
- Can provide some rain shielding to window
- Can trap water in window opening
- Aesthetic and operational concerns

Quote

Base Window Configuration			Base Window with CLEAR Storm Glass	
			U-FACTOR	SHGC
Wood	Single Glazed	Clear	0.45	0.62
	Dual Glazed	Clear	0.30	0.56
	Dual Glazed	Low-e	0.25	0.52
	Dual Glazed	Low-e Argon	0.25	0.52
Aluminum Clad Wood	Single Glazed	Clear	0.47	0.62
	Dual Glazed	Clear	0.34	0.56
	Dual Glazed	Low-e	0.29	0.49
	Dual Glazed	Low-e Argon	0.28	0.49
Aluminum	Single Glazed	Clear	0.63	0.62
	Dual Glazed	Clear	0.47	0.56
	Dual Glazed	Low-e	0.42	0.52
	Dual Glazed	Low-e Argon	0.42	0.52
Vinyl	Single Glazed	Clear	0.47	0.62
	Dual Glazed	Clear	0.32	0.56
	Dual Glazed	Low-e	0.26	0.49
	Dual Glazed	Low-e Argon	0.25	0.49

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DER Challenge – Mechanical Systems

Mechanical systems needed to do more in high performance homes

Mechanical system functions for high performance homes in the Northeast:

1. Heating
2. Water heating
3. Ventilation
4. Distribution/mixing
5. Cooling
6. Dehumidification,
7. Filtration

DER Challenge – Mechanical Systems

- Mechanical system do more in high performance homes than in “typical” homes
- Mechanical systems in DER need to do more than systems did pre-DER
- Relative to new construction, the high performance retrofit faces more challenges:
  - Constraints of the building
  - Availability of appropriate products
  - Constraints of fuel availability

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DER Challenge – Mechanical Systems

1950s Cottage Home

Tweedly residence pre-retrofit

Pre-Retrofit Conditions:

- Oil hydronic, pellet stove heating
- High cooling energy use, window AC units

DER project plan:

- Air barrier and Insulating sheathing - walls and roof
- New windows
- Foundation insulation and water management

What to do about the mechanical systems?

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DER Challenge – Mechanical Systems

1950s Cottage Home

Tweedly residence pre-retrofit

Making hot water is a pesky problem!

System parameters:

- Original oil-fired boiler
- Gas not available on site
- Existing hydronic baseboard
- Existing DHW storage tank
- High cooling energy use
- Portion of heating by pellet stove
- No interior modification planned
- Limited budget

DER Challenge – Mechanical Systems

Relative Fuel Cost – Mechanical System Choices

		Heating		Hot Water			Normalized Operational Cost	
Scenario	Configuration Description	Primary Heating Fuel	Primary Heating Efficiency	DHW Fuel	DHW Type	DHW Efficiency	$/MBtu Heating	$/100 gal DHW
0	Current Configuration	oil	0.70	oil	indirect-fired tank	0.64	$ 25.75	$ 1.63
1A	oil hydronic w/ HRV ventilation, minisplit cooling	oil	0.85	oil	indirect-fired tank	0.78	$ 21.21	$ 1.34
1B	oil hydronic w/ HP supplement, 2 AHU	oil	0.85	oil	indirect-fired tank	0.78	$ 21.21	$ 1.34
2A	oil hydro-air w/ HP supplement, 2 AHU	oil	0.85	oil	indirect-fired tank	0.78	$ 21.21	$ 1.34
3A	propane hydronic w/ HRV ventilation, minisplit cooling	propane	0.95	propane	indirect-fired tank	0.87	$ 57.84	$ 3.67
4A	HP w/ propane on-demand water heater back-up, 2 AHU	electric	8.5-9.5 HSPF	propane	on-demand	**0.95**	$ 18.60	$ 3.37
4B	HP w/ propane on-demand water heater back-up, central AHU	electric	8.5-9.5 HSPF	propane	on-demand	0.85	$ 18.60	$ 3.77
5A	propane hydro-air w/ HP supplement, 2 AHU	propane	0.95	propane	indirect-fired tank	0.87	$ 57.84	$ 3.67
6A	propane furnace w/ HP supplement	propane	0.95	propane	on-demand	0.85	$ 57.84	$ 3.77

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DER Challenge – Mechanical Systems

Propane/Oil/Electric Options

$5.00	Propane per gallon
91,000	Btu/gallon (NREL paper, HHV)
$0.055	dollars per thousand Btu

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DER Challenge – Mechanical Systems

Relative Fuel Costs Impact System Choices:

- High price of propane can make propane-based systems non-cost effective
- For projects with no access to natural gas, LP prices make the operational cost of LP systems higher than oil.
- *BUT* boiler replacement is expen$ive!

DER Challenge – Mechanical Systems

Question assumptions:

- Propane ~$5/gallon, or
- ~$3/gallon if customer owns tank
- $$$ for tank and installation!

Estimate propane usage:

- ~125 gallons / year with condensing water heater
- + ~80-100 if dryer and cooking switched over

Price appropriate size propane tank:

- 120 gallon tank < $1K installed*

* source: previous DER participant in nearby town

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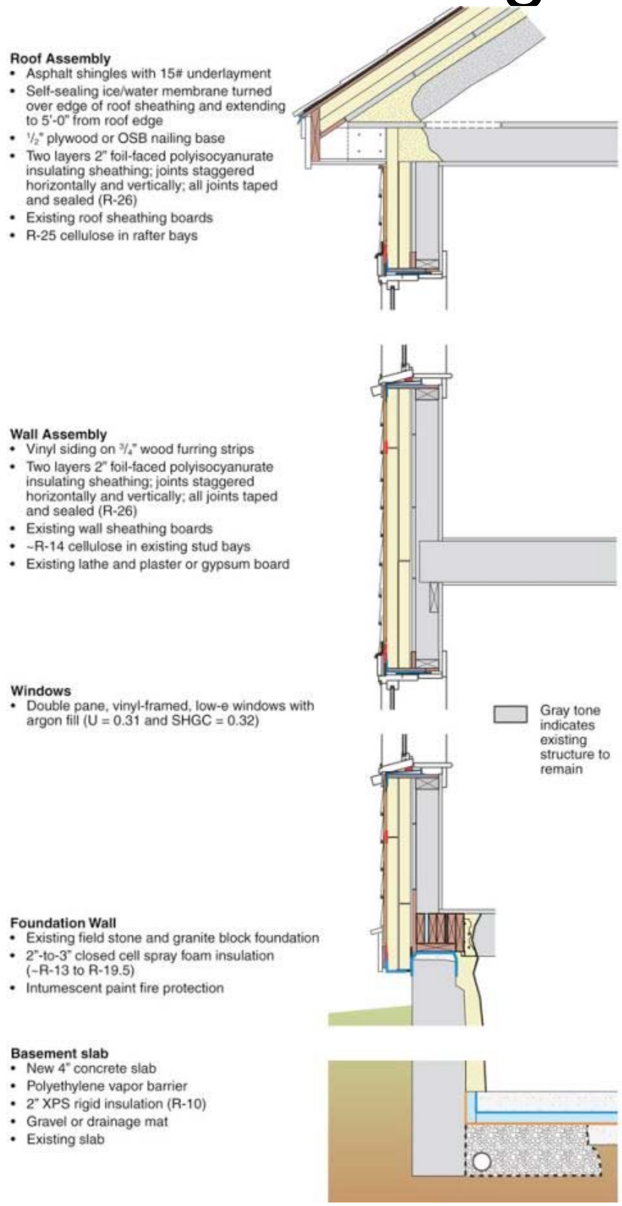
Questions?

May we move on to the next segment? (time check)

DER Challenge – Water Management



Changing the system: thick insulating sheathing

- Face of exterior insulation used as drainage plane

Bedford Farmhouse during demolition

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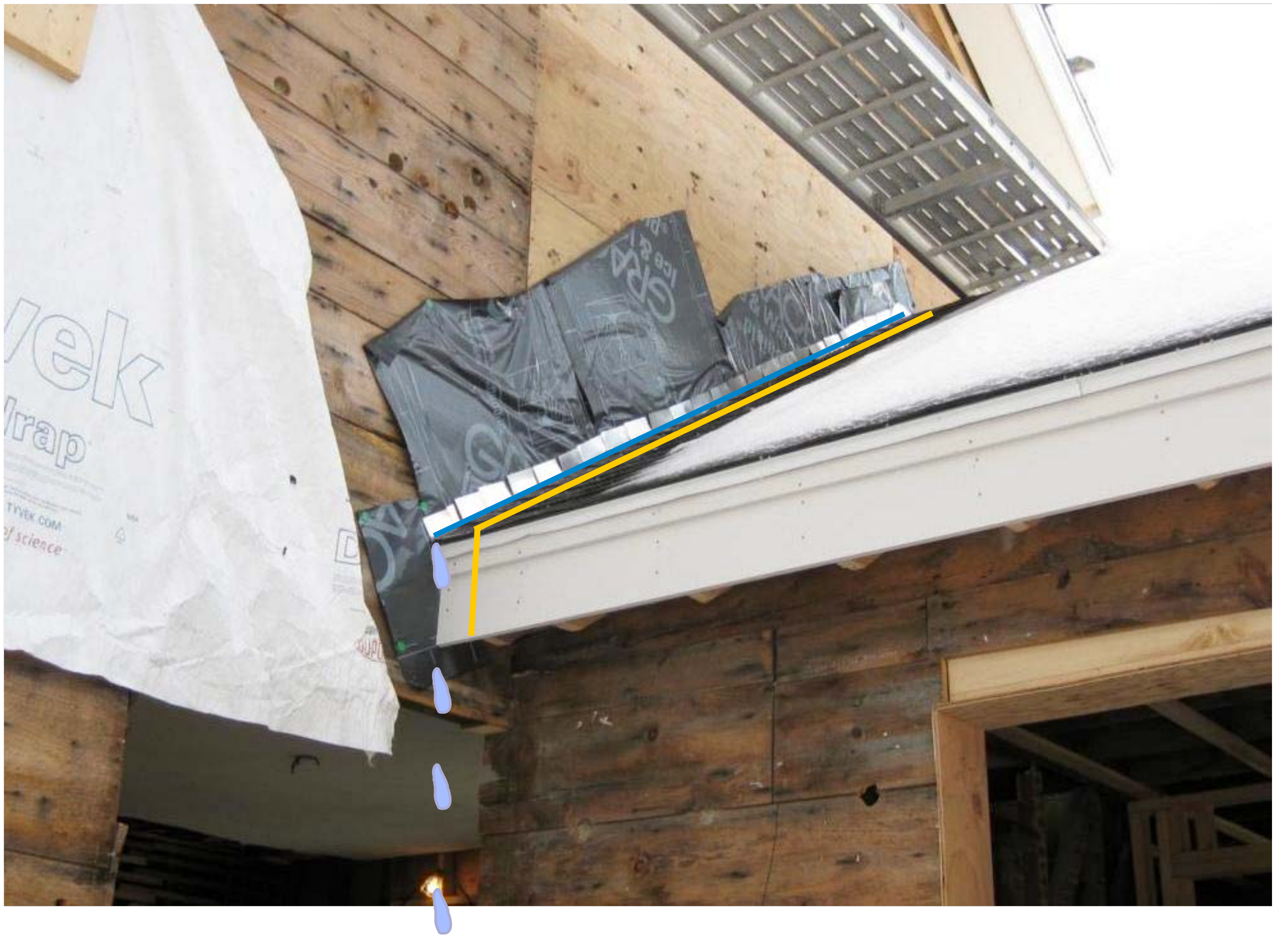
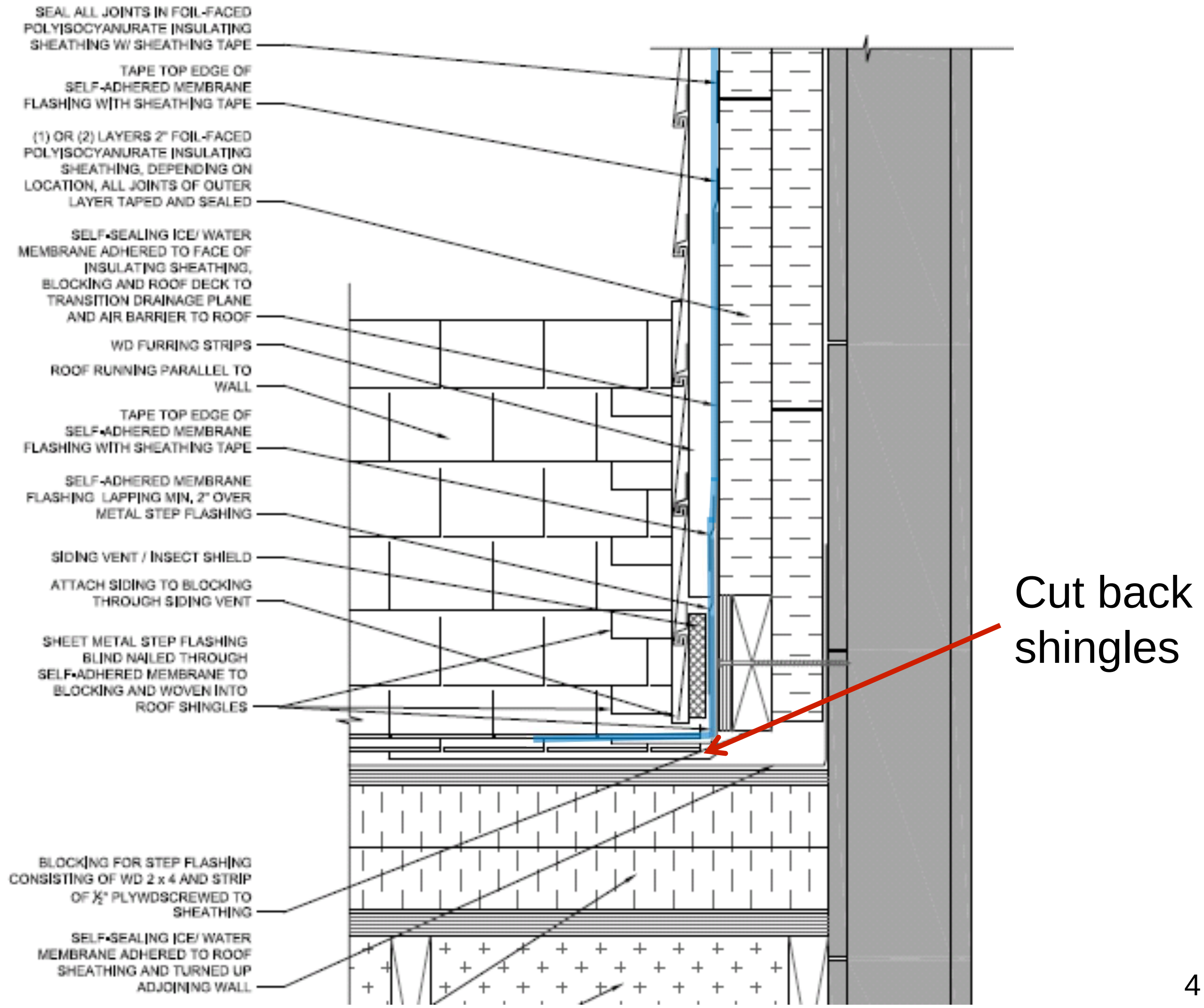
DER Challenge – Water Management

Exterior insulation drainage plane is not where it used to be



DER Challenge – Water Management

Drainage plane remediation detail



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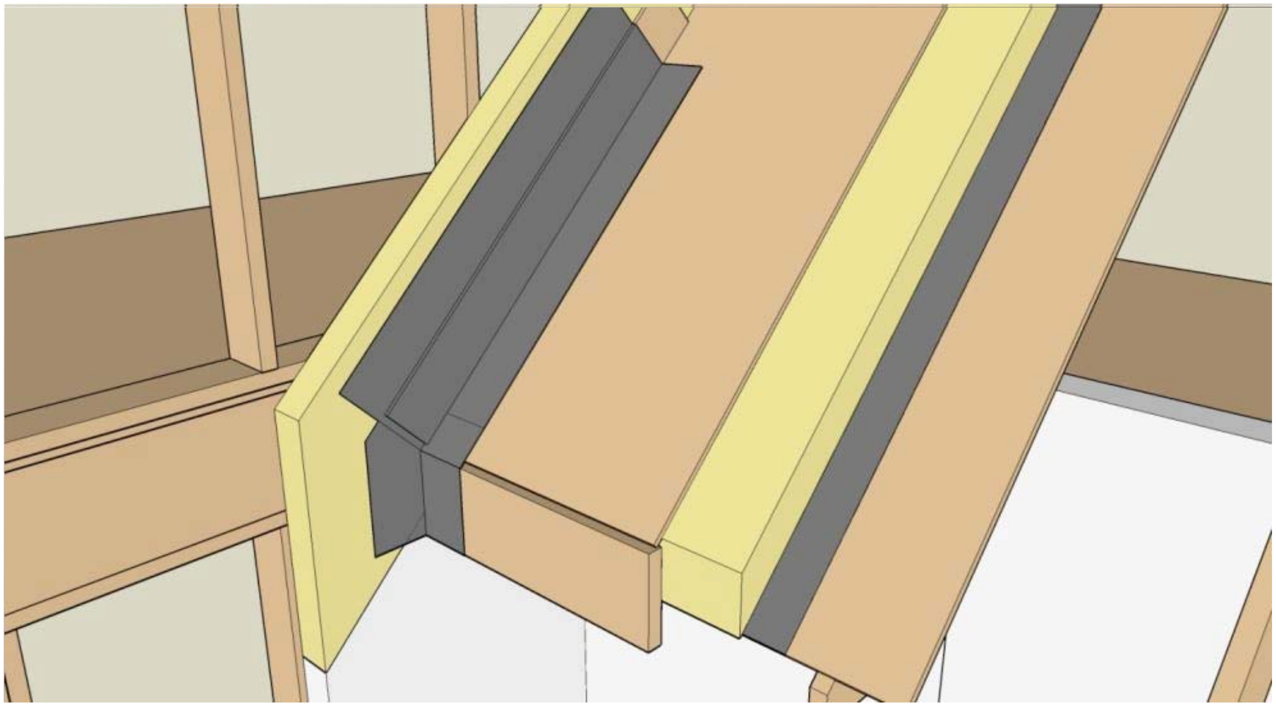
DER Challenge – Water Management

Remediation implementation

DER Challenge – Water Management

Exterior insulation drainage planes sequencing:



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DER Challenge – Airflow Control

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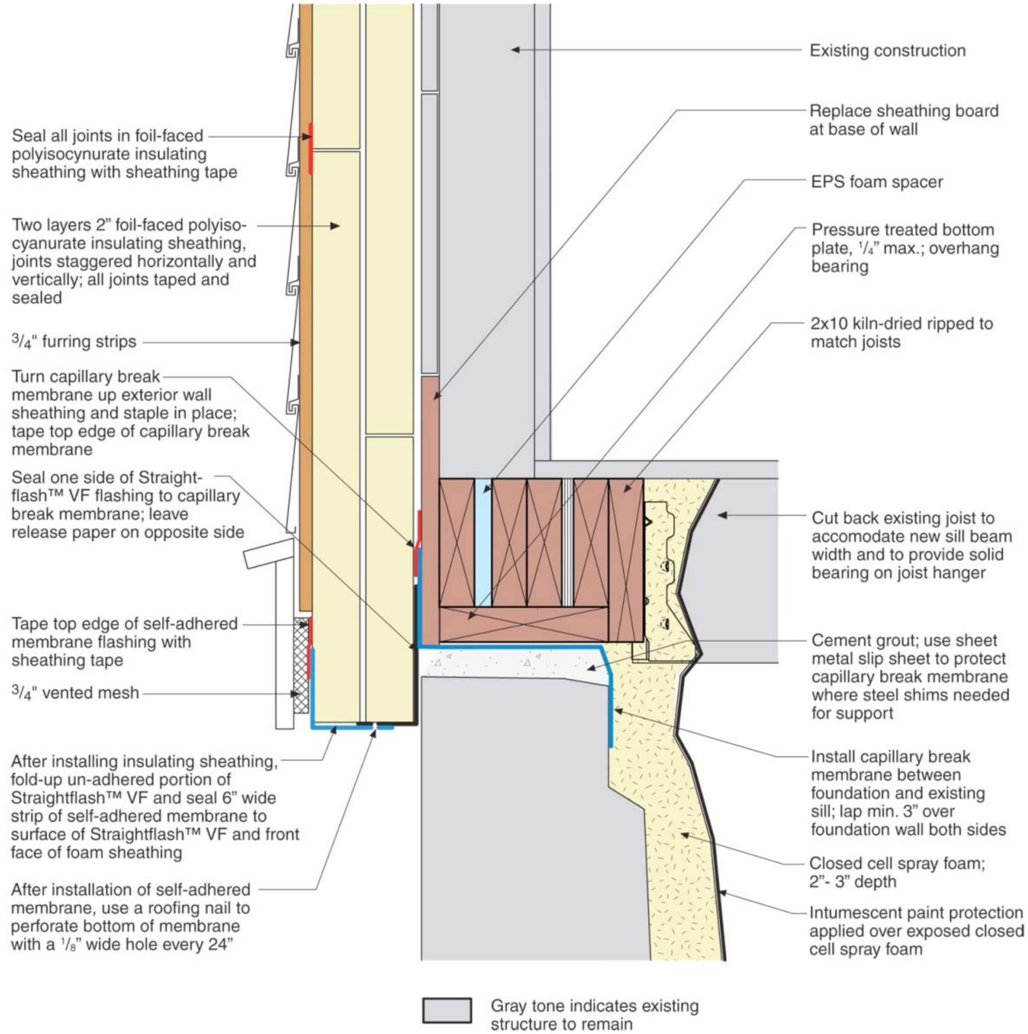
Air Barrier Challenges



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Air Barrier Challenges

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Air Barrier Challenges

Blower door fan installed in window

- Air Barrier Continuity – In-Process Quality Control

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DER Challenge – Airflow Control

Lessons Learned:

- It is very difficult to implement air control layer at face of exterior insulation
- Air control layer at face of exterior insulation is very dependent on workmanship
- Face of exterior sheathing provides better opportunity for effective air control

Basement Separation: Bold Approach

- Project proposed separating basement from conditioned space
- Air control and thermal control layers to be at floor over basement
- BSC has concerns based on experience

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Basement Separation: Bold Approach

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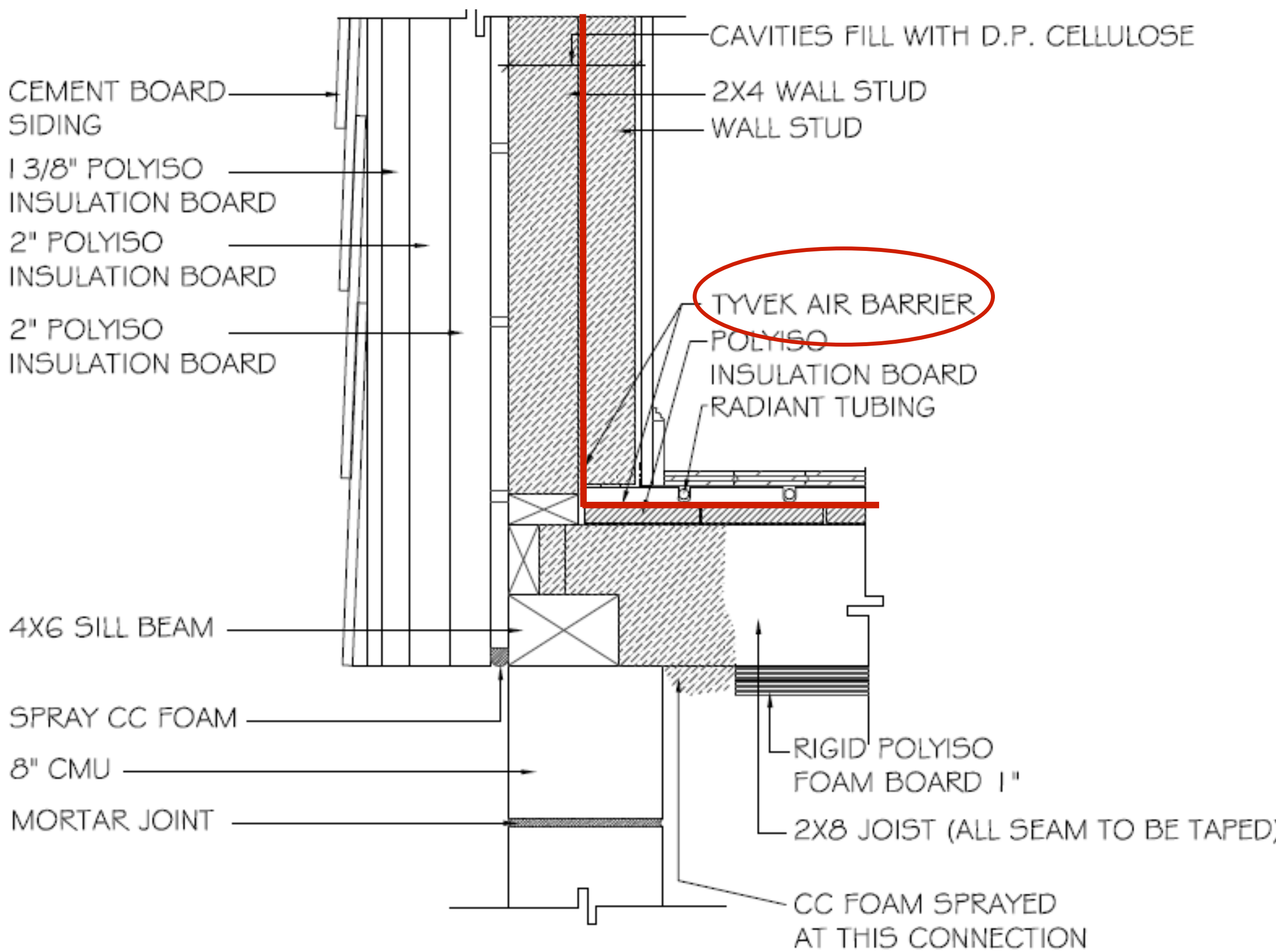
Basement Separation: Bold Approach

Project Proposal:

- Sheet good over subfloor
- Enclose floor framing within the thermal control layer
- Expose and seal bottom plates of partition walls
- Spray foam at perimeter

Basement Separation: Bold Approach



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