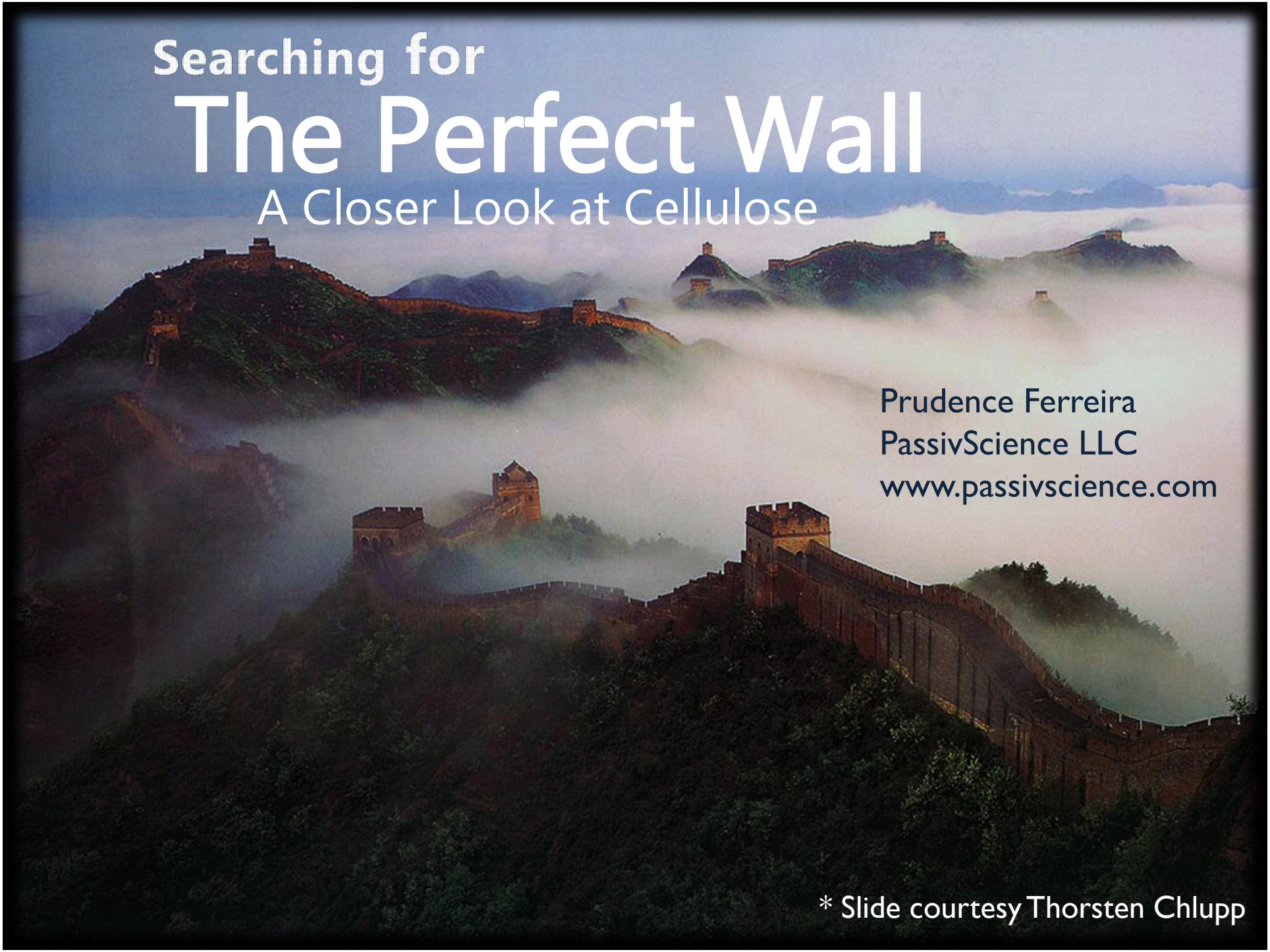

Searching for
The Perfect Wall
A Closer Look at Cellulose
Prudence Ferreira
PassivScience LLC
www.passivscience.com
* Slide courtesy Thorsten Chlupp

Moisture Control Best Practices

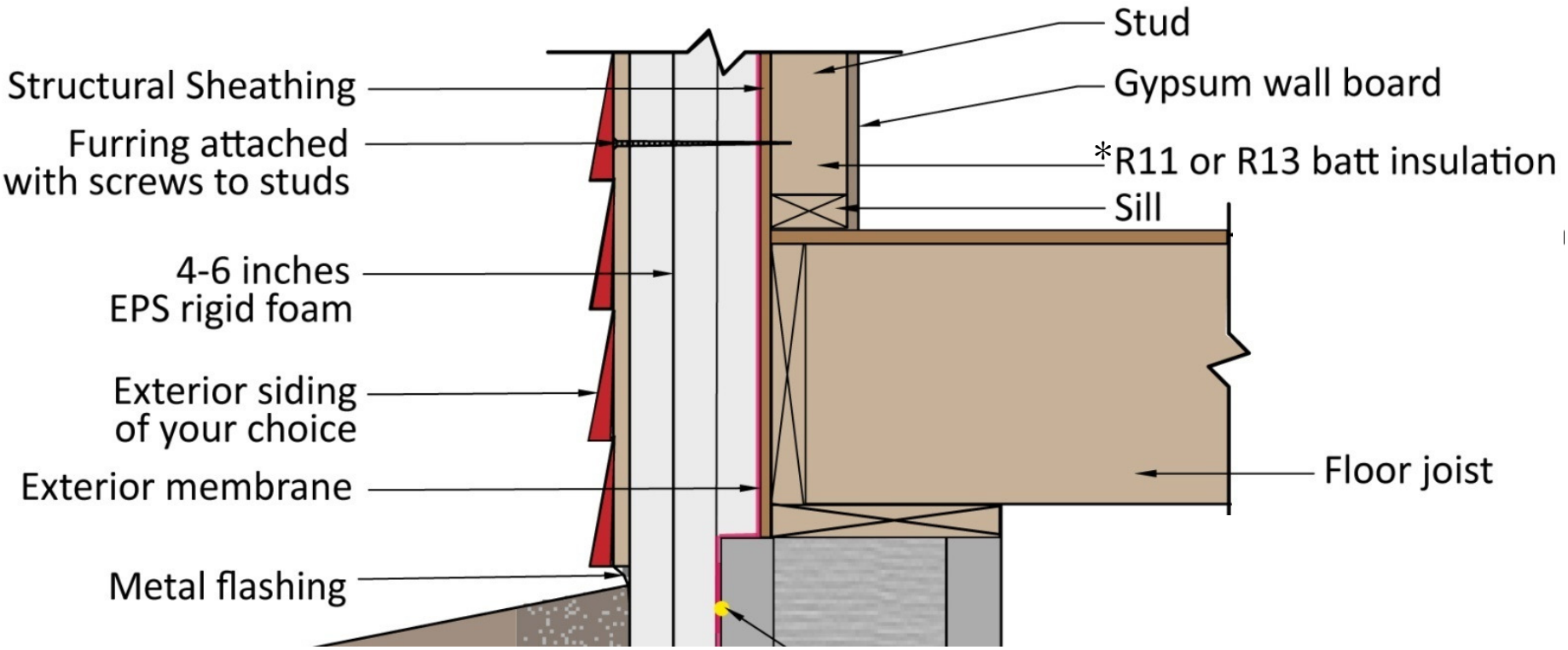
1. Avoid using vapor retarders where vapor permeable materials will provide satisfactory performance. Thereby encouraging drying mechanisms over wetting prevention mechanisms.
2. Avoid installation of vapor retarders on both sides of assemblies – i.e. "double vapor barriers" in order to facilitate assembly drying in at least one direction.
3. Aim for the use of diffusion open and hygroscopic materials over impermeable hydrophobic materials
4. Layer assemblies so that vapor retarding layers are close to the source of moisture and more sensitive, less durable materials are protected
5. Promote initial and ongoing drying and short-circuit accumulation by providing ventilation per ASHRAE 62.1, 62.2 or better

Central Question

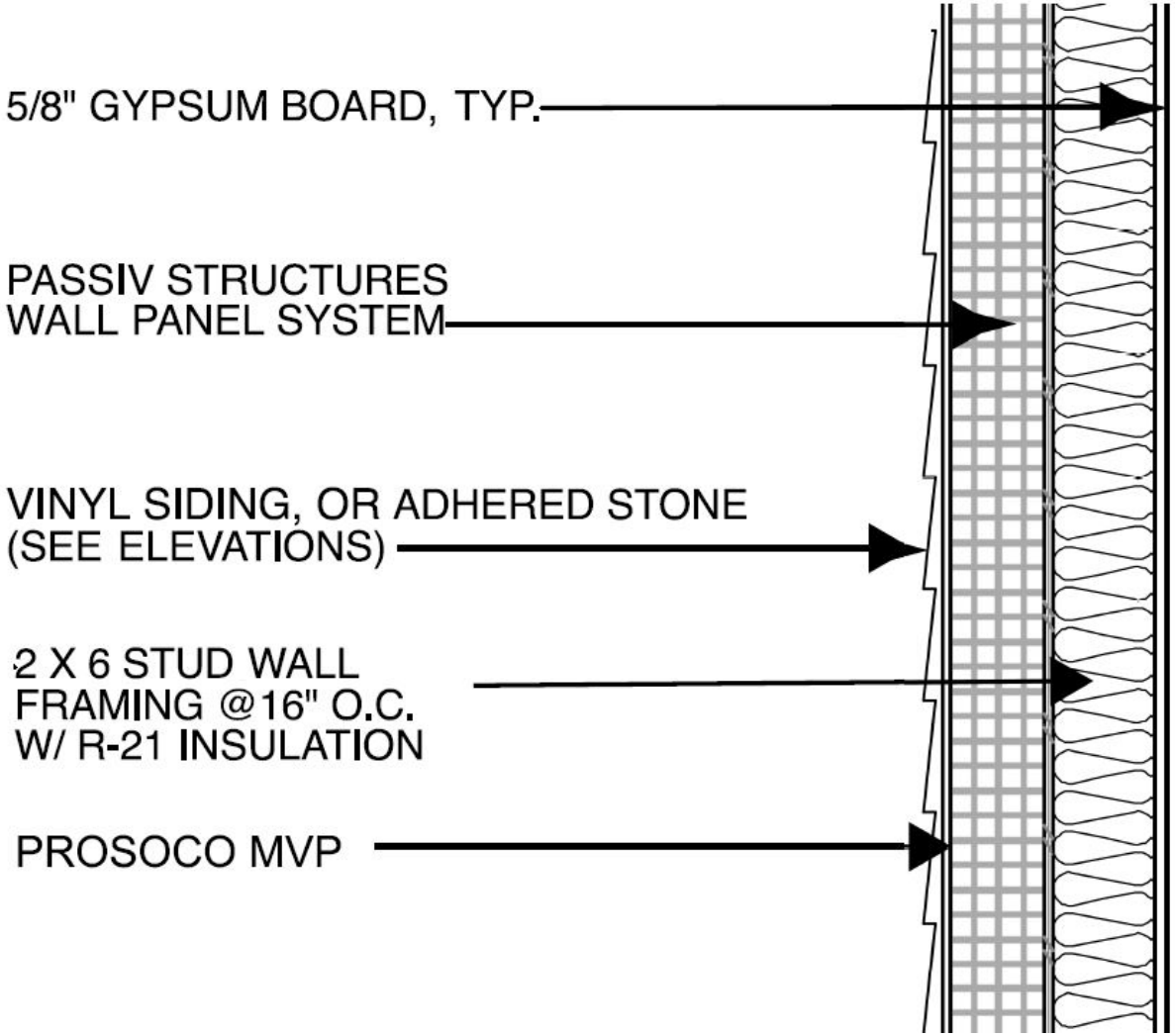
Aim for the use of diffusion open and hygroscopic materials over impermeable hydrophobic materials.

…..Is cellulose a good idea everywhere?

Residential Wall 1 - REMOTE



Residential Wall 2 – SIPS+



Residential Wall 3 – Ext Foam

1”+ WRB, 1 Perm, 0.1 perm | 2”-3” (1 perm, fiberglass)

LATEX PAINT

5/8” INTERIOR GWB

2x6” FRAMED WALL WITH DP CELLULOSE

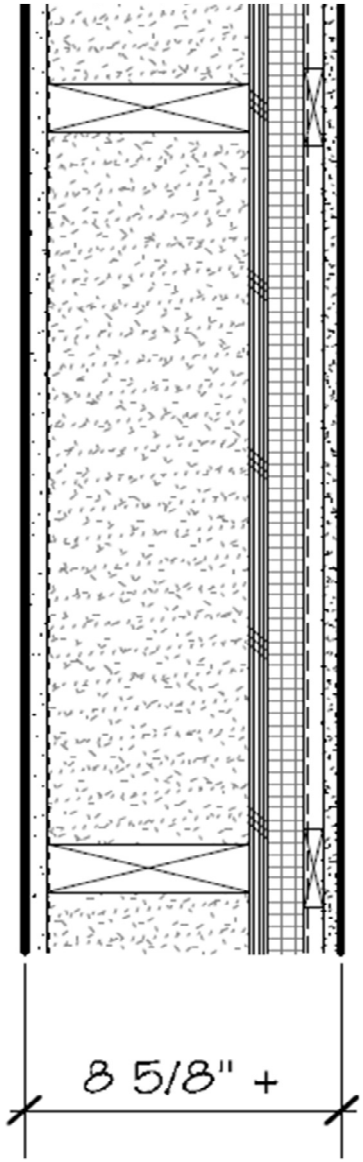
1/2” EXTERIOR PLYWOOD

BUILDING WRAP

1” EXPANDED POLYSTYRENE (EPS)

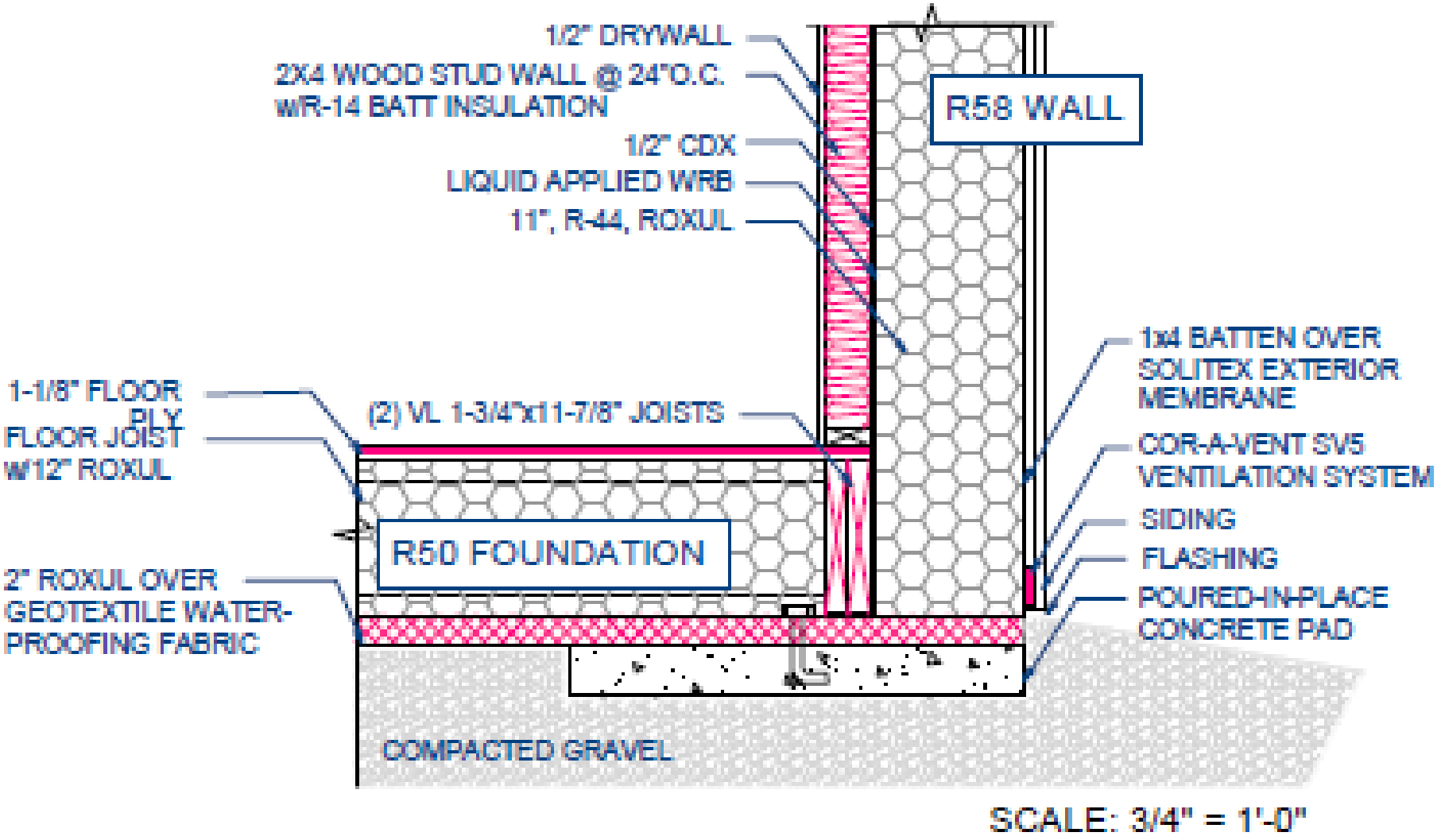
3/8” AIR GAP BETWEEN PT STRAPPING

3/4” FIBER CEMENT SIDING

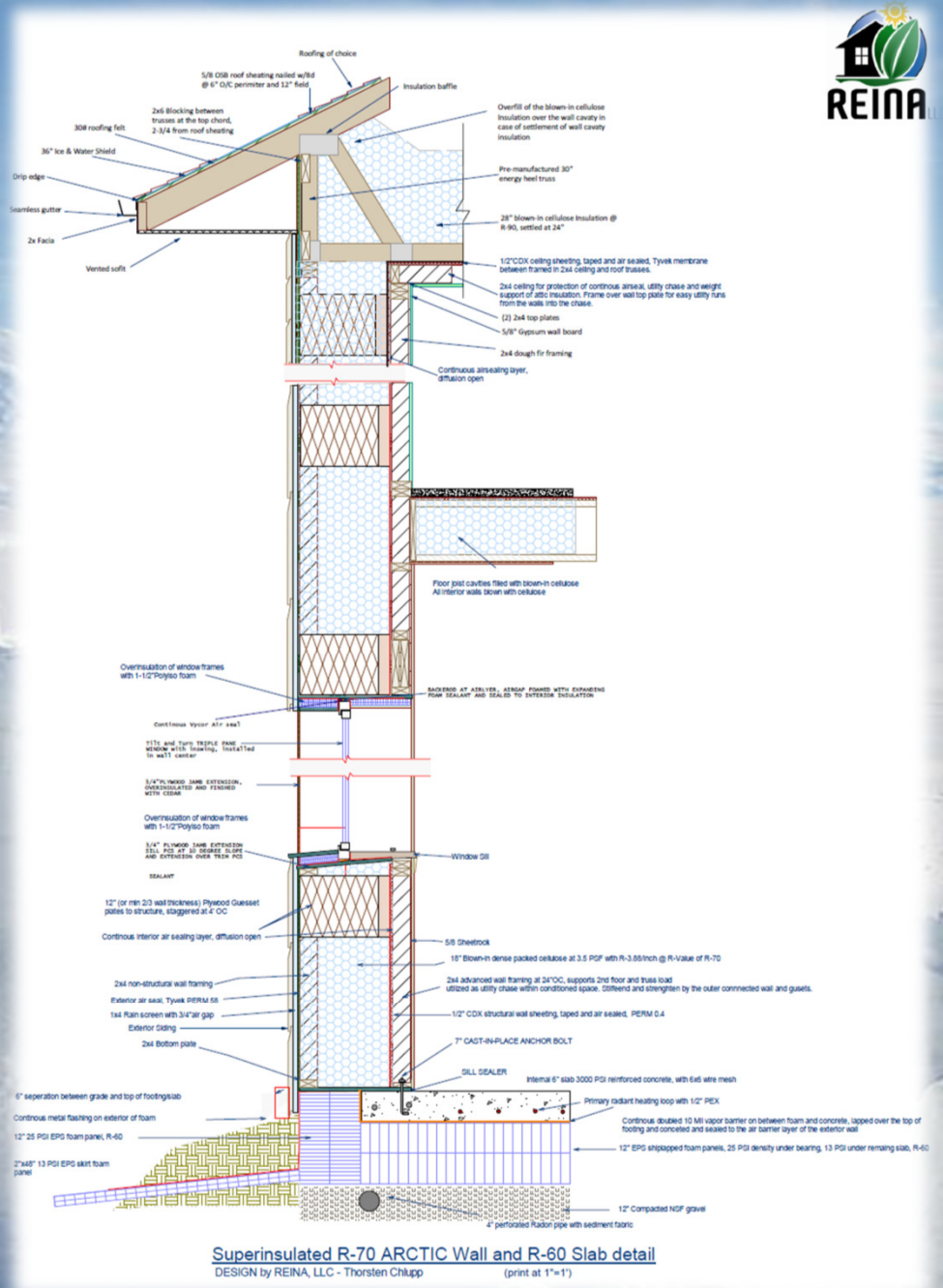


Residential Wall 4 – REMOTE-MW

Fiberglass cavity, fluid applied 17 perm/1 perm membrane on sheathing, 34 perm membrane over MW

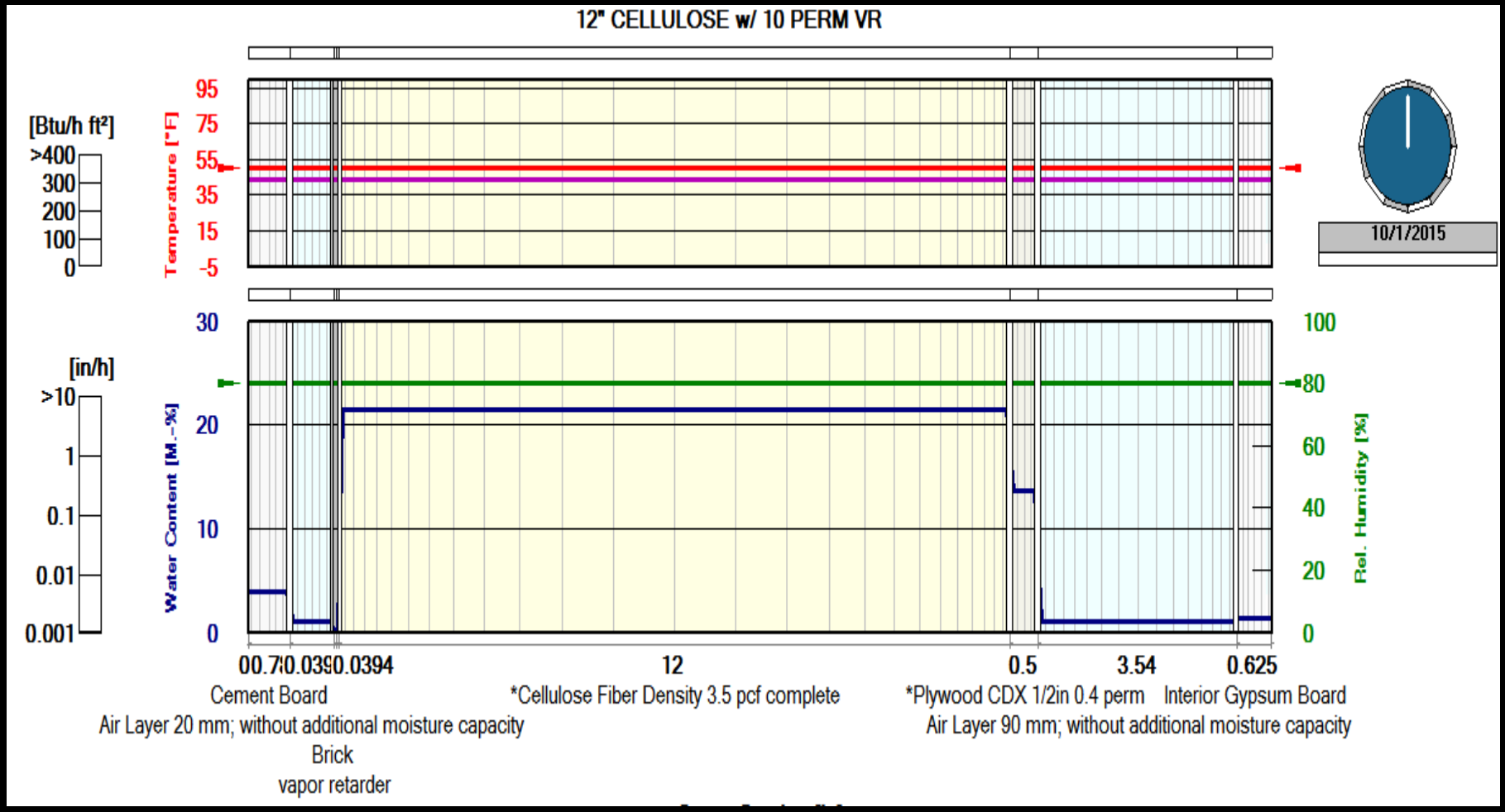


ARCTIC WALL

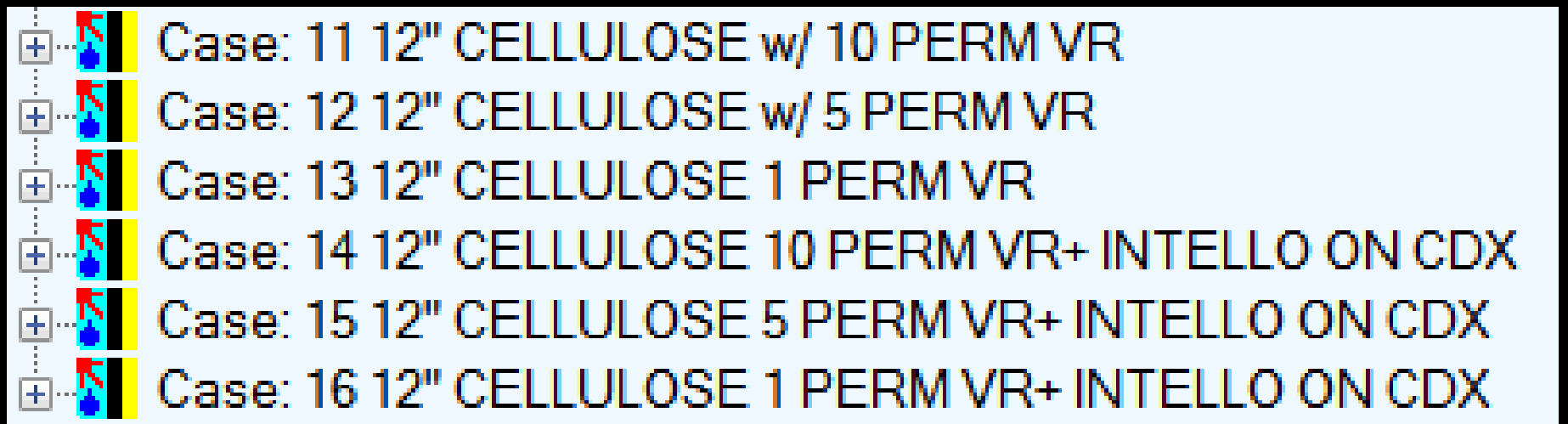


* Slide courtesy Thorsten Chlupp

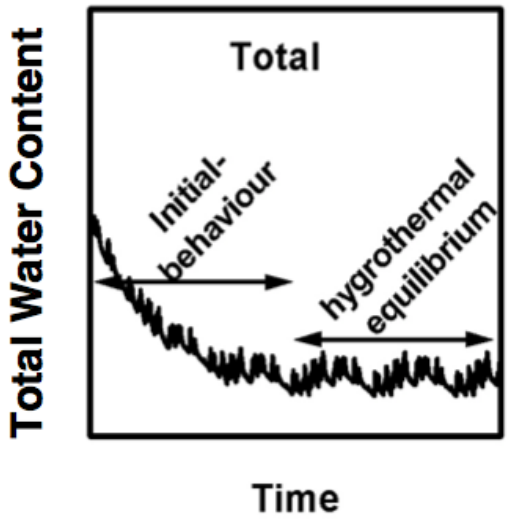
12” DOUBLE STUD WALL

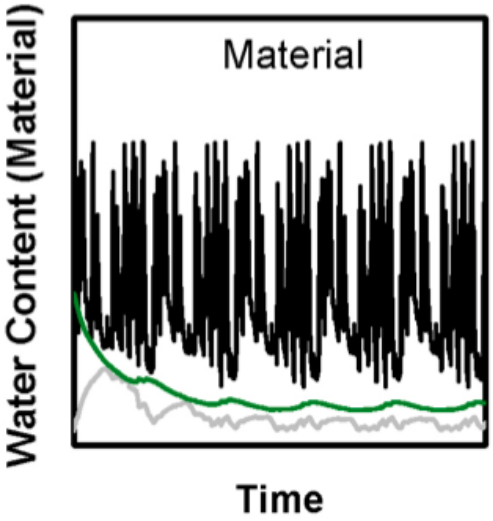


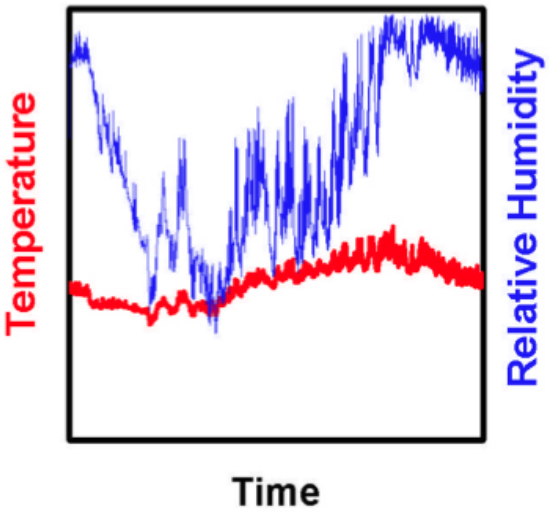
12″ DOUBLE STUD WALL

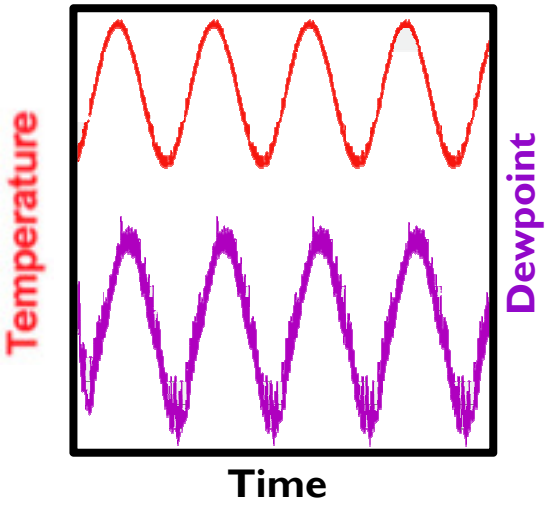


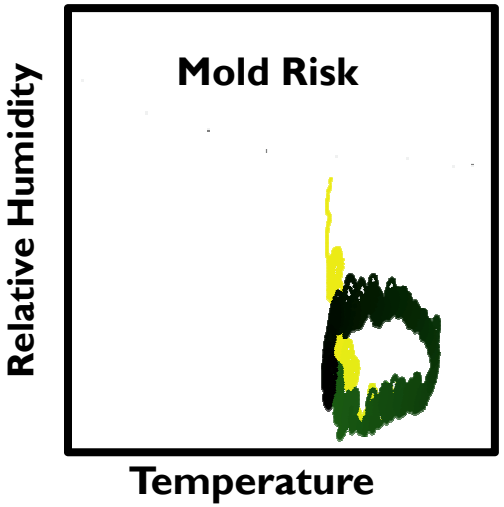
WUFI Results Data

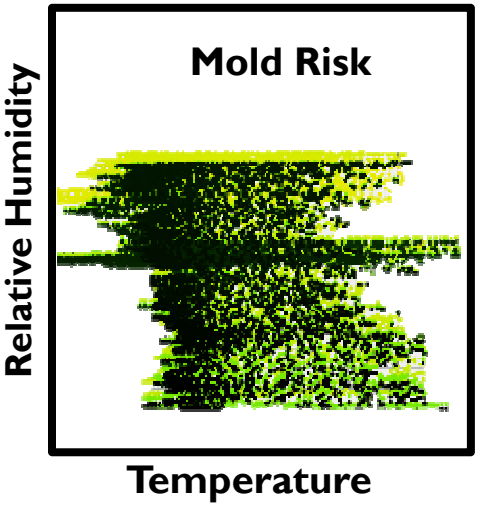












Specific Risk Thresholds: Mold

Spore presence MUST be assumed! But to germinate, fungi need the following conditions:

Nutrients: wood, paper, glues, paints, dust, dirt, soap

Favorable Temperature: 68°F -95°F is ideal, outside of 41°F-122°F growth stops

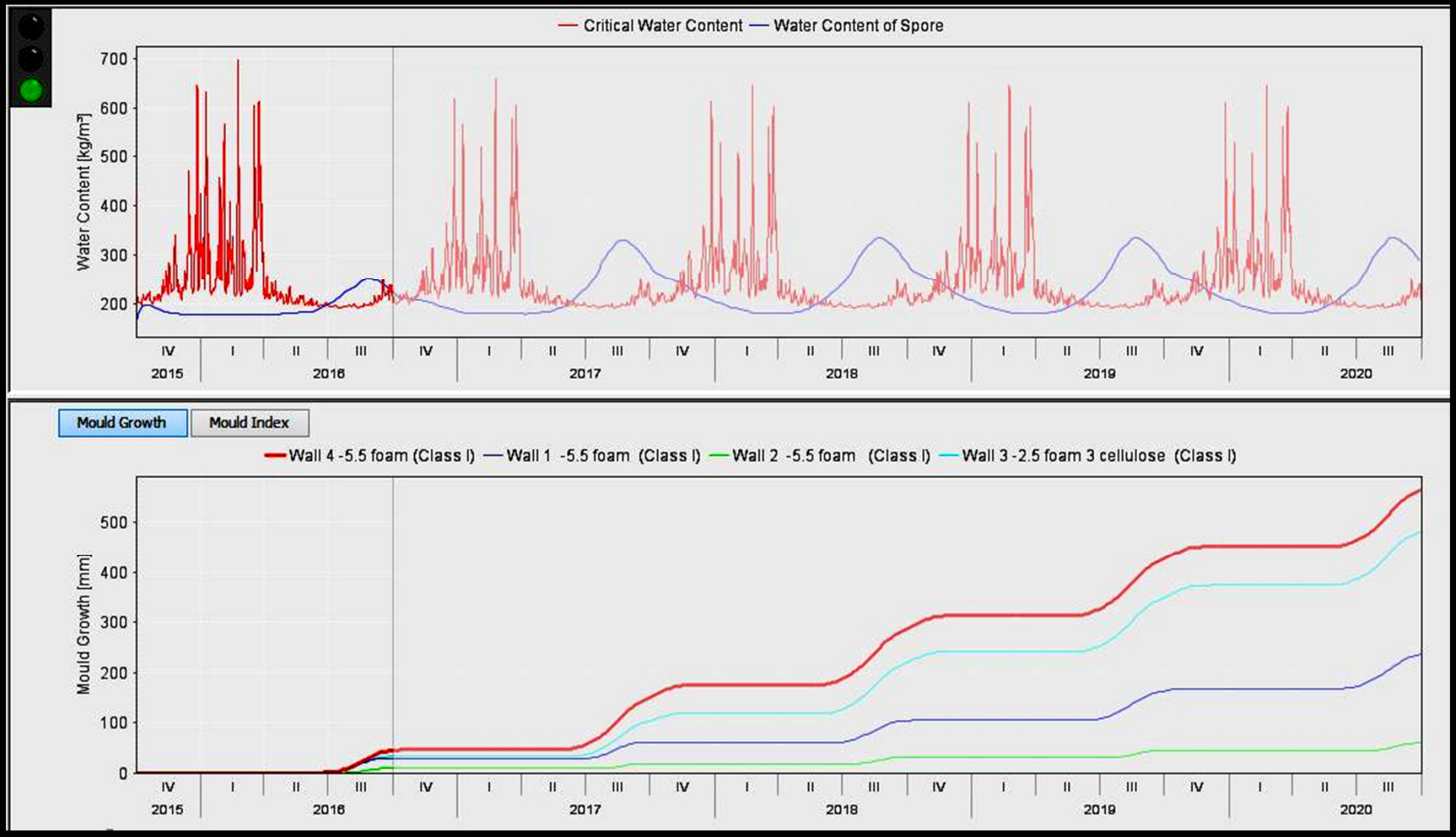
Moisture: Surface RH of 75-80%. Above 90-95% RH lack of oxygen stops fungal growth

WUFI BIO Post-Proc

- Klaus Sedebauer's Thesis
- Mold Growth in mm or Mold Index
- Models hygrothermal behavior of a mold spore which consists of envelope and living material inside
- Envelope is like a membrane, when humid membrane opens and it can live and germinate, when dry membrane is closed to keep moisture inside
- When critical water content is reached, germination is complete
- Other models just say when a specific RH and temp are reached then there is risk, this goes further to model hygrothermal behavior or spore and ascertain where germination (growth occurs)

**Use IEA Annex 55 use Hannu Viitanen Mold growth model for more accurate assessment*

WUFI BIO Post-Proc

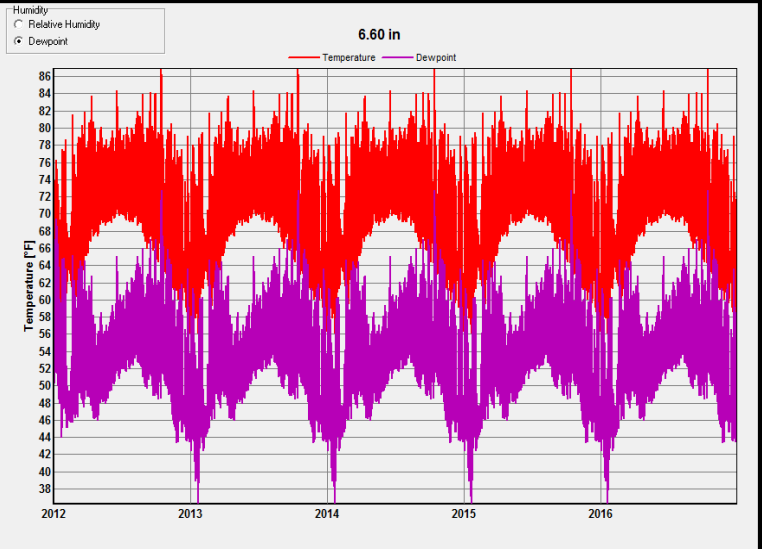


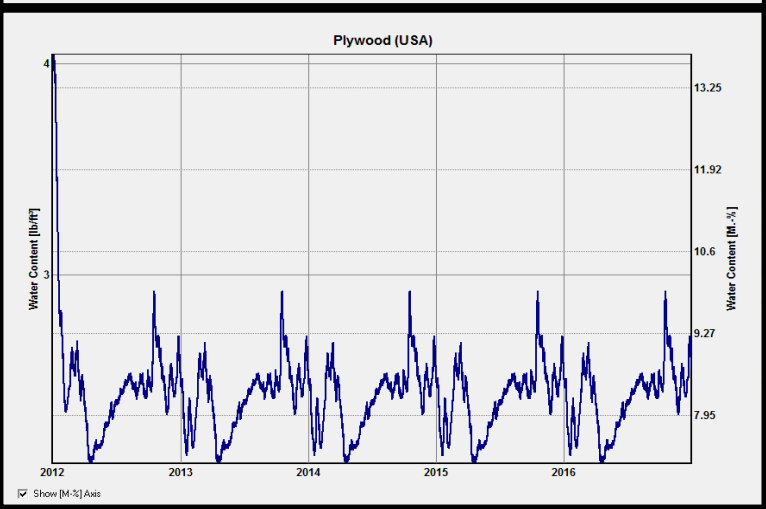
WUFI BIO Post-Proc

Mould index

Index:	Description:
0:	no growth
1:	some growth visible under microscope
2:	moderate growth visible under microscope, coverage more than 10%
3:	some growth detected visually, thin hyphae found under microscope
4:	visual coverage more than 10%
5:	coverage more than 50%
6:	tight coverage, 100%

Wood Decay





Wood Decay is due to fungal infections that require:

Favorable Temperature: > 50°F

Moisture: H20 content by weight > 20%-M

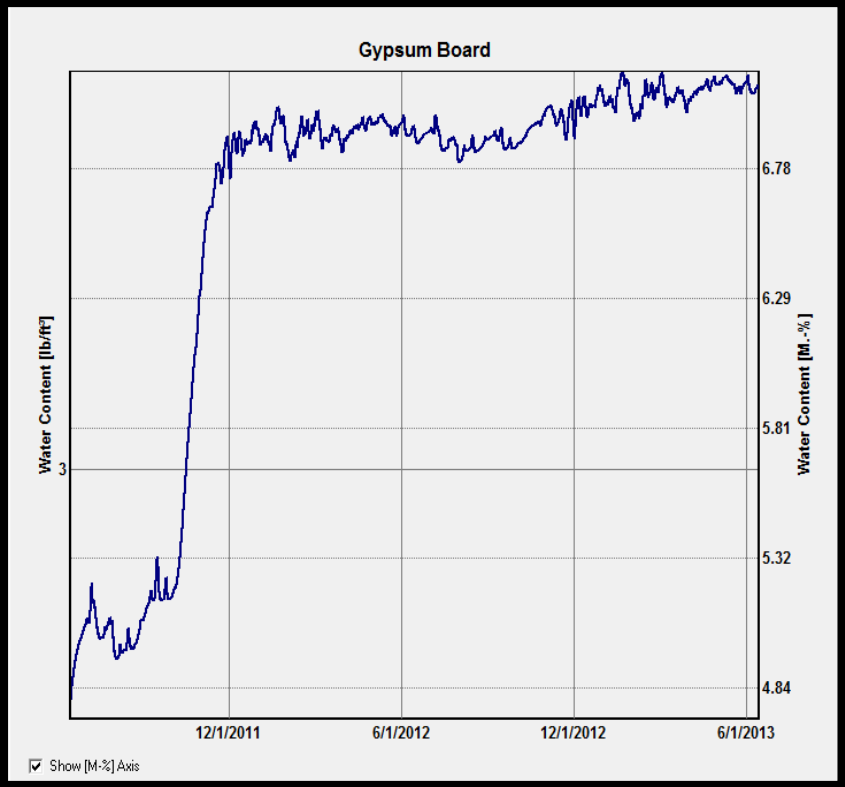
In example, temperature is often above 50°F

H2O Mass % is below 20%

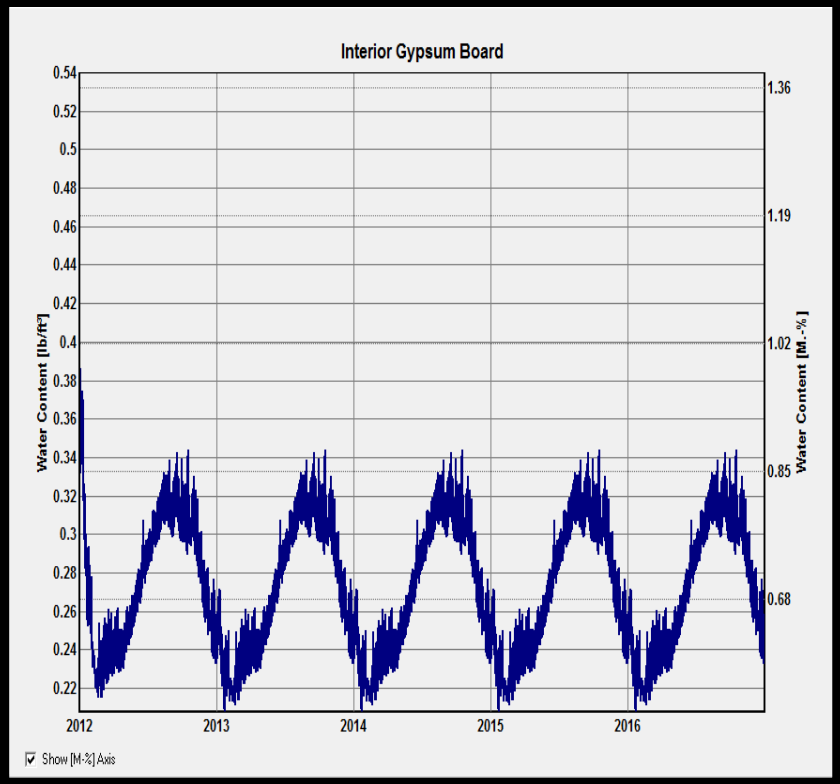
Wood rot risk is absent unless H2O Mass% increases

Water Content by Layer

BAD NEWS



BETTER



H2O content per construction layer should initially decrease and thereafter establish a regular pattern of seasonal fluctuation

Comparative Study Parameters

- 6 locations
  - Philadelphia
  - Chicago
  - NYC
  - Seattle
  - Houston
  - Salt Lake City
- 5 walls residential
- 17 total variations (4 with fiberglass cavity, 13 with cellulose)

Hygro Protocol

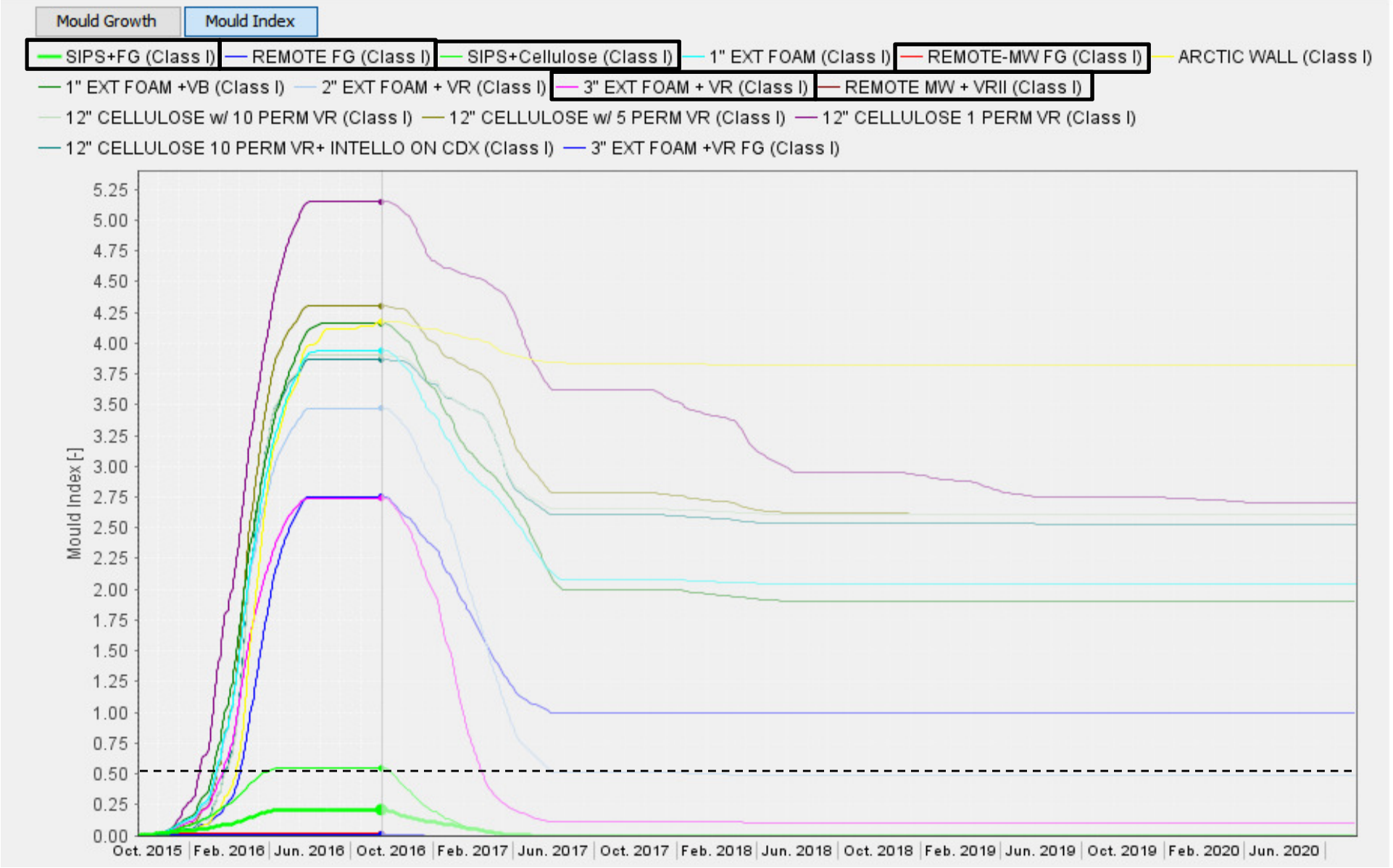
- 5 yr simulation
- Exterior - ASHRAE Yr 3
- Cladding ACH based on conservative interpretation of next slide
- 1% DR in whole layer of 1mm "Old Brick" ON WRB
- Sheathing modeled in 1/8" slices
- Interior – ASHRAE 160 Int Method: EN 15026 High Moisture Load

Results Analysis

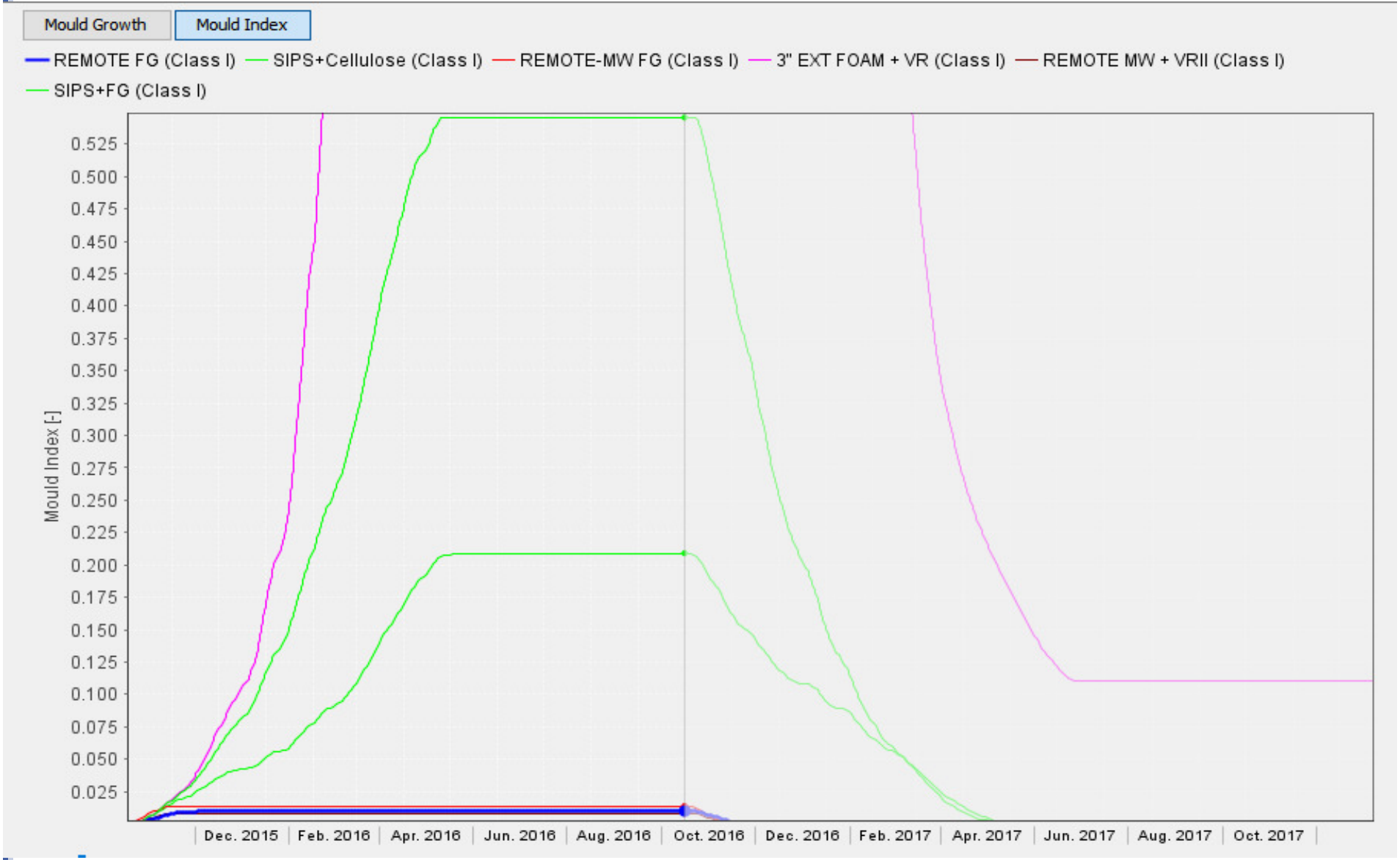
- WUFI Bio Mold Index analysis @highest RH location in moisture sensitive layers subject to air infiltration/exfiltration. Must have green light at least by yr 2 to pass.

- ~~Evaluate Mass % WC in sheathing layers of safest walls~~

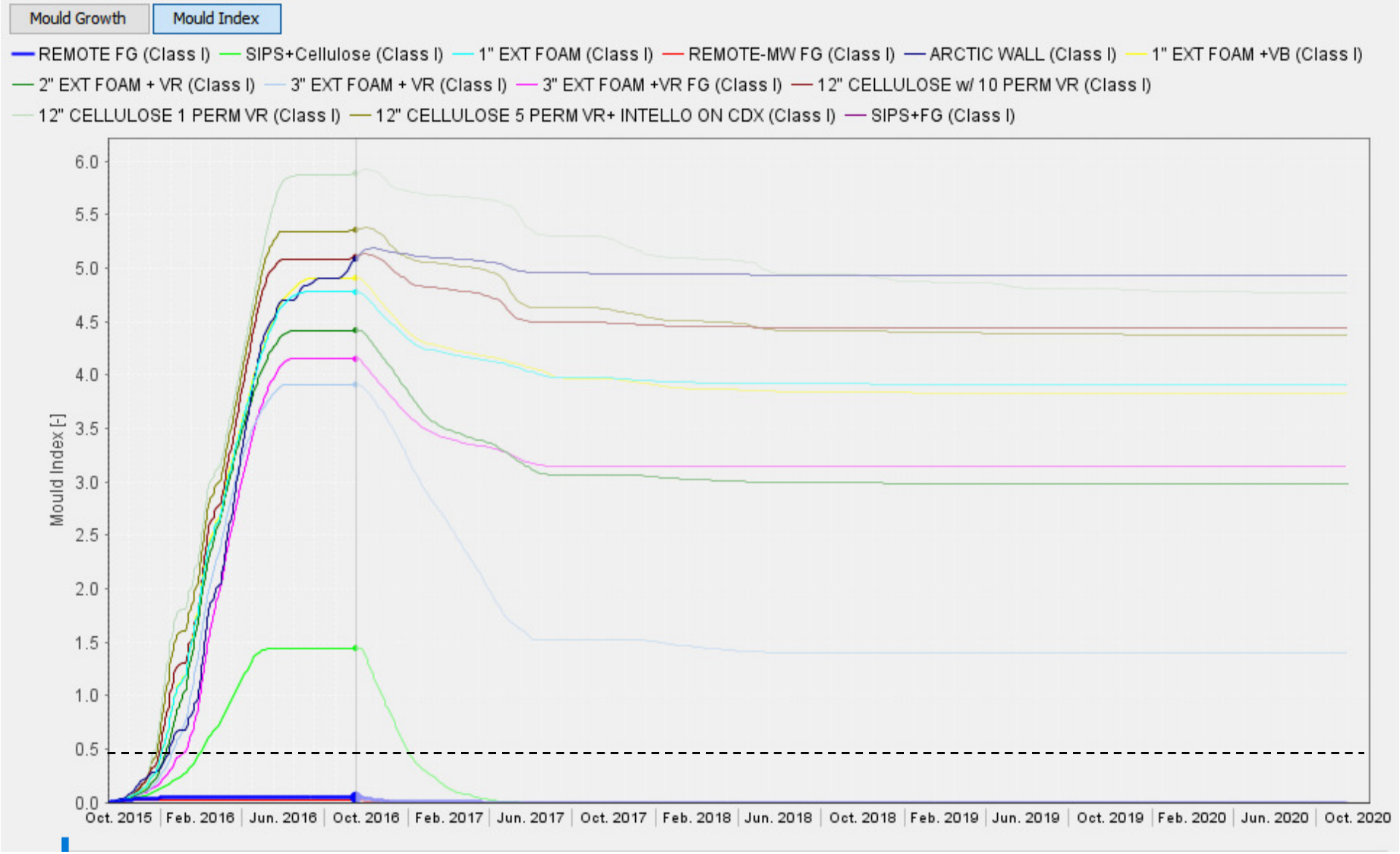
Philly Wall Comp



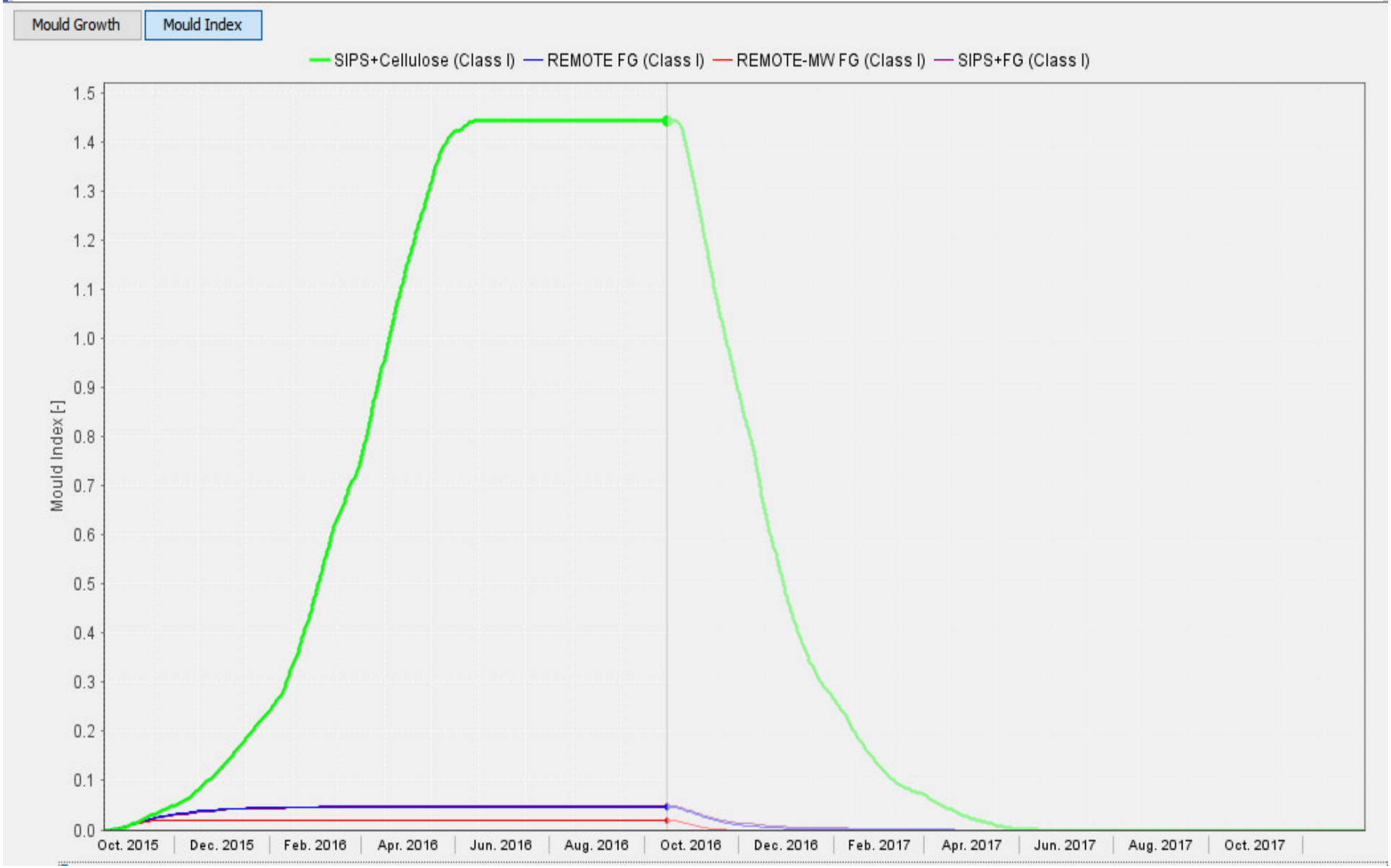
Philly Wall Comp



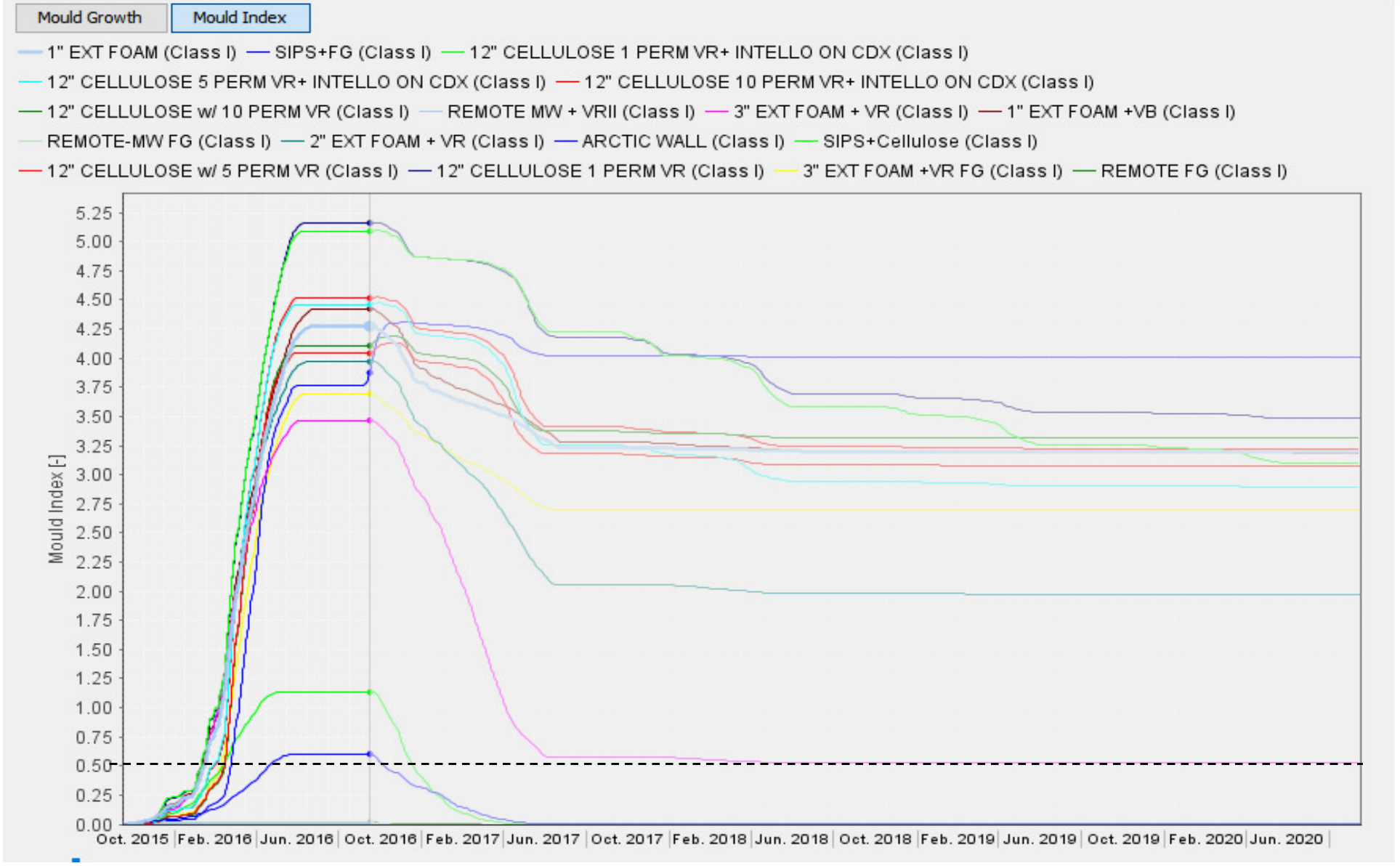
NYC Wall Comp



NYC Wall Comp



Chicago Wall Comp



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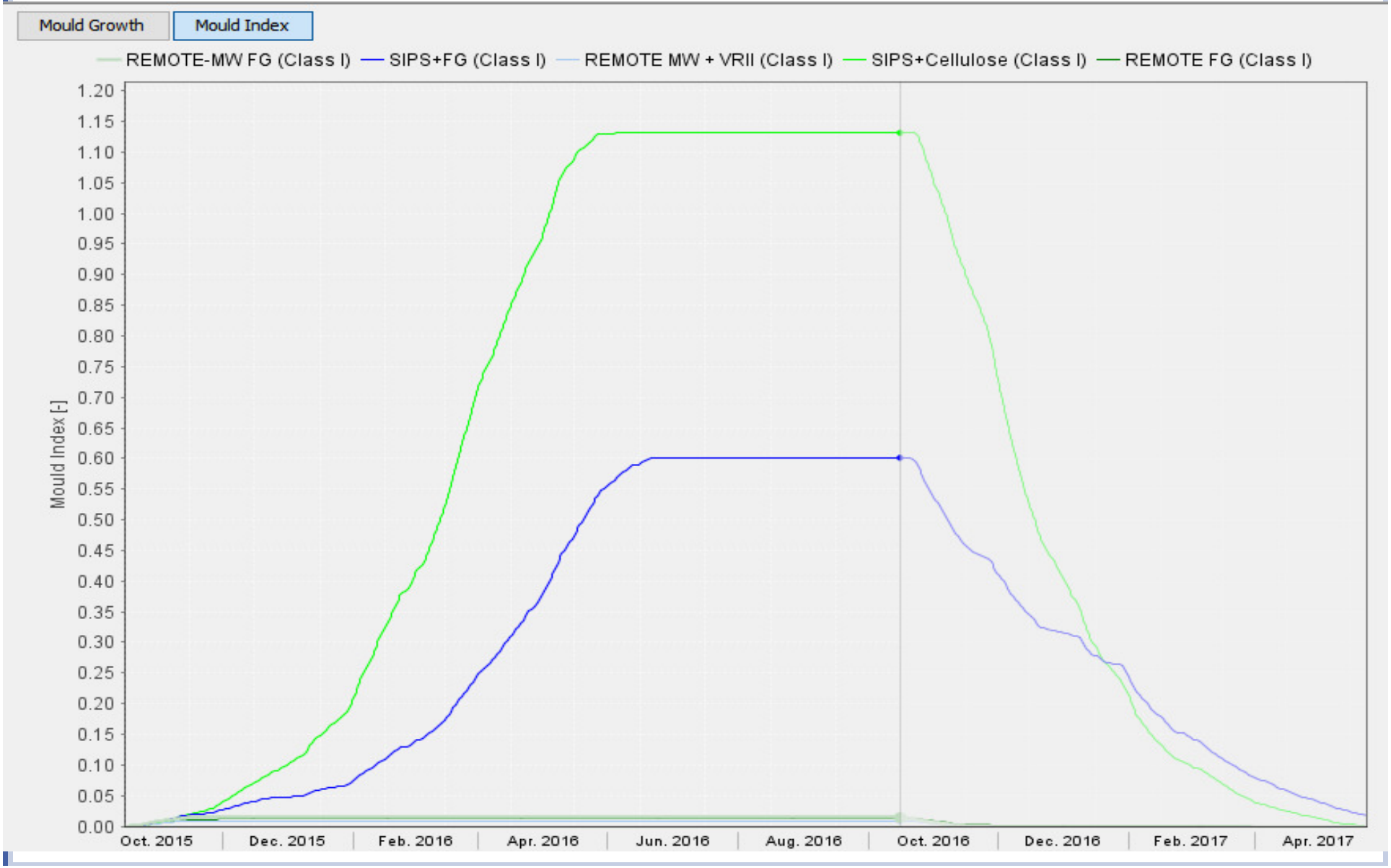
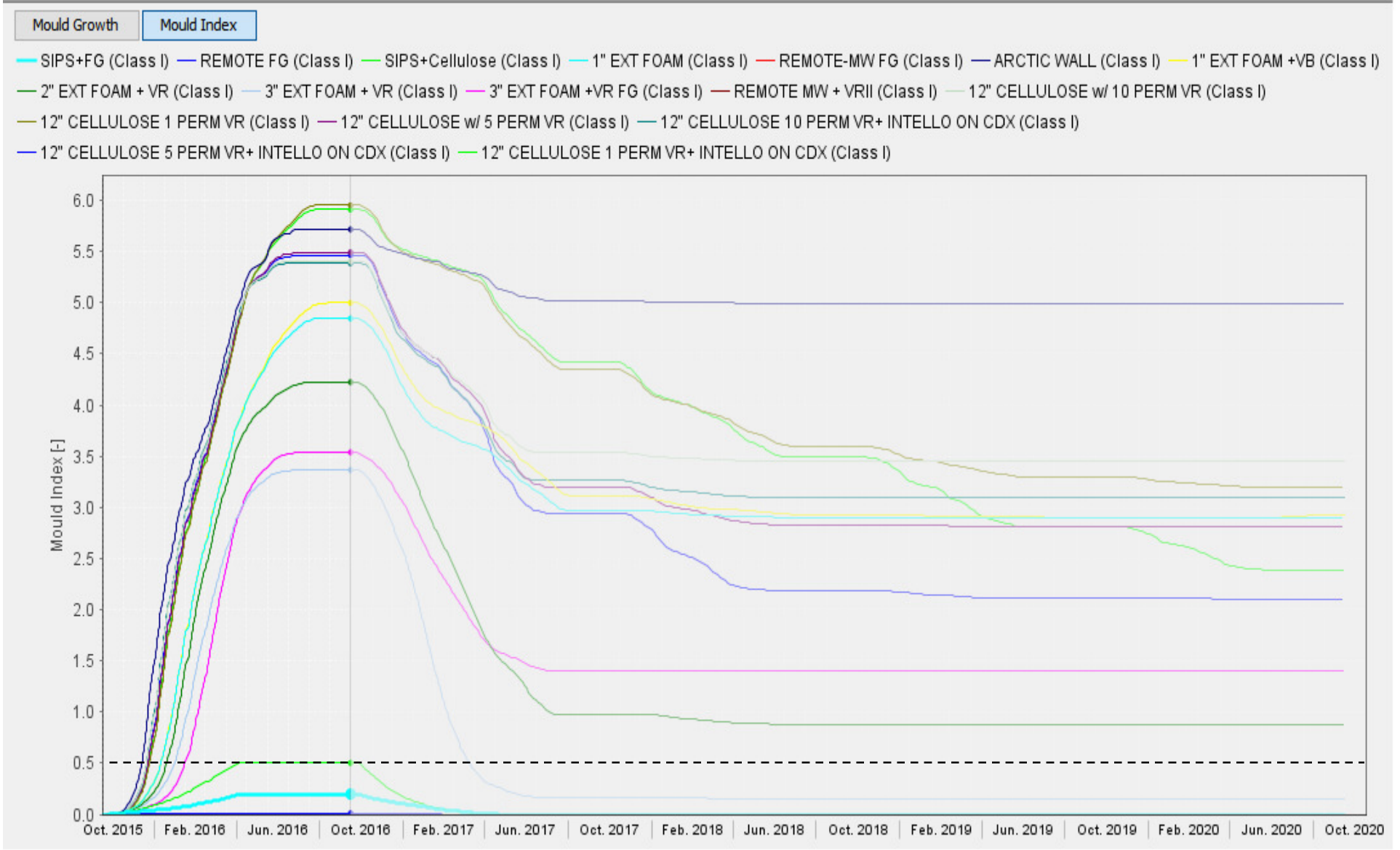


Seattle Wall Comp



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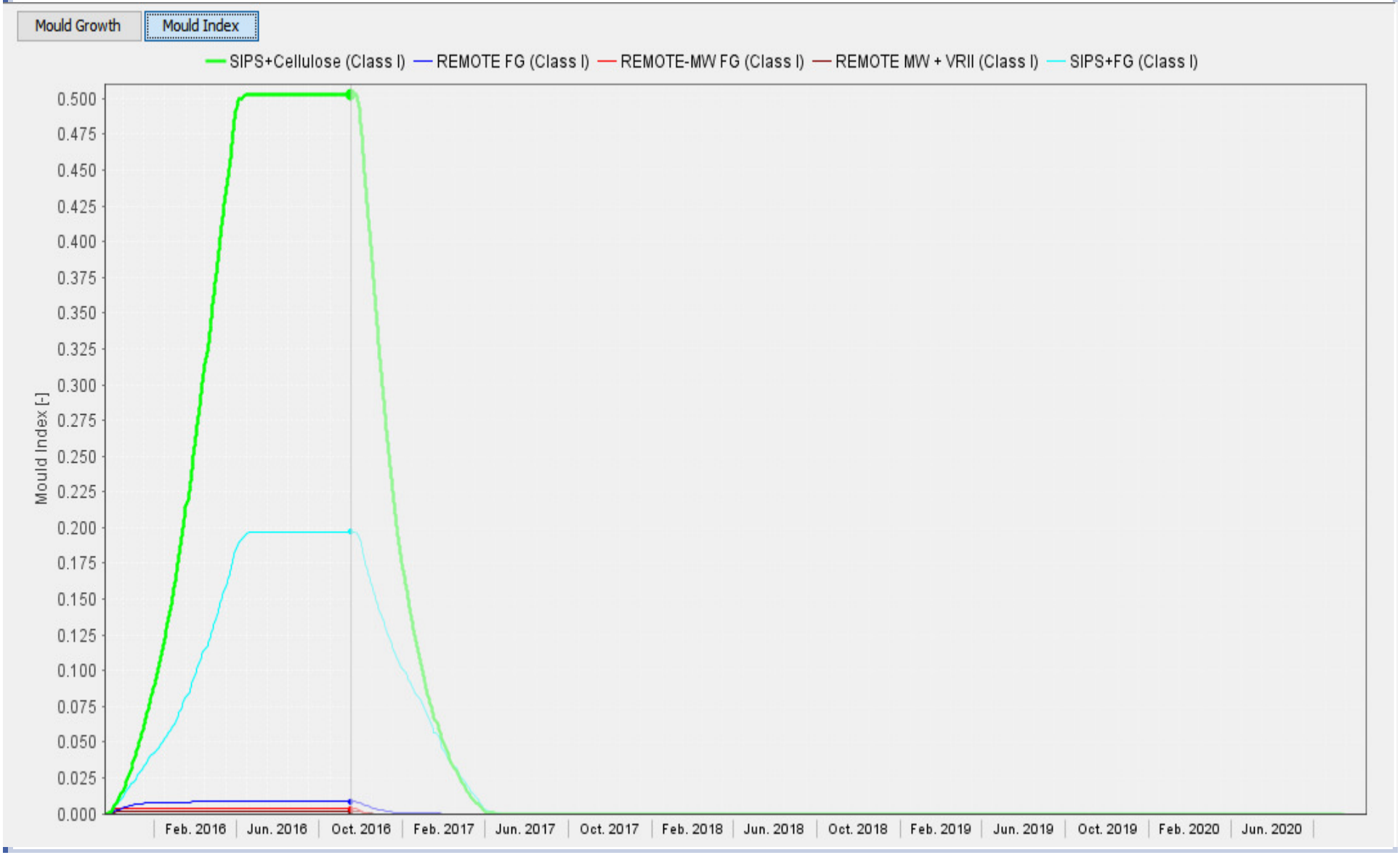
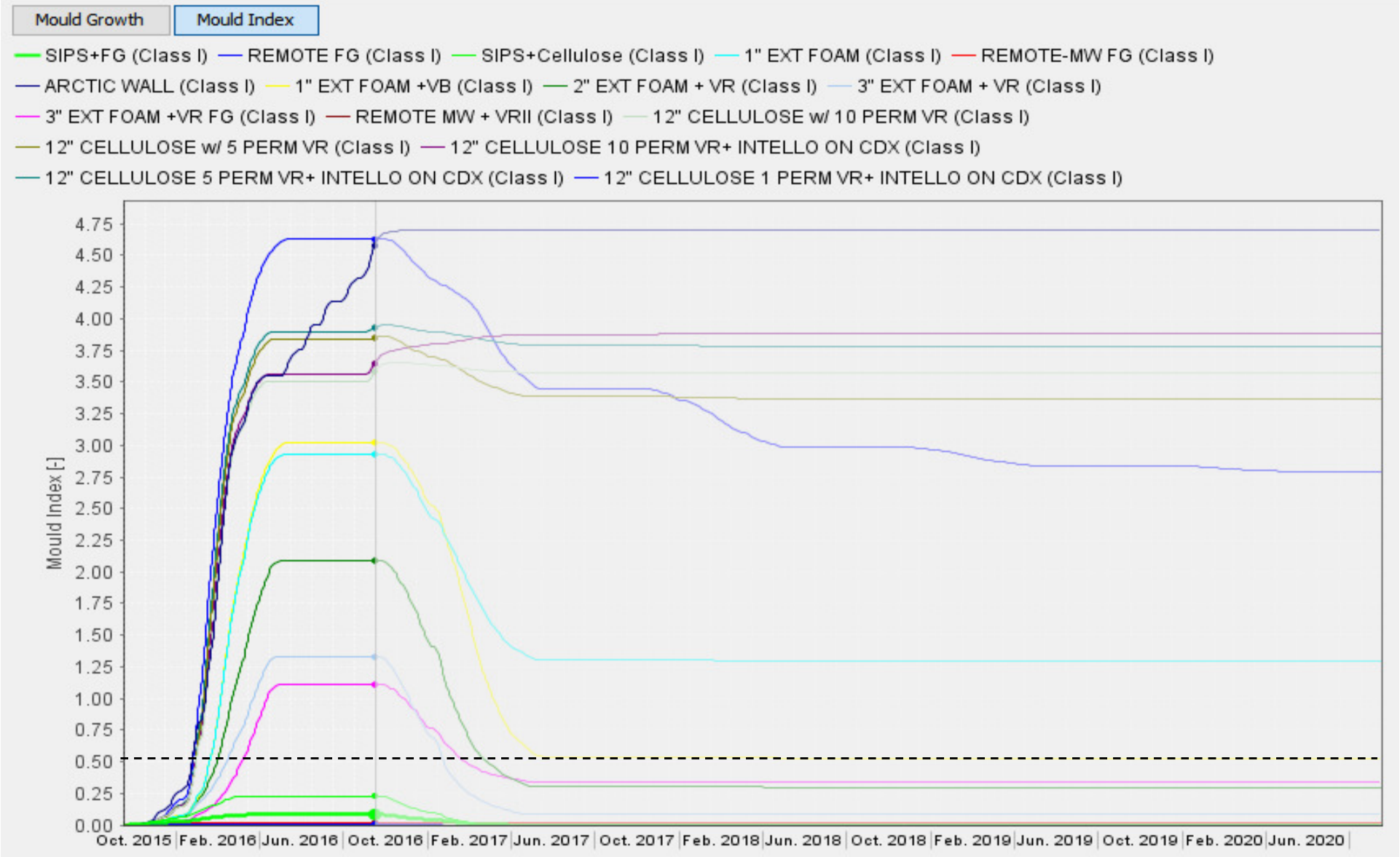
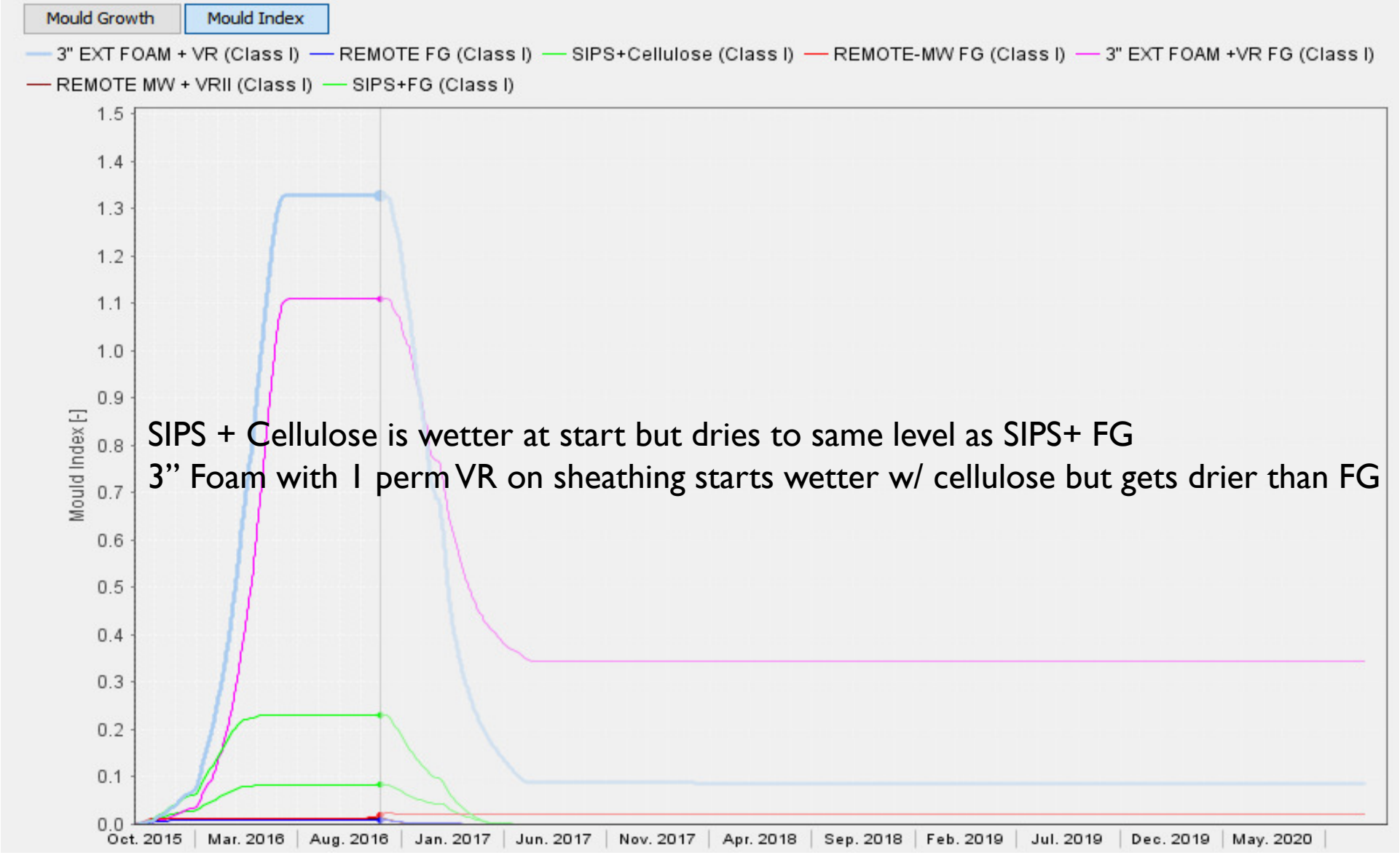


Houston Wall Comp



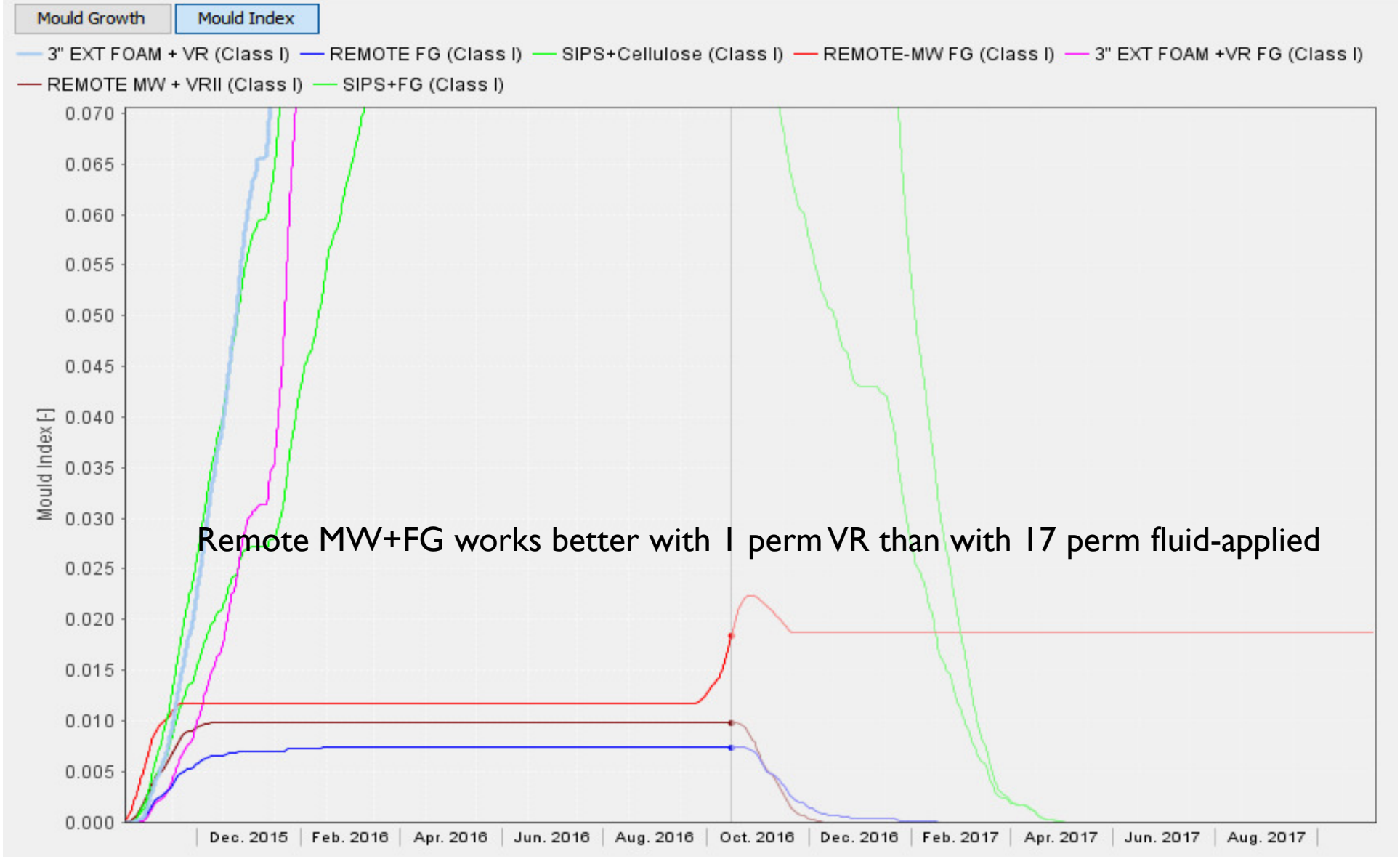
Houston Wall Comp



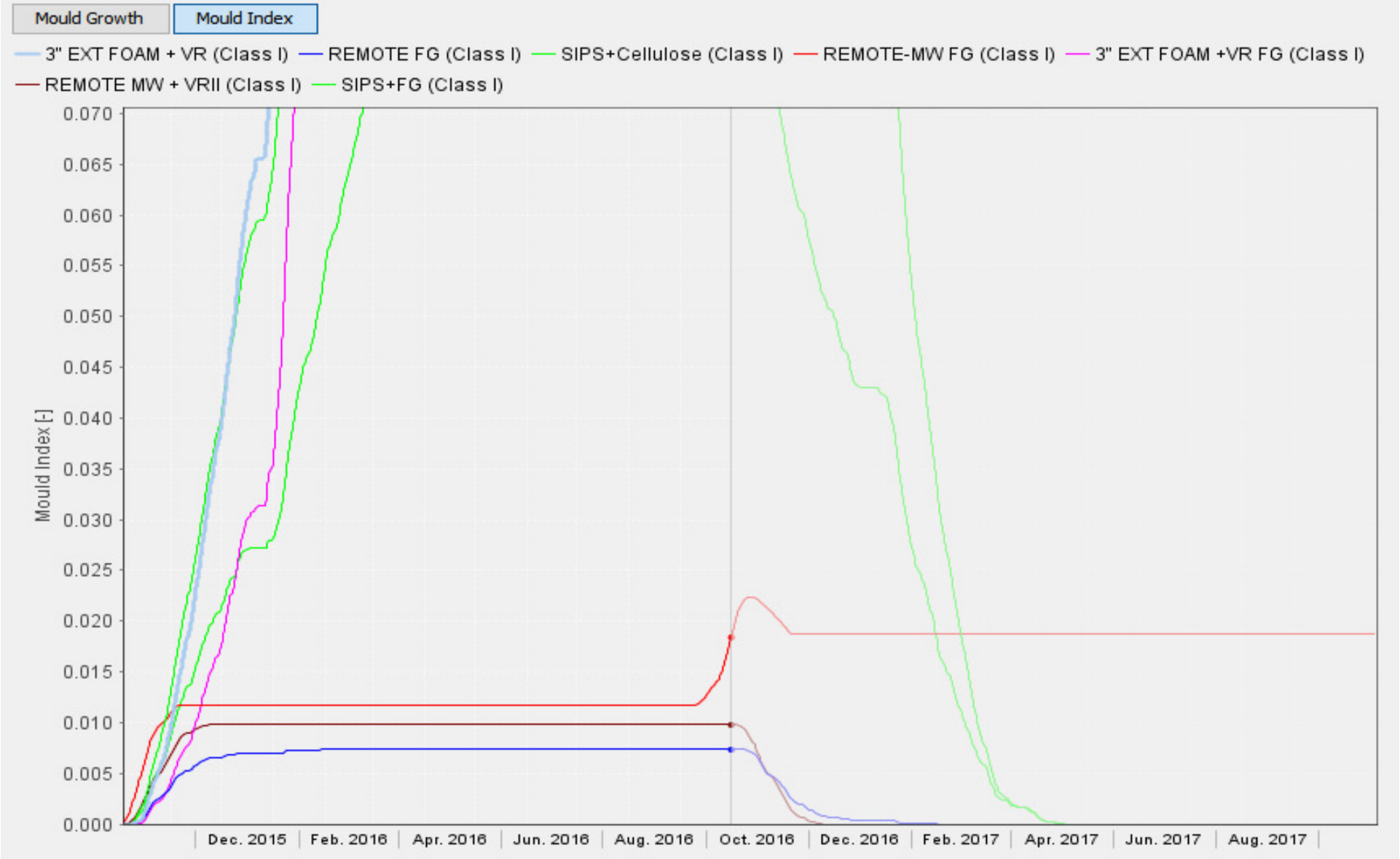
SIPS + Cellulose is wetter at start but dries to same level as SIPS+ FG

3" Foam with 1 perm VR on sheathing starts wetter w/ cellulose but gets drier than FG

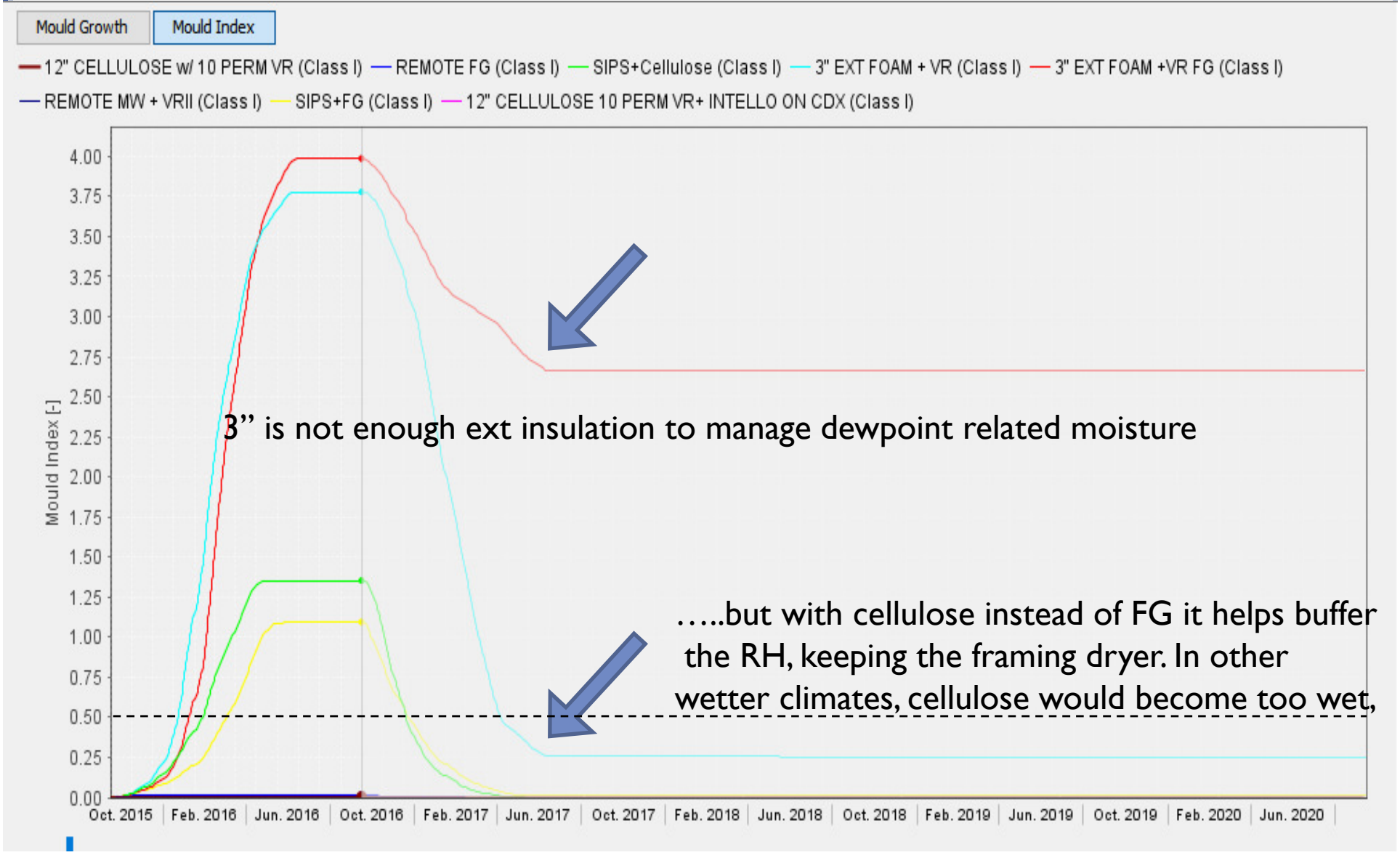
Houston Wall Comp



Houston Wall Comp



Salt Lake Wall Comp



MF Study Findings

2+D - 276 | 160,548 ft² (5.8)	SA/V	Comfort Wall R	PHIUS+ Min Wall R	Conc-Foam	EPS - FC	EPS - Brick	MW - FC	MW-Brick	BuildSmart
Philadelphia NE		6	25	R25 - 6"	R40 -5"	R43 - 5.5"	R29 - 2.5"	R43 - 5.5"	R35.5 - 2.5"
Chicago O'Hare		6.5	25	R25 - 6"	R45 - 6"	R45 - 6"	R37 - 4.5"	NO	R33 - 3.5"
NYC Central Park Obs		5	25	R25 - 6"	R42 - 5.5"	R43 - 5.5"	R29 - 2.5"	NO	R35.5 - 2.5"
Houston Bush Int	0.082	3	9	R9 - 2"	R34 - 3.5"	R37 - 4.0"	R10 - 2"	NO	R25 - 1.5"
Phoenix PHX		2.5	9	R9 - 2"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"
San Francisco SFO		2.2	9	R9 - 2"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"
Raleigh Durham Int		3.8	25	R25 - 6"	R40 -5"	R43 - 5.5"	R29 - 2.5"	NO	R25 - 1.5"
Roxbury - 43 | 43,392 ft² (1.6)		Comfort Wall R	PHIUS+ Min Wall R	Conc-Foam	EPS - FC	EPS - Brick	MW - FC	MW-Brick	BuildSmart
Philadelphia NE		6	33	R33 - 8"	R40 -5"	R43 - 5.5"	R29 - 2.5"	R43 - 5.5"	R35.5 - 2.5"
Chicago O'Hare		6.5	33	R33 - 8"	R45 - 6"	R45 - 6"	R37 - 4.5"	NO	R33 - 3.5"
NYC Central Park Obs		5	25	R25 - 6"	R42 - 5.5"	R43 - 5.5"	R29 - 2.5"	NO	R35.5 - 2.5"
Houston Bush Int	0.118	3	33	R33 - 8"	R34 - 3.5"	R37 - 4.0"	R10 - 2"	NO	R25 - 1.5"
Phoenix PHX		2.5	33	R33 - 8"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"
San Francisco SFO		2.2	23	R23 - 5.5"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"
Raleigh Durham Int		3.8	33	R33 - 8"	R40 -5"	R43 - 5.5"	R29 - 2.5"	NO	R25 - 1.5"
Copper Pass - 24 | 27,490 ft² (1)		Comfort Wall R	PHIUS+ Min Wall R	Conc-Foam	EPS - FC	EPS - Brick	MW - FC	MW-Brick	BuildSmart
Philadelphia NE		6	25	R25 - 6"	R40 -5"	R43 - 5.5"	R29 - 2.5"	R43 - 5.5"	R35.5 - 2.5"
Chicago O'Hare		6.5	23	R23 - 5.5"	R45 - 6"	R45 - 6"	R37 - 4.5"	NO	R33 - 3.5"
NYC Central Park Obs		5	23	R23 - 5.5"	R42 - 5.5"	R43 - 5.5"	R29 - 2.5"	NO	R35.5 - 2.5"
Houston Bush Int	0.123	3	23	R23 - 5.5"	R34 - 3.5"	R37 - 4.0"	R10 - 2"	NO	R25 - 1.5"
Phoenix PHX		2.5	27	R27 - 6.5"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"
San Francisco SFO		2.2	23	R23 - 5.5"	R9 - 2"	R14 - 2.5"	R10 - 1.5"	R10 - 1.5"	R25 - 1.5"

Conclusions ...

Any wall that doesn't have enough exterior insulation to keep dewpoint and related condensation away from sheathing + cavity is higher risk

There are several walls that are safest from a moisture standpoint in all locations analyzed… Embodied energy? Local?

Cellulose can be 'safe' , as long as its kept dry in outer layers of cavity

PHIUS+ static compliance requirements may be met with a wall R-value lower than is needed to ensure hygrothermal safety, esp in MF

Double stud walls filled with cellulose are much more risky than all other walls studied for these locations