PASSIVE HOUSE MASSACHUSETTS SYMPOSIUM

DECEMBER 10, 2024

SUCCESS STORIES FROM THE FIELD

LESSONS LEARNED TO SUCCESSFULLY DELIVER PASSIVE HOUSE BUILDINGS

→ **Marine Sanchez** | Principal, Passive House Specialist, Service Lead

→ **Mike O'Donnell** | Principal Building Systems Consultant

Photo: Andrew Latreille, for RDH Building Science

Presenters

Marine Sanchez | RDH Building Science

Principal, Passive House Certifier & Consultant

RDH's Passive House Service Lead

Focus

- → Delivering high-performance buildings, with focus on construction phase
- → Pushing the industry forward with finding solutions on new large, complex building typologies
- → Supporting municipalities with their implementation of carbon emissions reduction policies

Mike O'Donnell | Steven Winter Associates

Principal Building Systems Consultant

SWA's Passive House Field Verification Lead

Focus

- → Translating PH concepts to site teams and installers
- → Bridging the gap between design and construction
- → Performance testing of building verification

Steven Winter Associates | Overview

www.swinter.com

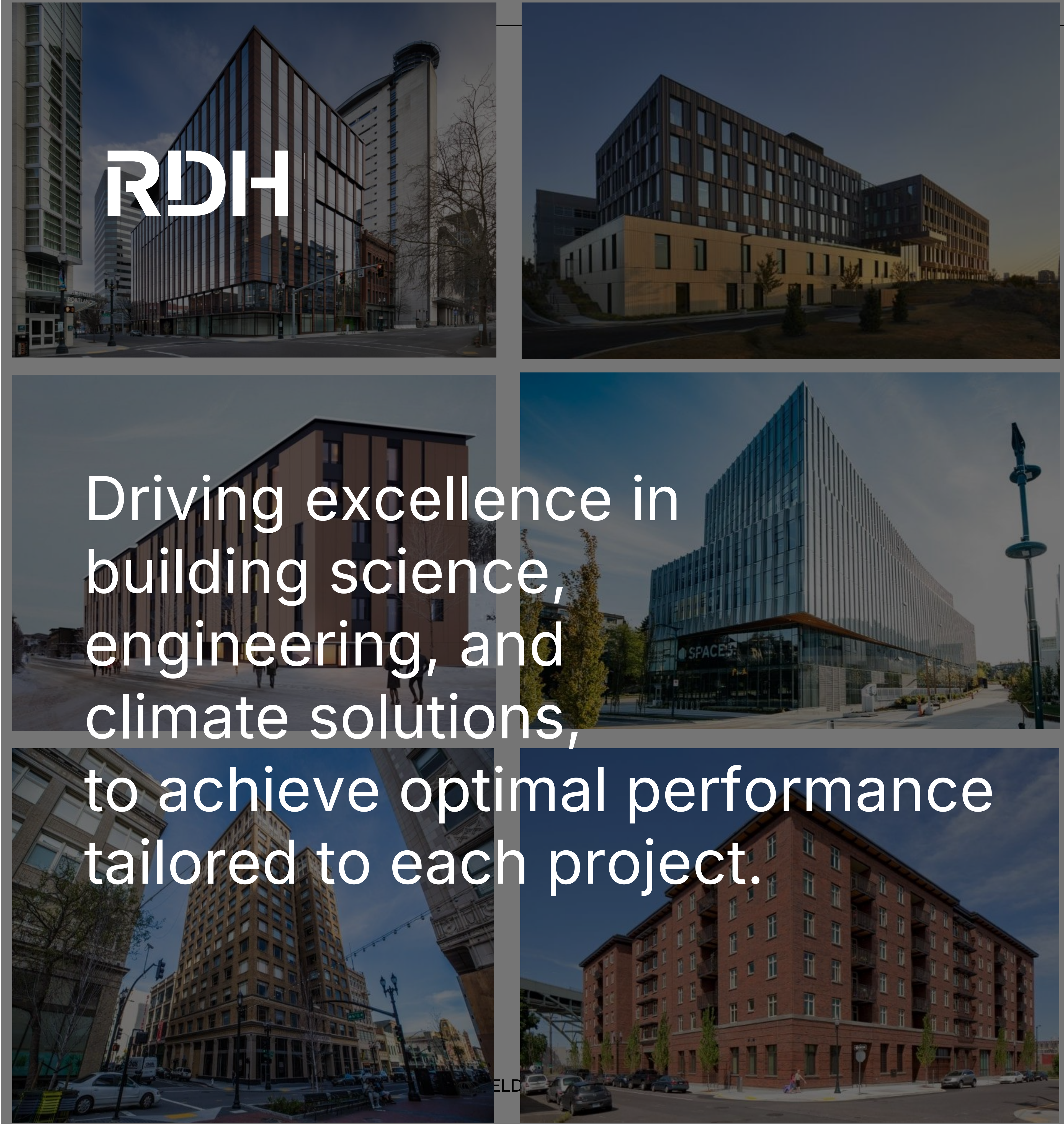
Since 1972, Steven Winter Associates, Inc. has been providing **research, consulting, and advisory services** to improve the built environment for private and public sector clients.

Our services include:

- Energy Conservation and Management
- Decarbonization
- Sustainability Consulting
- Green Building Certification
- Accessibility Consulting

Our teams are based across four office locations:

New York, NY | Washington, DC | Norwalk, CT | Boston, MA



RDH Building Science | Overview

www.rdh.com

RDH Building Science is a leading consulting and engineering firm specializing in **climate-responsive, low-carbon, and energy-efficient solutions** across North America. With 11 locations, we leverage our expertise to deliver high-performance, durable buildings that meet today's and future needs.

Our services and capabilities include:

- → Building Enclosure Engineering
- → Energy & Climate Solutions
- → Building and Portfolio Lifecycle Management
- → Research, Development, and Demonstration (RD&D)
- → Façade Engineering and Structural Engineering
- → Training and Publications

Our teams are based across eleven office locations:

Boston | Denver| Oakland | Portland | Seattle | Vancouver | Victoria | Courtney | Northern Canada | Waterloo | Toronto

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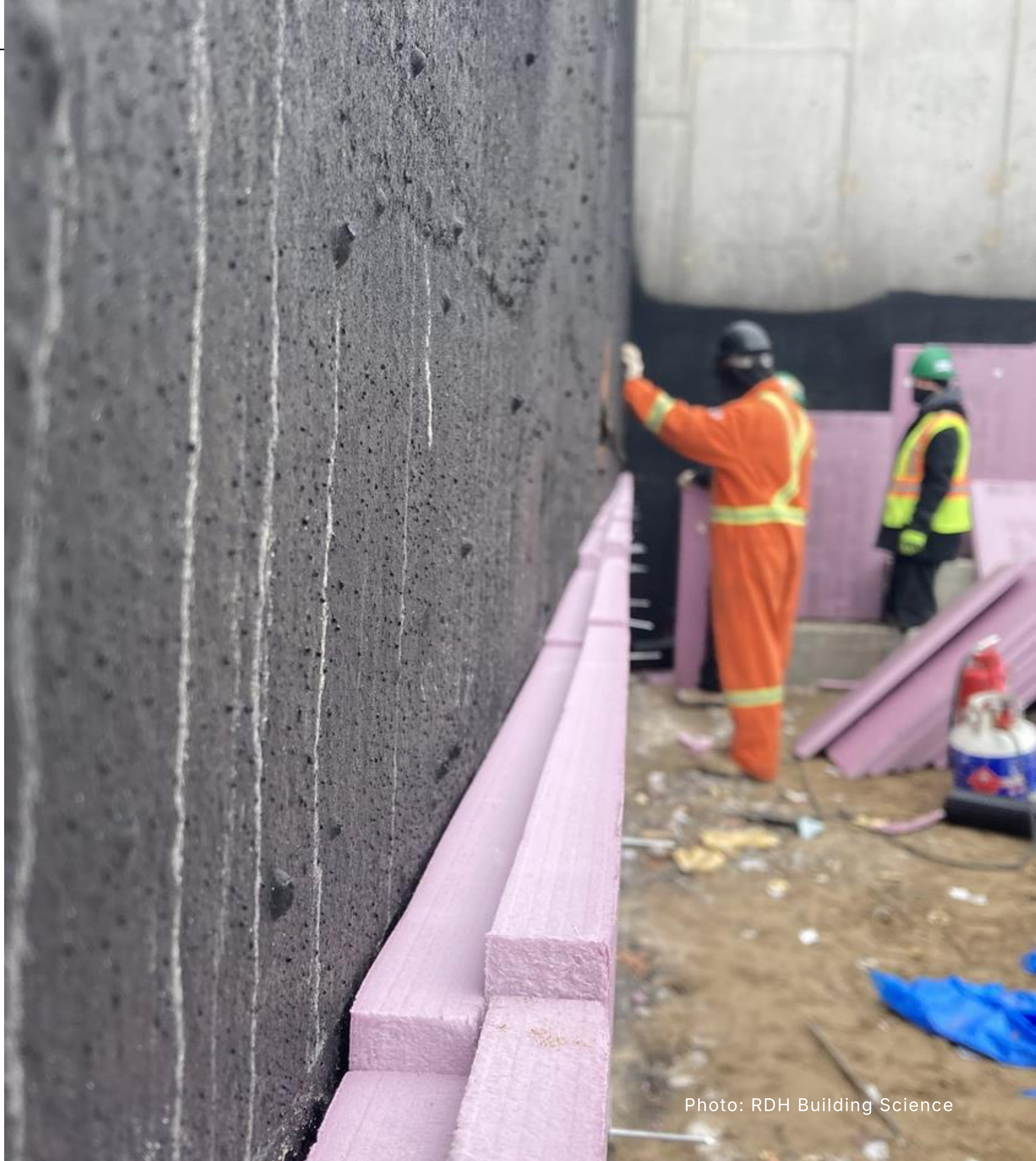
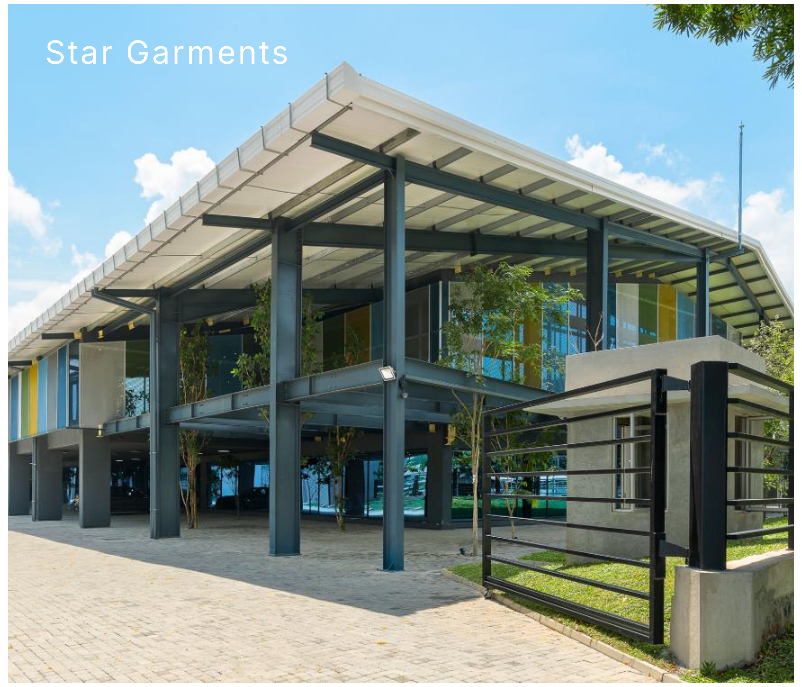


Photo: RDH Building Science

Site Verification Process Overview

Photo: Andrew Latreille, for RDH Building Science

Steven Winter Associates | Projects Overview



RDH Building Science | Projects Overview

Certification Process

GC's role & responsibility

= maintain performance during implementation

Roles

→ PH Consultant

→ PH Verifier

→ PH Certifier

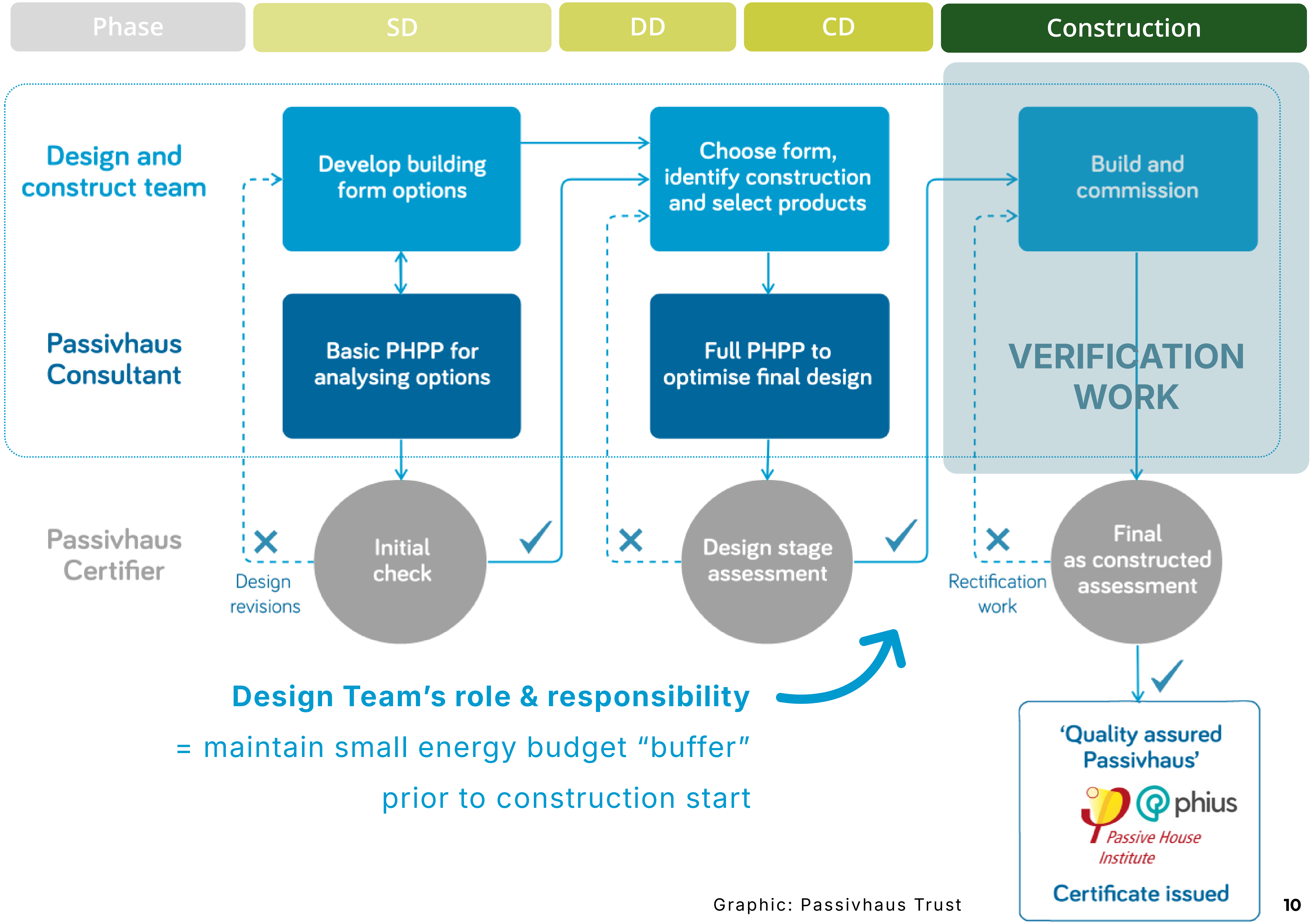
Verifier Role

→ (Education)

→ Compliance role against approved compliant design

→ Site QAQC

→ Site evidence collection



Design Team's role & responsibility

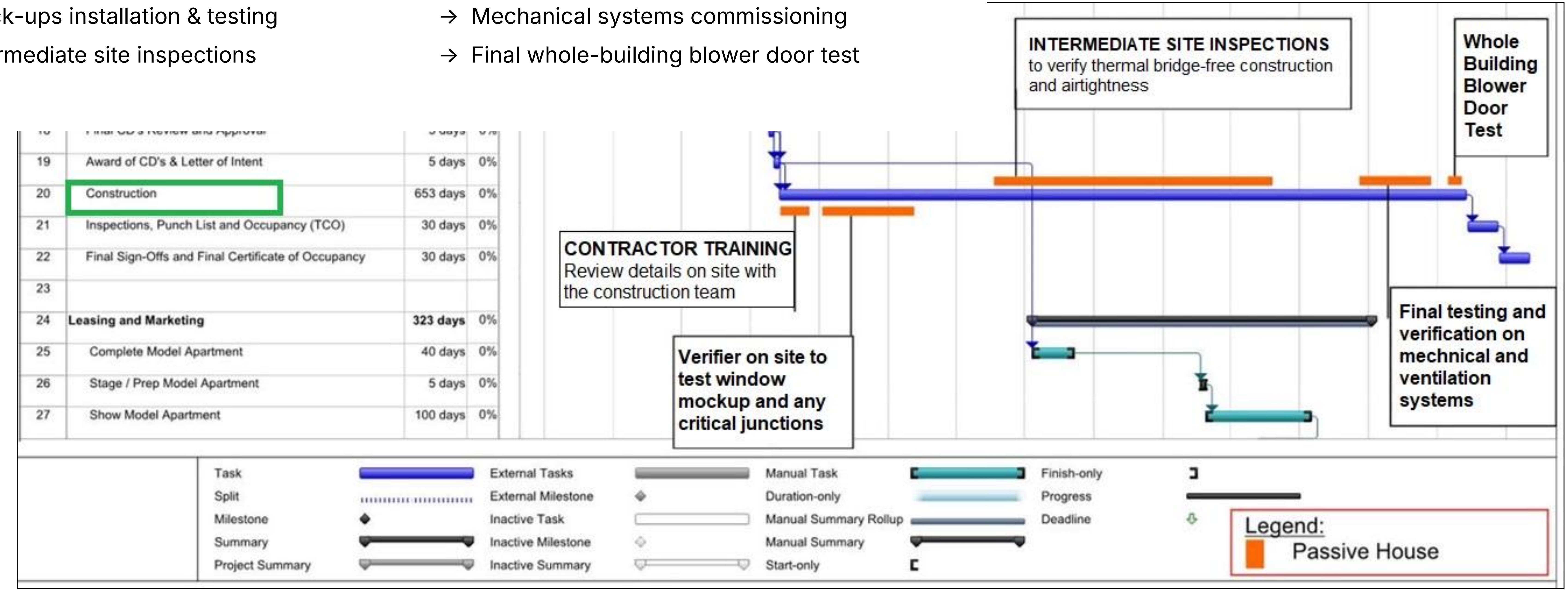
= maintain small energy budget "buffer" prior to construction start

Graphic: Passivhaus Trust

Project Schedule & Verification Milestones

Milestones

- Contractor training
- Mock-ups installation & testing
- Intermediate site inspections
- Ventilation testing & balancing
- Mechanical systems commissioning
- Final whole-building blower door test



2 Pre-Construction Approaches

BUILDING ENCLOSURE

Insulation Products

No.	Material	Proposed specs	Performance Target (SI)	Unit	Performance Target (IP)	Submittal received	Type / Location	Submittal specs	Photos (labels)	Photos (in situ)	Pro
1.1.0	**Closed Cell Spray Foam**	**Thermal conductivity**	**0.027**	**W/(mK)**	**(5.3 ft^2-h-F/Btu.in)**						
1.1.1	>> Sump Pit Walls/Cover	Thermal conductivity	0.027	W/(mK)	(5.3 ft^2-h-F/Btu.in)	Yes	Sump Pit Walls/Cover	07 21 19	No	Yes	BASF Walltite CM
1.1.2	>> Loading Bay Walls	Thermal conductivity	0.027	W/(mK)	(5.3 ft^2-h-F/Btu.in)	Not Yet	Loading Bay Walls	07 21 19	Not Yet	Not Yet	BASF Walltite CM
1.1.3	>> Entrance Soffit	Thermal conductivity	0.026	W/(mK)	(5.5 ft^2-h-F/Btu.in)	Not Yet	Entrance Soffit	07 21 19	Not Yet	Not Yet	BASF Walltite CM
1.1.4	>> Loading Bay Soffit	Thermal conductivity	0.026	W/(mK)	(5.5 ft^2-h-F/Btu.in)	Not Yet	Loading Bay Soffit	07 21 19	Not Yet	Not Yet	BASF Walltite CM
1.1.5	>> Exposed North Terrace Edge	Thermal conductivity	0.026	W/(mK)	(5.5 ft^2-h-F/Btu.in)	Not Yet	Exposed North Terrace Edge	07 21 19	Not Yet	Not Yet	BASF Walltite CM
1.2.0	**XPS Insulation**	**Thermal conductivity**	[illegible]	[illegible]	[illegible]						
1.2.1	>> Sump Pit Floors	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Sump Pit Floor	07 21 00	Yes	Yes	DuPont Styrofoa
1.2.2.	>> Elevator pit floor	[illegible]	[illegible]	[illegible]	[illegible]	Yes	Elevator pit floor	07 21 00	Yes	Yes	Owens Corning
1.2.3	>> Basement floor	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement floor	07 21 00	Yes	Yes	Owens Corning
1.2.4	>> L01 floor	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	L01 floor	07 21 00	Yes	Yes	Owens Corning
1.2.5	>> Elevator walls	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Elevator walls	07 21 00	Yes	Yes	Owens Corning
1.2.6	>> Basement walls	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement walls	07 21 00	Yes	Yes	Owens Corning
1.2.7	>> Roof parapet	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement walls	07 21 00	Not Yet	Not Yet	Kingspan Green
1.3.0	**Mineral Wool**	**Thermal conductivity**	**0.034**	**W/(mK)**	**(4.2 ft^2-h-F/Btu.in)**						
1.3.1	>> Steel stud cavity insulation	Thermal conductivity	0.040	W/(mK)	(3.6 ft^2-h-F/Btu.in)	Yes	Steel stud cavity	07 21 00	Not Yet	Not Yet	Rockwool Comf
1.3.2	>> external insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	Yes	External insulation layer	07 21 00	Not Yet	Not Yet	Rockwool Cavit
1.3.3	>> foil-faced internal insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	Yes	Internal insulation layer	07 21 00	Not Yet	Not Yet	Rockwook Rock
1.3.4	>> foil-faced external insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	N/A	External insulation layer	07 21 00	N/A	N/A	

Table: PH Construction Verification

2.1 Clarity of Construction Documents

GOAL: Provide translation of PH energy model into clear **performance requirements**

Document

- "Catch all" Sustainable Design Requirements **spec section**
- Specific criteria to be included throughout their respective sections and on drawings

017300	Execution Requirements	X
017329	Cutting and Patching	X
017419	Construction Waste Management - SWA	X
017700	Closeout Procedures	X
017823	Operating and Maintenance Data	X
018113	Sustainable Design Requirements: Passive House - SWA	X
018115a	Air Sealing Guide for Multifamily Construction - SWA	X
018116	Sustainable Building Requirements: Enterprise Green Communities - SWA	X
018116a	Sustainable Design Requirements: Enterprise Green Communities Checklist - SWA	X
018117	VOC Limits - SWA	X
019113	General Commissioning Requirements - SWA	X

Document

- **"Translation" of energy model inputs** into exhaustive checklist
  - Construction team with understanding of performance requirements

BUILDING ENCLOSURE

Insulation Products

No.	Material	Proposed specs	Performance Target (SI)	Unit	Performance Target (IP)	Submittal received	Type / Location	Submittal specs	Photos (labels)	Photos (in situ)	Product Name
1.1.0	**Closed Cell Spray Foam**	**Thermal conductivity**	**0.027**	**W/(mK)**	**(5.3 ft^2-h-F/Btu.in)**						
1.1.1	>> Sump Pit Walls/Cover	Thermal conductivity	0.027	W/(mK)	(5.3 ft^2-h-F/Btu.in)	Yes	Sump Pit Walls/Cover	07 21 19	No	Yes	BASF Walltite CM01
1.1.2	>> Loading Bay Walls	Thermal conductivity	0.027	W/(mK)	(5.3 ft^2-h-F/Btu.in)	Not Yet	Loading Bay Walls	07 21 19	Not Yet	Not Yet	BASF Walltite CM01
1.1.3	>> Entrance Soffit	Thermal conductivity	**0.026**	W/(mK)	(5.5 ft^2-h-F/Btu.in)	**Not Yet**	Entrance Soffit	07 21 19	**Not Yet**	**Not Yet**	BASF Walltite CM01
1.1.4	>> Loading Bay Soffit	Thermal conductivity	0.026	W/(mK)	(5.5 ft^2-h-F/Btu.in)	Not Yet	Loading Bay Soffit	07 21 19	Not Yet	Not Yet	BASF Walltite CM01
1.1.5	>> Exposed North Terrace Edge	Thermal conductivity	0.026	W/(mK)	(5.5 ft^2-h-F/Btu.in)	Not Yet	Exposed North Terrace Edge	07 21 19	Not Yet	Not Yet	BASF Walltite CM01
1.2.0	**XPS Insulation**	**Thermal conductivity**	**0.029**	**W/(mK)**	**(5 ft^2-h-F/Btu.in)**						
1.2.1	>> Sump Pit Floors	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Sump Pit Floor	07 21 00	Yes	Yes	DuPont Styrofoam Highload 100 XPS
1.2.2.	>> Elevator pit floor	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Elevator pit floor	07 21 00	Yes	Yes	Owens Corning Foamular C-350
1.2.3	>> Basement floor	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement floor	07 21 00	Yes	Yes	Owens Corning Foamular C-350
1.2.4	>> L01 floor	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	L01 floor	07 21 00	Yes	Yes	Owens Corning Foamular C-350
1.2.5	>> Elevator walls	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Elevator walls	07 21 00	Yes	Yes	Owens Corning Foamular C-350
1.2.6	>> Basement walls	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement walls	07 21 00	Yes	Yes	Owens Corning Foamular C-350
1.2.7	>> Roof parapet	Thermal conductivity	0.029	W/(mK)	(5 ft^2-h-F/Btu.in)	Yes	Basement walls	07 21 00	**Not Yet**	**Not Yet**	Kingspan GreenGuard Type IV XPS
1.3.0	**Mineral Wool**	**Thermal conductivity**	**0.034**	**W/(mK)**	**(4.2 ft^2-h-F/Btu.in)**						
1.3.1	>> Steel stud cavity insulation	Thermal conductivity	0.040	W/(mK)	(3.6 ft^2-h-F/Btu.in)	Yes	Steel stud cavity	07 21 00	**Not Yet**	**Not Yet**	Rockwool Comfortbatt
1.3.2	>> external insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	Yes	External insulation layer	07 21 00	**Not Yet**	**Not Yet**	Rockwool Cavityrock
1.3.3	>> foil-faced internal insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	Yes	Internal insulation layer	07 21 00	Not Yet	Not Yet	Rockwook Rockboard 40
1.3.4	>> foil-faced external insulation layer	Thermal conductivity	0.034	W/(mK)	(4.2 ft^2-h-F/Btu.in)	N/A	External insulation layer	07 21 00	N/A	N/A	

2.2 PH Construction Kick-off Meeting

GOAL: Clarify **expectations** ahead of construction

<u>Content</u>

→ Review of PH roles (consultant, verifier, certifier)

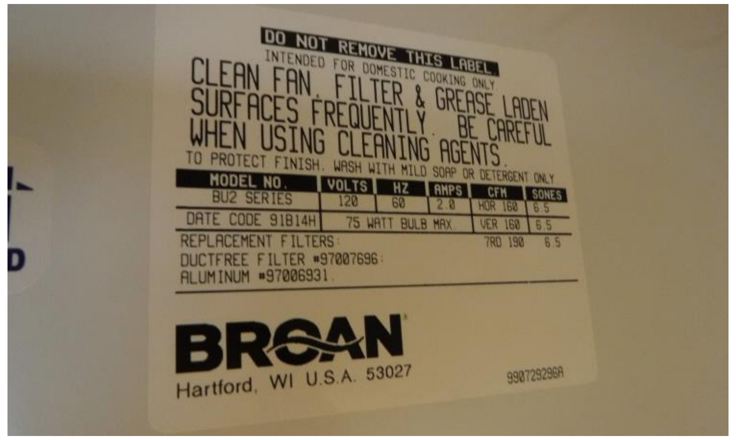
→ Review of PH Metrics & certification process

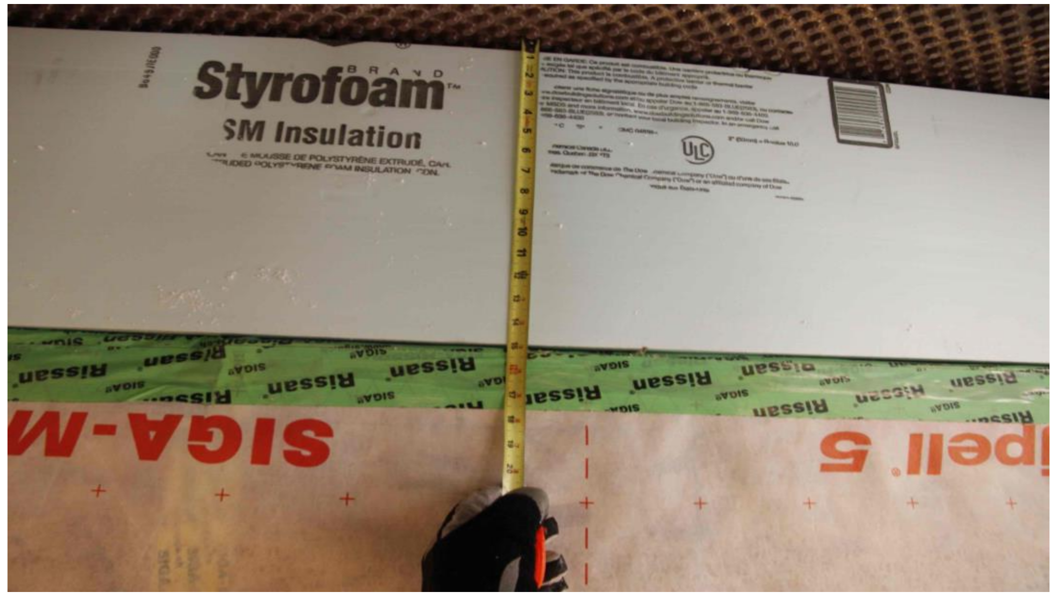
→ **Passive House champion role**

→ **Airtightness testing & Air boss role**

→ **Construction documentation requirements**

→ Commissioning requirements





2.3 PH Site Inspections

GOAL: Highlight **key conditions** to review, test and/or document

Checklists

List of PH site inspections, including:

→ Conditions which must be documented for PH certification

→ Unique conditions (more complex detailing)

The following items must be inspected and/or tested by SWA before being made inaccessible.

Project Phase	Item #	Description
Start of Construction	U-1	Electrical Penetrations
	U-2	Plumbing Penetrations
	U-3	Gas Meter Room Penetrations
	U-4	Foundation Details at Garage Entrance and East Property Line
	U-5	Below Grade Insulation
	U-6	Connection from Below to Above Grade
Above Grade / Prior to Drywall	U-7	Cantilever Floors
	U-8	Ground Floor Exterior Louvers
	U-9	Residential Entry Canopy
	U-10	Thermally Broken Cladding Attachments
	U-11	Window Details
	U-12	PTHP Installation
	U-13	Trash Chute
	U-14	AAC Parapets
	U-15	AAC Connection at Wall to Roof Setback
	U-16	EIFS to Brick Transitions (if applicable)
Top Out	U-17	Door Saddle
	U-18	Typical Roof Vent Plumbing Penetrations
	U-19	Roof Drain Insulation
	U-20	Roof Curbs
	U-21	Equipment Dunnage/ Platforms
	U-22	Smoke Dampers

PH site inspections: list of unique conditions

Construction Phase	Inspection Item	Timeline	Details
Start of Construction	Sub-slab and below grade insulation	In progress, prior to backfill	• Sub-slab insulation installed to correct thickness with boards tightly joined together and no gaps/ any gaps filled with spray foam • Foundation wall insulation installed to correct thickness with boards tightly joined together and no gaps/ any gaps filled with spray foam
	Above grade air barrier	At commencement, every 1-2 floors	• Wall/window mockup review and SWA testing for air tightness. Recommend both a brick and metal panel condition. • AVB is continuous and installed per manufacturers' instructions • Transitions from below grade to above grade AVB • Transitions at slab edges • Window opening flashing strategy
	Above grade insulation	At commencement, every 1-2 floors	• Wall mockup installation review for insulation • Exterior rigid insulation is correct thickness and flat against the substrate with no gaps/ any gaps filled with spray foam • Install thermally broken cladding attachments (brick ties, shelf angles, thermal break pads etc.); any other material penetrating the insulation layer is thermally broken where applicable • Install 2 courses of AAC block at the base of parapets
Prior to Drywall / Start of Drywall Installation	Building envelope air sealing	At commencement, concentrated early in the construction process	• Smoke testing of penetrations and envelope transitions to be conducted throughout construction. Including: • Wall/window installs • Intermediate spot testing (sampling of windows, doors, & unique rooms e.g. gas meter room) • Whole building blower door test (final test, see below)
	Duct sealing	Prior to enclosure with drywall shafts; SWA to attend first day of Aeroseal	• Ductwork thoroughly sealed with mastic for all HVAC systems. Do not pin ducts to the ceiling, leave space for mastic application. • Ventilation ductwork Aerosealed once **all** ductwork is installed (risers, horizontal branches, registers etc.). SWA to attend first day of Aeroseal. Provide Aeroseal reports to SWA for all central ventilation ductwork. • CAR dampers (adjustable recommended) at all supply and exhaust registers in apartments and commons areas where applicable • Gaps between drywall and duct openings to be sealed prior to final register/diffuser installations at all locations
	Roof insulation	When work is in progress	• Roof insulation installed to the correct thickness with boards tightly joined together and no gaps/ any gaps filled with spray foam • SWA must inspect the installation in progress • Thermal break pads installed at mechanical and structural supports where applicable
	Pipe insulation Duct Insulation	At commencement, in progress, prior to drywall enclosure	• Pipe insulation installed to the correct thicknesses for domestic hot water (including crotons), domestic cold water, heating hot water, and refrigerant lines • Duct insulation installed to the correct thickness • Proper installation and air sealing of duct insulation and vapor barrier on ducts between outside ERVs and the interior
	Window & door installation and sealing	At commencement, every 1-2 floors	• Testing as described above in the building envelope air sealing section • Visual inspections for remaining window & door installations
	Drywall installation, air sealing visual inspection	When work is in progress	• Ensuring drywall seams are sealed to the ceiling, floor, and each other • Apartment air sealing details to be observed being implemented as outlined in the drawings • Install cement board or similar (#ASTM #D3273 compliant) behind tub/shower enclosures
	HVAC equipment installations	Once on site, after all equipment installations	• HVAC equipment to match schedules, meet efficiency requirements, and have associated controls installed
	Roof drains	Prior to enclosure with drywall shafts	• Roof drain lines installed and insulated to the correct depth
Construction Completion	Lighting and lighting controls	At commencement, at 100% completion	• Lighting and lighting controls (e.g. occupany sensors) where required. Keep boxes of LED fixtures to confirm makes/models.
	Appliances	Once arrived at the site	• Appliances, clothes washers, and dryer model numbers to match submittals
	Plumbing fixtures	Sampling of apartment units	• All installed plumbing fixtures (toilets, kitchen faucets, bathroom faucets, shower heads) are the correct GPM flow rates
	Exterior door sealing	At 100% completion	• All exterior doors are sealed with weatherstripping & mechanically fastened door sweeps
	Air tightness testing (blower door)	Whole building blower door test at 100% completion	• Whole building must pass air leakage testing maximum of 0.6 ACH @ 50 Pa • Whole building systems must be put in operating state as outlined in the Blower Door Test plan
	Testing & balancing	Once equipment is started up, prior to occupancy	• Test and balance all air-side systems and provide TAB reports to SWA once complete. A full TAB report from a third party that is AABC or NEBB certified is required. We strongly recommend having a meeting with the TAB contractor before they begin working to ensure we're all on the same page. • Final TAB documentation to occur prior to occupancy.
	ERV testing	At 100% completion	• ERV supply and exhaust flows must be at least 100% of design flow and within 10% of each other. • Access to main trunks coming off the ERV or access to Swegon control screen and indicator panel is required for testing. • MERV 13 filters for ERVs
	Metering (electric)	At 100% completion	• Tenants are individually metered for electricity (meter banks)

PH site inspections: list of inspections required
PH-specific criteria in red

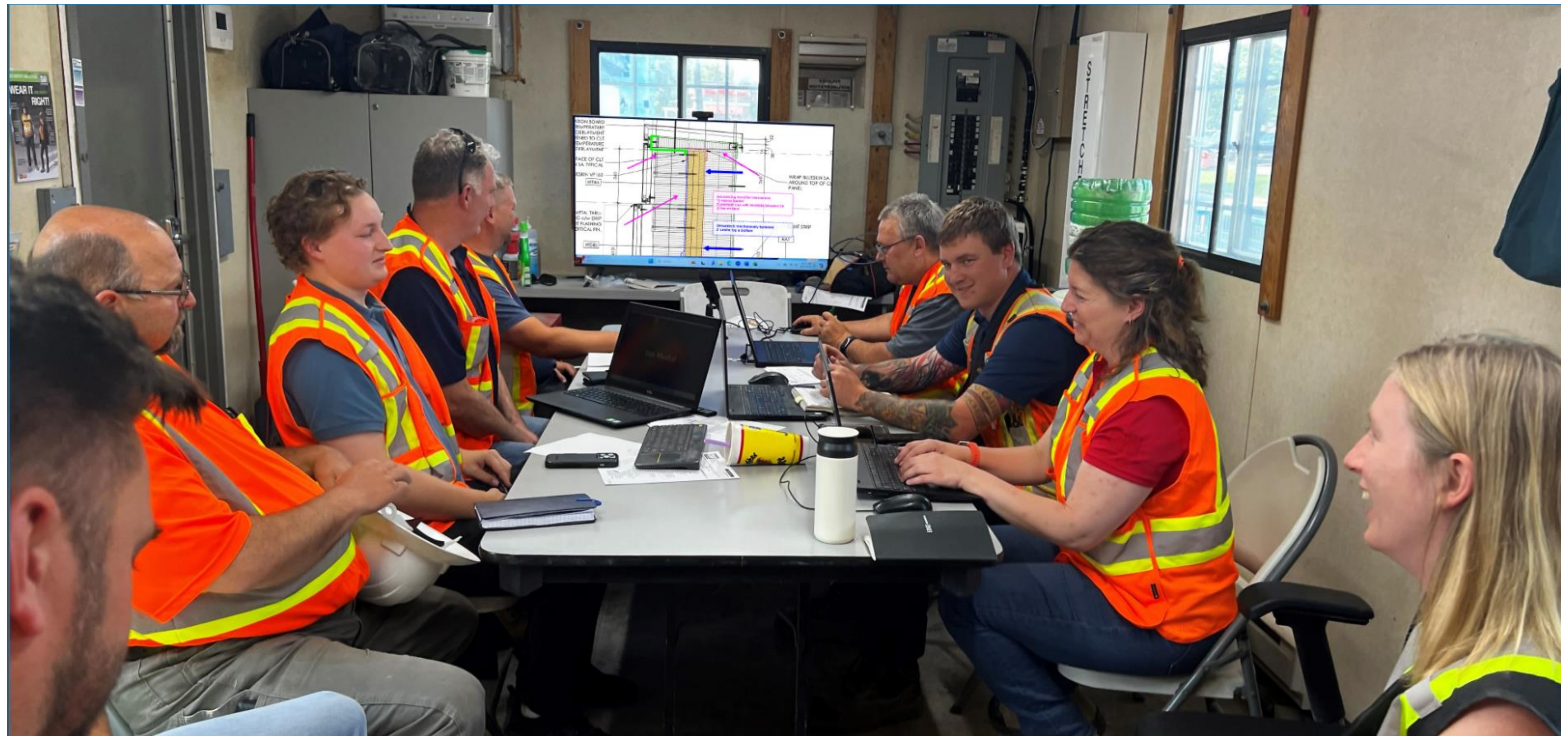
2.4 PH Contractor Training

GOAL: **get buy-in** from trades supers + installation teams

GOAL: move to a **blame-free, collaborative** mind set

Content

- Review project-specific details
- Start conversation of coordination between trades
- Sessions: x1 Building Enclosure trades + x1 MEP trades



Start of Construction – Typical Pitfalls

Difficulties

- → IFCs not finalized before construction start
- → PH model not approved by certifier before construction start
- → Reactive approach at construction start
- → Unfamiliar with new PH roles (Air Boss, PH Site Super)
- → Staff turnover with new PH roles

Solutions

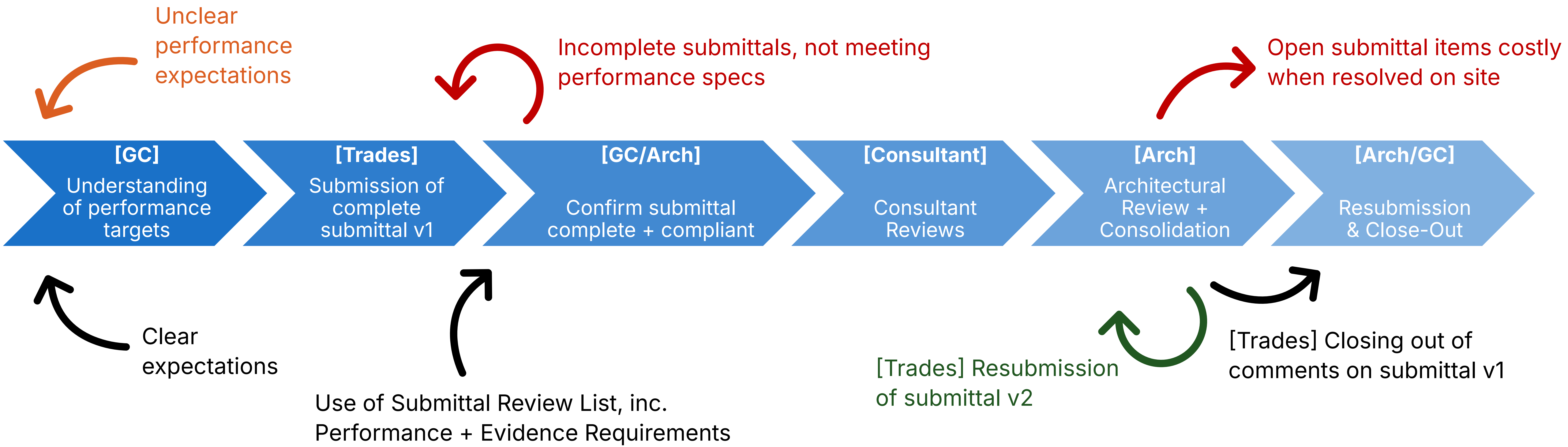
- → IFCs **before** construction start
- → Design pre-certification (DSR) **before** construction start
- → **Time to act** after kick-off meeting
- → **Recognized** roles
- → Staff **retention** tactics

3 Submittal Process

Photo: RDH Building Science

Best Practice – “Airtight” Submittal Process

- → Higher scrutiny
- → No uncertainty left during construction as it relates to building performance
- → All comments to be resolved
- → Easier field review process

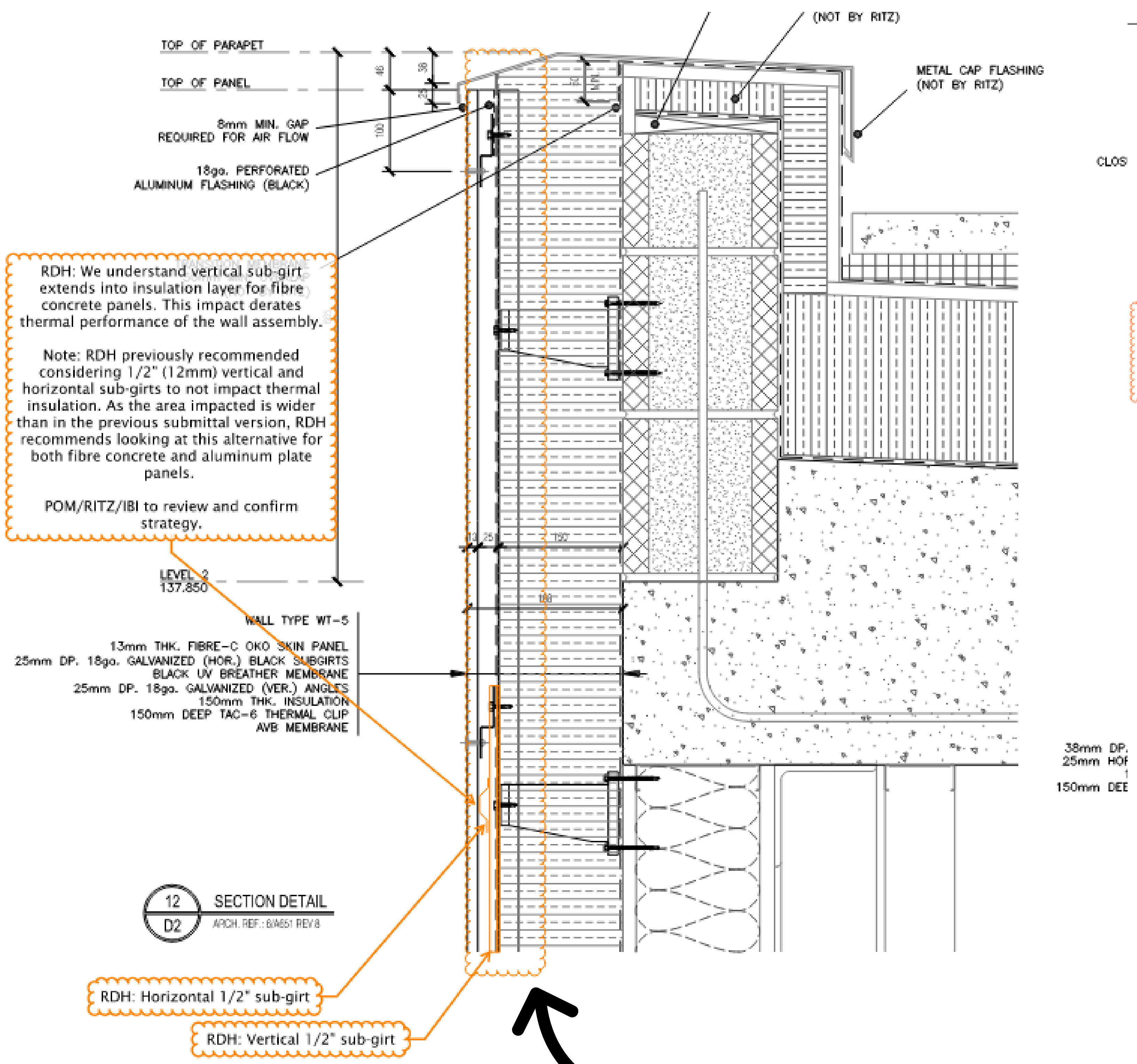


Submittals Process – Goals vs Reality

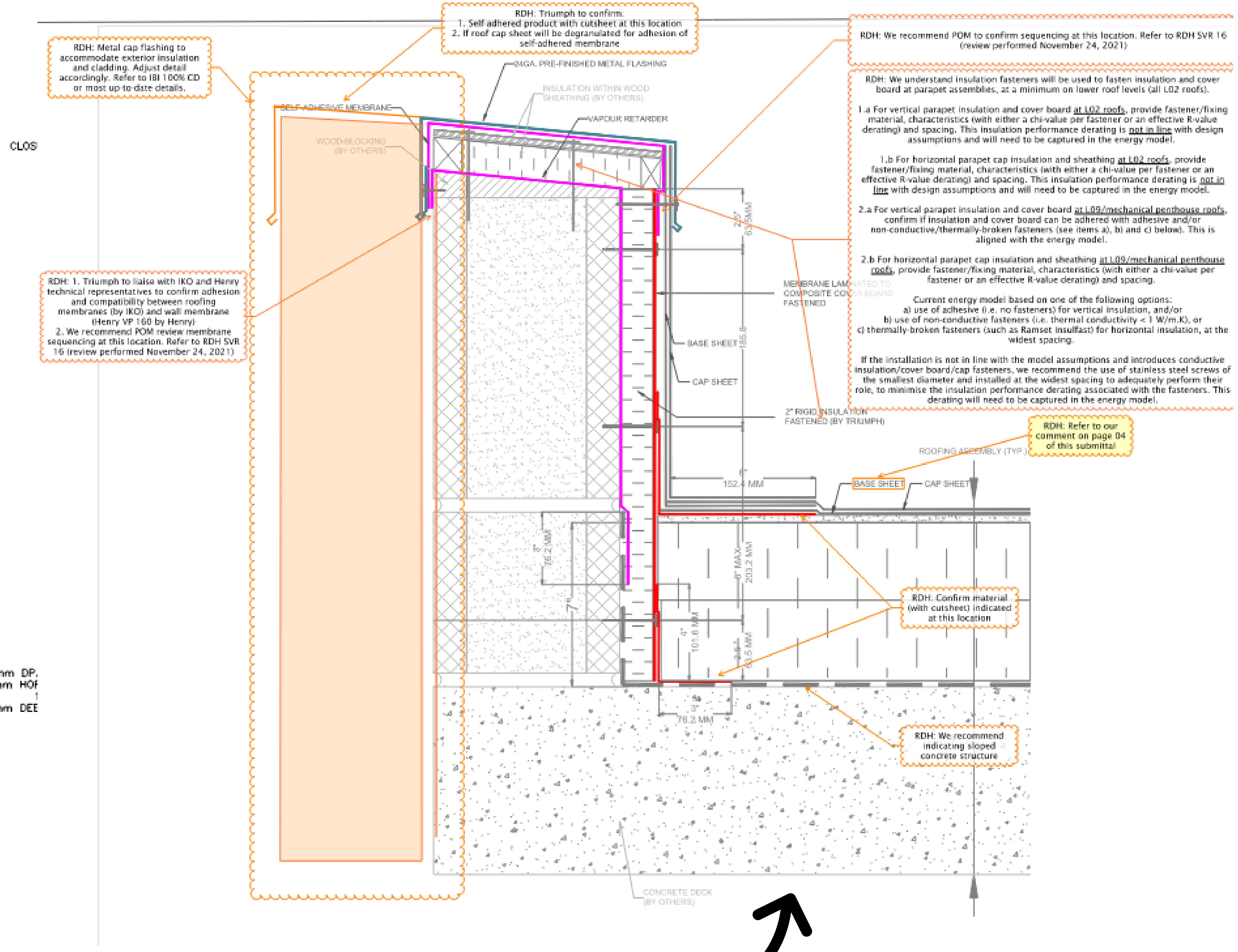
GOALS

- → Full & **complete submittals** with test data and thermal modeling
- → Performance data **identified** and **compliant** with design-certified energy model inputs
- → Thermal bridging details **aligned with model and architectural drawings**
- → **Coordinated** shop drawings
- → Finalize submittals & shop drawings **early**

Submittals Process – Goals vs Reality



Cladding scope submittal



Roofing scope submittal

Submittal Process – Typical Pitfalls

Difficulties

→ No submittal

→ Verifier omitted from relevant, critical submittal reviews

→ Lack of submittal management platform (e.g., Procore)

→ Submittal provided, after products already on site

→ No implementation of "Approved as Noted" stamp comments

→ Submittal process incomplete prior to site installation

Solutions

→ Partnership with **trusted trades**

→ Submittal **review list**, inc. verifier's involvement

→ Use of submittal management **platform**

→ Upfront, clear, proactive approach with recommended submittal process, inc. **non-compliance repercussions**

→ (see above)

→ Budget allowance for **additional site visits**, for "on-the-job problem solving"

4 Construction Challenges & Successes

Photo: RDH Building Science

Site Review/Work Plan – Goals vs Reality

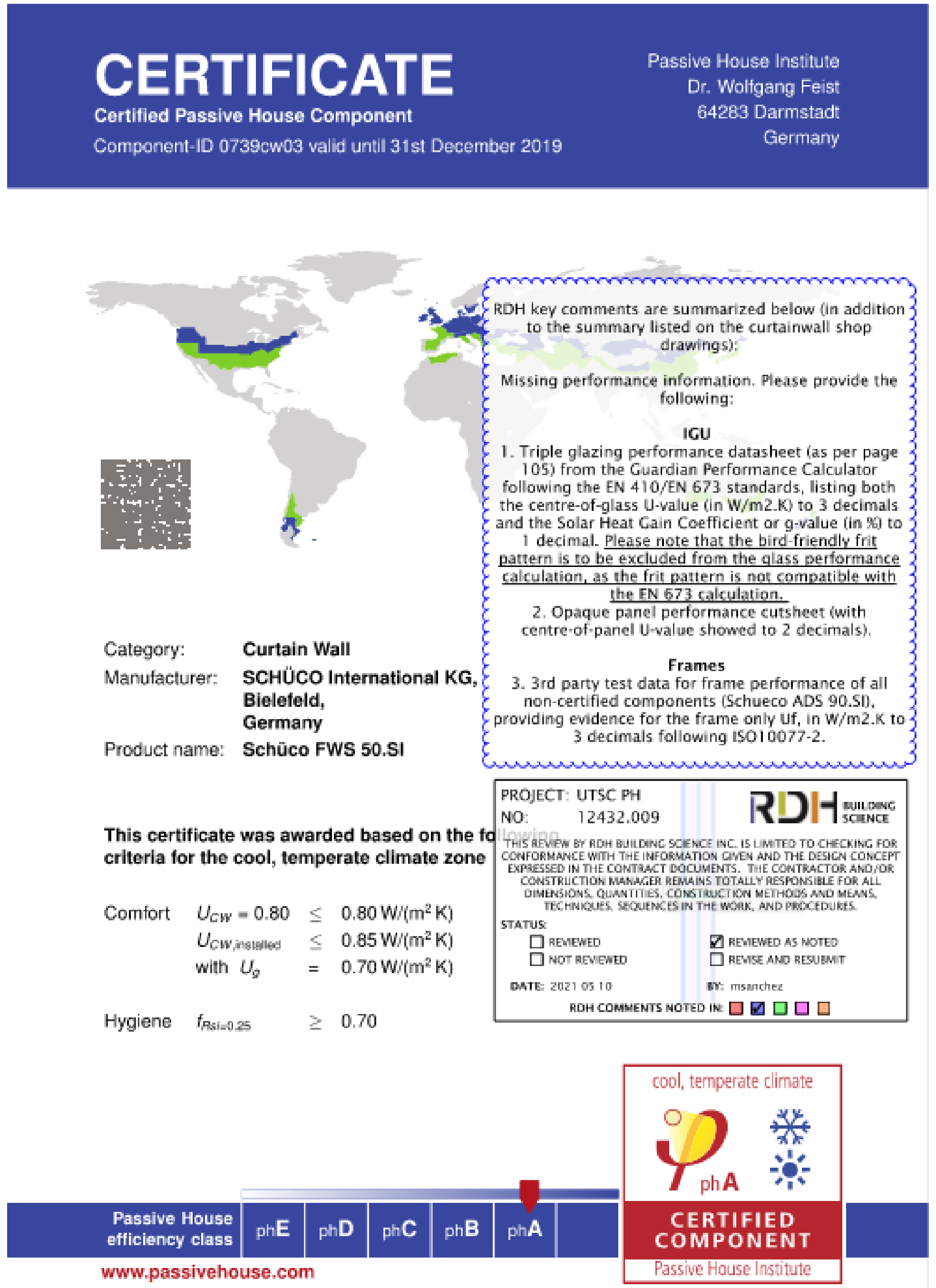
GOALS

- → Confirm **product procurement** in compliance with IFCs/submittals
- → Confirm **compliance of site installation** as per IFCs/submittals (aligned with energy model performance assumptions)
- → Provide **site QA/QC**
- → **Support** crew changes/late trades introduction
- → **Photographic evidence** collection (procurement + installation)
- → Derisking through **installation mock-ups**

RDH FIELD REVIEW SCHEDULE		
Review No.	Date	Key elements of building enclosure work
SV 1	March 12, 2024	• Waterproofing and insulation at elevator pit slabs
SV 2	March 26, 2024	• Waterproofing and insulation at elevator pit walls and footing • Penetrations at elevator pit walls
SV 3	April 17, 2024	• Sub-slab vapour barrier and penetrations • Sub-slab insulation installation • Elevator pit wall assembly interface with sub-slab assembly
SV 4	May 27, 2024	• Waterproofing and insulation at foundation wall and footing
SV 5	June 25, 2024	• Mass timber panel installation • Mass timber moisture management plan implementation
SV 6	June 25, 2024	• Ground floor window rough openings • Ground floor window installations
Water Test 1	July 8, 2024	• Water testing of 2 ground floor windows
SV 9	Sept 4 2024	• Roof and parapet air barrier membrane
SV 10	Sept 4 2024	• Interior plumbing vent stack insulation installation
SV 11	Sept 10 2024	• Roof insulation • Roof membrane • Roof penetrations • Parapet assembly
SV 12	Sept 10 2024	• Rooftop mechanical installation • Level 1-4 wall insulation application • Level 1-4 wall panel application
WBATT #1	Sept 17 2024	• Mid-Construction Whole-Building Compliance Airtightness Test
SV 13	Nov 21 2024	• Punched window exterior panel mock-up
SV 14	Nov 21 2024	• Typical base of wall interface at grade • Ground level wall insulation application
SV 16	Dec 2024	• Second punched window exterior panel mock-up • Typical wall panel application
SV 17	Dec 2024 – Feb 2025	• Door installation mock-up
Recommend Add SV	Dec 2024	• Typical canopy connection to exterior wall, • Typical roof to wall upturn interface at the penthouse.
Recommend Add SV	Dec 2024	• Roof doghouse, • MUA shaft penetration at roof, • Rooftop mechanical installation • Level 2-6 wall insulation application • Level 2-6 wall panel application

Site Review – Goals vs Reality

PRODUCT PROCUREMENT



CERTIFICATE
Certified Passive House Component
Component-ID 0739cw03 valid until 31st December 2019

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

RDH key comments are summarized below (in addition to the summary listed on the curtainwall shop drawings):

Missing performance information. Please provide the following:

IGU

1. Triple glazing performance datasheet (as per page 105) from the Guardian Performance Calculator following the EN 410/EN 673 standards, listing both the centre-of-glass U-value (in W/m2.K) to 3 decimals and the Solar Heat Gain Coefficient or g-value (in %) to 1 decimal. Please note that the bird-friendly frit pattern is to be excluded from the glass performance calculation, as the frit pattern is not compatible with the EN 673 calculation.
2. Opaque panel performance cutsheet (with centre-of-panel U-value showed to 2 decimals).

Frames

3. 3rd party test data for frame performance of all non-certified components (Schueco ADS 90.SI), providing evidence for the frame only Uf, in W/m2.K to 3 decimals following ISO10077-2.

Category: **Curtain Wall**
Manufacturer: **SCHÜCO International KG, Bielefeld, Germany**
Product name: **Schüco FWS 50.SI**

PROJECT: UTSC PH
NO: 12432.009
RDH BUILDING SCIENCE

THIS REVIEW BY RDH BUILDING SCIENCE INC. IS LIMITED TO CHECKING FOR CONFORMANCE WITH THE INFORMATION GIVEN AND THE DESIGN CONCEPT EXPRESSED IN THE CONTRACT DOCUMENTS. THE CONTRACTOR AND/OR CONSTRUCTION MANAGER REMAINS TOTALLY RESPONSIBLE FOR ALL DIMENSIONS, QUANTITIES, CONSTRUCTION METHODS AND MEANS, TECHNIQUES, SEQUENCES IN THE WORK, AND PROCEDURES.

STATUS:
☐ REVIEWED ☑ REVIEWED AS NOTED
☐ NOT REVIEWED ☐ REVISE AND RESUBMIT

DATE: 2021 05 10 BY: msanchez
RDH COMMENTS NOTED IN:

This certificate was awarded based on the following criteria for the cool, temperate climate zone

Comfort	$U_{CW} = 0.80$	$\leq$	0.80 W/(m² K)
	$U_{CW,installed}$	$\leq$	0.85 W/(m² K)
	with U_g	=	0.70 W/(m² K)
Hygiene	$f_{Rsi=0.25}$	$\geq$	0.70

cool, temperate climate
phA
CERTIFIED COMPONENT
Passive House Institute

Passive House efficiency class: phE phD phC phB phA
www.passivehouse.com

Frame values		Frame width b_f mm	*U*-value frame U_f [1] W/(m² K)	*Ψ*-panel edge Ψ_g W/(m K)	Temp. Factor $f_{Rsi=0.25}$ [-]
Top fixed	(tof)	50	0.88	0.035	0.79
Side fixed	(sf)	50	0.88	0.034	0.79
Bottom fixed	(bof)	50	0.88	0.035	0.79
Mullion fixed	(m)	50	0.88	0.034	0.79
Transom fixed	(tf)	50	0.88	0.035	0.79
Transom 1 casement	(t1)	156	1.20	0.031	0.79

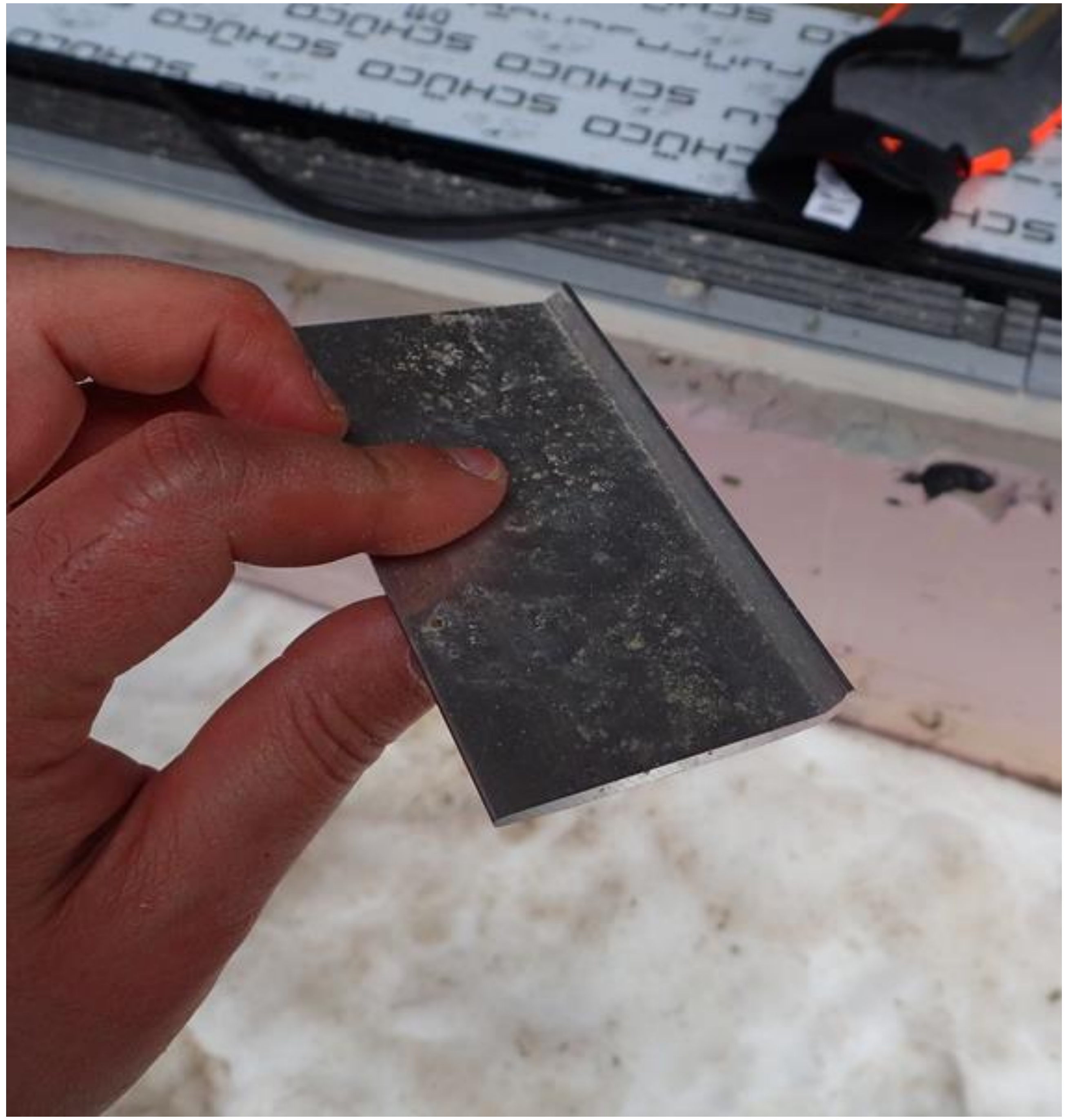
Spacer: SWISSPACER Ultimate — Secondary seal: Polysulfide

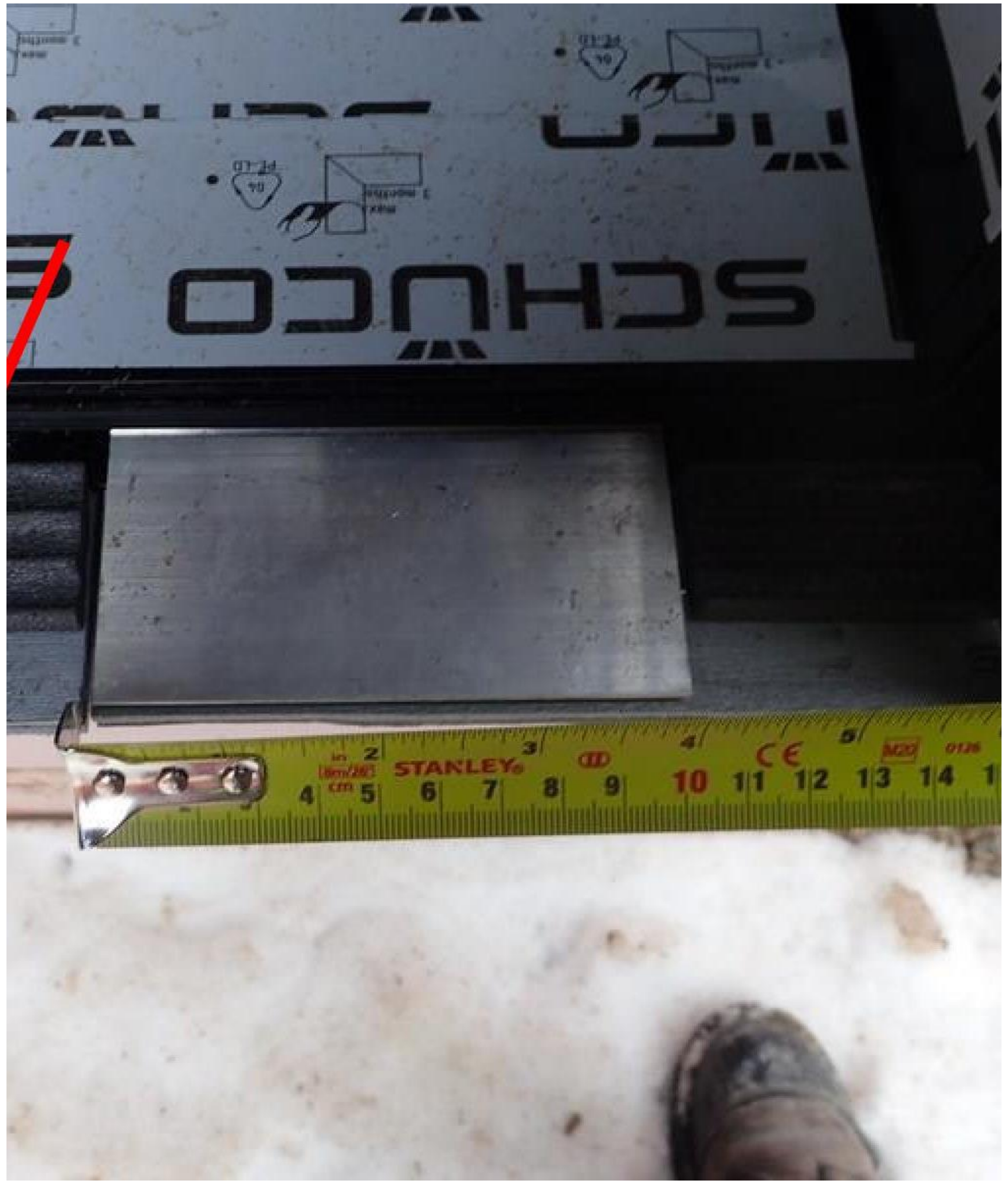
Thermal glass carrier bridge [2] χ_{GT} = 0.014 W/K

[2] Determined through 3D - FEM Simulation . Glass carrier type : Non-Metallic Glass Carrier with Screws

Site Review – Goals vs Reality

PRODUCT PROCUREMENT





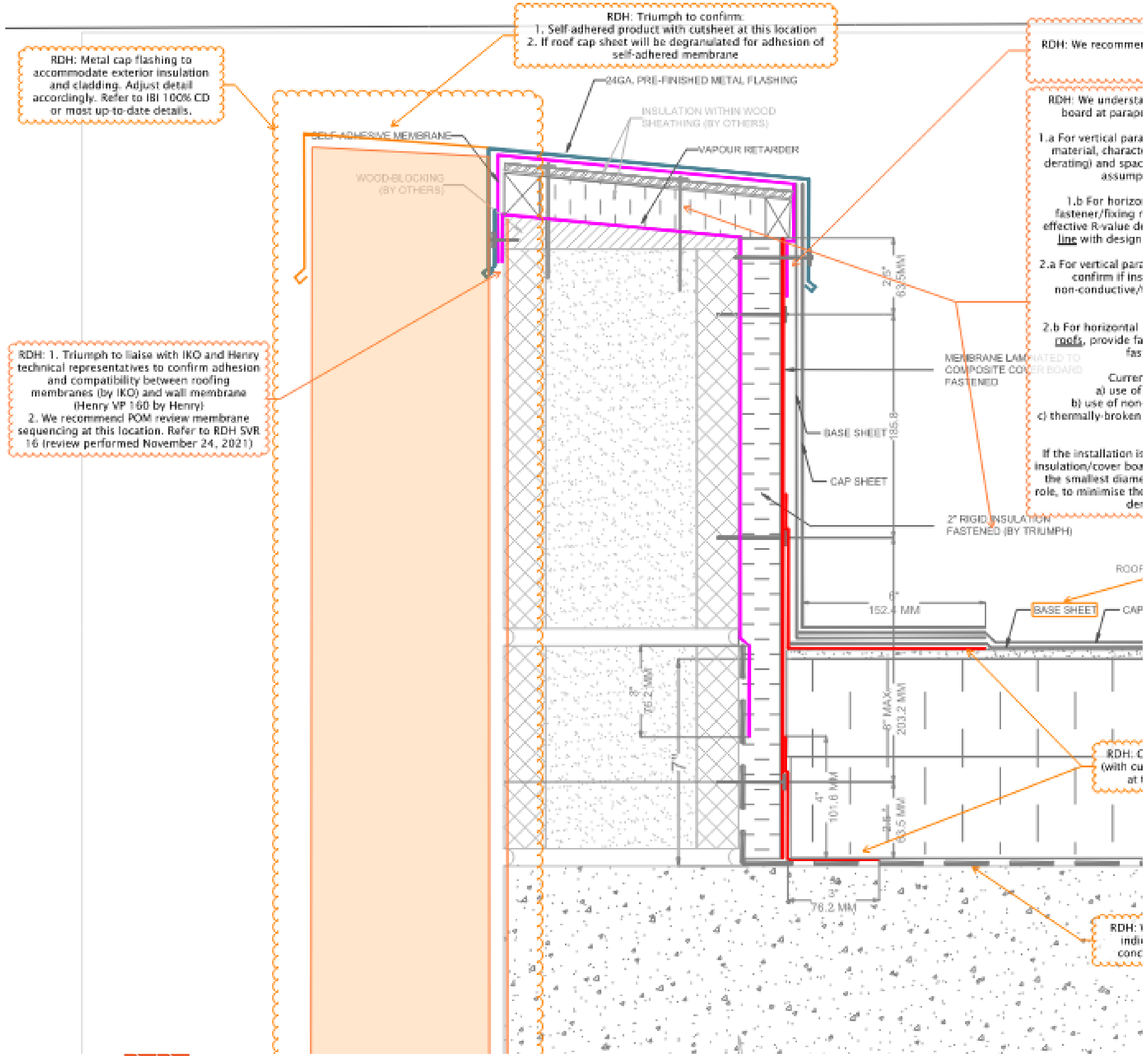
Curtain Wall Glass Carriers

- → PH certificate: non-conductive
- → Quote: non-conductive
- → Submittals: non-conductive
- → Shipped to site: aluminum

= Construction change from 0.014 to 0.040 W/K per glass carrier (with 2 carriers per CW IGU)

Site Review – Goals vs Reality

SUBTRADES COORDINATION



Site Review – Goals vs Reality

CREW CHANGE

- → Crew changed for the air barrier installation trade partway through the project

Site Review – Goals vs Reality

POST-INSTALLED PENETRATIONS

→ No site PH induction for electrical trades, joining the project at a later stage

Site Review – Goals vs Reality

OTHERS

Mock-up Preparation

GOAL: Derisking construction

→ Try, adjust, finalise approach through mock-up preparation

→ "Do it once, and do it right"

→ Early sample procurement (after submittal)

→ Carve additional early-stage coordination time (trades joining for mock-up day)



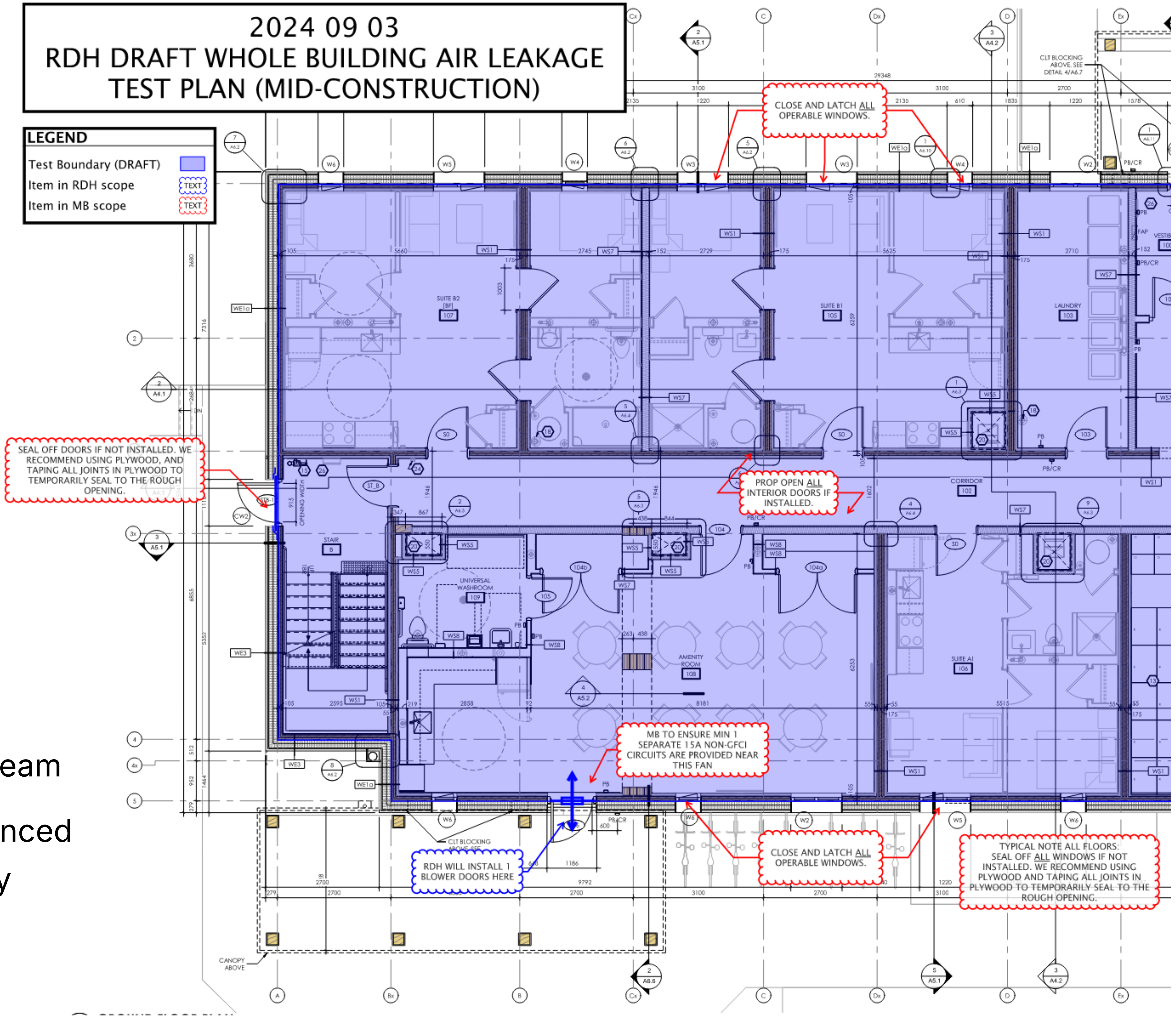

Photo: RDH Building Science

Photo: Steven Winter Associates

5 Airtightness Testing & Ventilation Commissioning

Photo: RDH Building Science

Airtightness Test Plan



Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Table 2 – Test Configuration of Intentional Openings and Firm Responsible for Setting the Opening

Key: HVAC Contractor; Plumber; GC / Builder

Intentional Opening	Test Setting	Notes
Windows and doors in the building enclosure	Closed and latched	
Typical doors inside the test enclosure	Doors open	Use interior doors and stairways to connect all zones of the building.
Door to the gas meter room	Door closed	Door to gas meter room closed and weather stripped
Waste handling system and equipment. (2x) Trash chute runs from the cellar compactor room, through chute access rooms on each floor, and terminates with an open duct with rain protection on the roof.	Chute termination at roof - unmasked Chute intake doors closed Doors to chute access rooms on each floor and compactor room, closed	Trash room doors to be weather stripped along with compactor rooms
Heating & cooling systems (VRF)	Thermostat set to 'off', supply and return ducts open & uncovered.	
Heating & cooling systems (PTHPs)	Thermostat set to 'off', supply and return ducts open & uncovered.	Taped off for the first test. Un-taped for the second test.
ERV-C-1, ERV-C-2, ERV-C-3 ERV-C-4, ERV-C-5, ERV-1-1, ERV-1-2, ERV-1-3, ERV-1-4, ERV-1-5	Units turned off, damper closed, and not otherwise sealed.	These ERVs don't run 24/7 so dampers closed, but not sealed.
RTU-1 through RTU-10	Unit turned off, taped off.	Ventilation is continuous, so dampers closed and sealed
Smoke purge fans (PFSP-1, 2, 3, 4 & 5)	Unit turned off, damper closed, and not otherwise sealed.	
PGX-1 and PGX-2 (Garage exhaust fans)	Fans turned off.	
CKX-1 (residential kitchen exhaust)	Fan off. Can be taped if running 24/7, otherwise rely on dampers.	Confirm if running 24/7.
DRX-1, 2A, 2B MUA-1, 2A, 2B	Units turned off, taped off.	Units run 24/7 so can be taped off.
TX-C-1,2,3,4,5,6 TX-1-1,2,3,4,5,6	Fans off. Can be taped if running 24/7, otherwise rely on dampers.	Confirm if running 24/7.
Smoke vents at the top of each stairwell and elevator shaft	Dampers closed, but not sealed.	

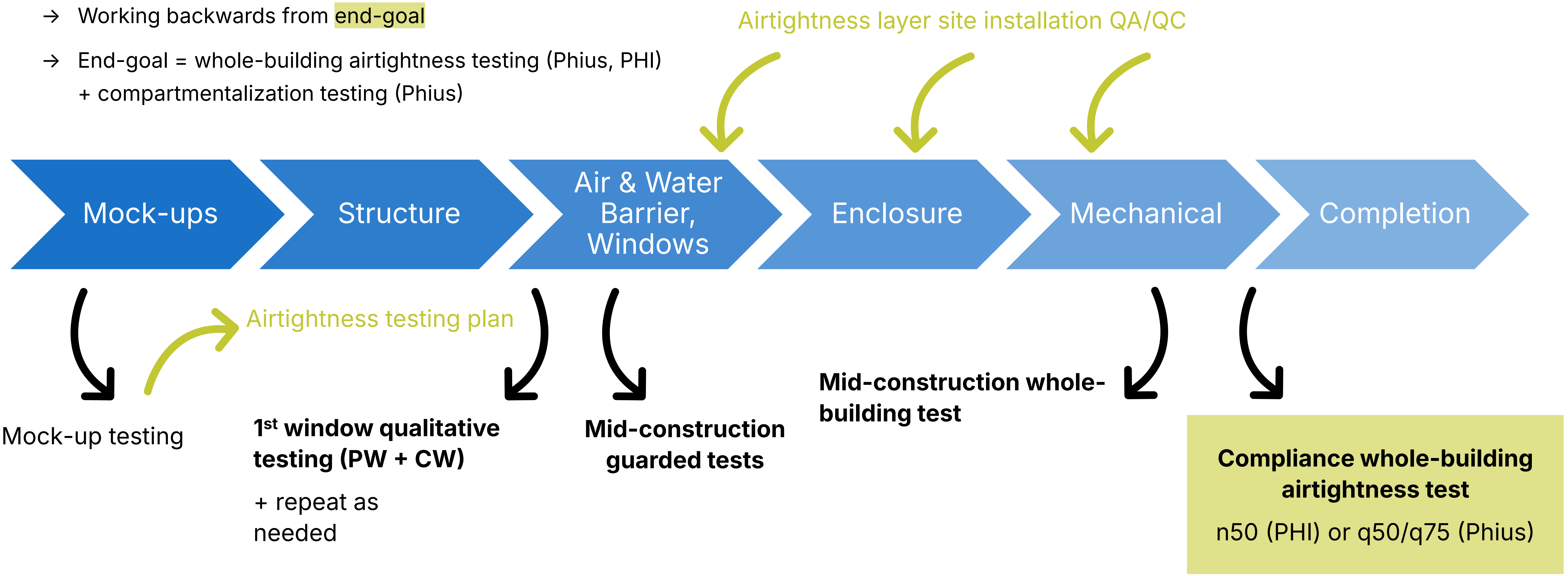
4

Process

- → Plan preparation
- → Plan review with full team
- → Ensure tester experienced with building typology

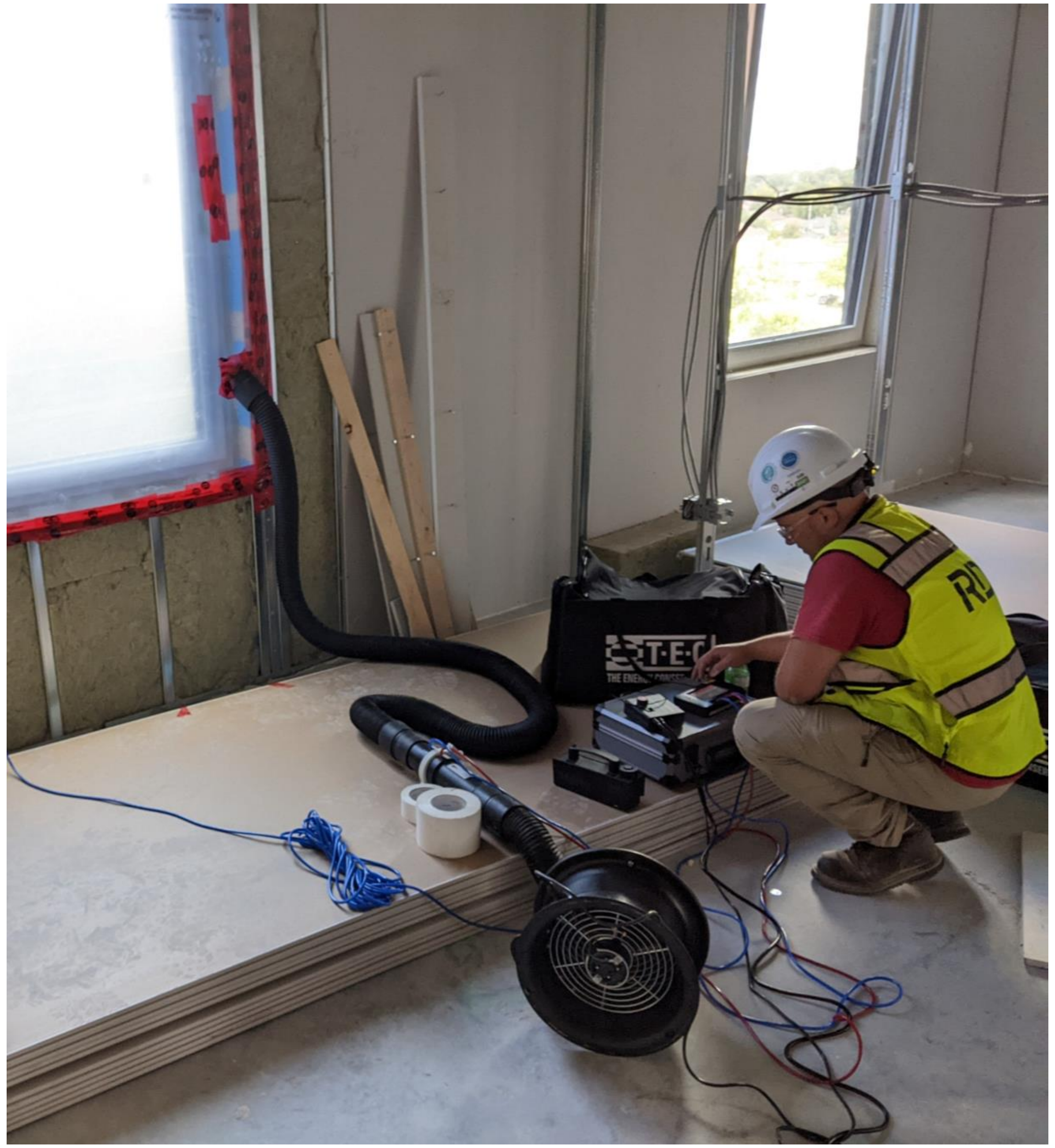
Airtightness Risk Management

- → Risk management approach
- → Working backwards from end-goal
- → End-goal = whole-building airtightness testing (Phius, PHI) + compartmentalization testing (Phius)



Airtightness Testing

WINDOW AIR LEAKAGE TESTING



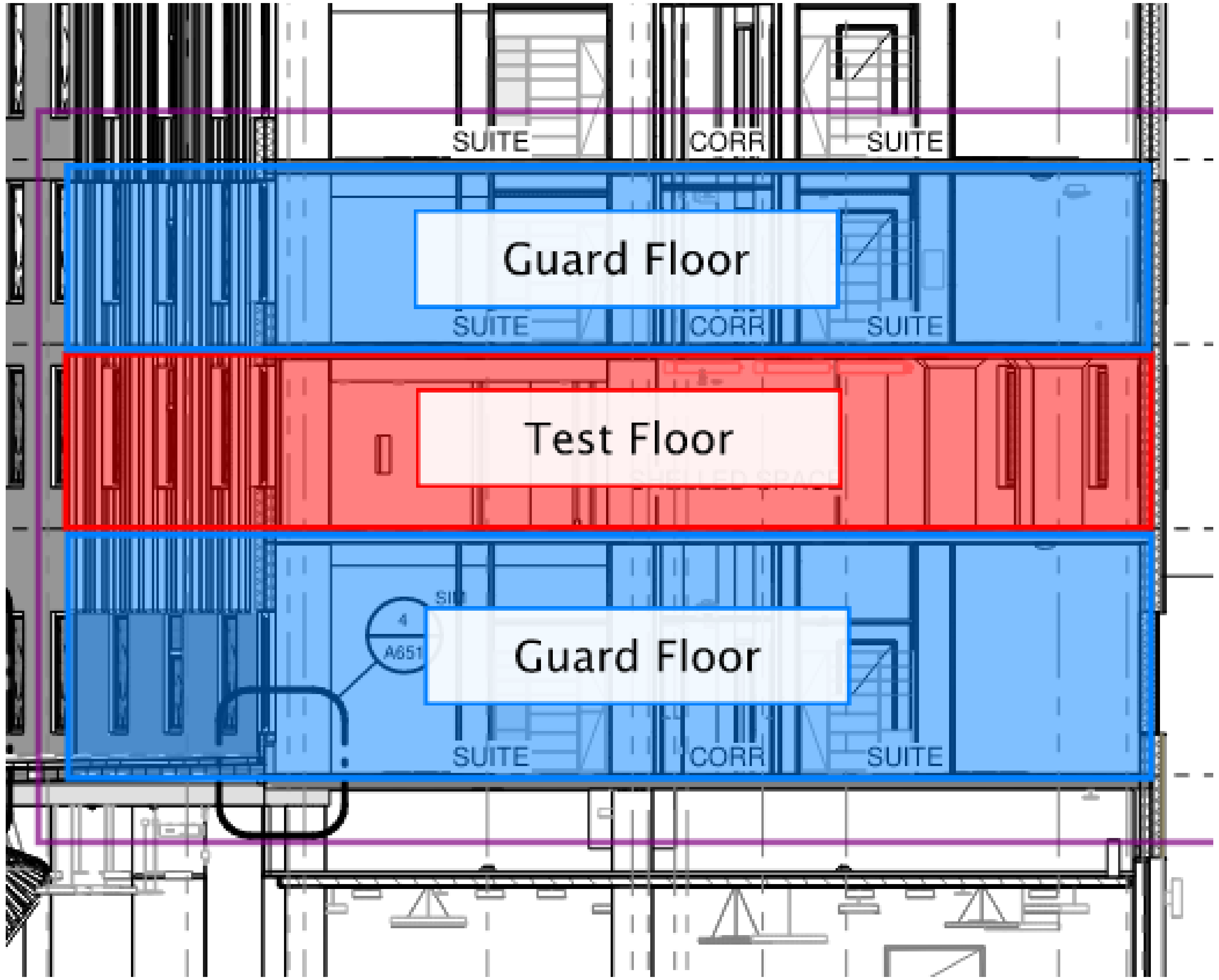
Window installation air leakage testing

Diagnostic testing

Leak detection with smoke testing

Airtightness Testing

(LEVEL) GUARDED TEST



Visualization of guarded test approach

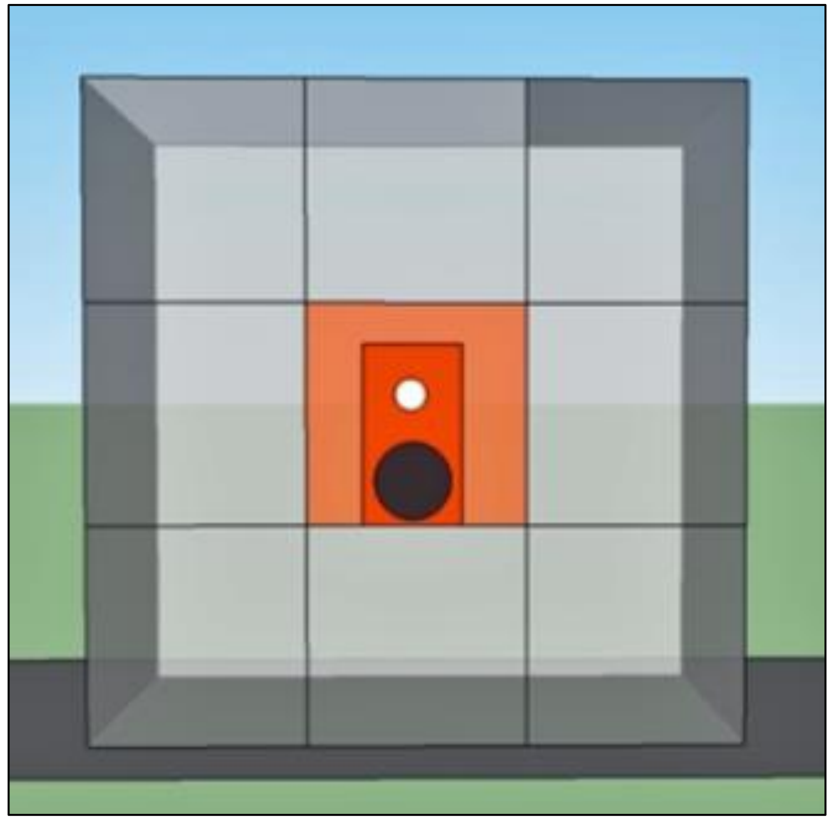
Location of guarded test

Airtightness Testing

COMPARTMENTALIZATION TESTING

Approach

- → Phius mandatory requirement
- → **Attention to detail** when doing layout, framing, and finishing of apartments
- → Different testing preparation & scope from whole-building airtightness testing (more similar issues to guarded airtightness test)



Ventilation Commissioning

Clarity of commissioning requirements

- → Approach (bottom-up)
- → Information required (total OA/EXH: more than BAU)
- → Ventilation unit under which operating “mode” (standard vs boost, VAVs with sensors, modulating systems)
- → Time commitment
- → Access to building (after occupancy)

Approach

- → Review TAB procedures beforehand
- → Set up review meeting with GC, TAB, and mechanical contractors prior to TAB start to confirm clarity of PH requirements
- → Optional: bring verifier to site for TAB start (alignment)

TAB contractor to provide:
- documentation of filters grade,
- filters state,
- filters direction of installation, and filters fit as listed in the PH Cx Requirements document issued by RDH on 2023 07 05.

DATE ______
PAGE No. 2 OF 53

AHU TEST FORM

Measurement at Fan in AHU

Sum of internal grilles

PROJECT TITLE: ______

Total O/A or EXH (= Fan measurements, as 100% DOAS)

AHU-1 imbalance (actual Cx): (2613-2438)/2613 = 6.7% < 10%, meeting PH Cx requirements

UNIT ID No.	AHU-1 (SF)	AHU-1 (EF)
UNIT TYPE	ROOFTOP AIR HANDLING UNIT SUPPLY FAN	ROOFTOP AIR HANDLING UNIT EXHAUST FAN
LOCATION	ROOF	ROOF
AREA SERVED	NORTH WEST WING LEVELS 2 TO 9	NORTH WEST WING LEVELS 2 TO 9
MANUFACTURER	SWEGON	SWEGON
MODEL	GOLD 50 ARX	GOLD 50 ARX
SERIAL No.	-	-

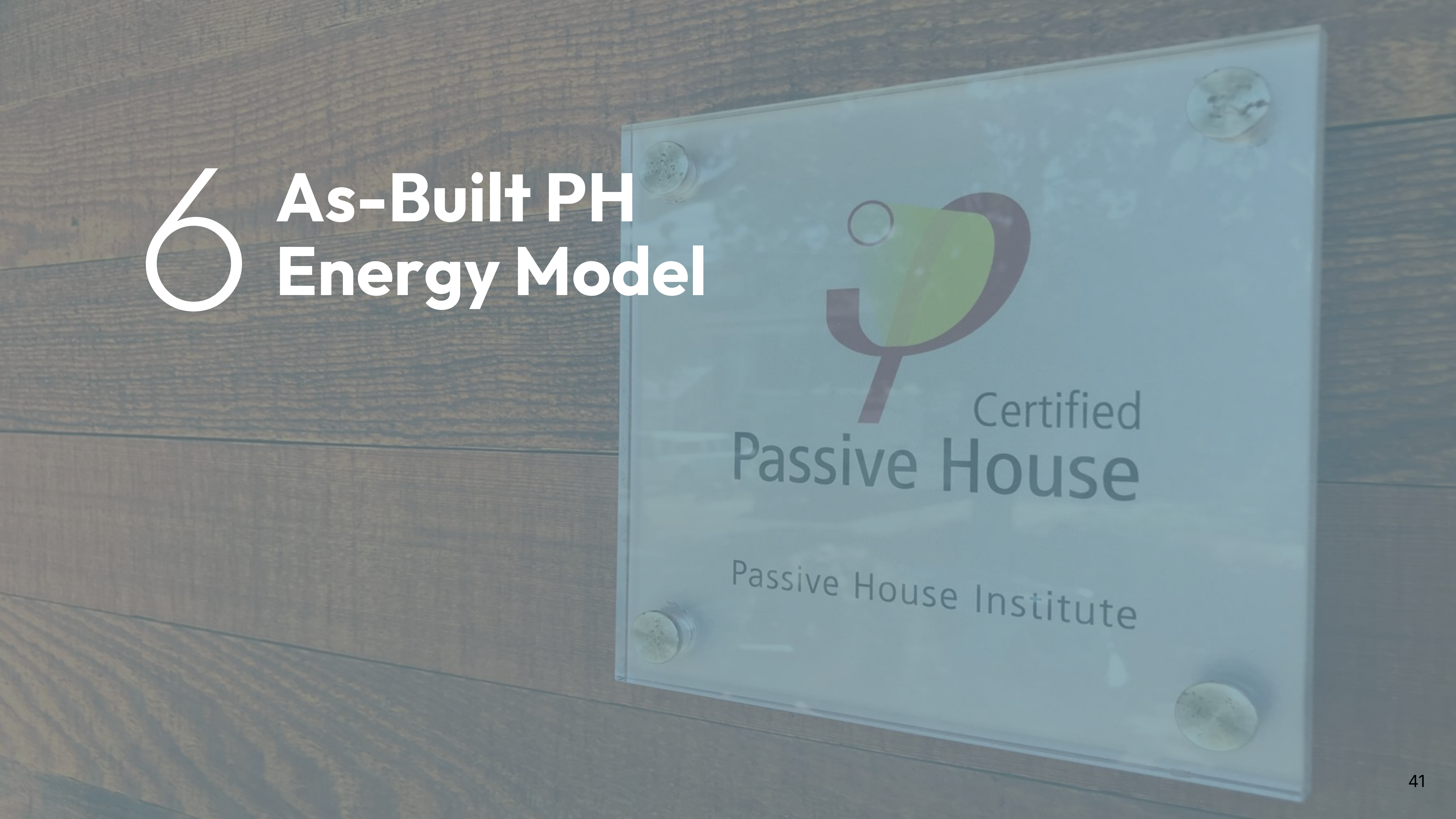
OPERATING CONDITIONS		SPECIFIED	ACTUAL	SPECIFIED	ACTUAL
TOTAL FLOW - FAN (L/s)		2,407	Total OA 2,613	2,407	Total EXH 2,438
TOTAL FLOW - AIR TERMINALS (L/s)		2,820	2,604	2,575	2,401
OUTSIDE AIR CONTENT (L/s)		2,820	2,613	-	
RETURN AIR CONTENT (L/s)		-	-	-	-
EXHAUST AIR CONTENT (L/s)		-	-	2,575	2,401
TOTAL STATIC ΔP (Pa)		1,158	235	468	295
EXTERNAL STATIC ΔP (Pa)		187	78	157	91
OUTSIDE AIR TEMPERATURE (°C)					-
RETURN AIR TEMPERATURE (°C)					-
MIXED AIR TEMPERATURE (°C)					-
OUTSIDE AIR (%)		100%	100%		-
FAN SPEED (rpm)		1,169	715	1,157	639
FAN SHEAVE SIZE & TYPE			*Direct Drive*		*Direct Drive*
FAN BORE SIZE & TYPE			-		-
MOTOR SHEAVE SIZE & TYPE			-		-
MOTOR BORE SIZE & TYPE			-		-
BELTS No. TYPE & SIZE			-		-
MOTOR MANUFACTURER		*2 motors*	Domel	*2 motors*	Domel
MOTOR SPEED (rpm)		1,440 (x2)	715	1,400 (x2)	639
MOTOR POWER (kW)		6.50	-	6.50	-
BRAKE HORSEPOWER (kW)		2.45	-	2.33	-
MOTOR S.F. / FAN EFFICIENCY			1.15 / 0.63		1.15 / 0.63
TESTED VFD SETPOINT (Hz)			ECM Motor		ECM Motor
OVERLOAD RELAY SETTING (A)			-		-
MOTOR VOLTAGE	PHASE 1	575-3-60	*N.A.*	575-3-60	*N.A.*
	PHASE 2		*N.A.*		*N.A.*
	PHASE 3		*N.A.*		*N.A.*
MOTOR AMPERAGE	PHASE 1	16.00	*N.A.*	16.00	*N.A.*
	PHASE 2	16.00	*N.A.*	16.00	*N.A.*
	PHASE 3	16.00	*N.A.*	16.00	*N.A.*

Detrimental impact on energy model (design < actual)

REMARKS:
1. *Supply air setpoint =2,535 L/s on the unit controller to match the flow on the floor outlets. (AFS Field Calibrated)*
2. *Exhaust air setpoint = 1,911 L/s on the unit controller to match the flow on the floor outlets. (AFS Field Calibrated)*
3. N.A. = No access, There is no location available to measure operating electrical data.
4. N.A. = The unit is not furnished with static measurement points cannot measure TSP or internal pre

TAB contractor to take reading of specific fan power under "actual" conditions (as measured above). Specific fan power (in W/(m3.hr)) under normal operation to be read on the Swegon control panel

6 As-Built PH Energy Model



Passive House Metrics

Based on Delivery

(not on design intent)

Stringent

("best-in-class")

Absolute

(set allowance, not % better than moving baseline)

Holistic

(whole-building approach)

Non-prescriptive

(flexibility)

Including all CONSTRUCTION CHANGES

FINAL whole-building airtightness testing...

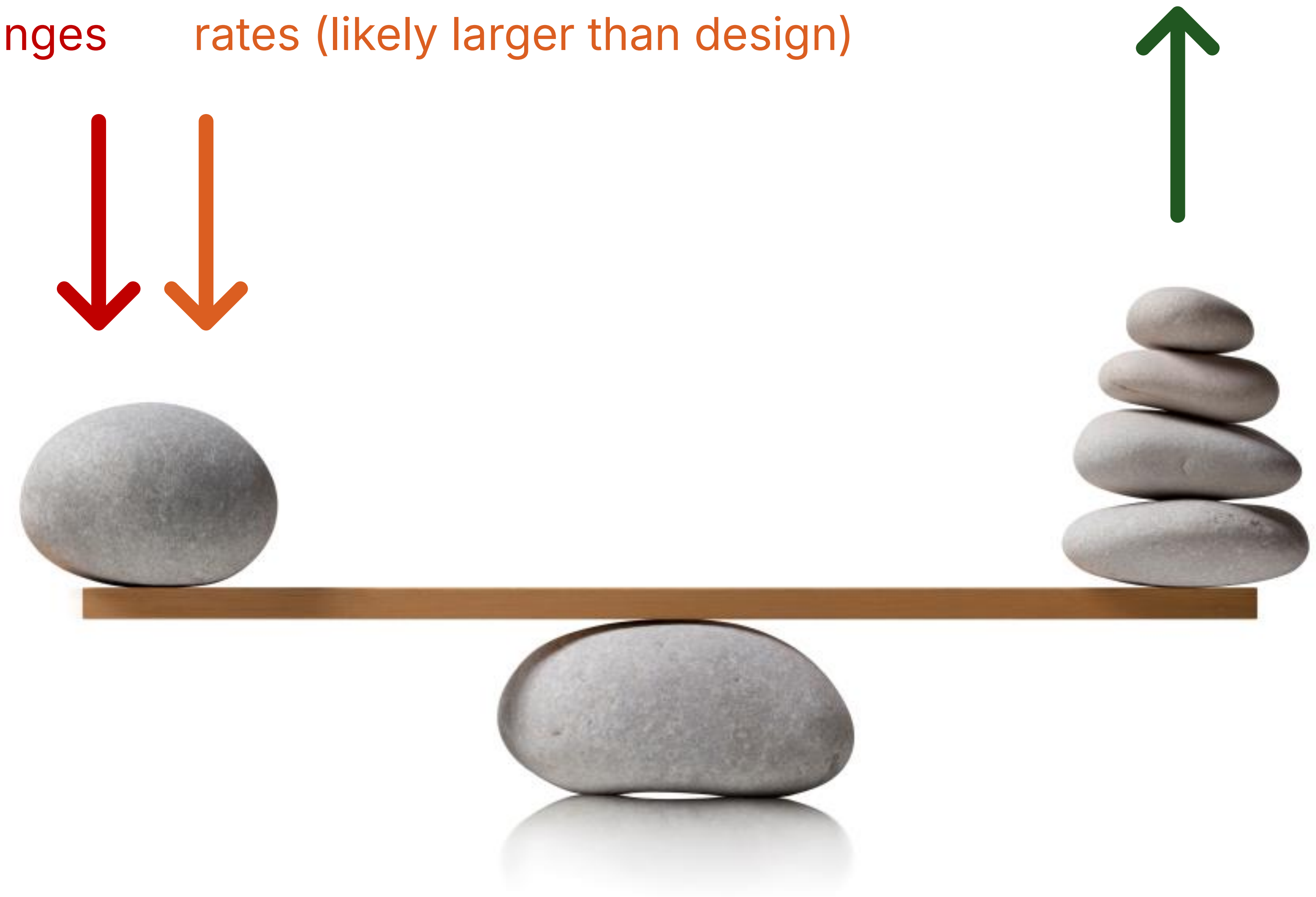
COMMISSIONED ventilation flow rates...

...in **final** PH energy model

Energy Levers

CONSTRUCTION CHANGE TRACKING

Example



Need for CONTINUOUS FEEDBACK from Verifier to Designer:

1. **Track** construction changes
2. **Test** construction changes in energy model to approve/deny them
3. **Update** energy model with approved changes

Be proactive!

Don't wait until the end!

Model Sensitivity – Airtightness vs Ventilation Commissioning

Example

Airtightness Results	0.6 ACH @ 50Pa	0.5 ACH @ 50Pa	0.4 ACH @ 50Pa
Air permeability (CFM/ft² @ 75Pa)	0.10	0.09	0.07
Space Heating Demand (kBtu/ft².yr)	4.47	4.28	4.09
Primary/Source Energy (kBtu/ft².yr)	**41.9**	**41.8**	**41.6**
Primary/Source Energy Margin (%)	**0%**	**0.27%**	**0.53%**

Ventilation Flow Rates	As Designed	+2%	+5%	+10%
Total Flow Rates (CFM)	24,220	24,710	25,430	26,640
Space Heating Demand (kBtu/ft².yr)	4.47	4.54	4.60	4.75
Primary/Source Energy (kBtu/ft².yr)	**41.9**	**42.0**	**42.1**	**42.3**
Primary/Source Energy Margin (%)	**0%**	**-0.18%**	**-0.46%**	**-0.88%**

Complete "As-Built" Certification Packages

GOAL: Provide **complete** certification package to certifier

Content

- → Photographic evidence
- → Whole-building airtightness testing report
- → Ventilation commissioning report
- → Other systems commissioning reports
- → Construction manager's declaration (list of "as-built" drawings, or IFCs with list of site instructions/change orders)
- → "As-built" PH energy model (inc. all information listed above)
- → Checklists – Passive House-related
- → Checklists – Co-requisites (Phius requirements only)

7 Key Takeaways

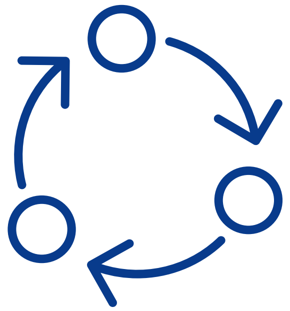
Passive House Strategies for Successful Delivery

STRINGENT TARGETS, MET BY ADAPTING THE CURRENT DELIVERY PROCESS

Clarity & Completeness
of Construction Documents

Budget Management Approach
to energy & air leakage

Attention to Detail
to maintain building performance throughout construction



Enhanced QA/QC Processes
benefiting all aspects of the build

Air Boss & PH Site Supervisor
(with PH Tradesperson training for all key personnel)

Stringent targets, met by adapting the current delivery process

Takeaways

→ Get ahead of things!

→ **Communication, communication, communication**

→ Holistic approach to site QAQC

→ Transfer knowledge from CPHD/C to construction team

- Understand project requirements
- Understand details (trades training)
- Understand submittal process and expectations (knowledge transfer to trades & GC)

→ Knowledge retention

→ Air Boss & PH Site Supervisor present from the beginning

Takeaways

- Mindset shift: **Deep** attention to detail. Not your “average” drawing details.
- Role: Messenger of path ahead, **removing obstacles.**
- Approach: **Proactive** energy budget management.
- Knowledge: Passive House + **“industry standard”** to foresee where pitfalls will be.
- Quality: Trades to treat **all work** (air barrier, insulation, etc.) as if it were finish carpentry.

Discussion and Questions

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THANK YOU!

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