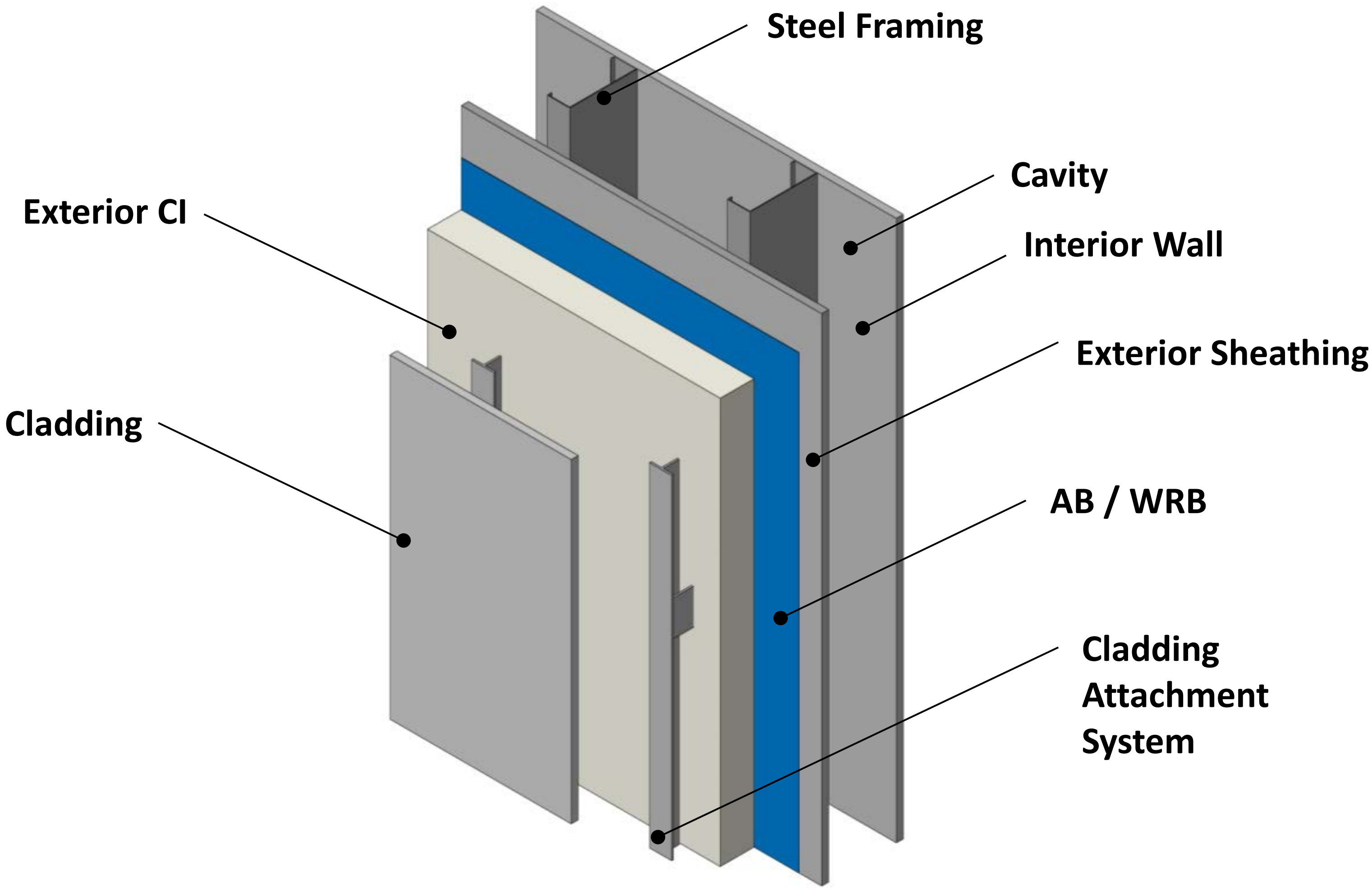
Convective Heat Loss:

A Critical Analysis of Conventional Rainscreen Design

Conventional Rainscreen Design



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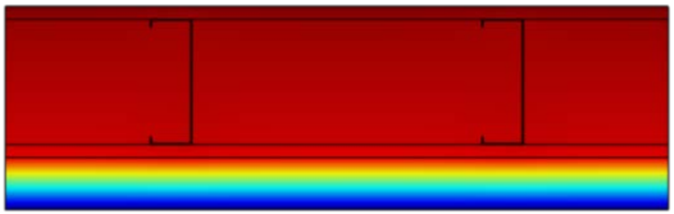
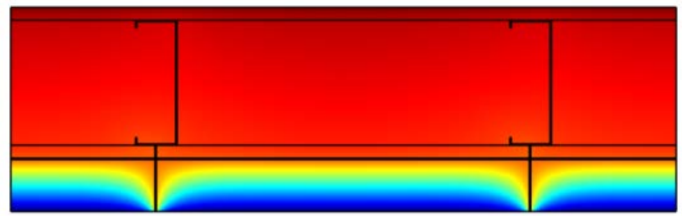
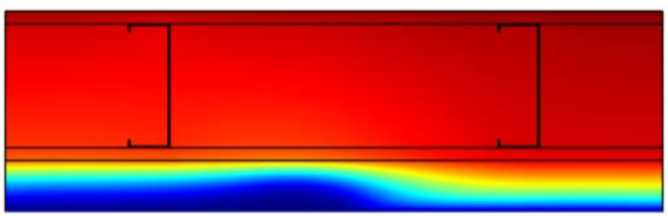
New Design Considerations



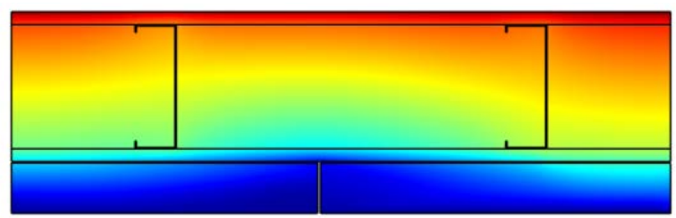
Continuous Insulation



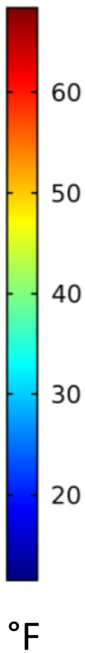
Thermal Bridging



Wind-Washing



Wind-Washing + Gaps



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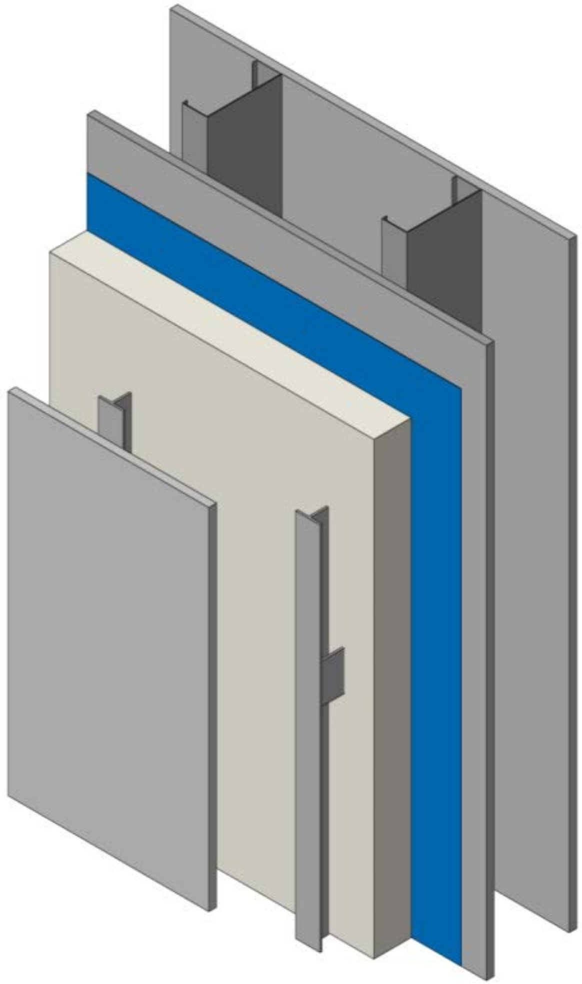
New Design Considerations

Heat Transfer

- Thermal Bridging
- Convective Heat Loss



Moisture Transport

- Rainscreen-WRB Disjoined
- Reduced Drainage Efficiency
- Reduced Vapor Transport with Low-Perm WRBs

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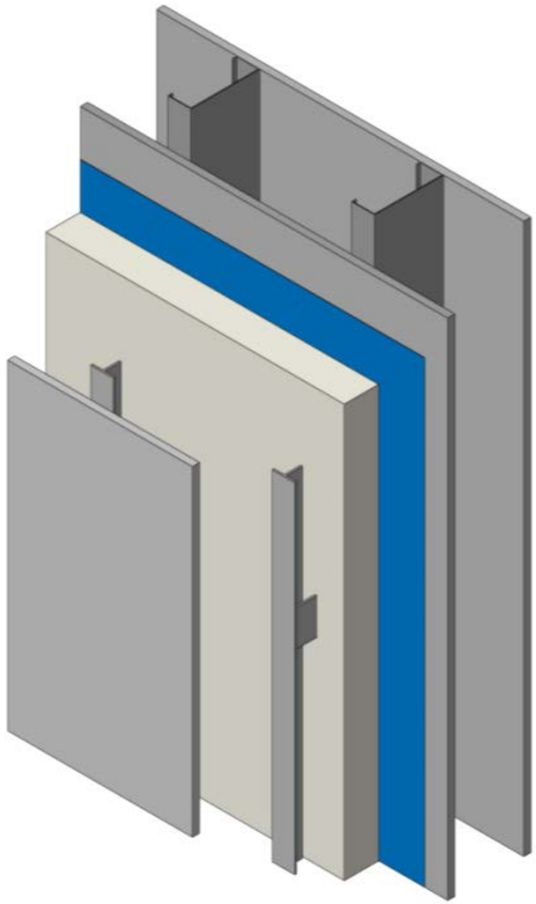
The Rainscreen Paradox



Heat

Minimize
Heat Transfer….

Moisture

Maximize
Moisture Transport

General Approach

Using Building Simulations to Assess Risks

Heat

Computational Fluid Dynamics: COMSOL
- Rainscreen Airflows in Whole Buildings
- Convective Heat Loss in Decoupled Walls

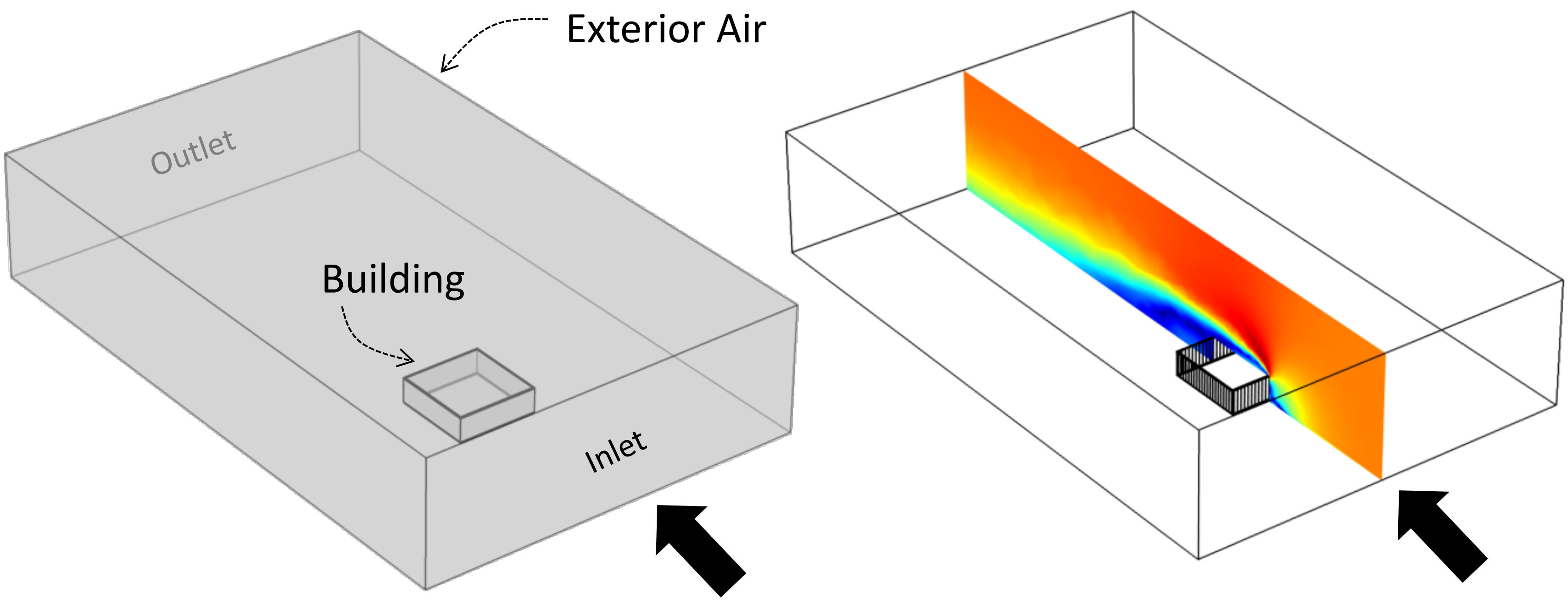
Moisture

H.A.M. Transfer: COMSOL + WUFI
- Steady-State CFD with 3D Models
- Steady-State & Transient 1D (WUFI)

***The Challenge*:**

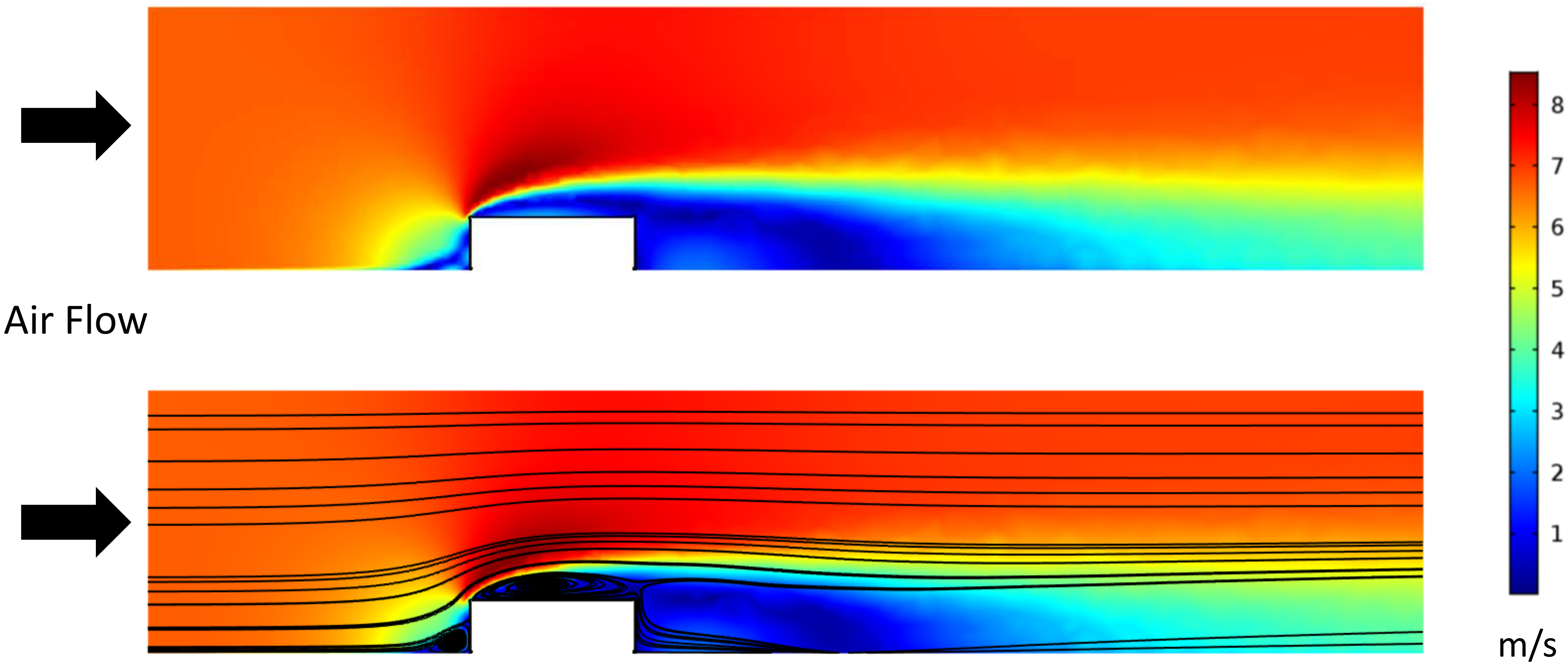
Simultaneously assess heat, air, and moisture transport thru porous media.

Airflow Around Buildings

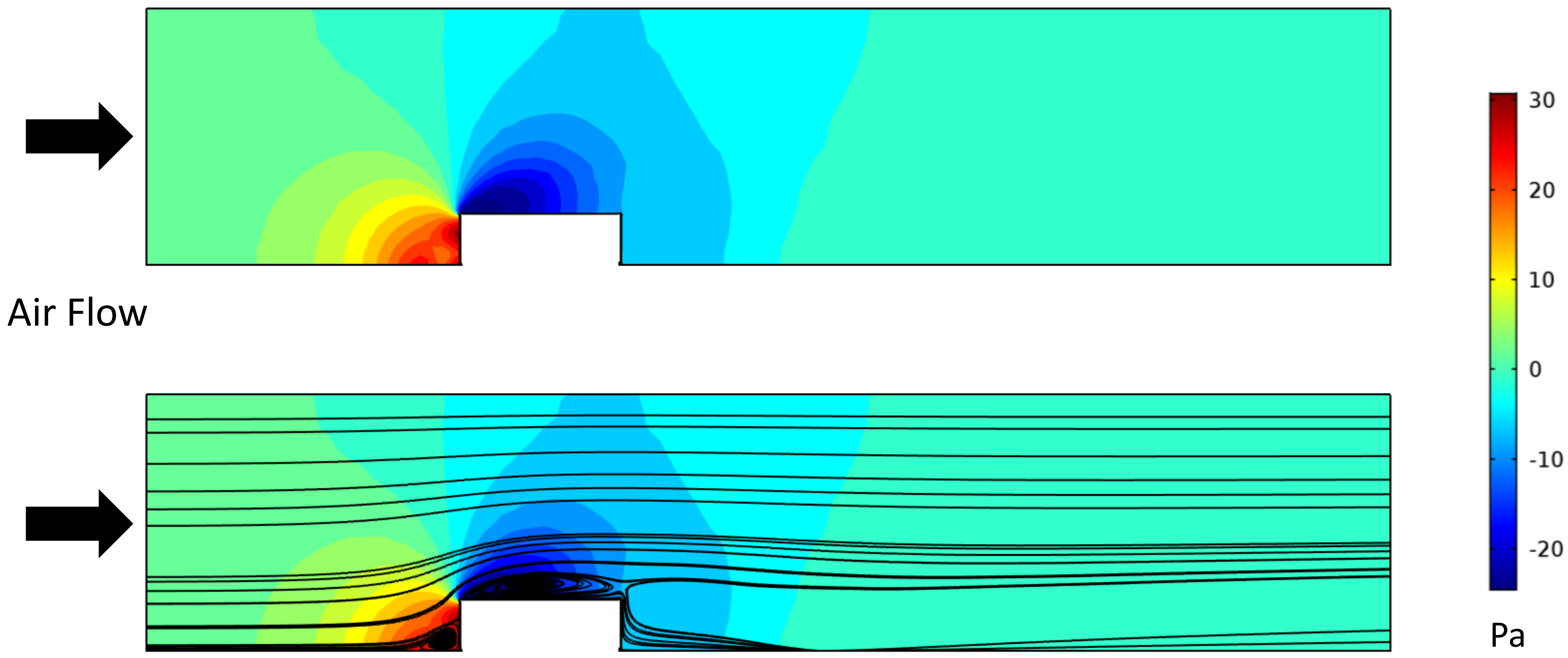


Inlet = 6.7 m/s (15 mph)
Winter Design Conditions ASHRAE Handbook

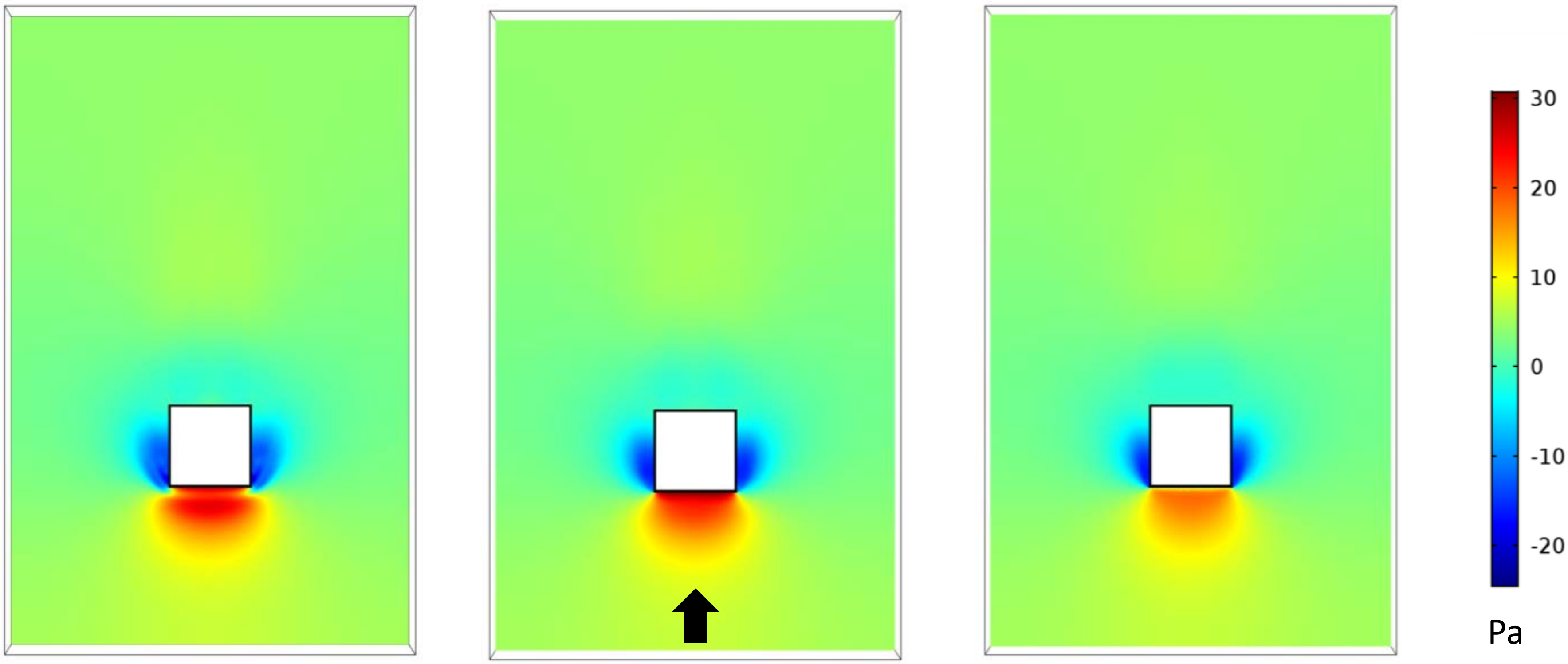
Airflow Around Buildings



Airflow Around Buildings



Airflow Around Buildings

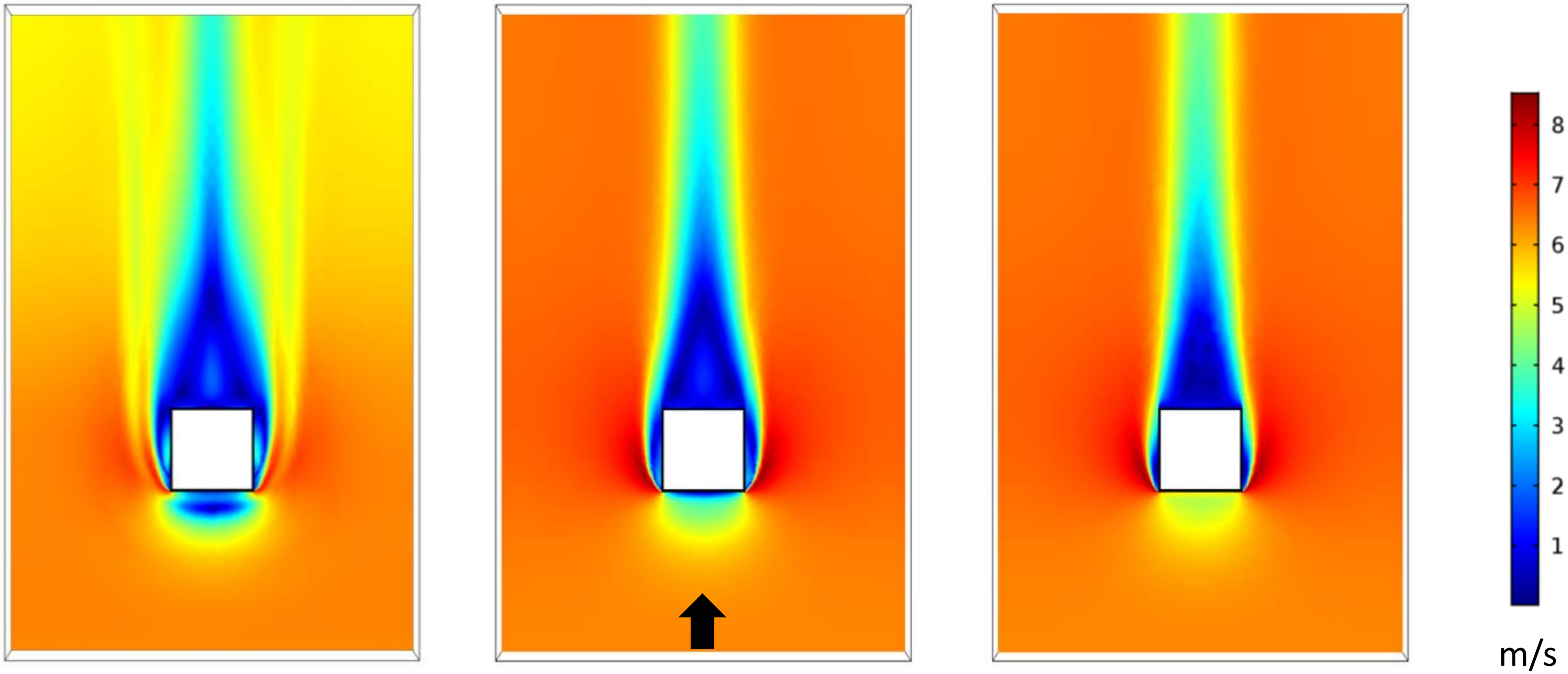


At Grade

Mid-Height

At Roof Coping

Airflow Around Buildings



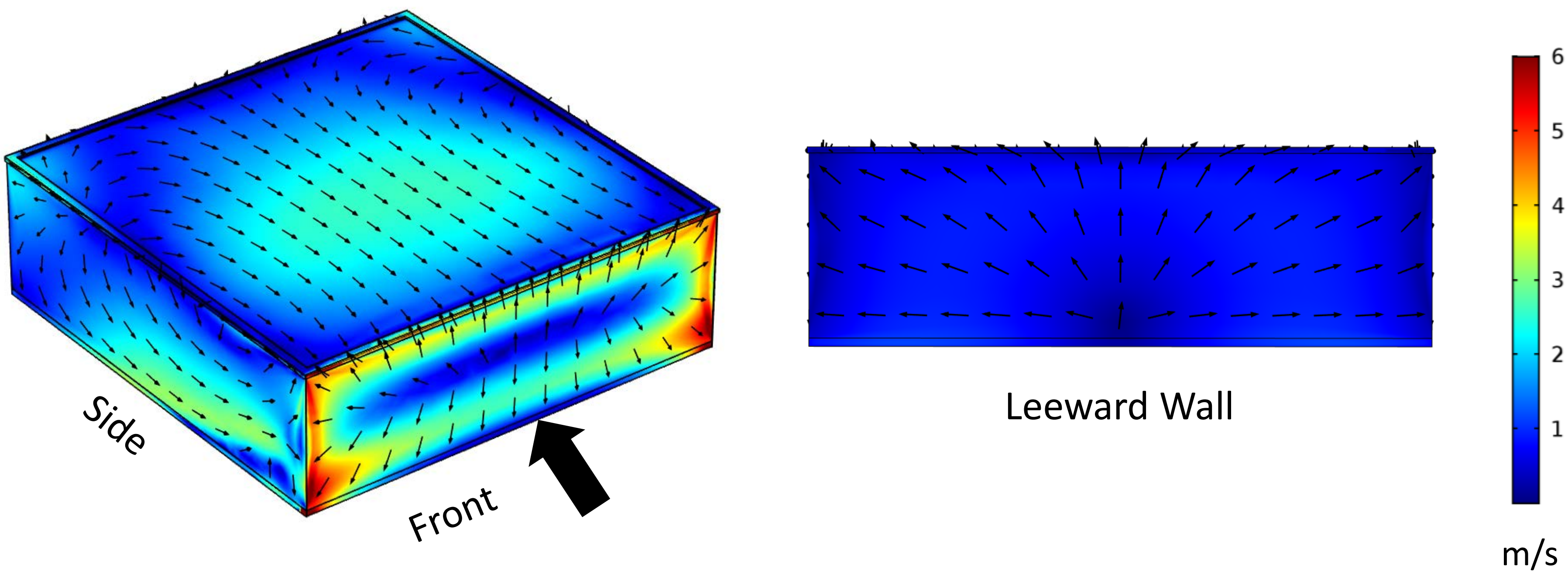
At Grade

Mid-Height

At Roof Coping

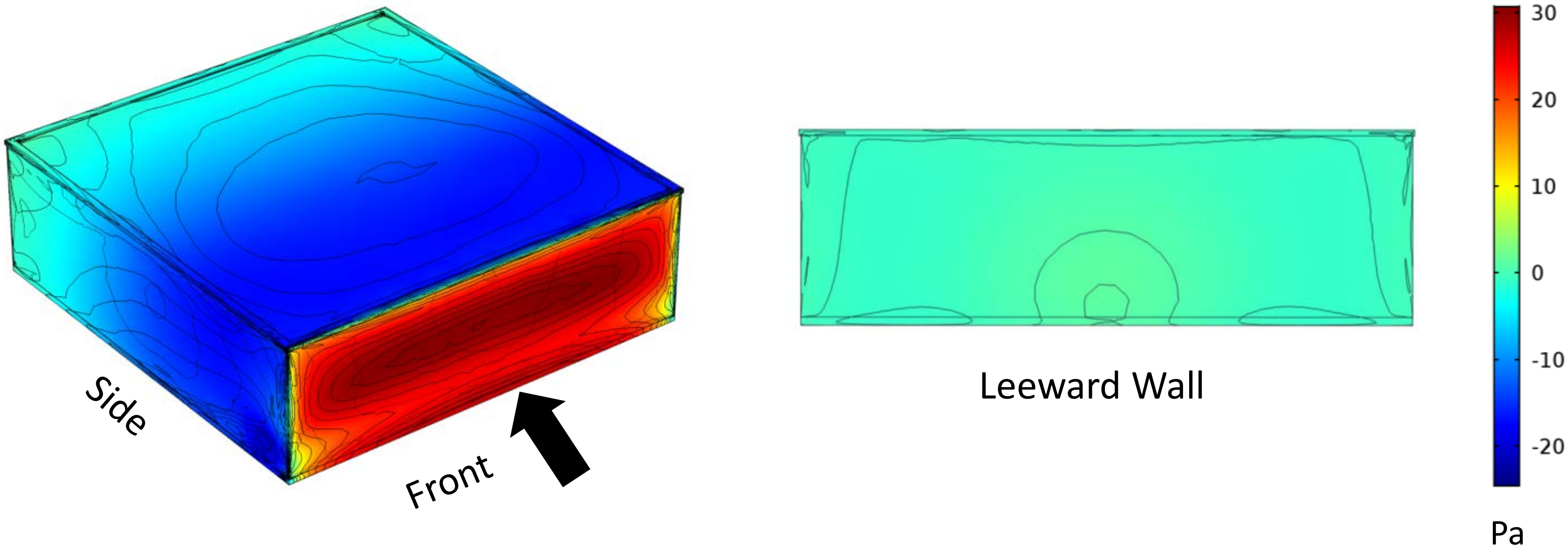
Exterior Building Surfaces

Velocity Magnitudes & Flow Patterns

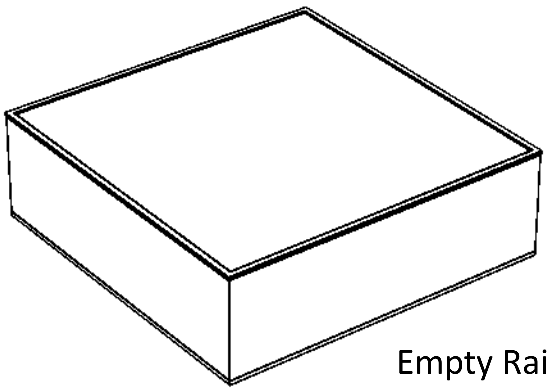


Exterior Building Surfaces

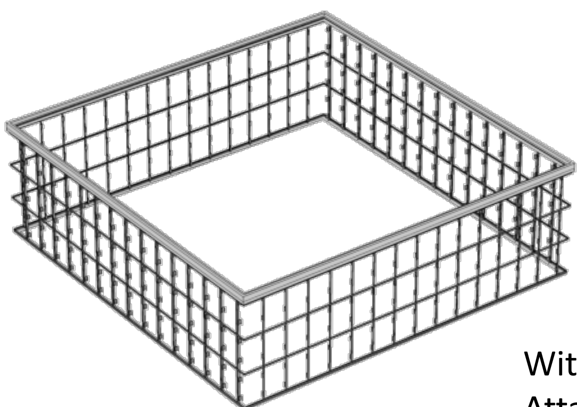
Surface Pressures



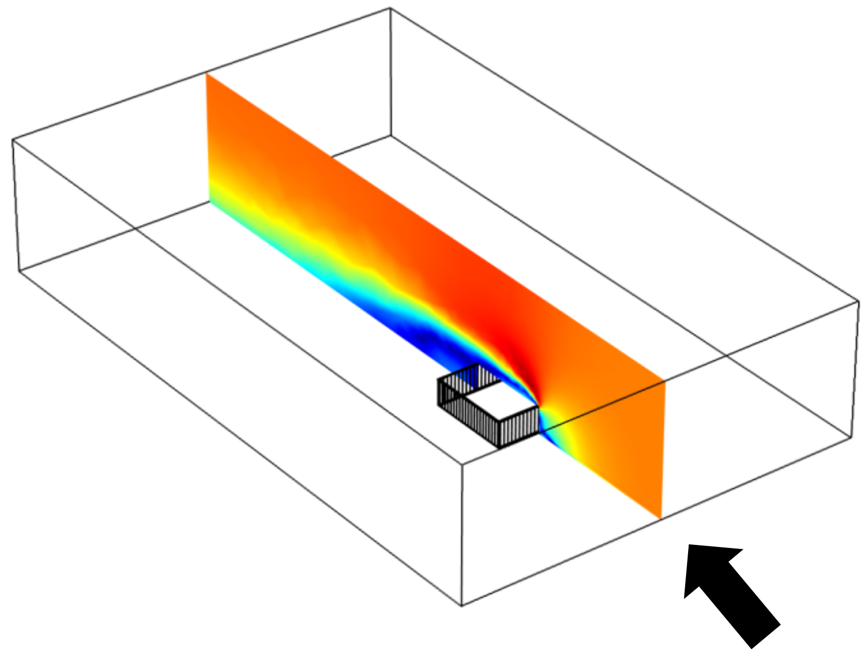
Rainscreen Airflows



Empty Rainscreen Space

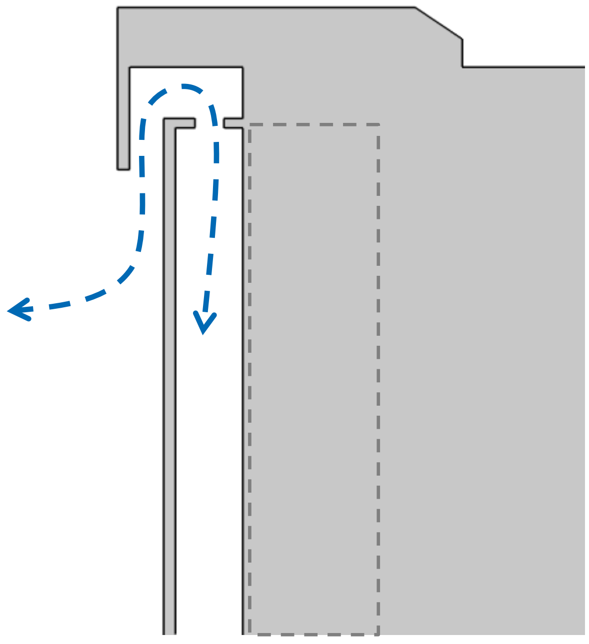


With Cladding
Attachment System

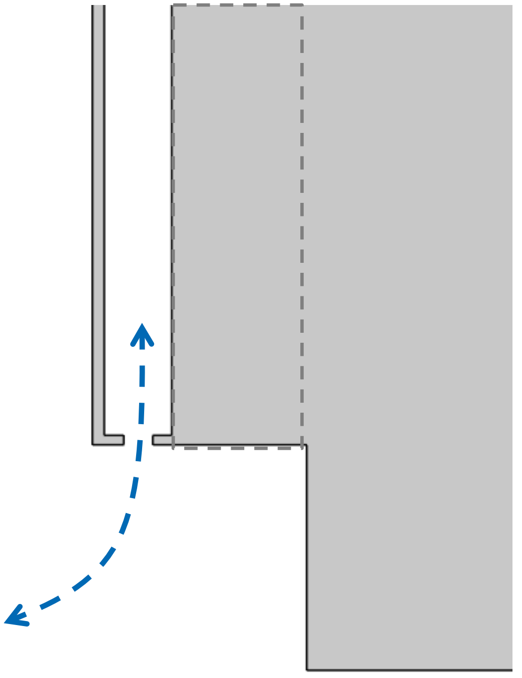


Inlet = 6.7 m/s (15 mph)
Winter Design Conditions ASHRAE Handbook

Ventilation Inlets



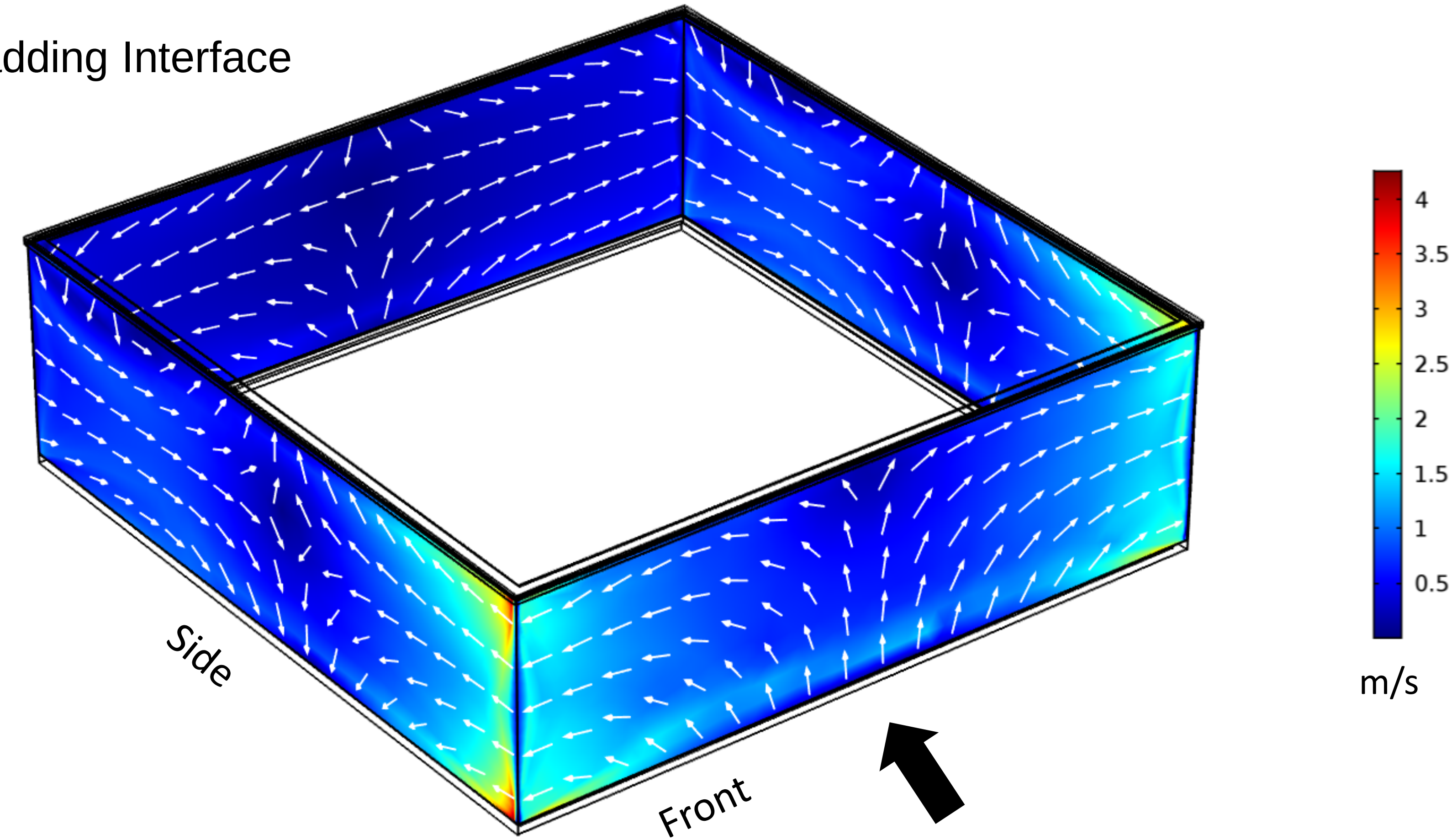
Top of Wall



Base of Wall

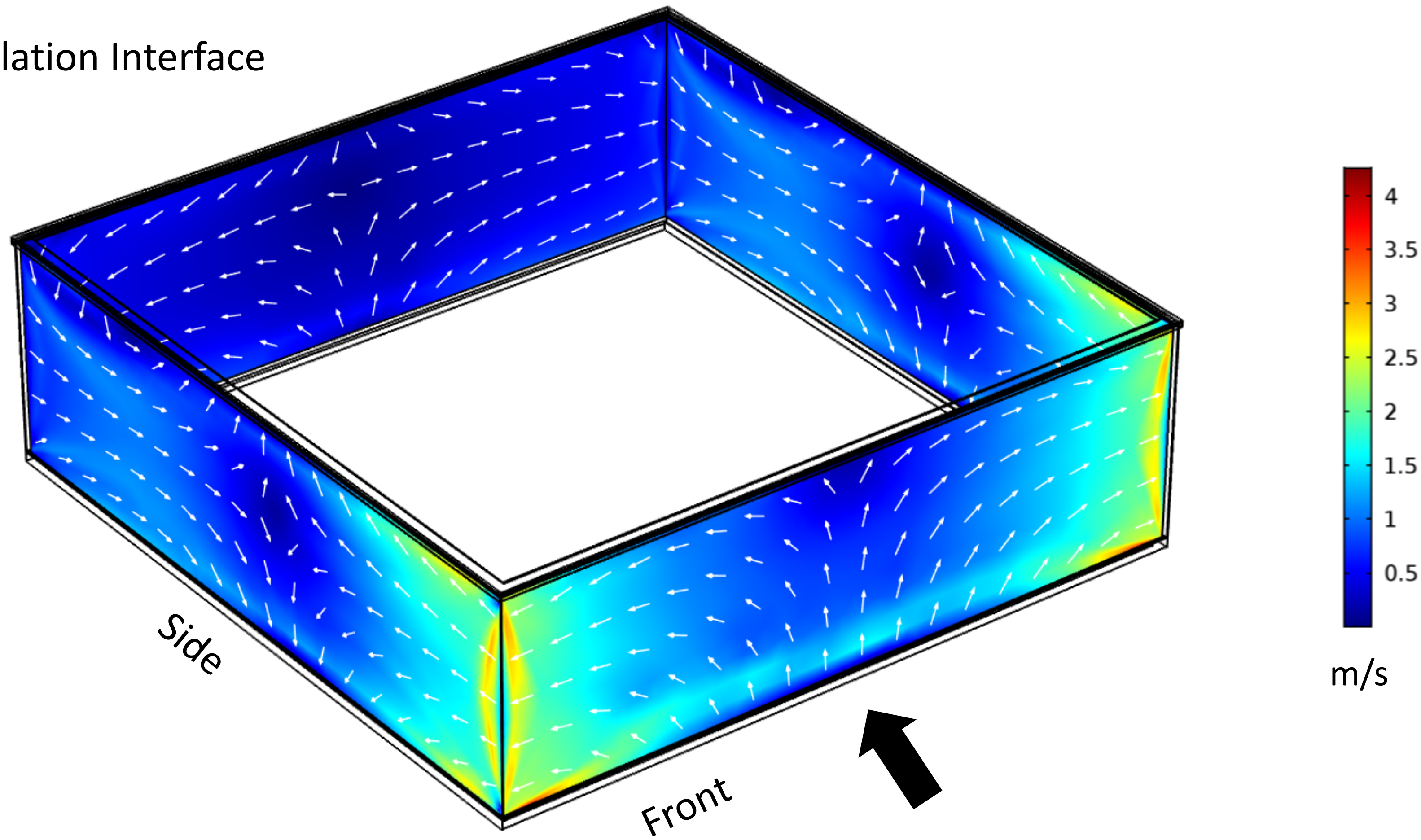
Rainscreen Airflows

At Cladding Interface



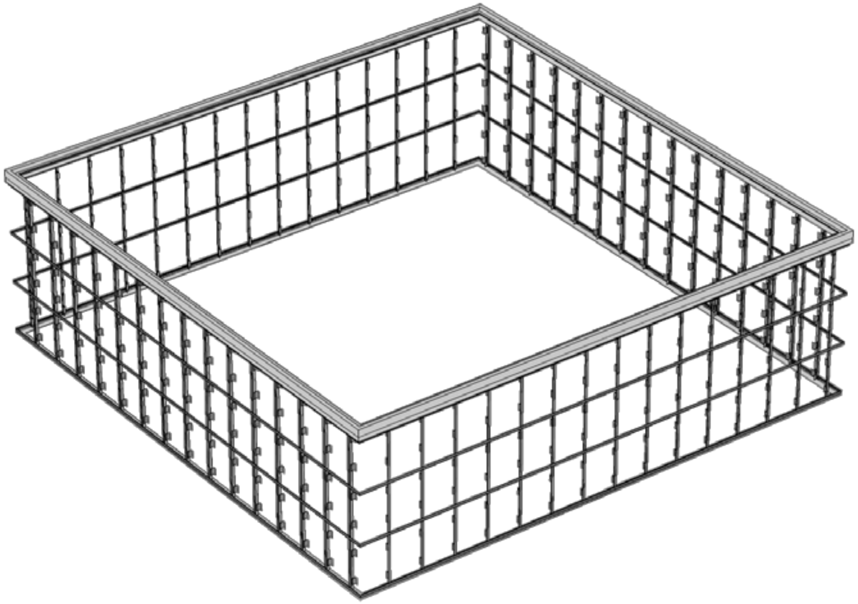
Rainscreen Airflows

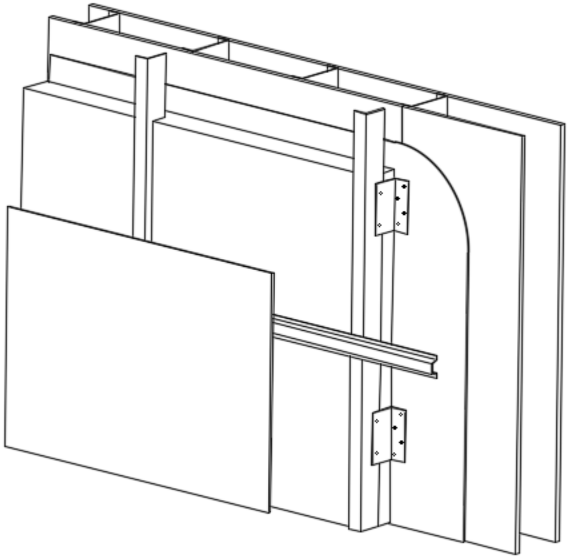
At Insulation Interface



Cladding Attachment System

Complex Model Geometries





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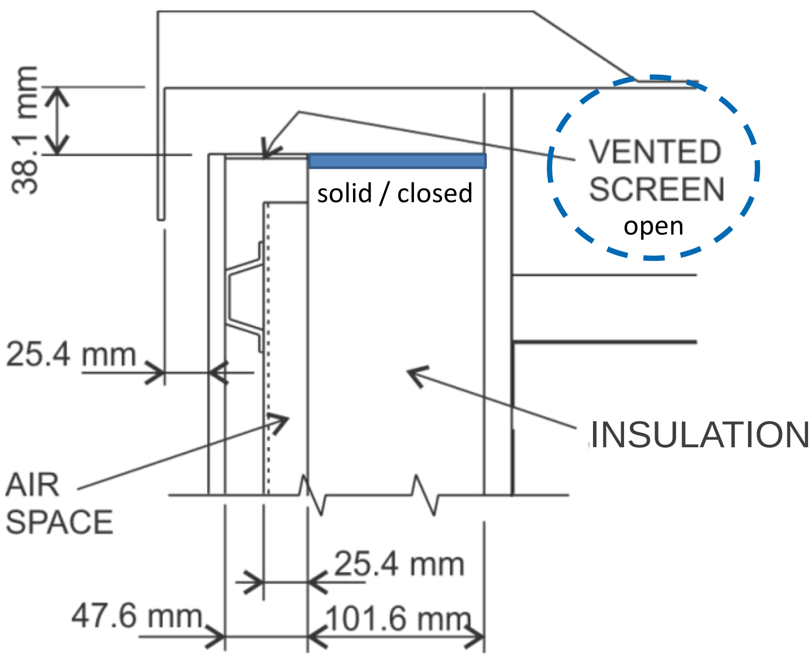
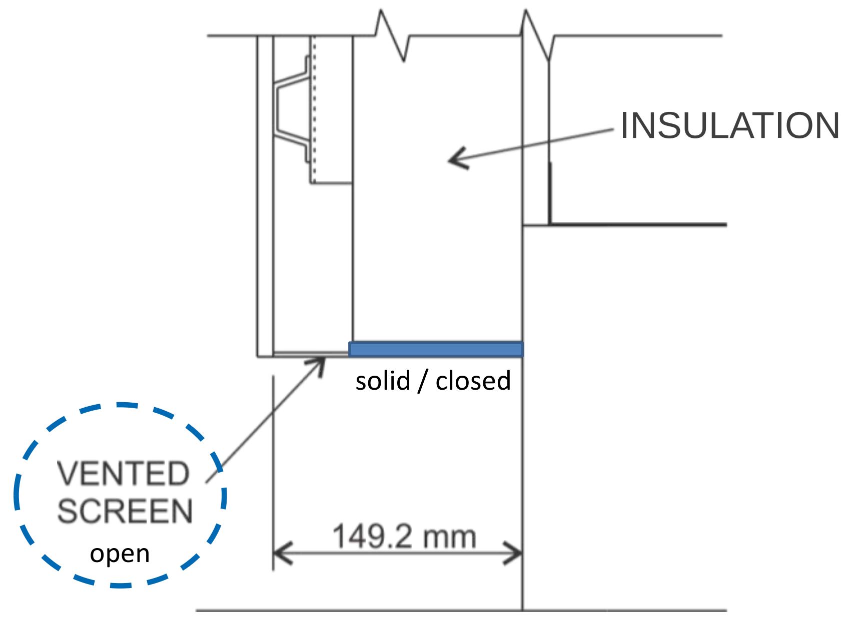
Ventilation Inlets



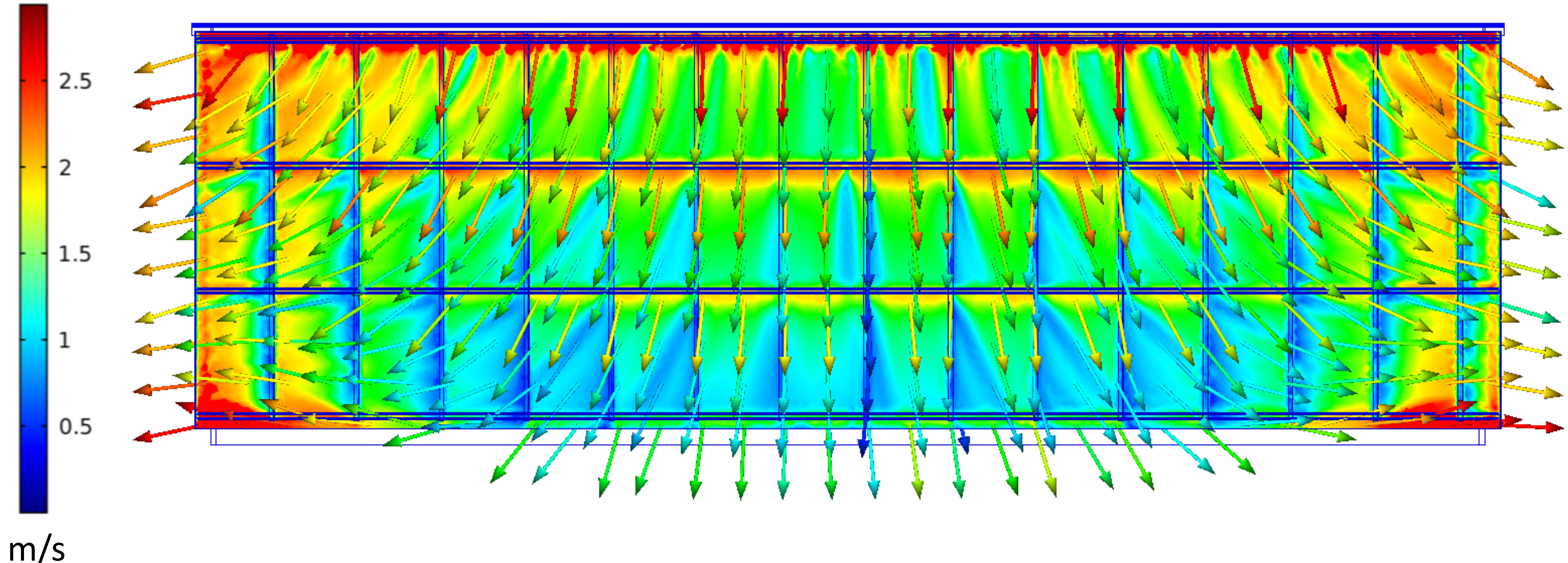
Top of Wall



Base of Wall

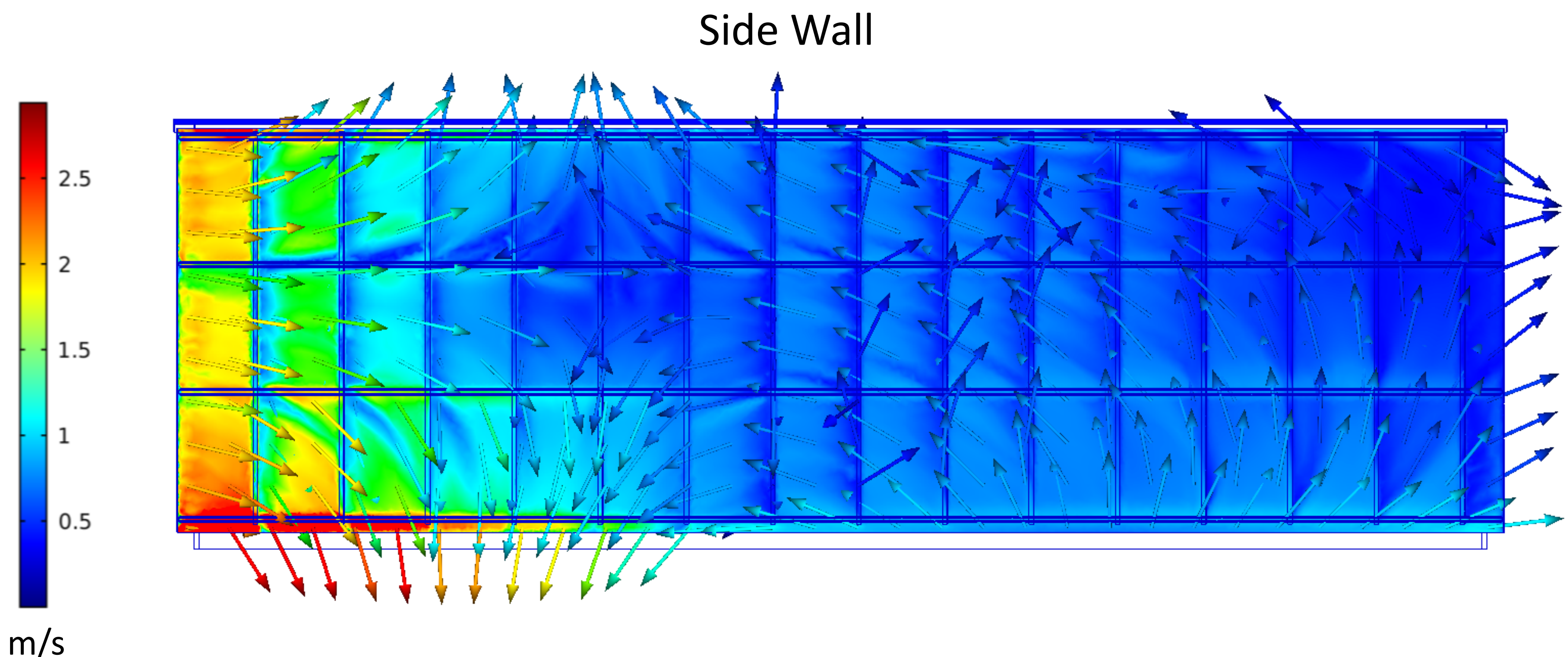
Rainscreen Airflows

Windward Wall



Rainscreen Velocities: 0.1 to >3 m/s

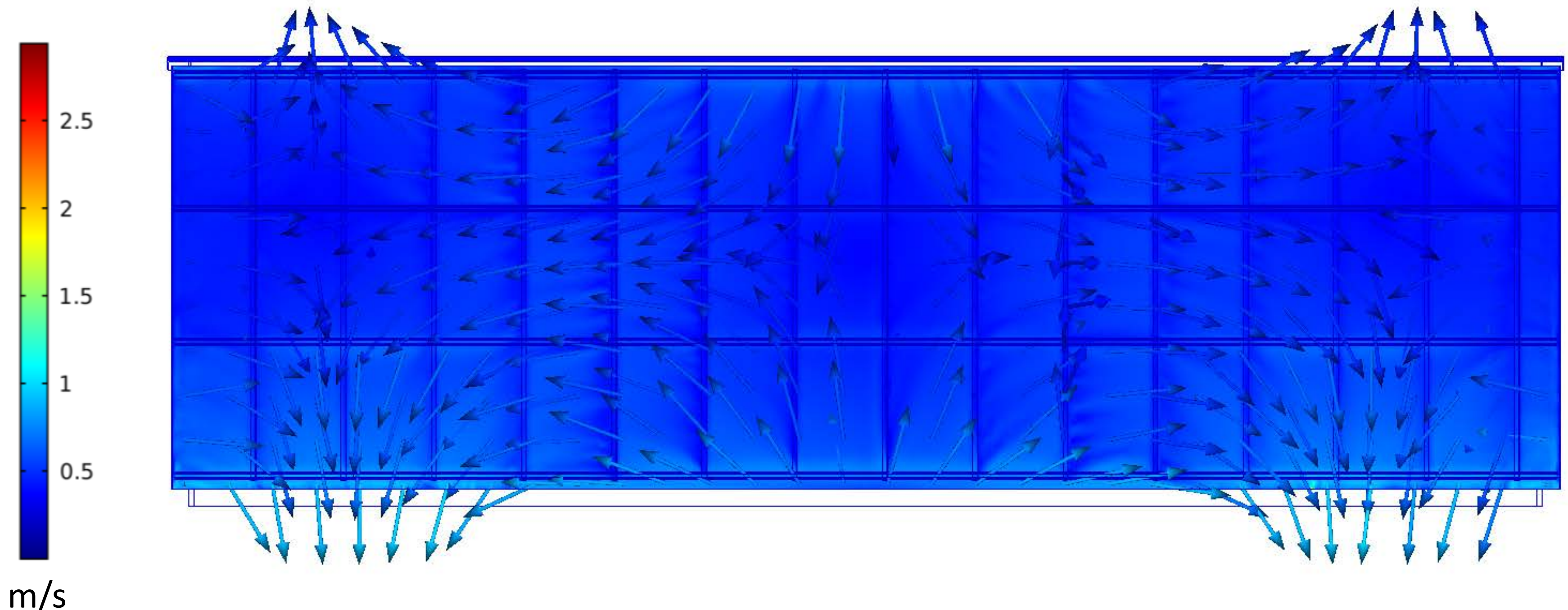
Rainscreen Airflows



Rainscreen Velocities: 0.1 to >3 m/s

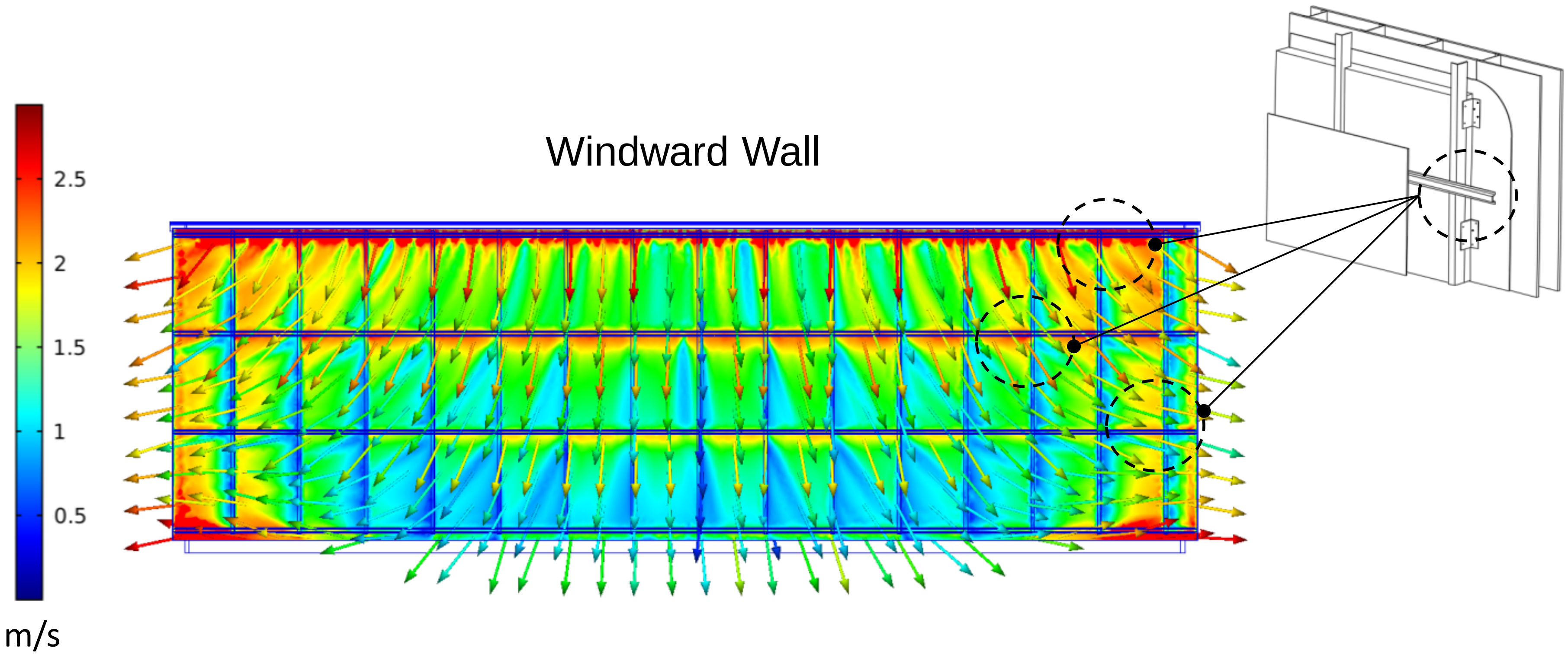
Rainscreen Airflows

Leeward Wall

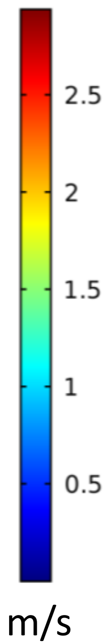


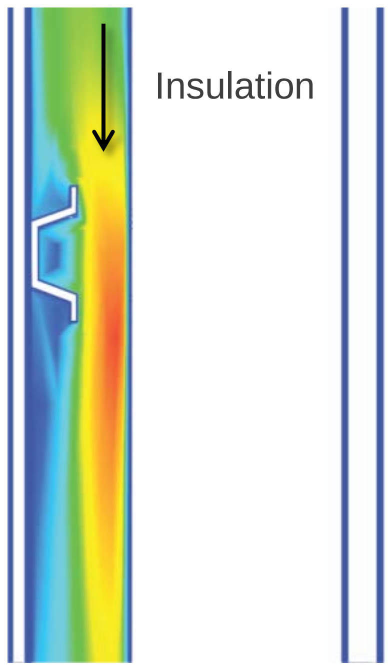
Rainscreen Velocities: 0.1 to >0.8 m/s

Rainscreen Airflows

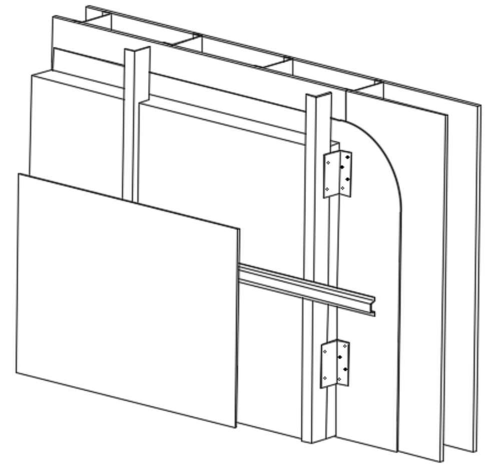


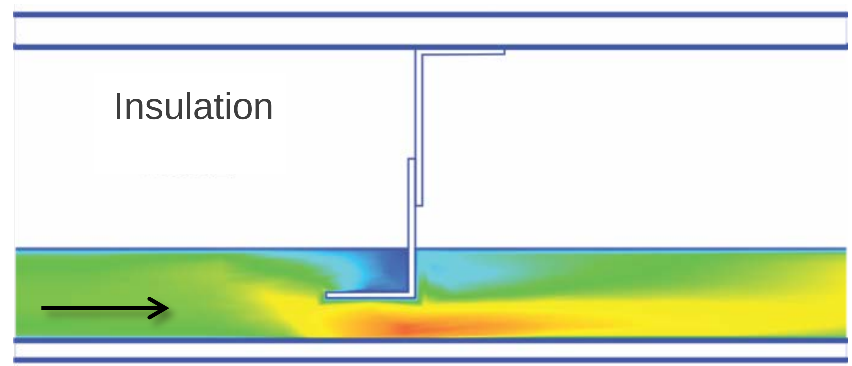
Rainscreen Airflows





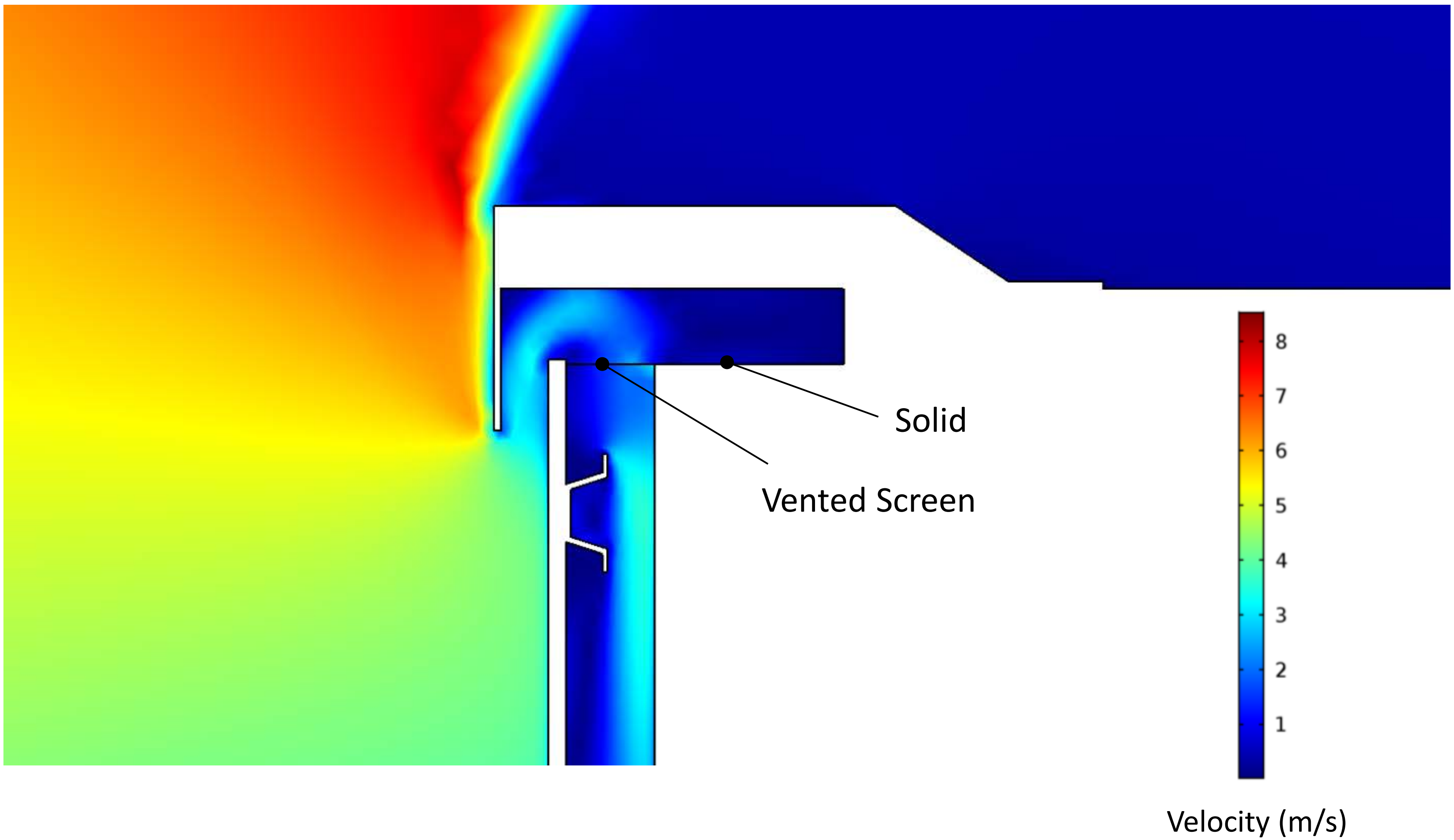
Section View



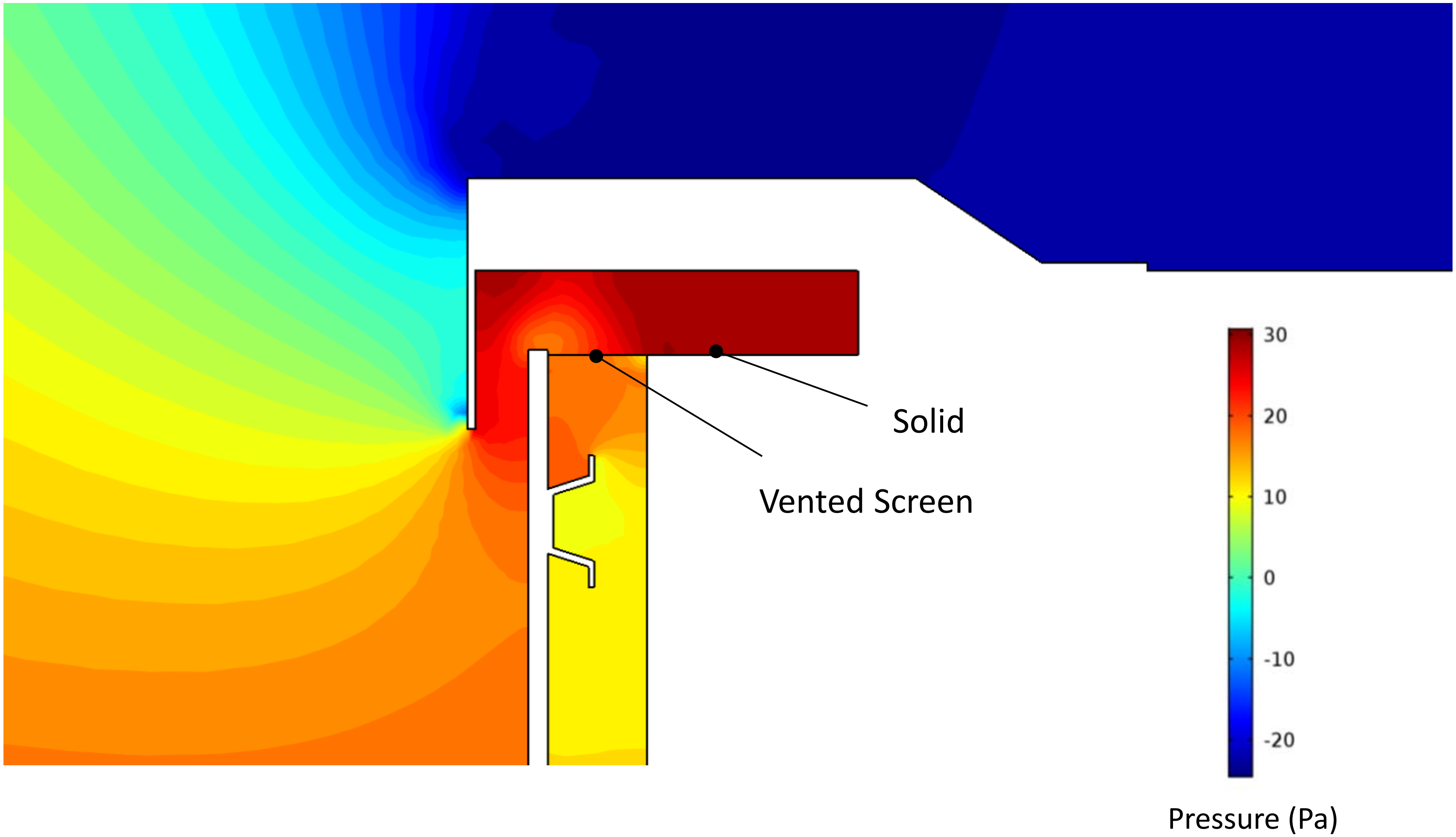


Plan View

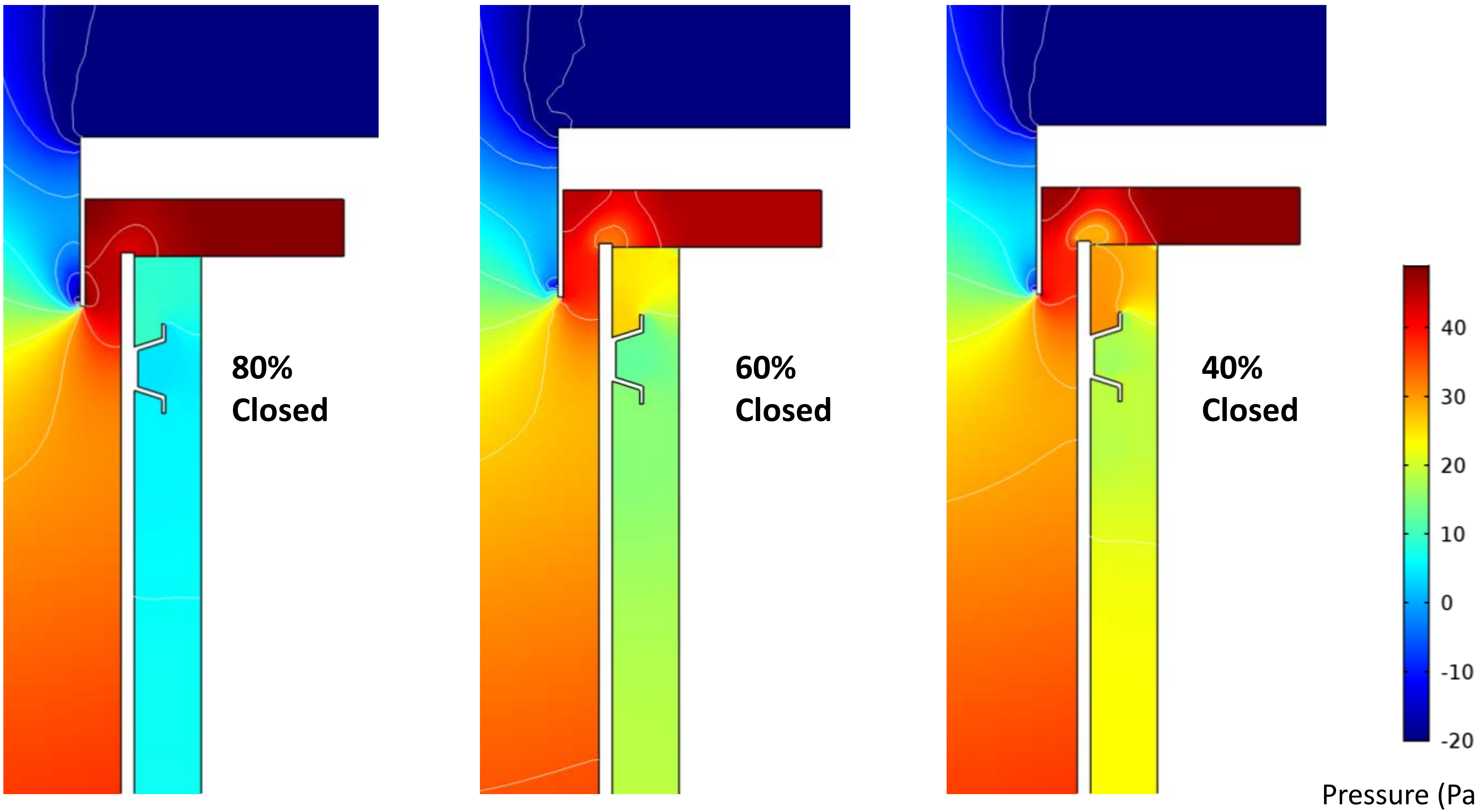
Ventilation Inlets: Velocity



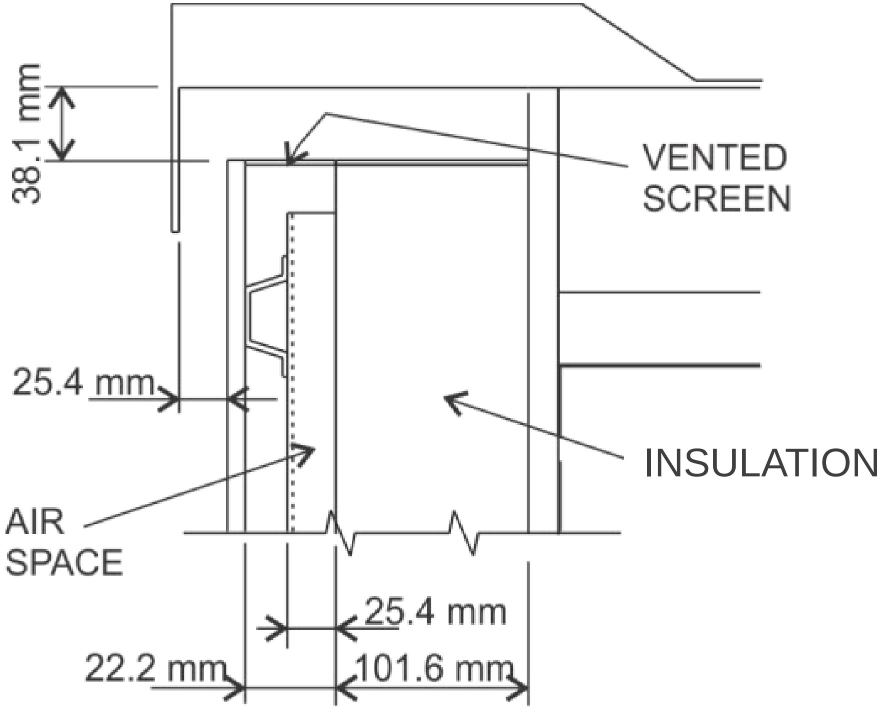
Ventilation Inlets: Pressure

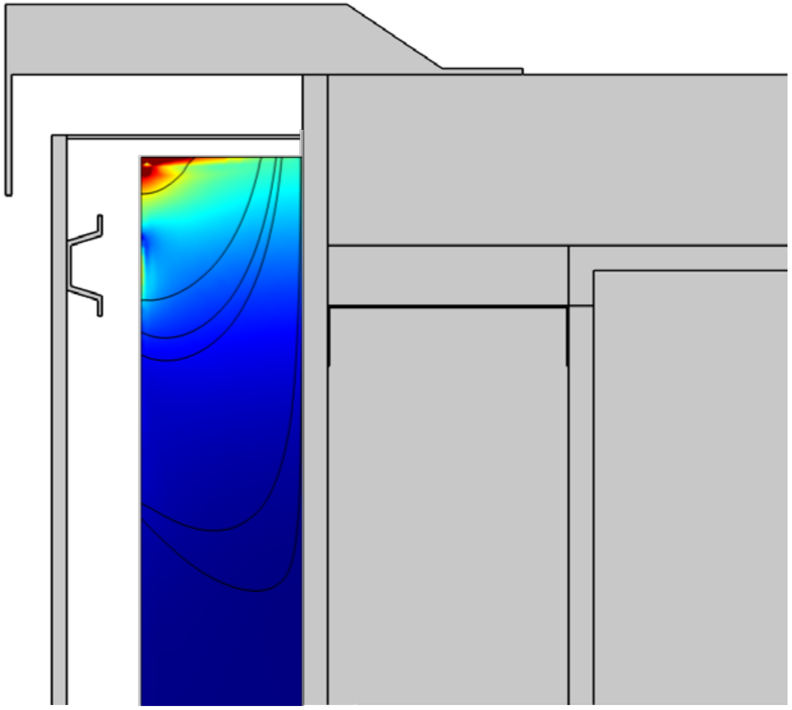


Ventilation Inlets



Rainscreen Airflows





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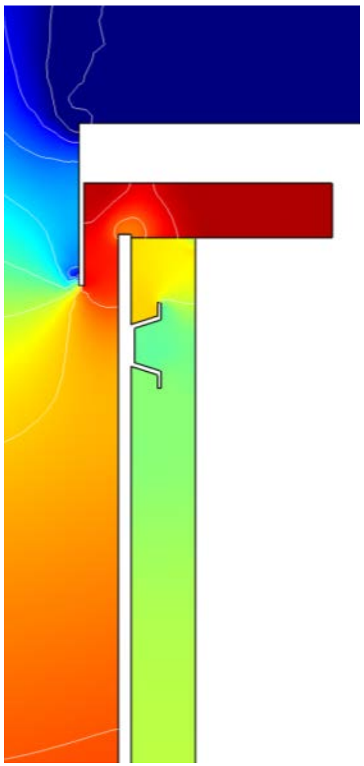
Rainscreen Airflows



01 Airflow velocities are 2x – 5x greater than expected.

02 Governing Factors:

- Rainscreen Geometry
- Inlet Configuration
- Wind Speed
- Rainscreen Cavity Depth

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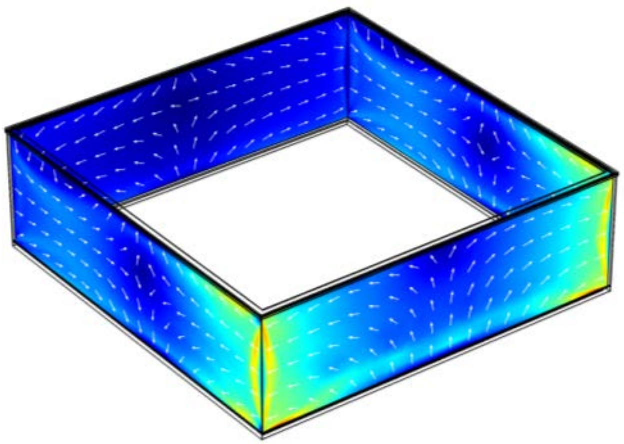
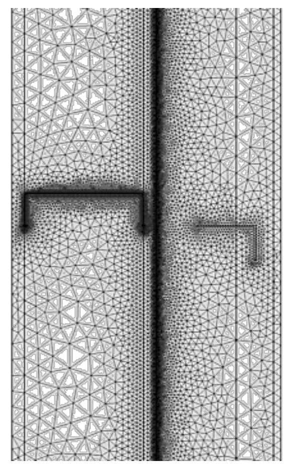
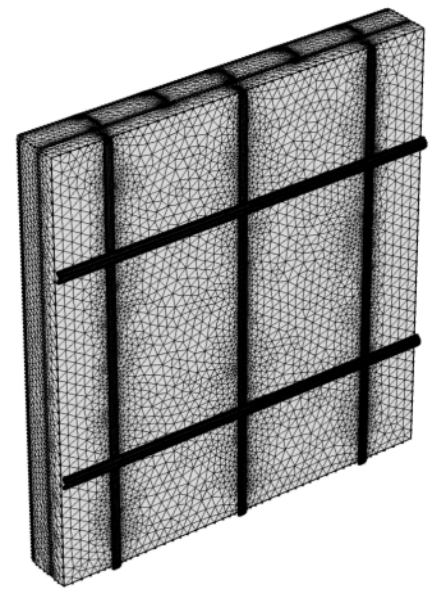
Convective Heat Loss



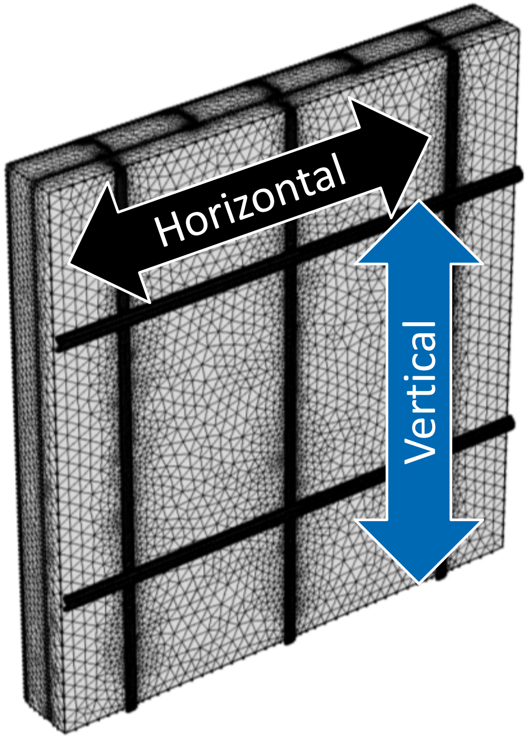


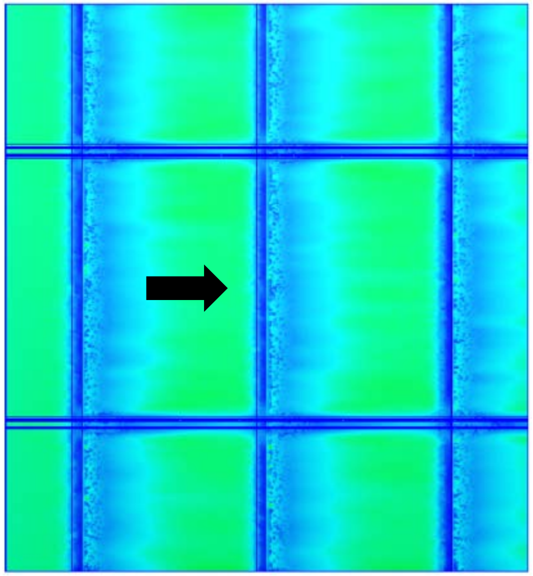
Meshing



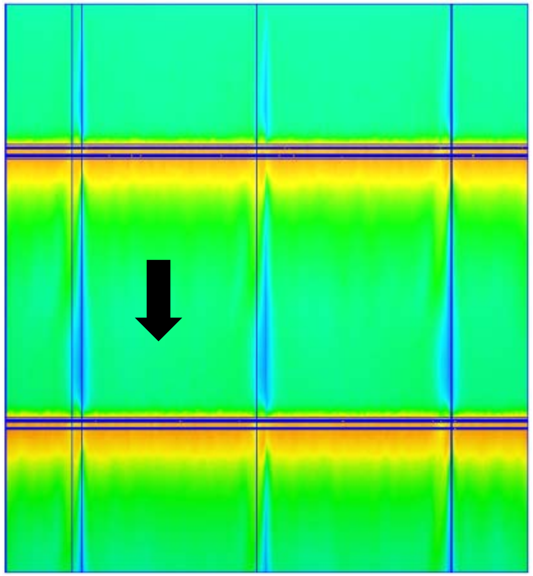
Decoupled
8’ x 8’
Panel

Convective Heat Loss





Horizontal Flows



Vertical Flows

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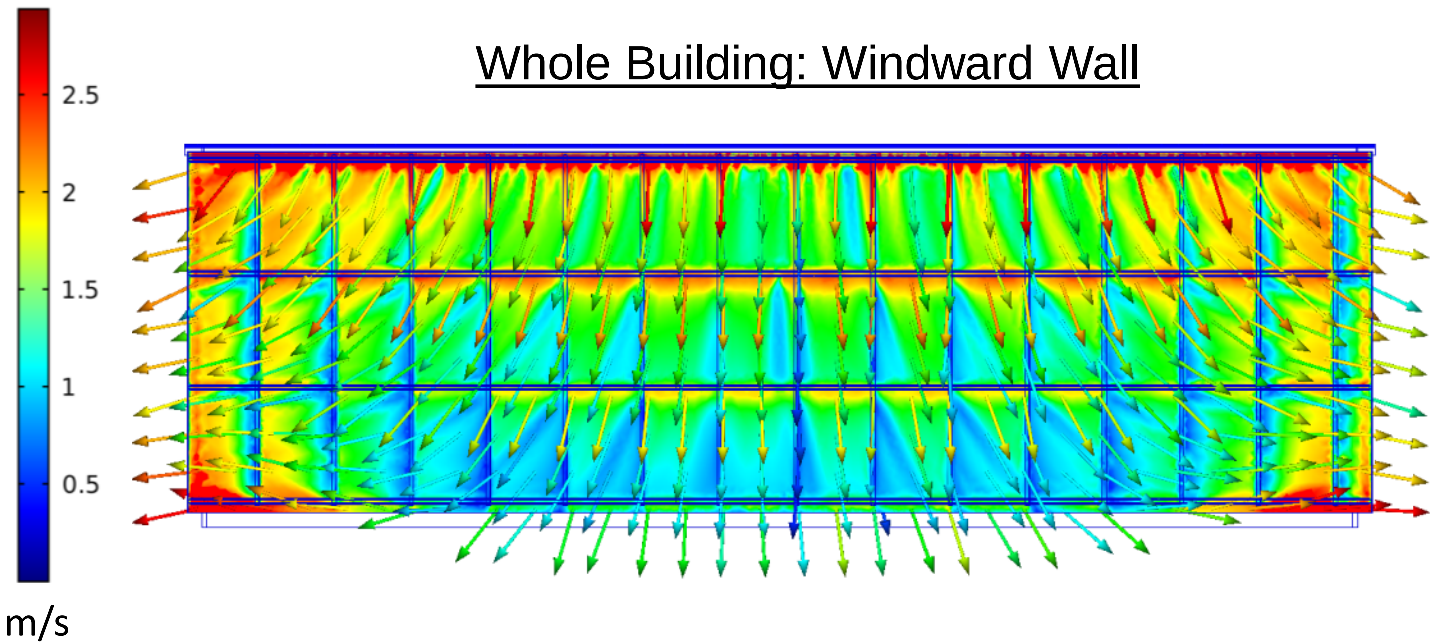
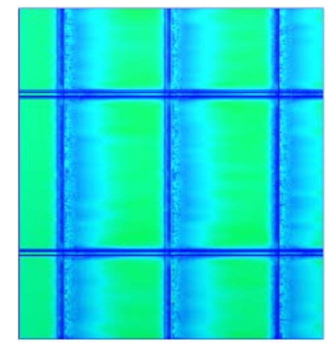
Rainscreen Airflows

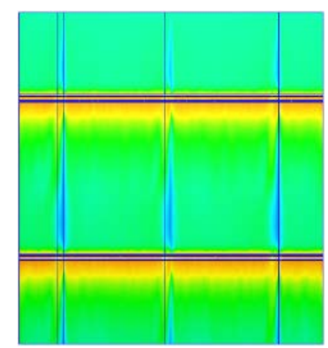
Whole Building: Windward Wall



Decoupled

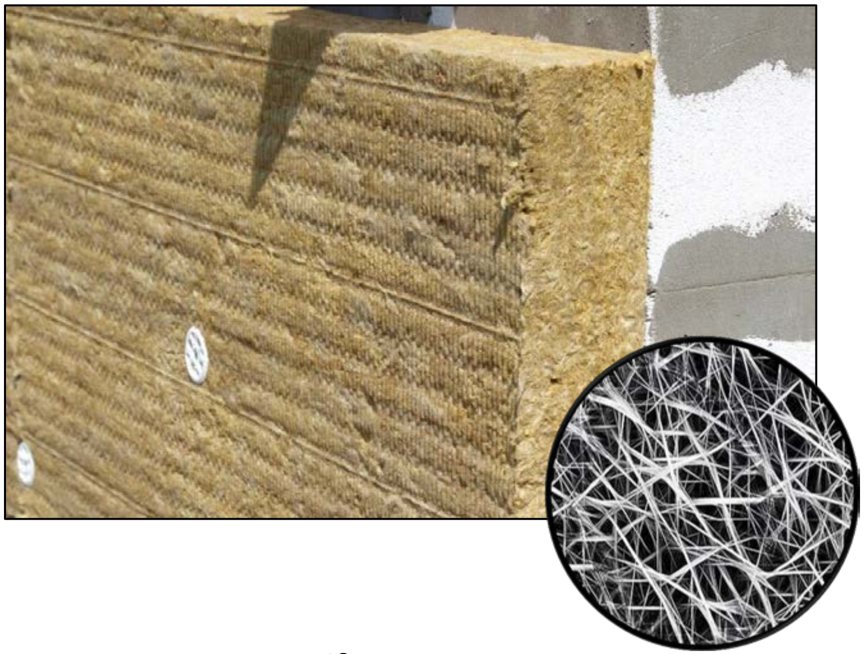


Horizontal Flows
1 m/s

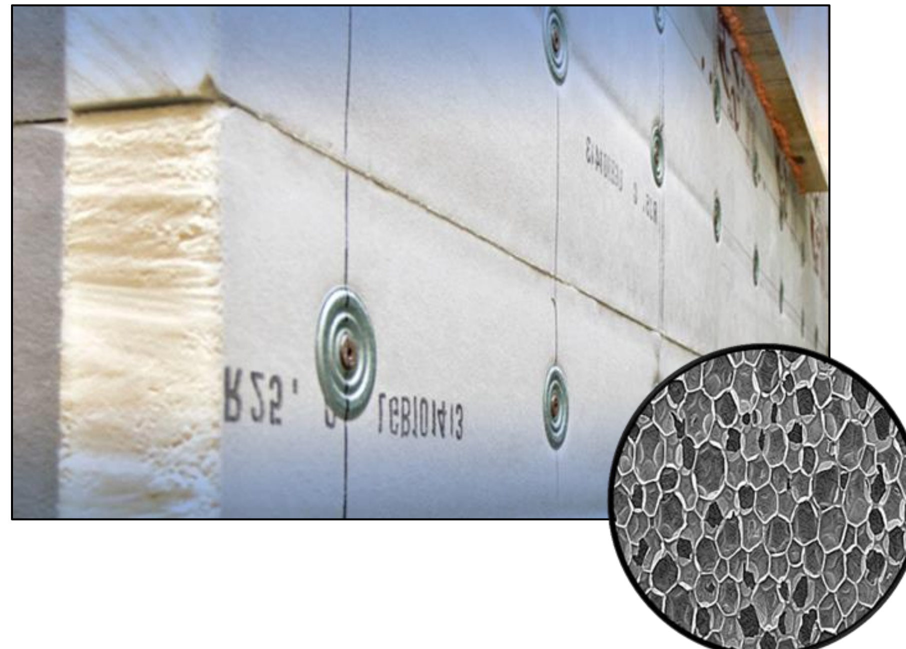


Vertical Flows
1 m/s

Convective Heat Loss

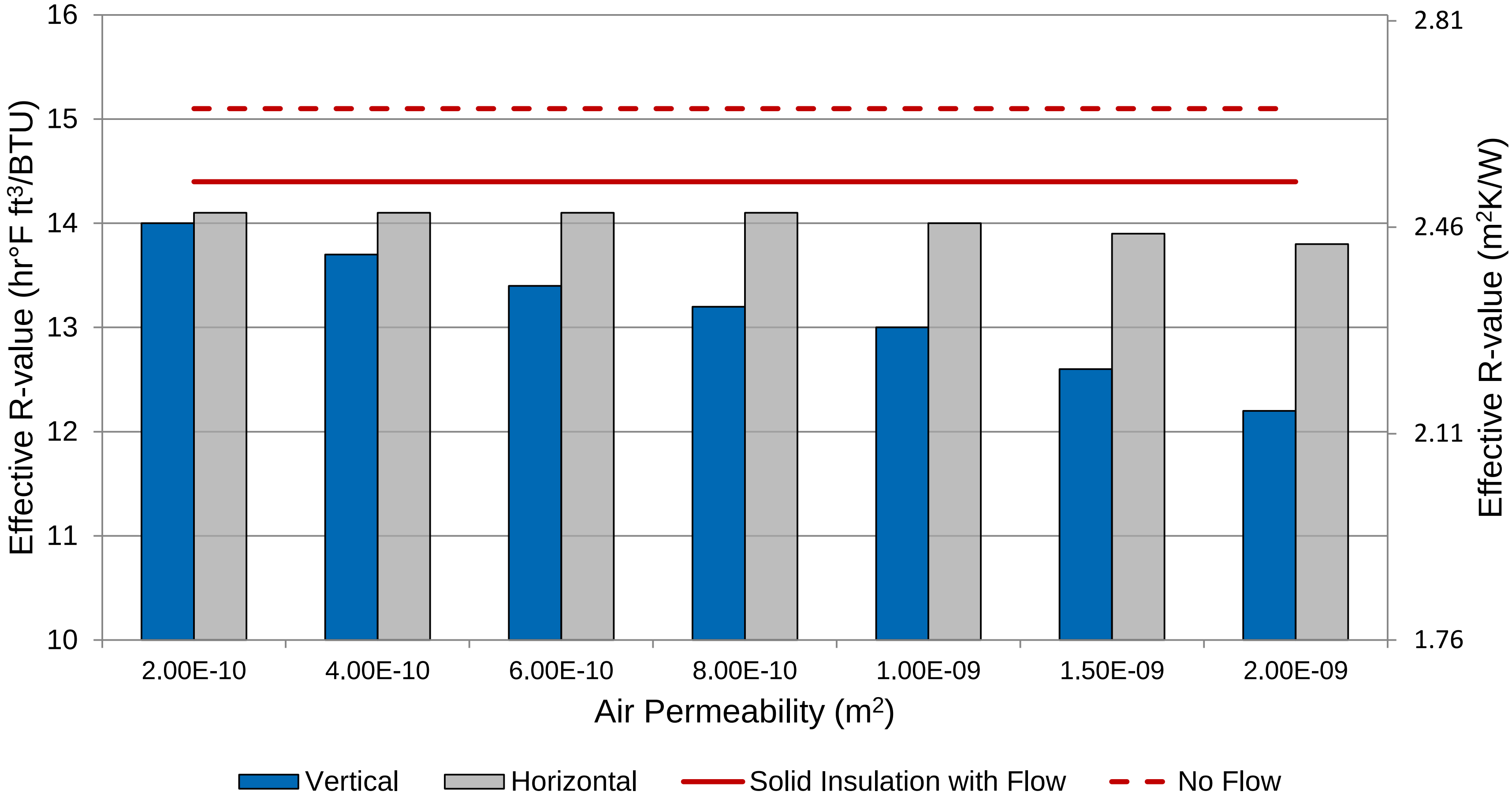


Open Pore Fibrous
Permeable
Permeability is density-dependent



Closed Pore Cellular Foams
Impermeable at encountered pressures

Effective R-Values: 1 m/s



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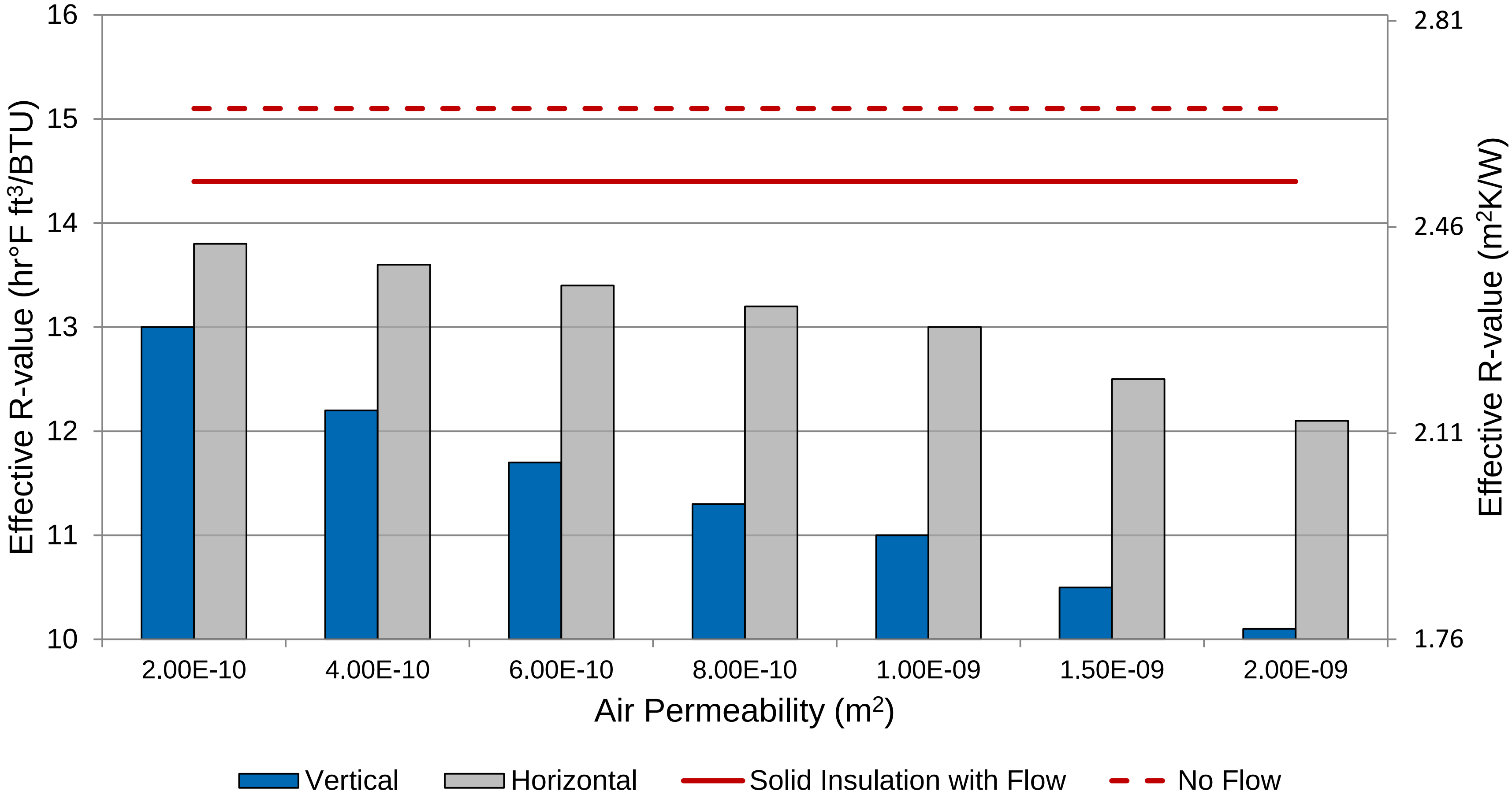
Effective R-Values: 2 m/s



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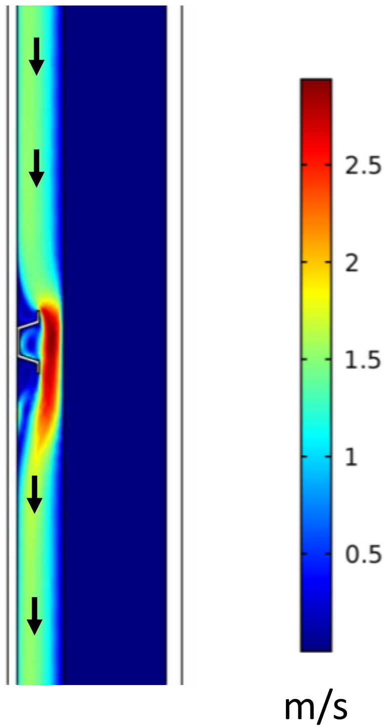
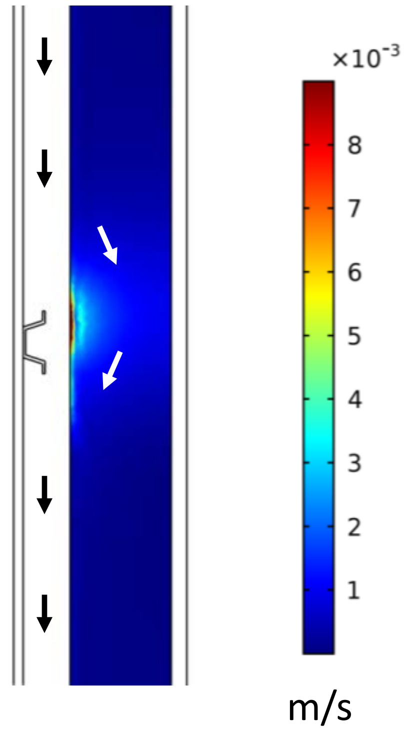
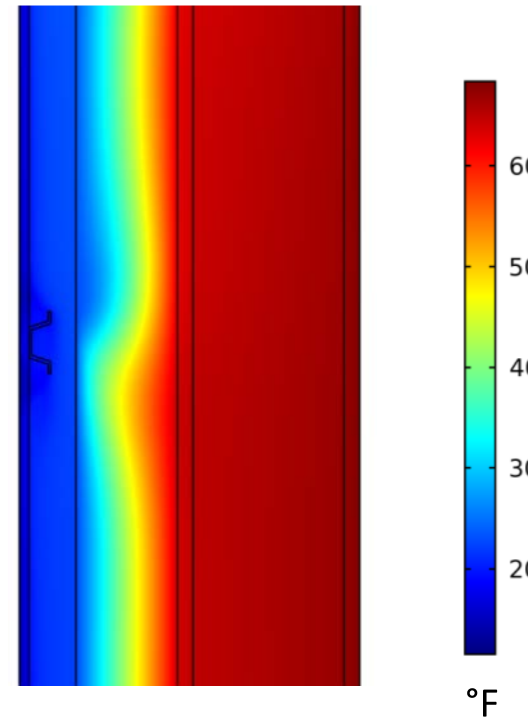
Inlet Velocity: 1 m/s

Velocity

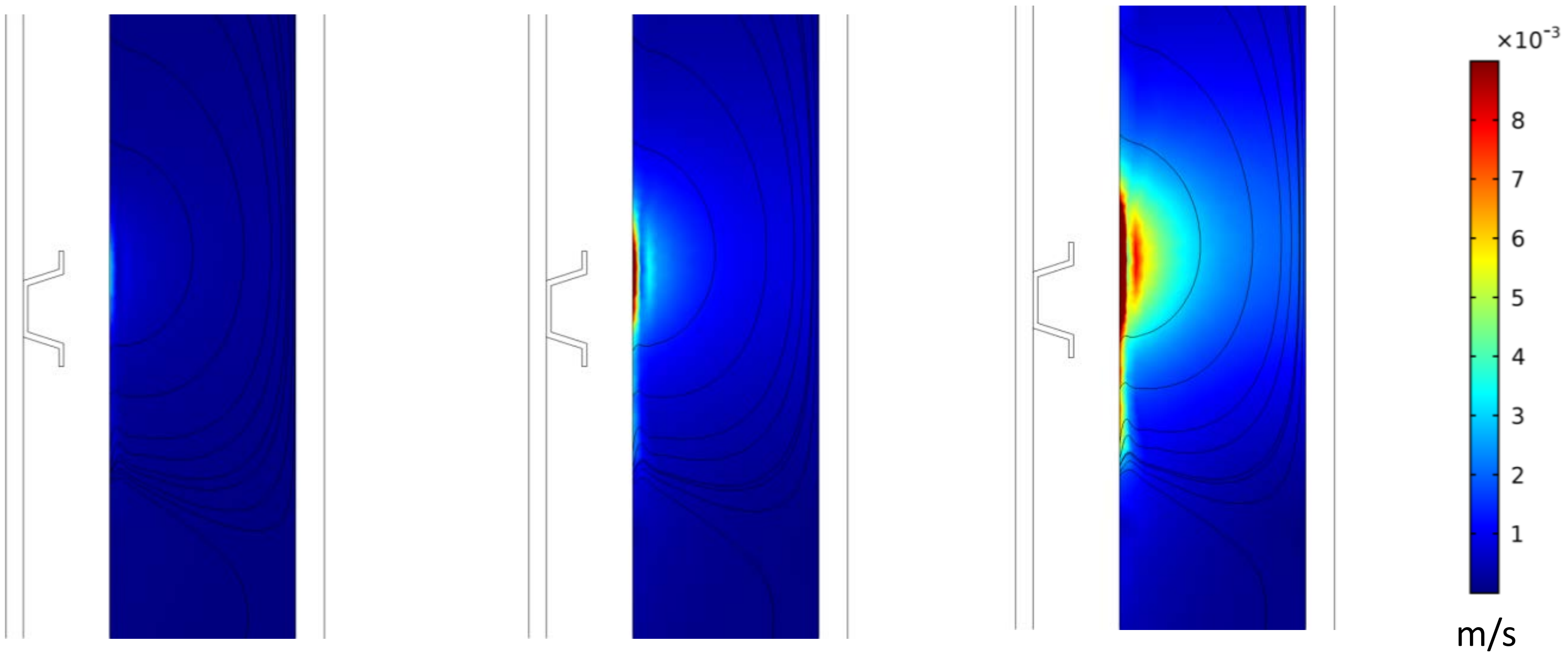




Temperature



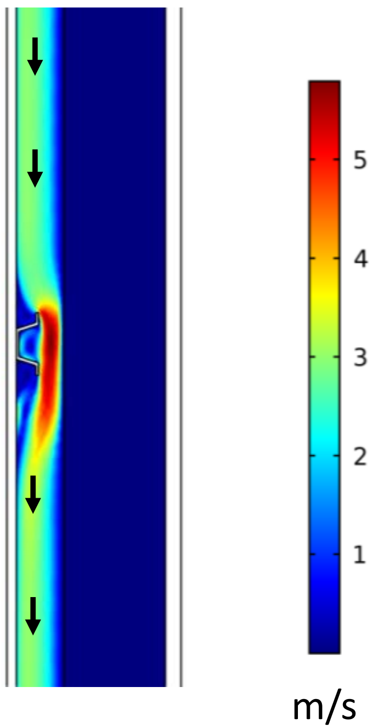
Inlet Velocity: 1 m/s

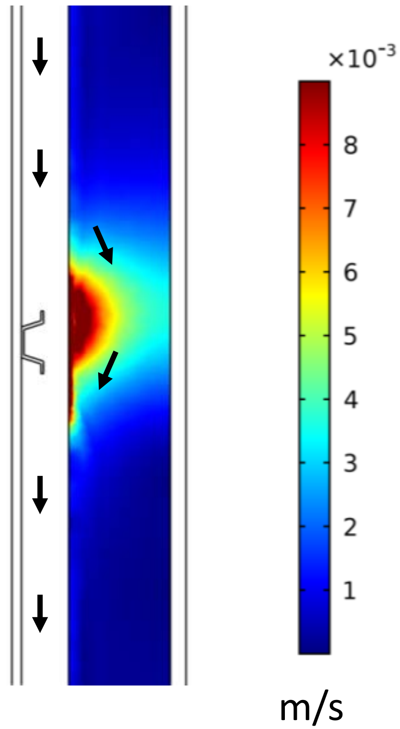


$2x10^{-10}$ m^2	**$8x10^{-10}$ m^2**	**$2x10^{-9}$ m^2**
Density ~160 kg/m^3	**Density ~70 kg/m^3**	**Density ~30 kg/m^3**
Density ~10 lb/ft^3	**Density ~4.4 lb/ft^3**	**Density ~1.9 lb/ft^3**

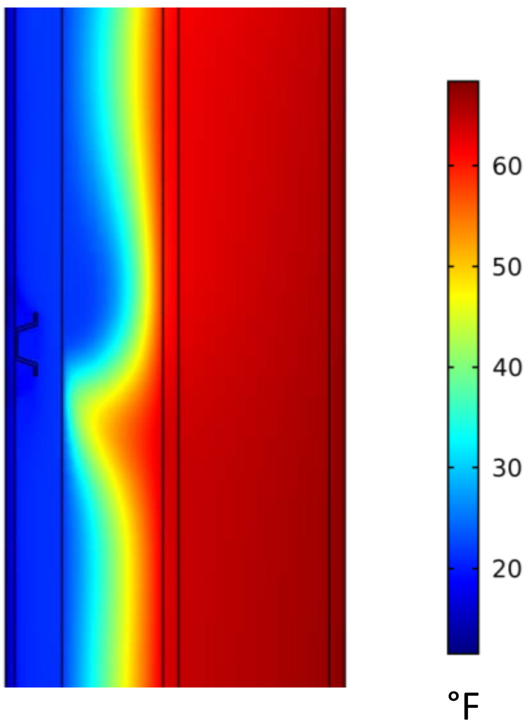
Inlet Velocity: 2 m/s

Velocity

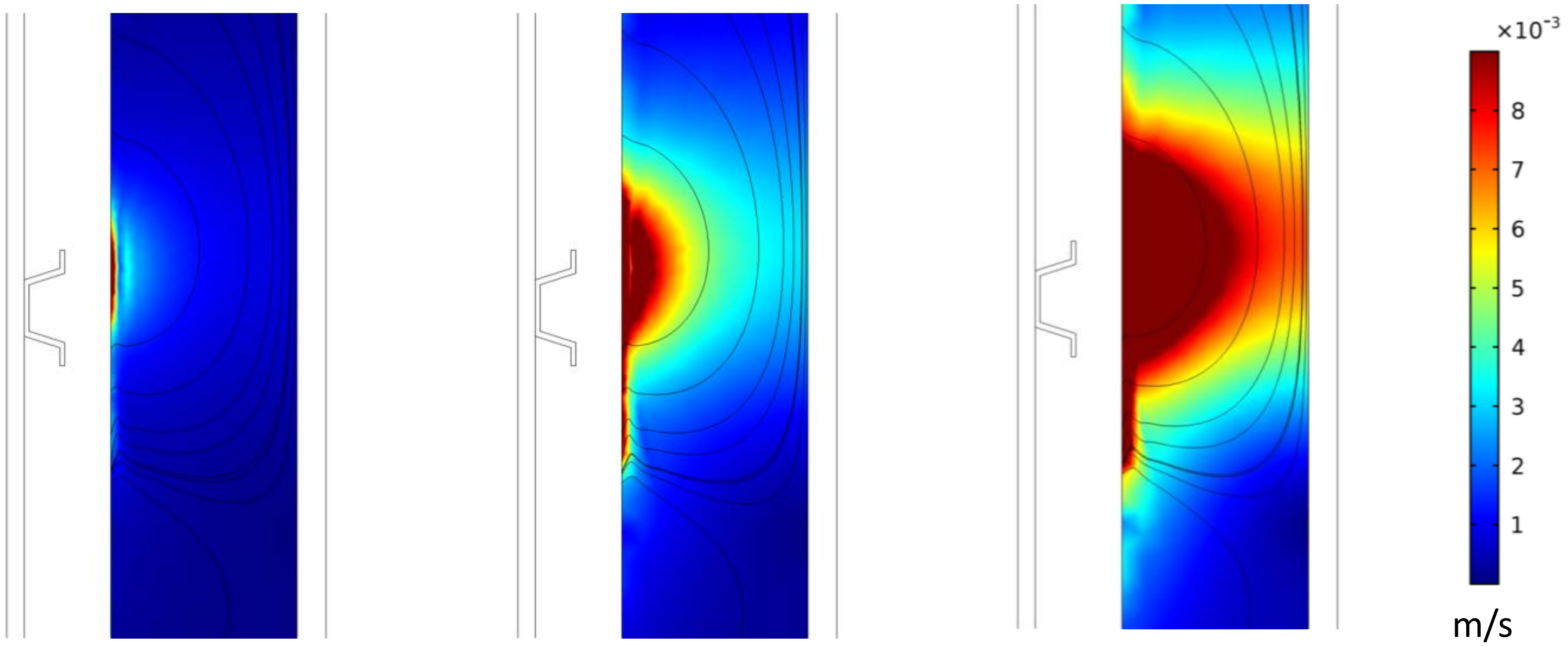




Temperature

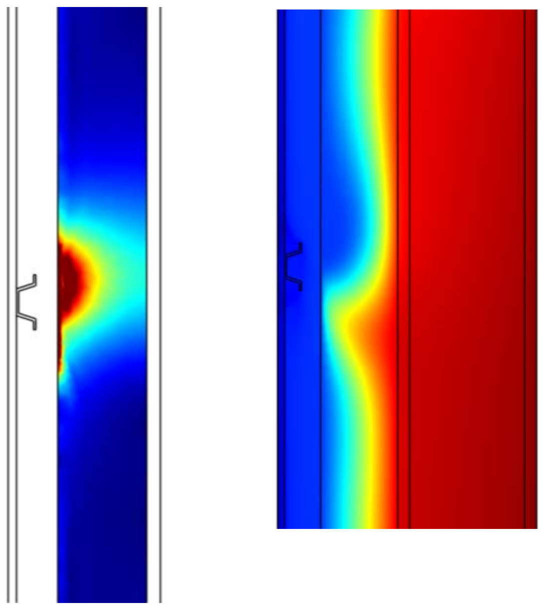


Inlet Velocity: 2 m/s

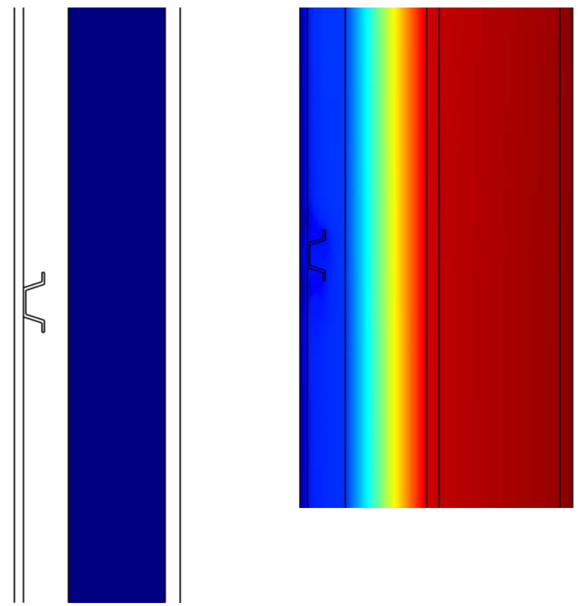


2x10^{-10} m^2	8x10^{-10} m^2	2x10^{-9} m^2
Density ~160 kg/m^3	Density ~70 kg/m^3	Density ~30 kg/m^3
Density ~10 lb/ft^3	Density ~4.4 lb/ft^3	Density ~1.9 lb/ft^3

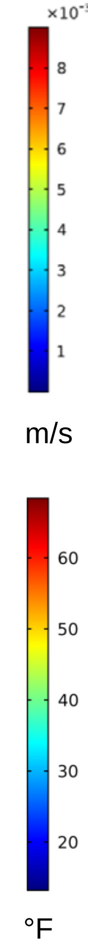
Inlet Velocity: 2 m/s



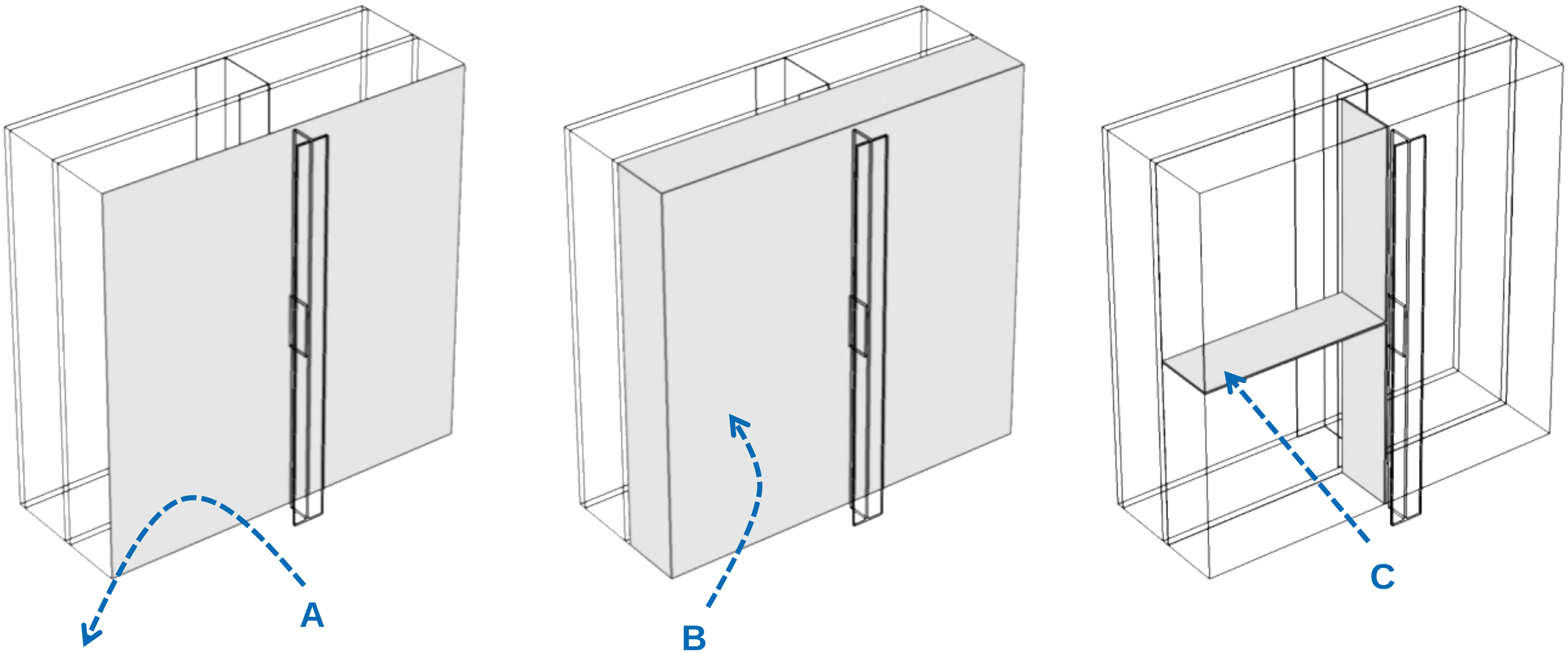
Open Pore / Fibrous Insulation
(2 m/s; Density ~70 kg/m^3)



Closed Pore / Cellular Insulation
(2 m/s)



Convective Mechanisms

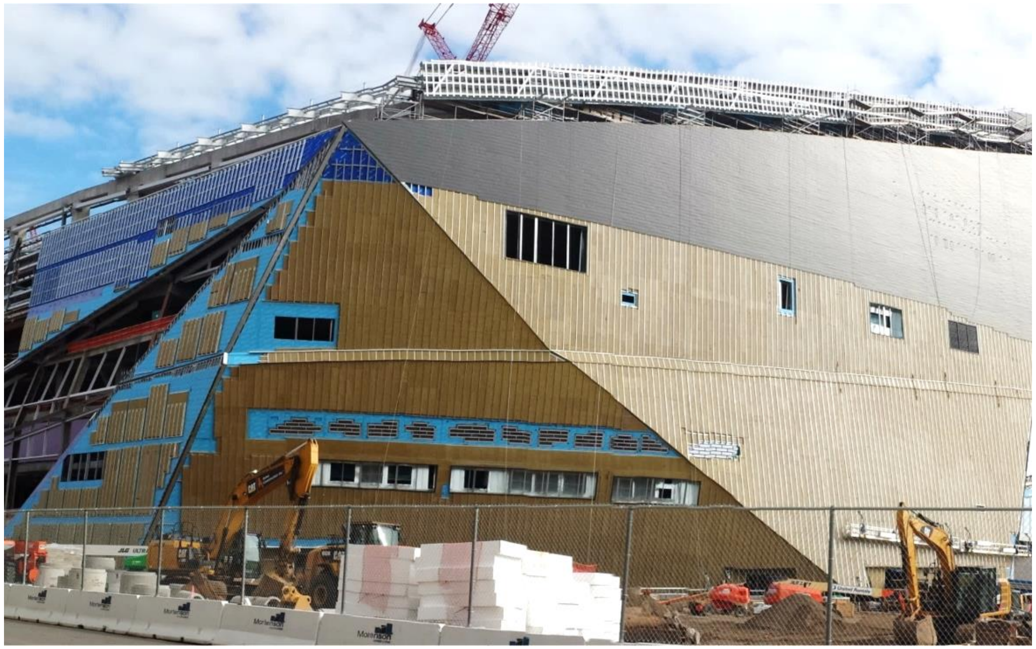


A) Surface Convection

B) Open Pore Volume

C) Gaps

Insulation Gaps



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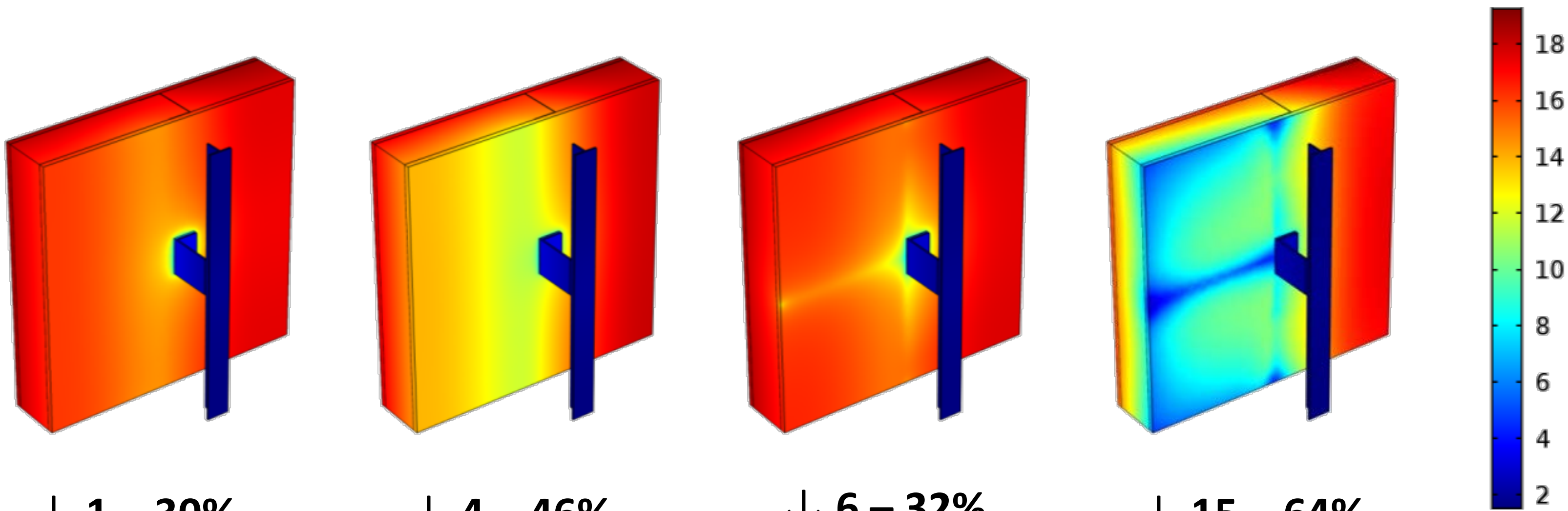
Effective R-Values

Open Pore Fibrous Insulation



°C

↓ 1 – 30%
Surface / Open Pore Flow

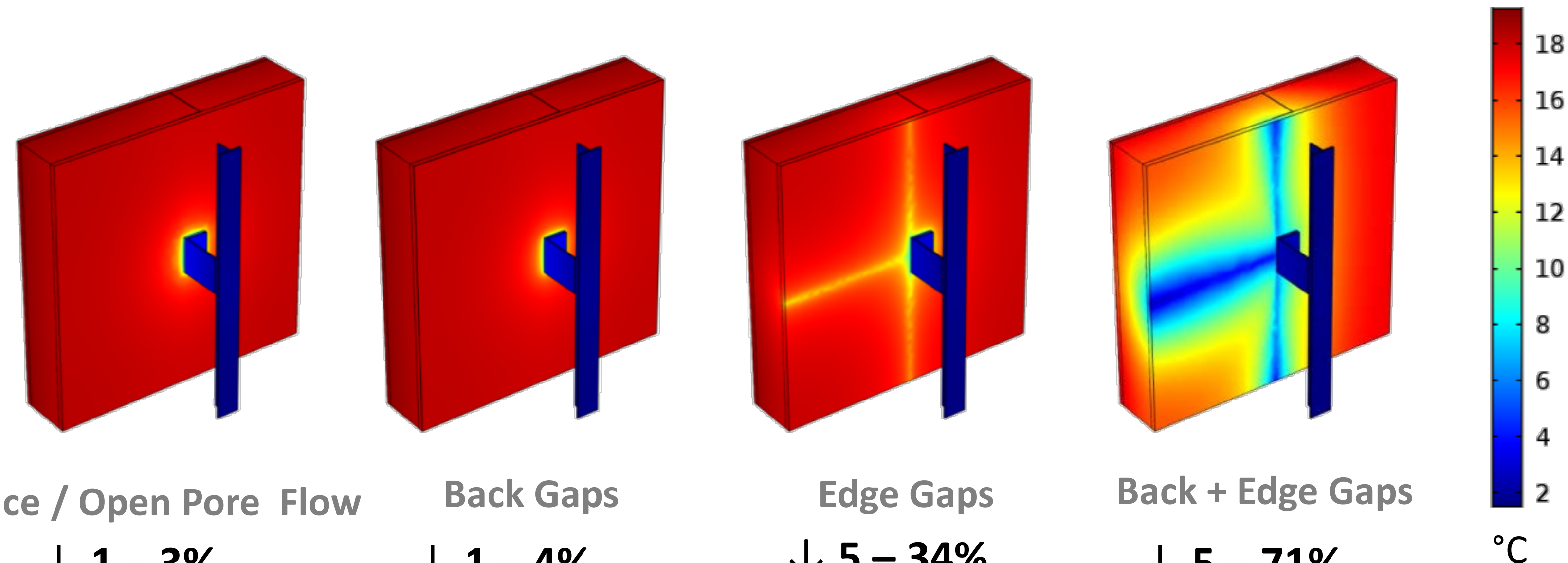
↓ 4 – 46%
Back Gaps

↓ 6 – 32%
Edge Gaps

↓ 15 – 64%
Back + Edge Gaps

Effective R-Values

Closed Pore Cellular Insulation



Surface / Open Pore Flow	Back Gaps	Edge Gaps	Back + Edge Gaps
↓ 1 – 3%	**↓ 1 – 4%**	**↓ 5 – 34%**	**↓ 5 – 71%**

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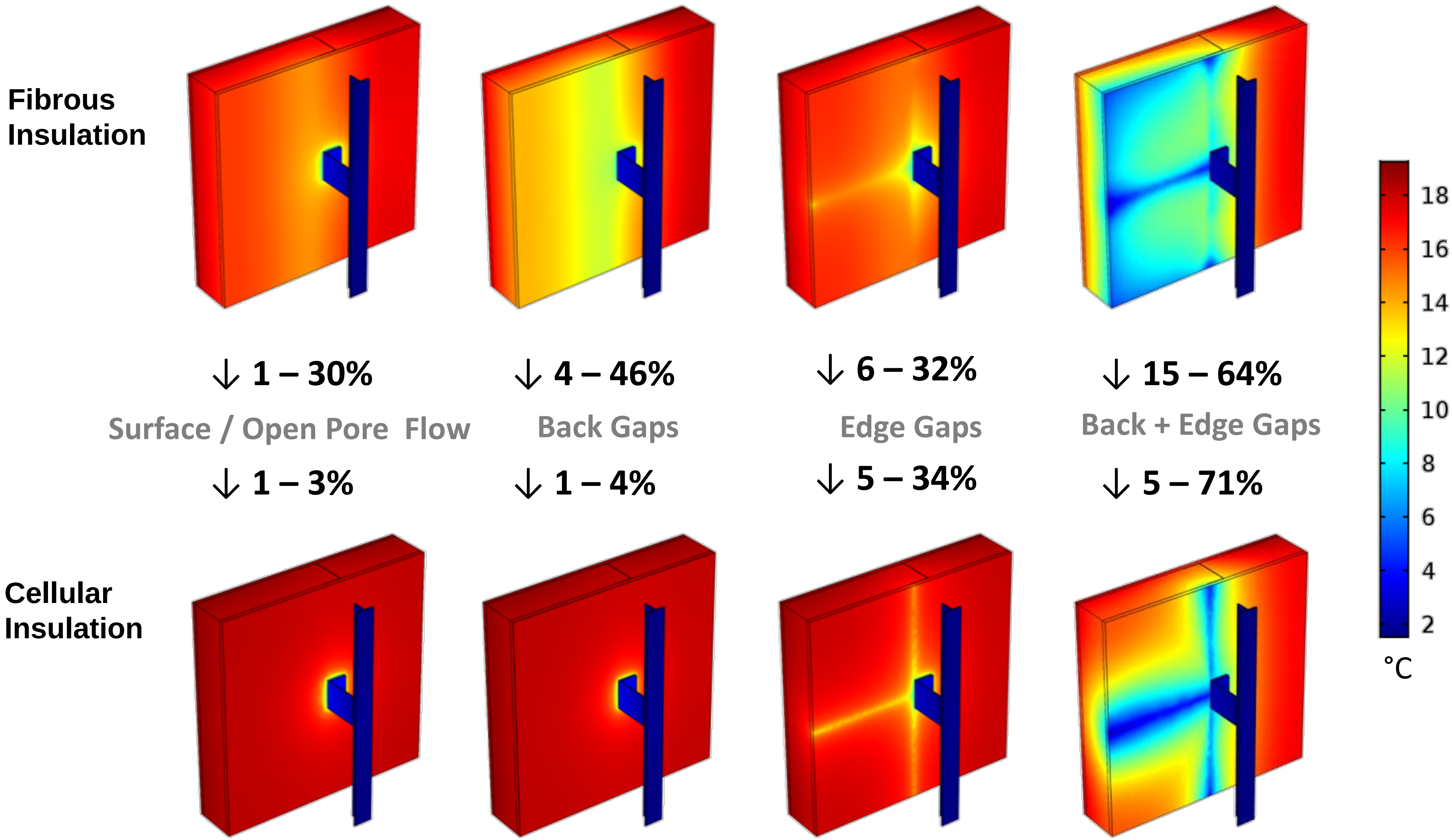
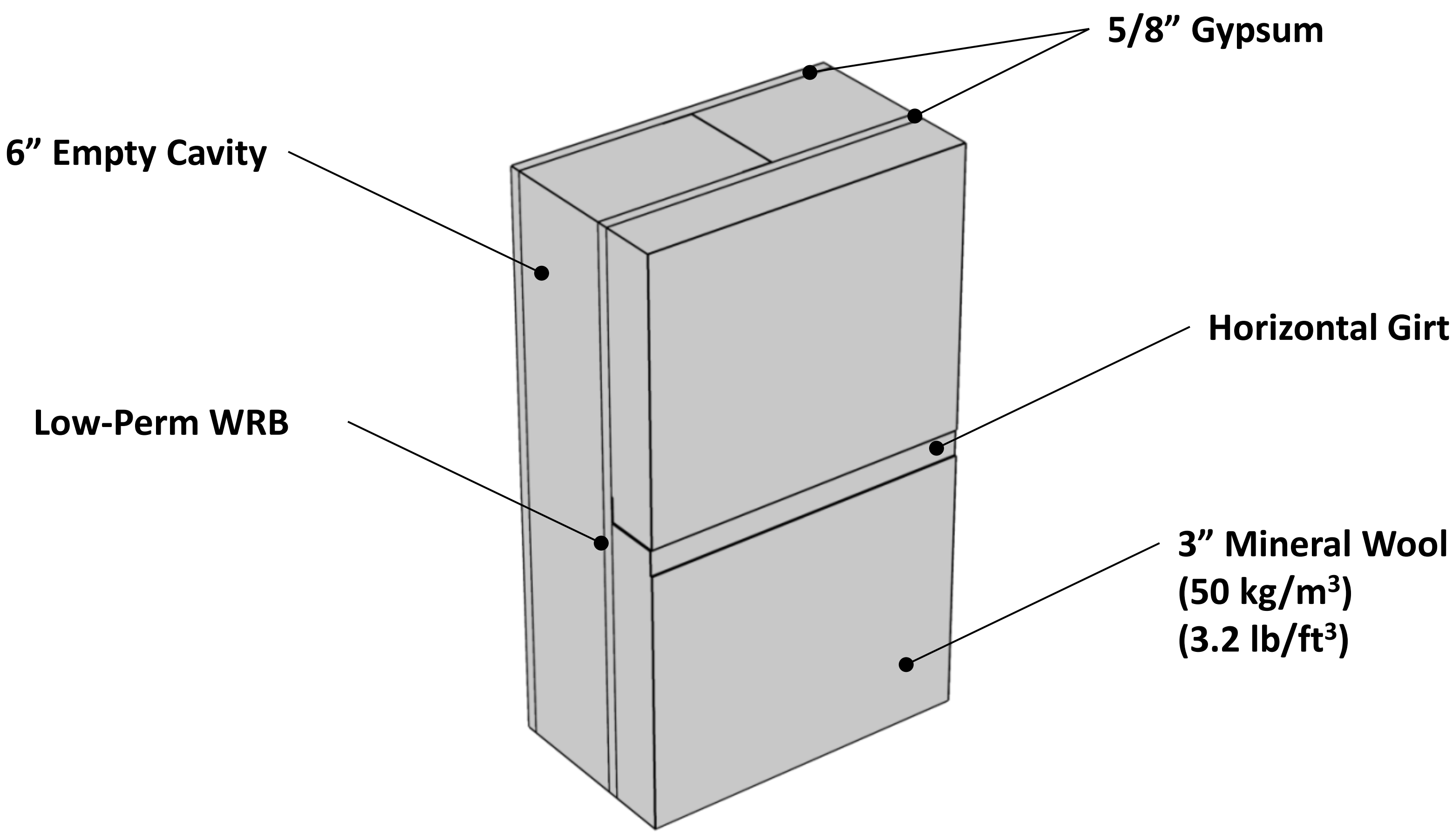
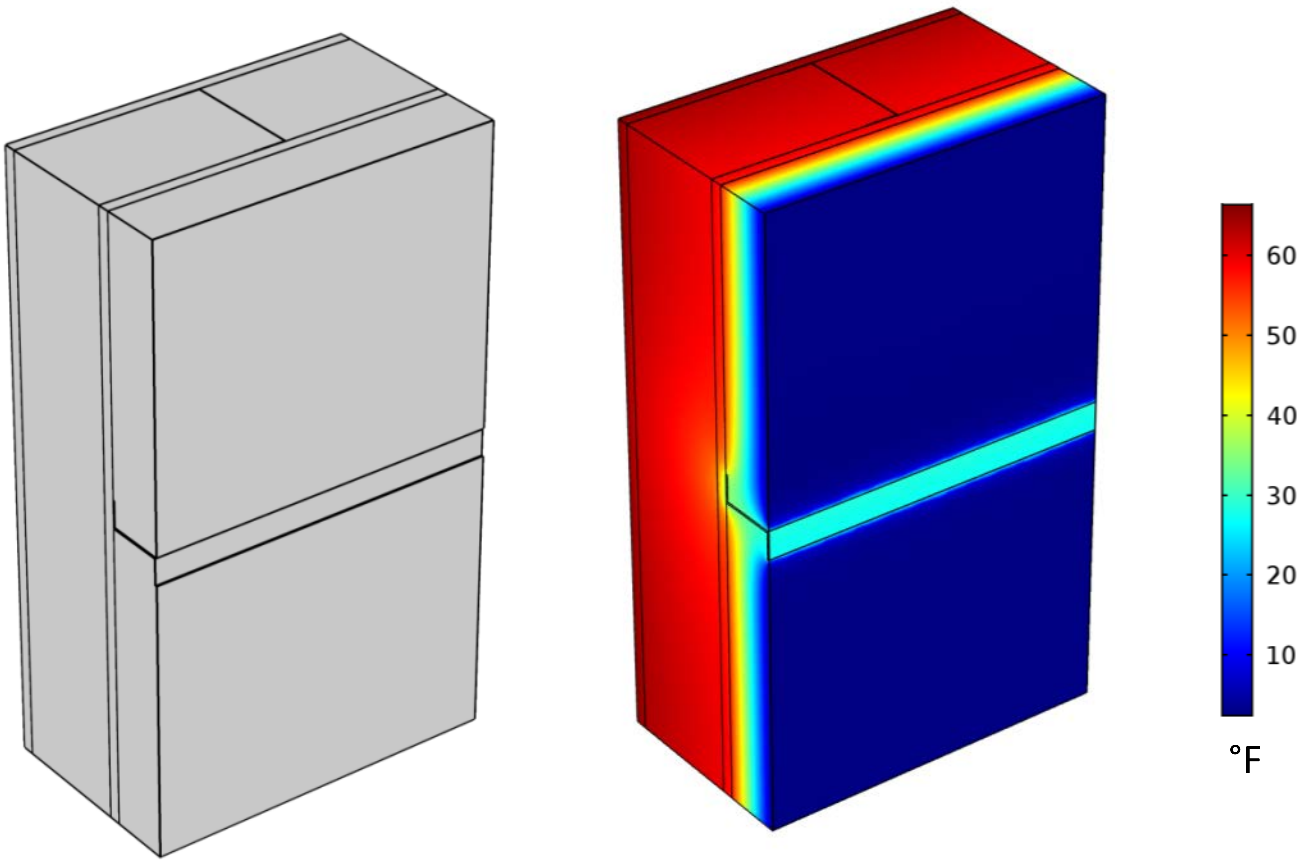
Effective R-Values



Thermal Bridging & Condensation



Thermal Bridging & Condensation



U-Factor
0.064
(R = 15.6)

Nominal R
15.6

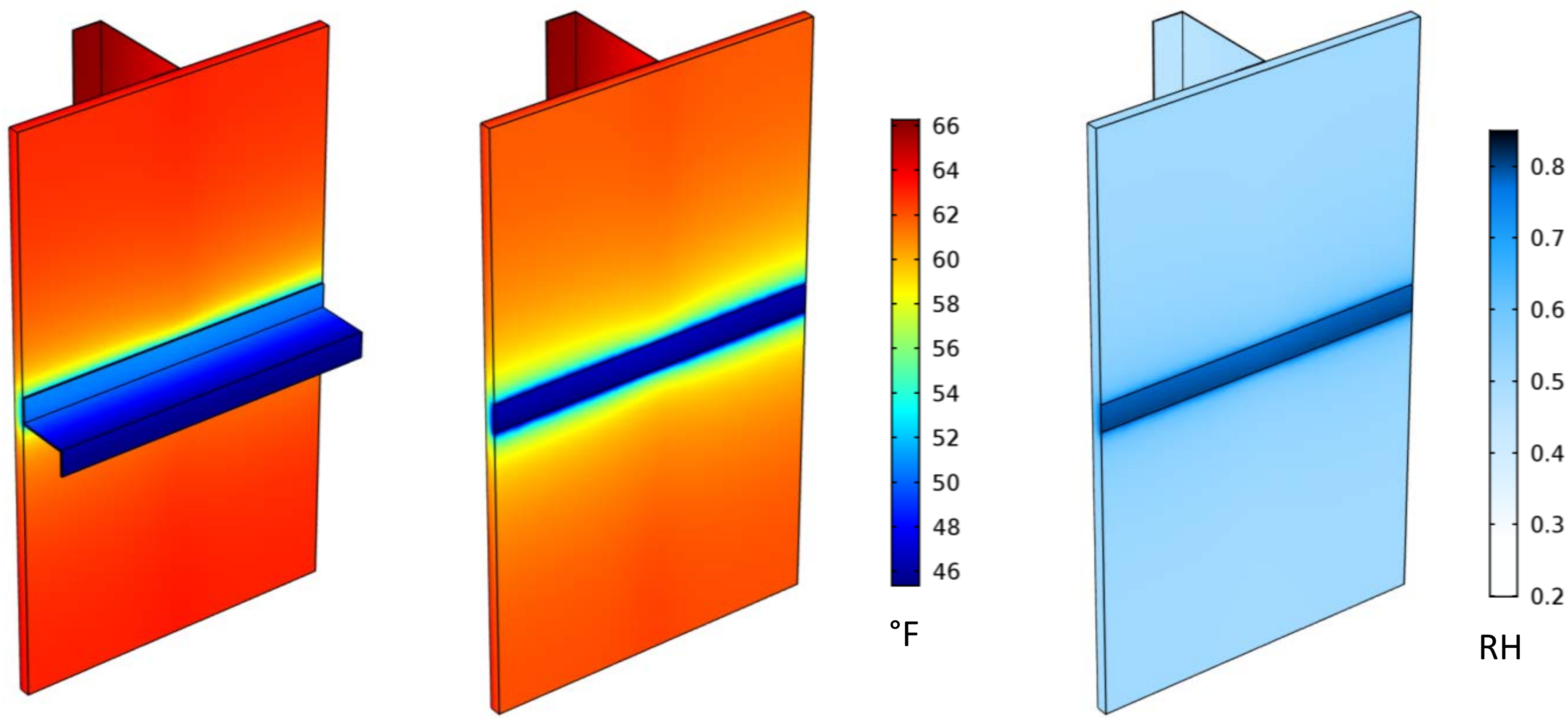
Effective R
7.6 to 11.7

Reduction
24.1 - 51.9%

(excludes fasteners)

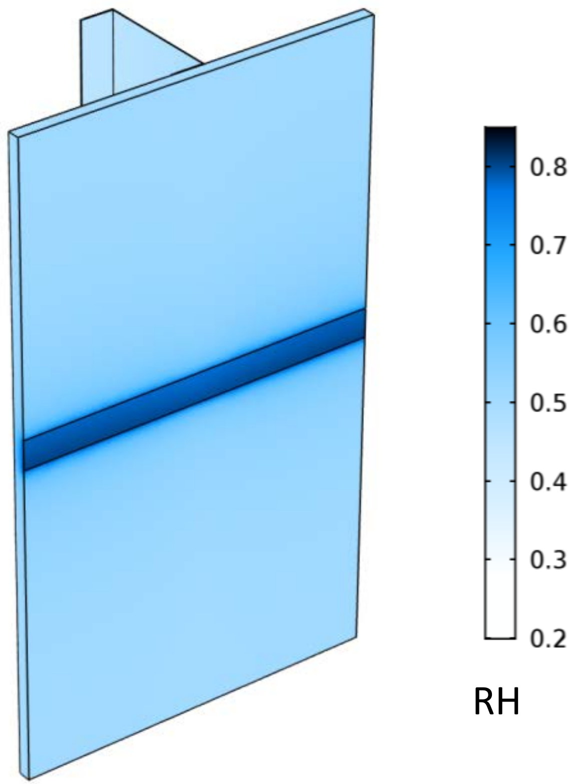
Thermal Bridging & Condensation

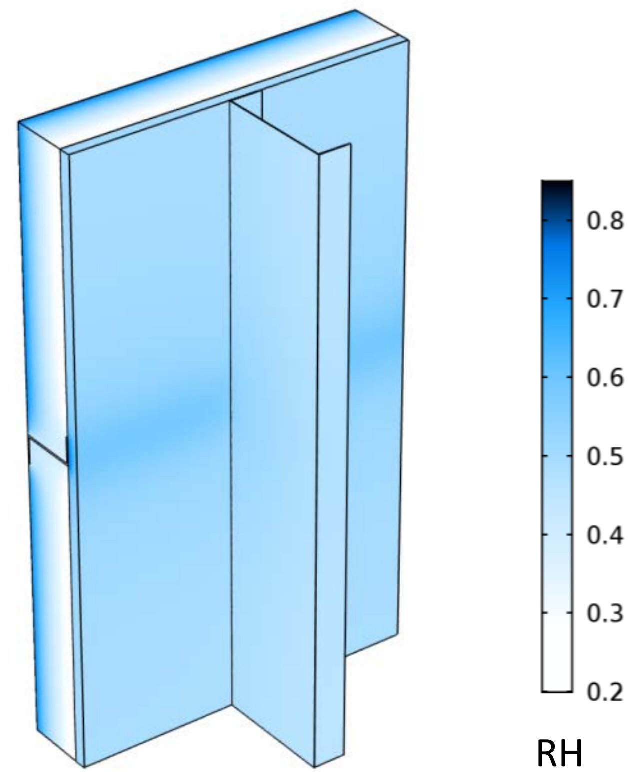
Interior: 40% RH; 70°F   Exterior: 80% RH; 0°F or 30°F



Thermal Bridging & Condensation

Interior: 40% RH; 70°F   Exterior: 80% RH; 30°F

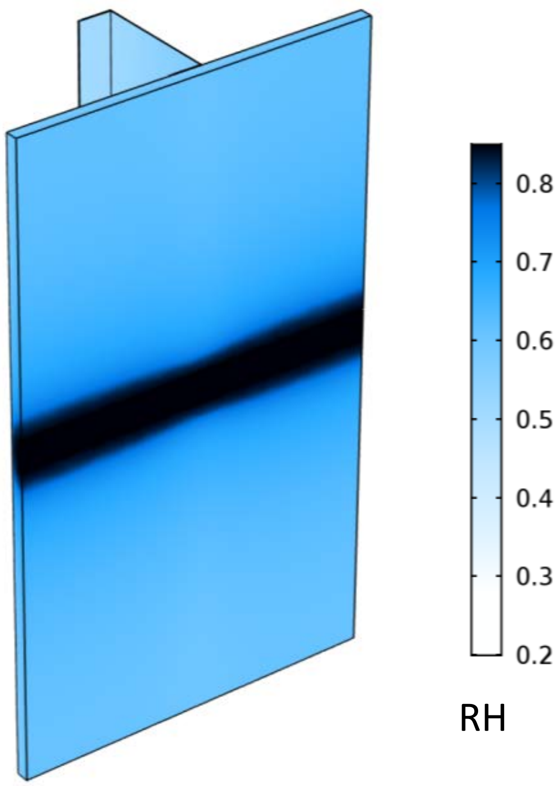


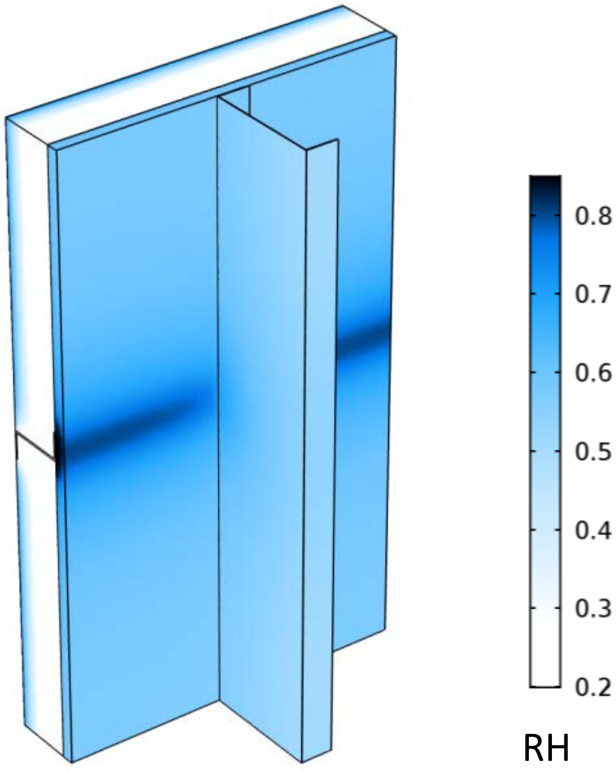


Thermal Bridging & Condensation

Interior: 40% RH; 70°F

Exterior: 80% RH; 0°F





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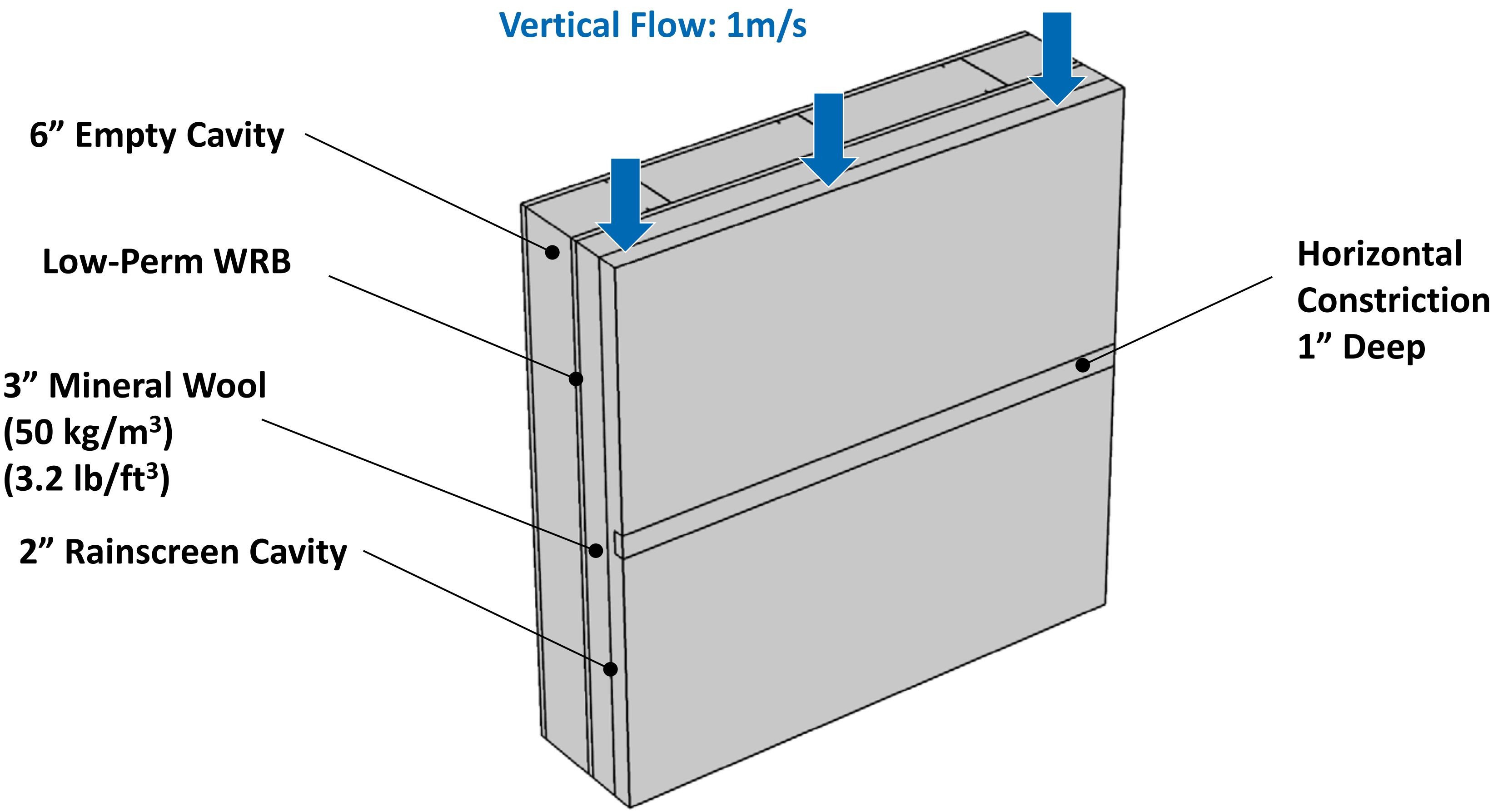
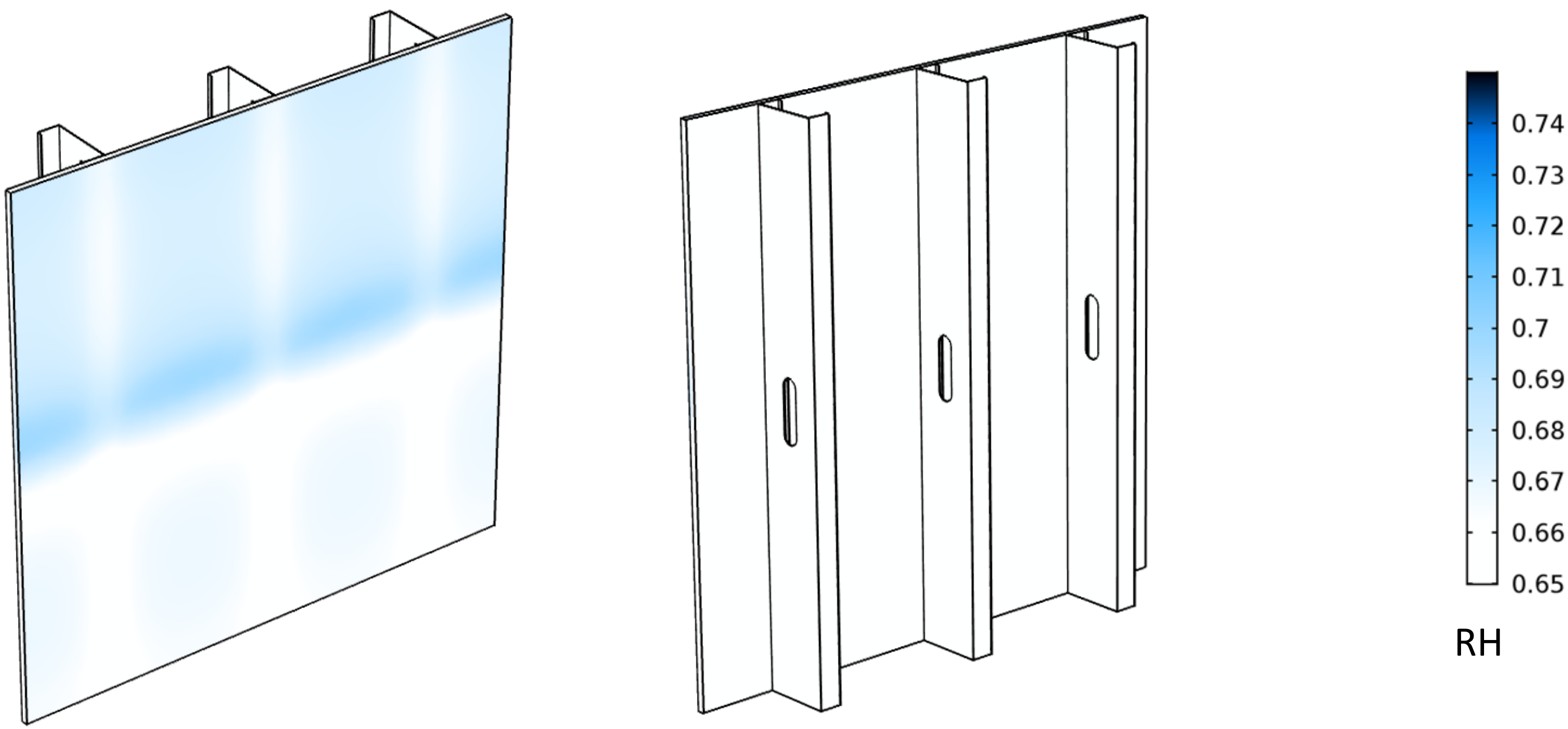
Convective Cooling & Condensation



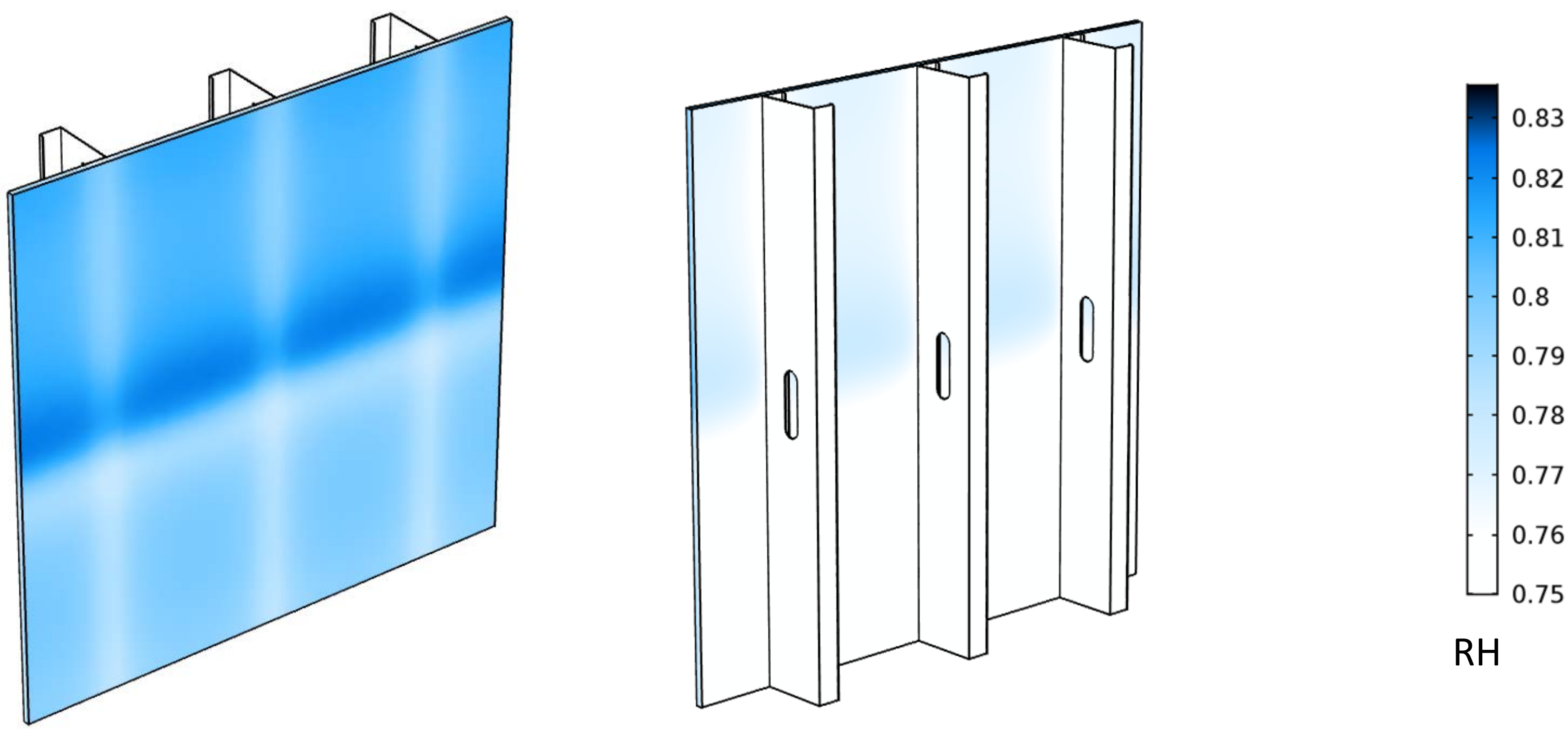
Convective Cooling & Condensation

Interior: 40% RH; 70°F   Exterior: 80% RH; 0°F   Flow = 1 m/s



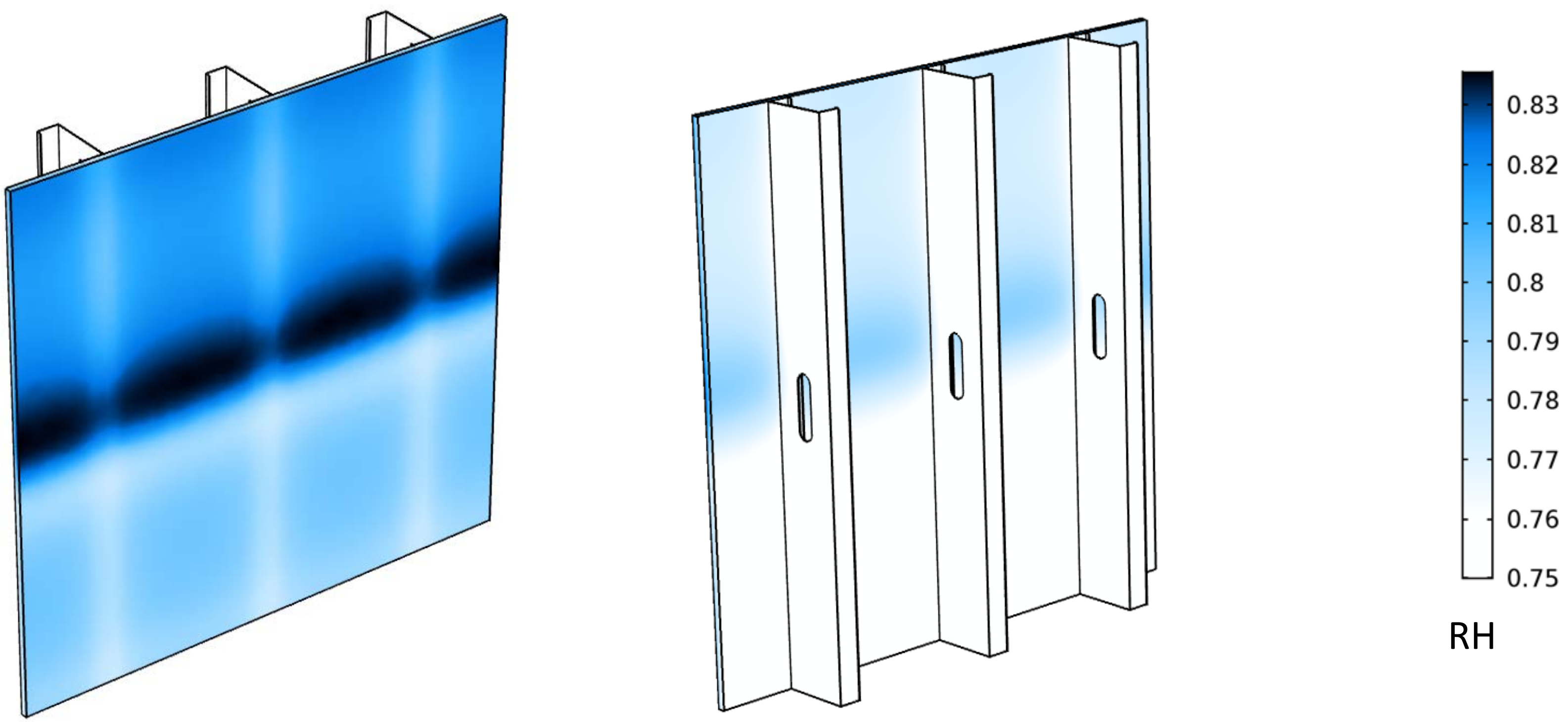
Convective Cooling & Condensation

1) Increase Flow or Indoor RH; or 2) Decrease Temperature or Insulation Density



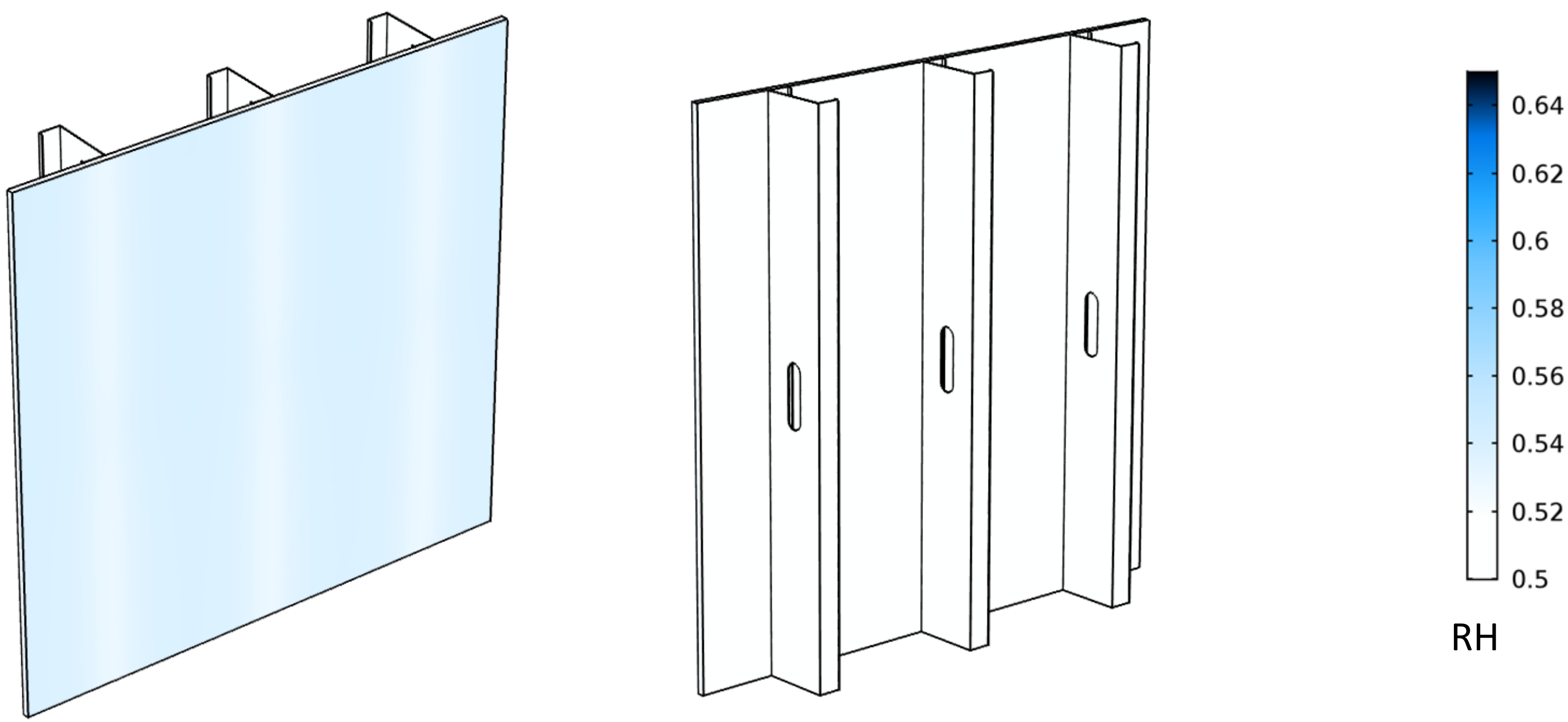
Convective Cooling & Condensation

1) Further Increase Flow or Indoor RH; or 2) Further Decrease Temp. or Density

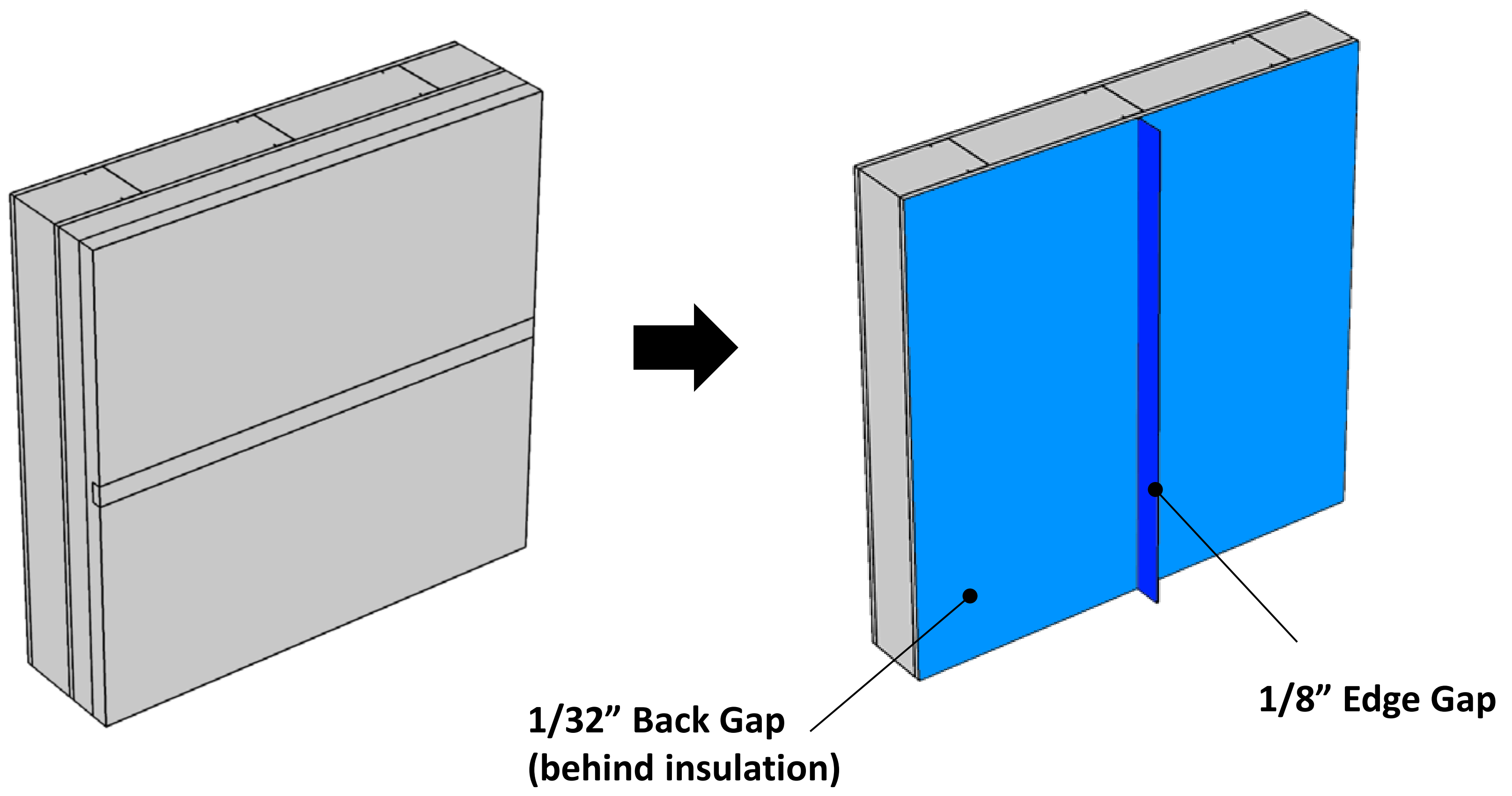


Convective Cooling & Condensation

Same Conditions with Solid Insulation

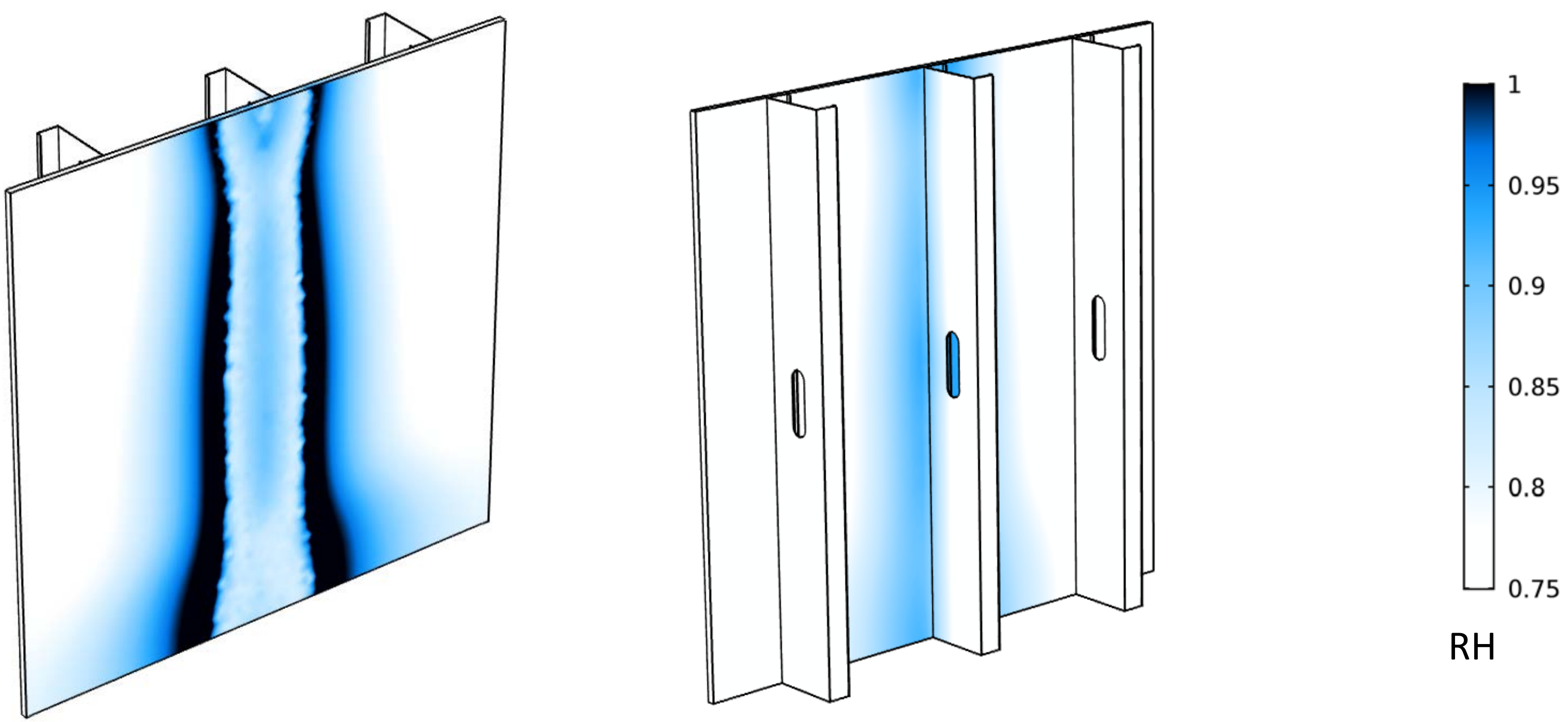


Gaps & Convective Cooling



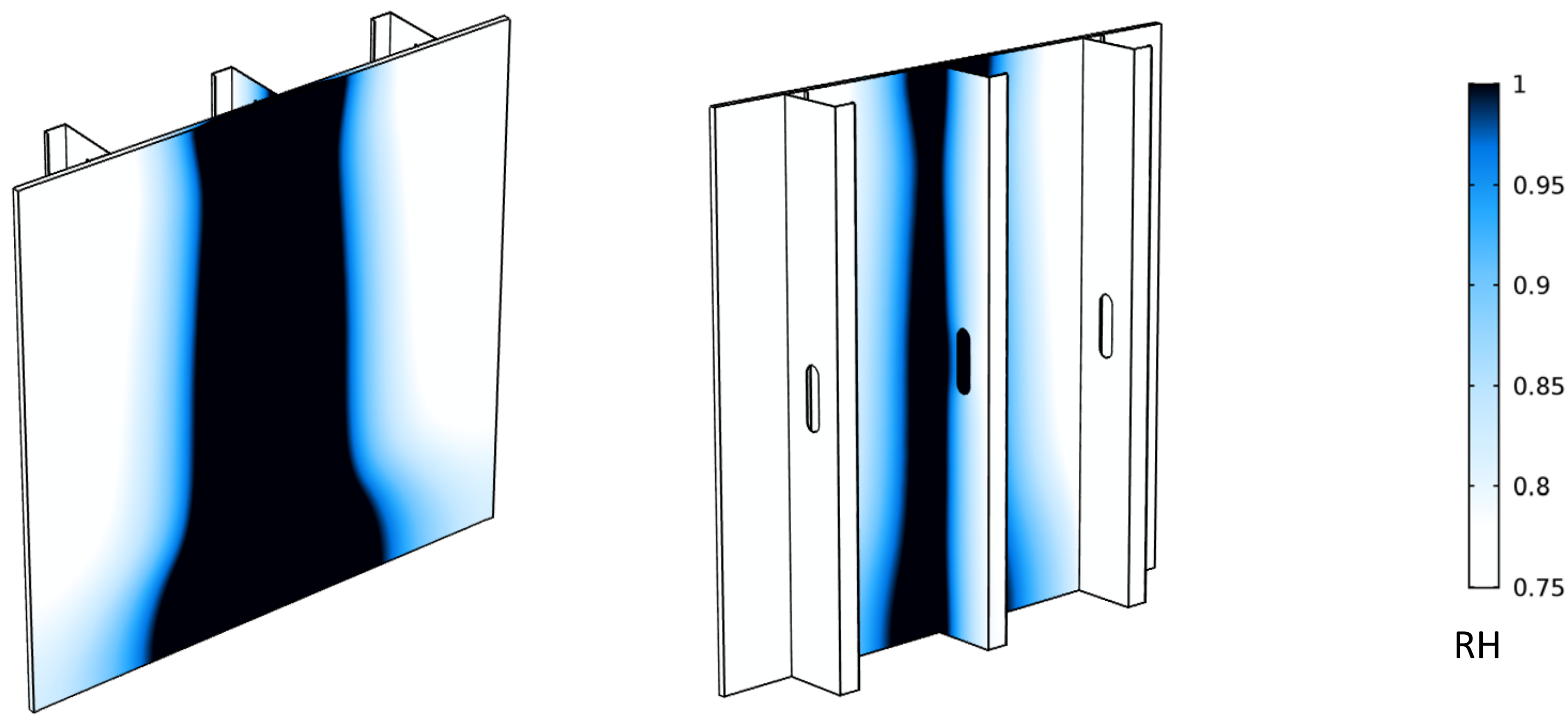
Gaps & Convective Cooling

Interior: 40% RH; 70°F   Exterior: 80% RH; 30°F   Flow = 1 m/s



Gaps & Convective Cooling

Interior: 40% RH; 70°F   Exterior: 80% RH; 0°F   Flow = 1 m/s



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Addressing the Rainscreen Paradox

01 **Smart Rainscreen Geometries**
Avoid airflow diversion against insulation surfaces.

02 **Ventilation Openings**
Understand inlet areas & prevent airflow against insulation edges.

03 **Product Selection**
Use higher density fibrous insulation or cellular insulation.

04 **Gaps**
Treat edge gaps. Adhere / securely fasten to prevent back gaps.

Addressing the Rainscreen Paradox

05 Ventilation Rates

Avoid over-ventilation. Reduce air change rates where possible.

06 Prescriptive Approaches

Avoid prescriptive minimalistic U-factors. Avoid hybrid approaches.

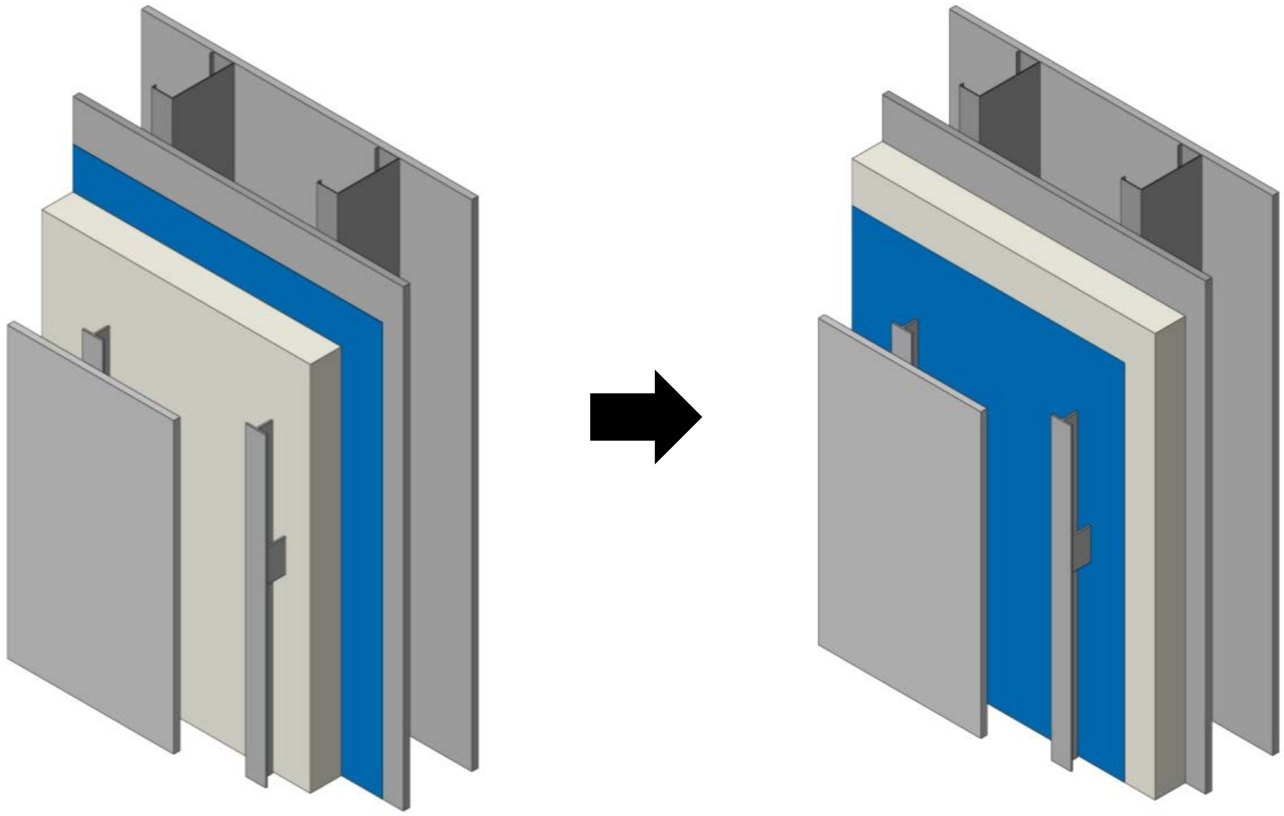
07 Low-Perm WRB

Avoid low-perm Air / WRBs.

08 WRB Placement

Move AB / WRB to exterior face of insulation.

Addressing the Rainscreen Paradox



Thank You!

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