CHARLES PANKOW FOUNDATION

Thermal Performance of Spandrels

SUSTAINABLE DEVELOPMENT LEADERSHIP AND INVESTMENT OPPORTUNITIES

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Who We Are

CHARLES PANKOW FOUNDATION

Building Innovation through Research

Independent, private
grant-making foundation delivering
better ways to design and build.

Our ambitions are large-scale, and require collective action and significant levels of investment, know-how and influence.

We provide leaders and organizations
catalytic capital and
the framework of success.

All work product is publicly shared for collective use and industry change.

$15M

FUNDED

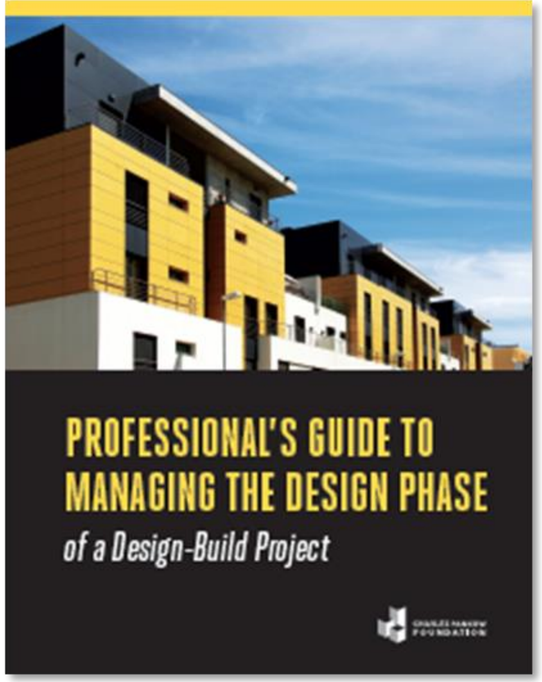
94

RESEARCH GRANTS

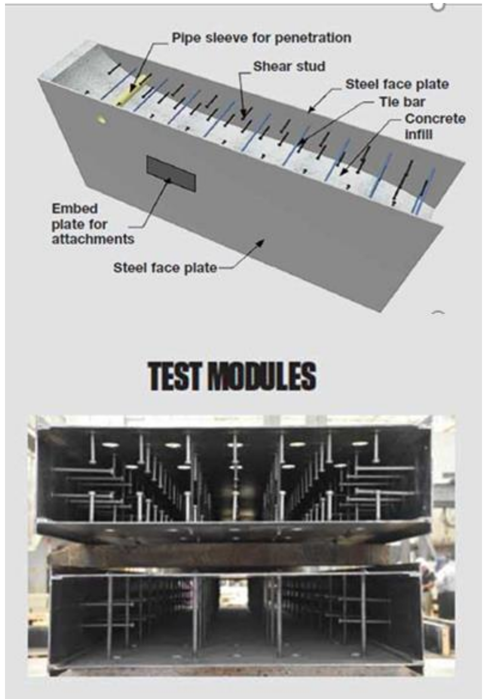
37

ORGANIZATIONS

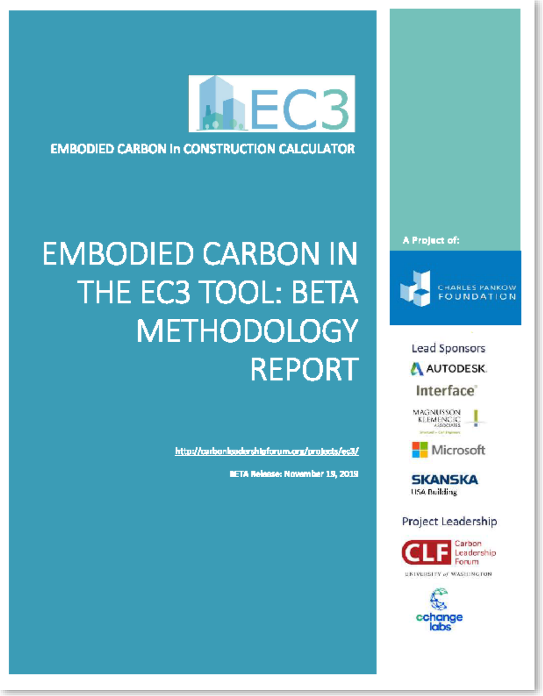
Founded 2005



COLLABORATIVE PROJECT DELIVERY



NOVEL STRUCTURAL SYSTEMS & ADVANCED MATERIALS



ENVIRONMENTAL TRANSPARENCY

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Our Operating Model

Industry Champions — Identify Problem

Principal Investigators | Industry Advisors — Frame Problem; Inform Research

Market Implementation Partners | Material Contributors | Co-funding Partners — Support & Amplify Research

CHARLES PANKOW FOUNDATION
Building Innovation through Research

The Team

CHARLES PANKOW FOUNDATION
Building Innovation through Research

- **The Engineering Team** → MI, RDH, SGH
- **The Lab Team** → OAK RIDGE National Laboratory, BERKELEY LAB
- **Industry Champion** → BIRCH POINT Consulting

3 to 4 Years

Phase 1
- Literature Review
- Industry Survey
- 3D CFD Analysis
- Define Test Program

Phase 2

Hot box tests ⇄ Thermal modeling

Phase 3

Compute U Factors and Other Performance Data for Various Spandrel Systems

Phase 4

Prepare Spandrel Design Guidance Document

Code and Standards Adoption

Agenda

Good

Why use spandrels?

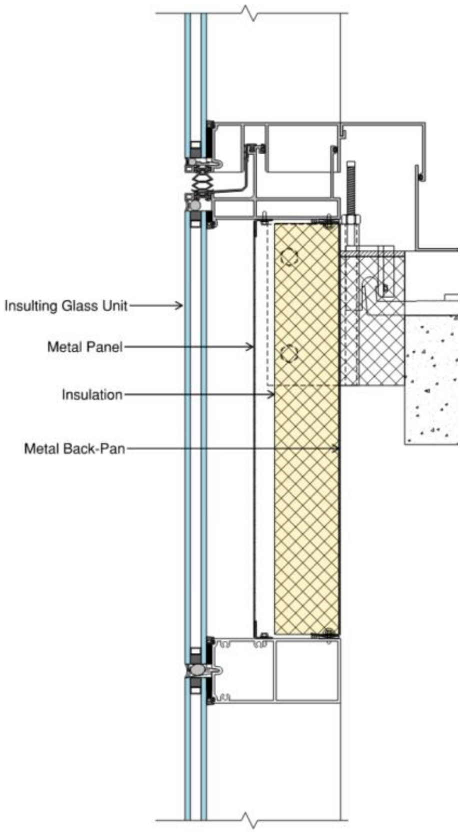
Bad

What do we **not** know about spandrels?

Ugly

What is the current future of “spandrels” ?

Glazed Wall Spandrel Systems



A non-vision application of a fenestration product; typically used to hide or obscure features of the building structure or used for visual effect. **(NFRC 100)**

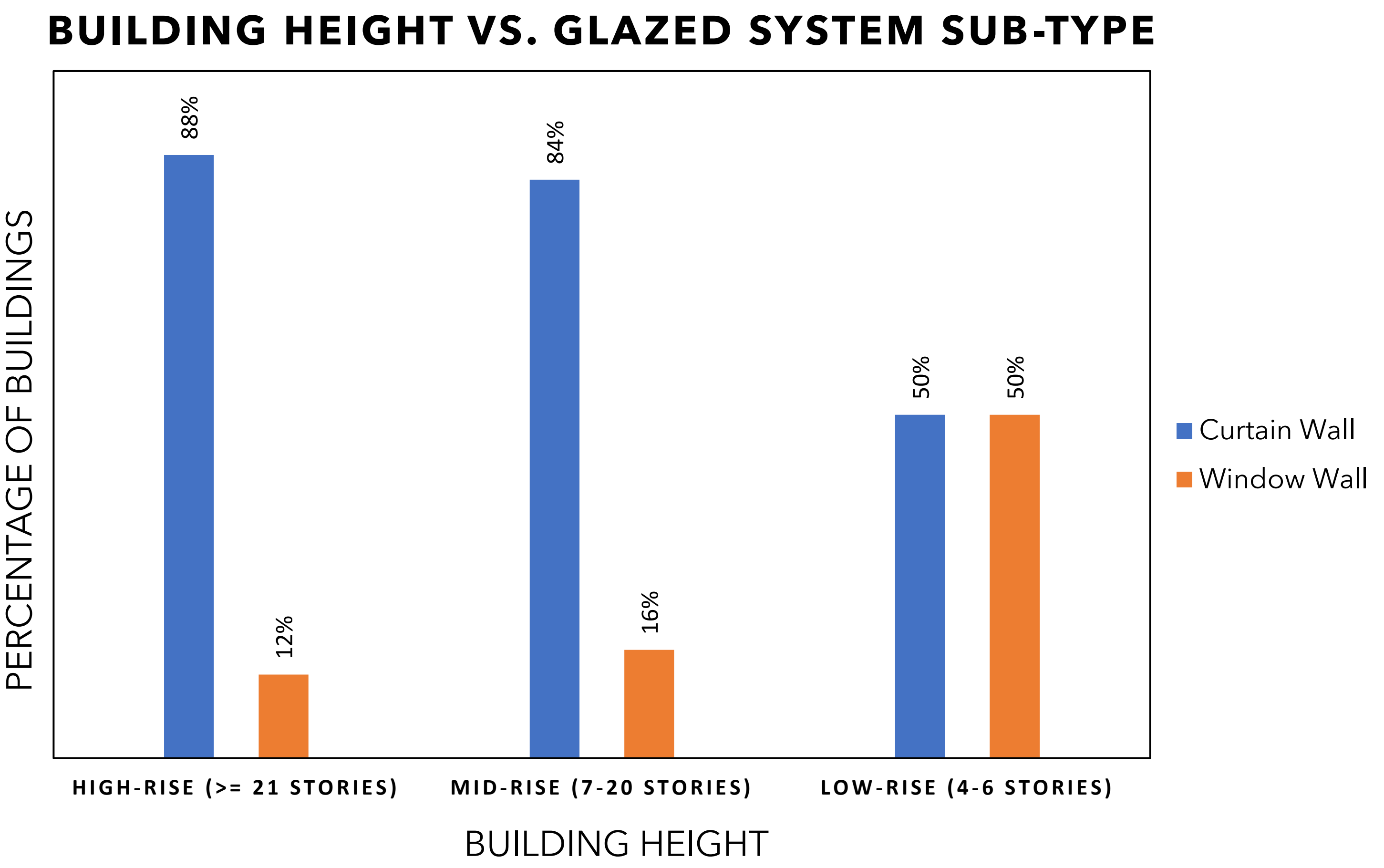
CHARLES PANKOW FOUNDATION
Building Innovation through Research

Prevalence of Glazed Wall Systems

Glazed wall systems represent roughly 40% of the building facade systems used in the downtown core of several major cities.

North American Glass Curtain Wall Market estimated
> $8.4 Billion in 2023

(Stellar Market Research, 2023)



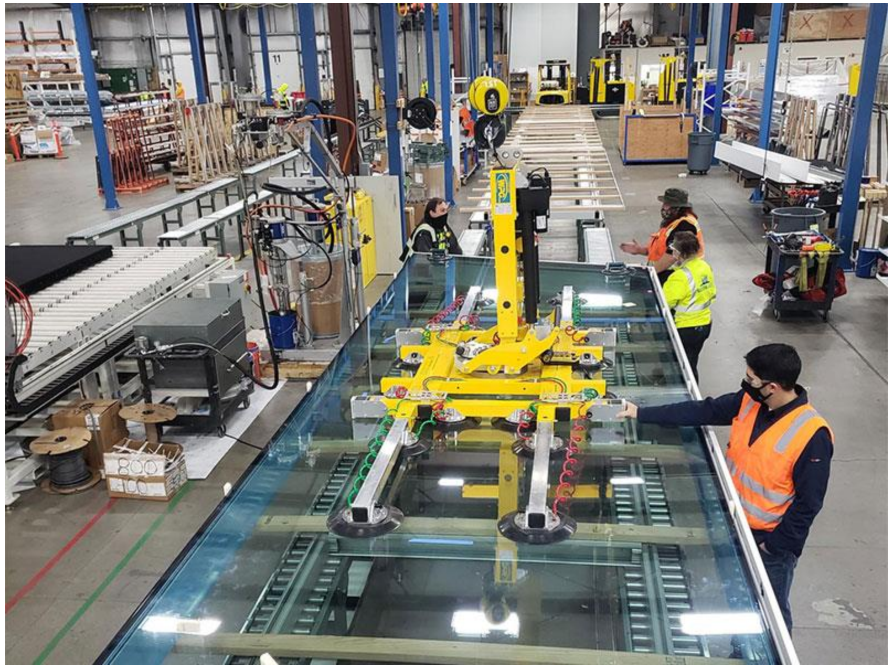
CHARLES PANKOW FOUNDATION
Building Innovation through Research

Aesthetic

Customization

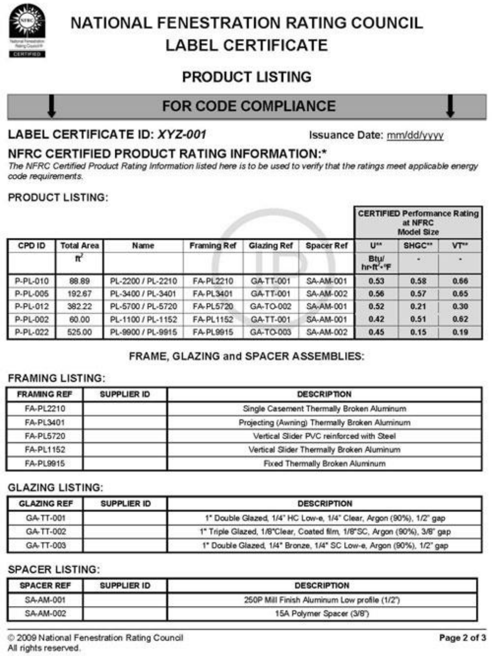
Speed of Construction

Other Advantages



QA/QC

Potential for high levels of quality control and tight tolerances with factory production



NATIONAL FENESTRATION RATING COUNCIL
LABEL CERTIFICATE

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: *XYZ-001* Issuance Date: mm/dd/yyyy

NFRC CERTIFIED PRODUCT RATING INFORMATION:*

The NFRC Certified Product Rating Information listed here is to be used to verify that the ratings meet applicable energy code requirements.

PRODUCT LISTING:

CPD ID	Total Area	Name	Framing Ref	Glazing Ref	Spacer Ref	CERTIFIED Performance Rating at NFRC Model Size		
						U**	SHGC**	VT**
	ft^2					Btu/ $hr \cdot ft^2 \cdot °F$	-	-
P-PL-010	88.89	PL-2200 / PL-2210	FA-PL2210	GA-TT-001	SA-AM-001	0.53	0.58	0.66
P-PL-005	192.67	PL-3400 / PL-3401	FA-PL3401	GA-TT-001	SA-AM-002	0.56	0.57	0.65
P-PL-012	382.22	PL-5700 / PL-5720	FA-PL5720	GA-TO-002	SA-AM-001	0.52	0.21	0.30
P-PL-002	60.00	PL-1100 / PL-1152	FA-PL1152	GA-TT-001	SA-AM-001	0.42	0.51	0.62
P-PL-022	525.00	PL-9900 / PL-9915	FA-PL9915	GA-TO-003	SA-AM-002	0.45	0.15	0.19

FRAME, GLAZING and SPACER ASSEMBLIES:

FRAMING LISTING:

FRAMING REF	SUPPLIER ID	DESCRIPTION
FA-PL2210		Single Casement Thermally Broken Aluminum
FA-PL3401		Projecting (Awning) Thermally Broken Aluminum
FA-PL5720		Vertical Slider PVC reinforced with Steel
FA-PL1152		Vertical Slider Thermally Broken Aluminum
FA-PL9915		Fixed Thermally Broken Aluminum

GLAZING LISTING:

GLAZING REF	SUPPLIER ID	DESCRIPTION
GA-TT-001		1" Double Glazed, 1/4" HC Low-e, 1/4" Clear, Argon (90%), 1/2" gap
GA-TT-002		1" Triple Glazed, 1/8"Clear, Coated film, 1/8"SC, Argon (90%), 3/8" gap
GA-TT-003		1" Double Glazed, 1/4" Bronze, 1/4" SC Low-e, Argon (90%), 1/2" gap

SPACER LISTING:

SPACER REF	SUPPLIER ID	DESCRIPTION
SA-AM-001		250P Mill Finish Aluminum Low profile (1/2")
SA-AM-002		15A Polymer Spacer (3/8")

Page 2 of 3

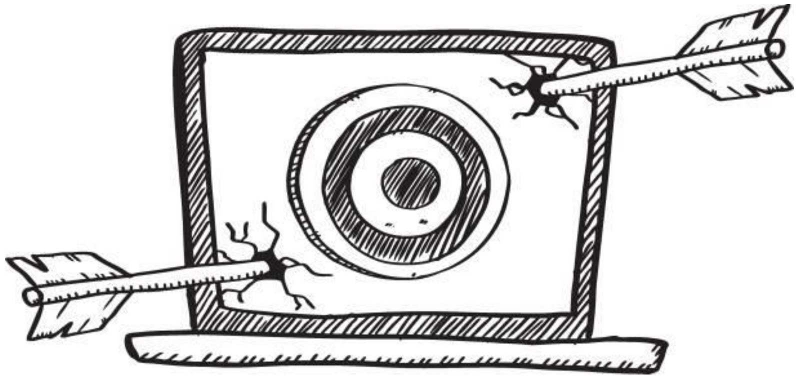
3rd Party Rating

Spandrel Panel Systems are included in NFRC

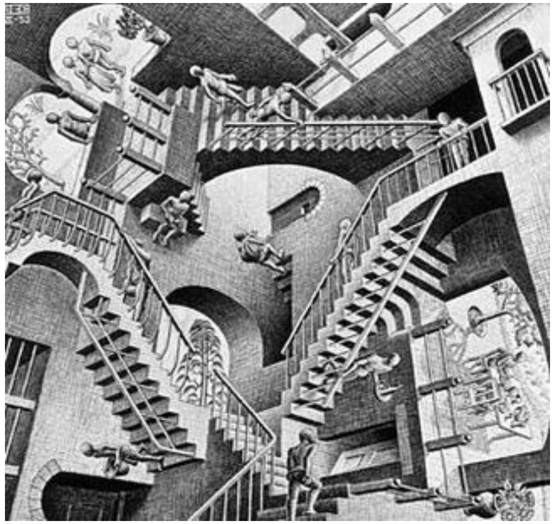
What’s in a label?

The Bad

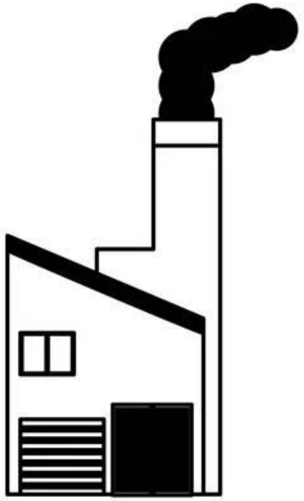
The truth about spandrel thermal performance....



Inaccurate thermal performance

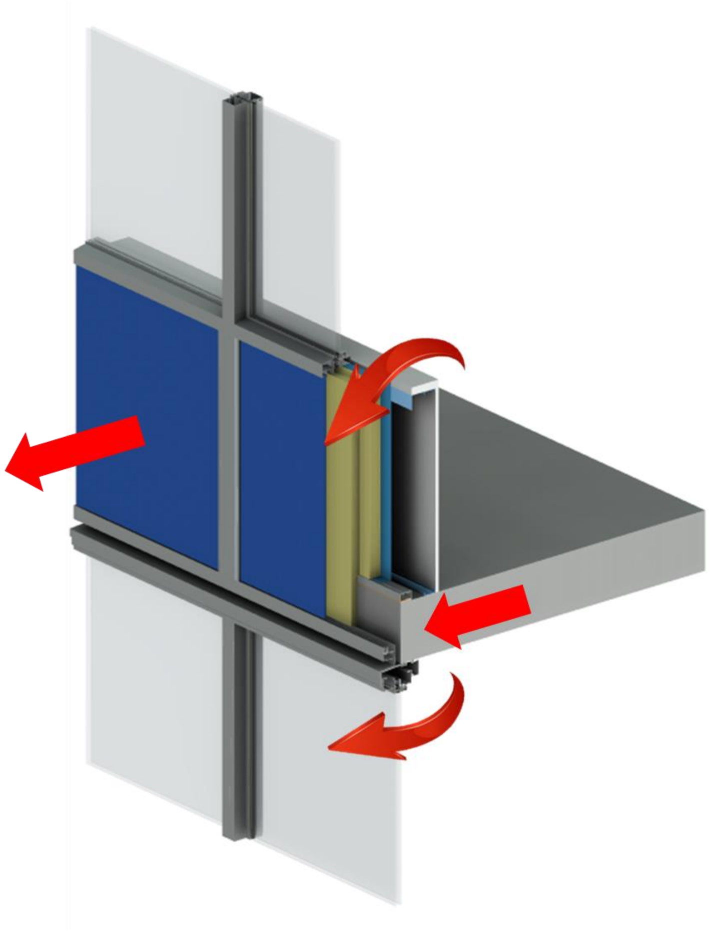


Nonrepresentative conditions



Misleading energy performance and carbon emissions

Inaccurate Thermal Performance

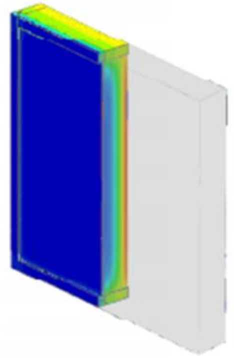


Derated performance due to thermal bridging

Spandrel with R-16.8 insulation

'Actual' **R-6.5!**

Hotbox Lab Measurement



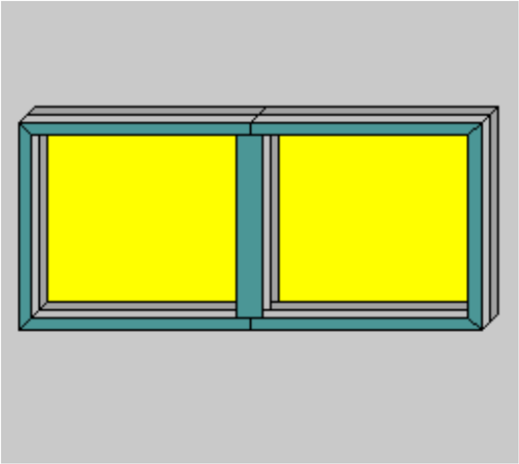
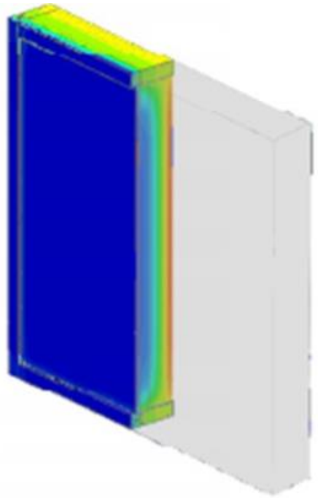
3D Analysis

2D Analysis

Approach	Thermal Transmittance W/m²K (BTU/ft²hr°F)	Effective R-value m²K/W (ft²hr°F/BTU)	Percent Difference Compared to Hotbox Measurement
Hotbox Measurement	**0.87 (0.153)**	**1.2 (6.5)**	-
3D Analysis	0.87 (0.153)	1.2 (6.5)	0%
2D NFRC-100	0.63 (0.111)	1.6 (9.0)	32%
2D NFRC Modified	0.68 (0.120)	1.5 (8.3)	24%

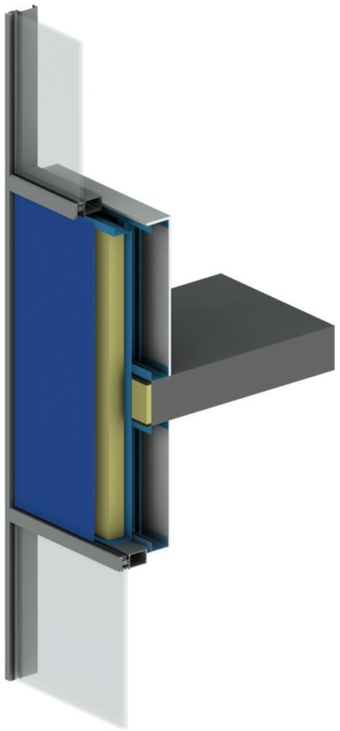
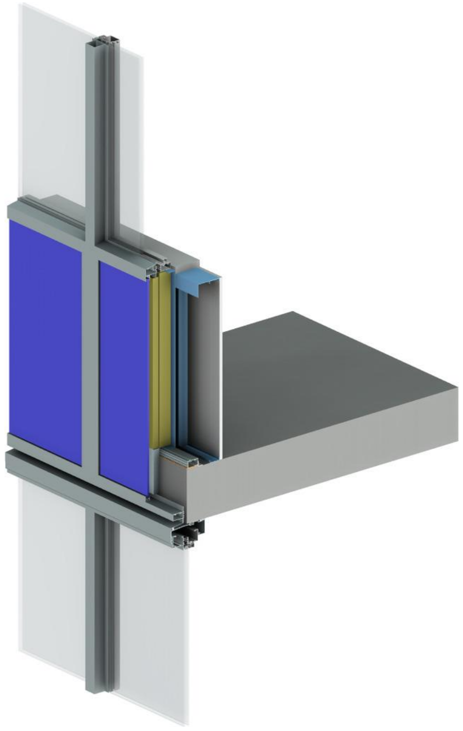
CHARLES PANKOW FOUNDATION
Building Innovation through Research

Nonrepresentative Conditions

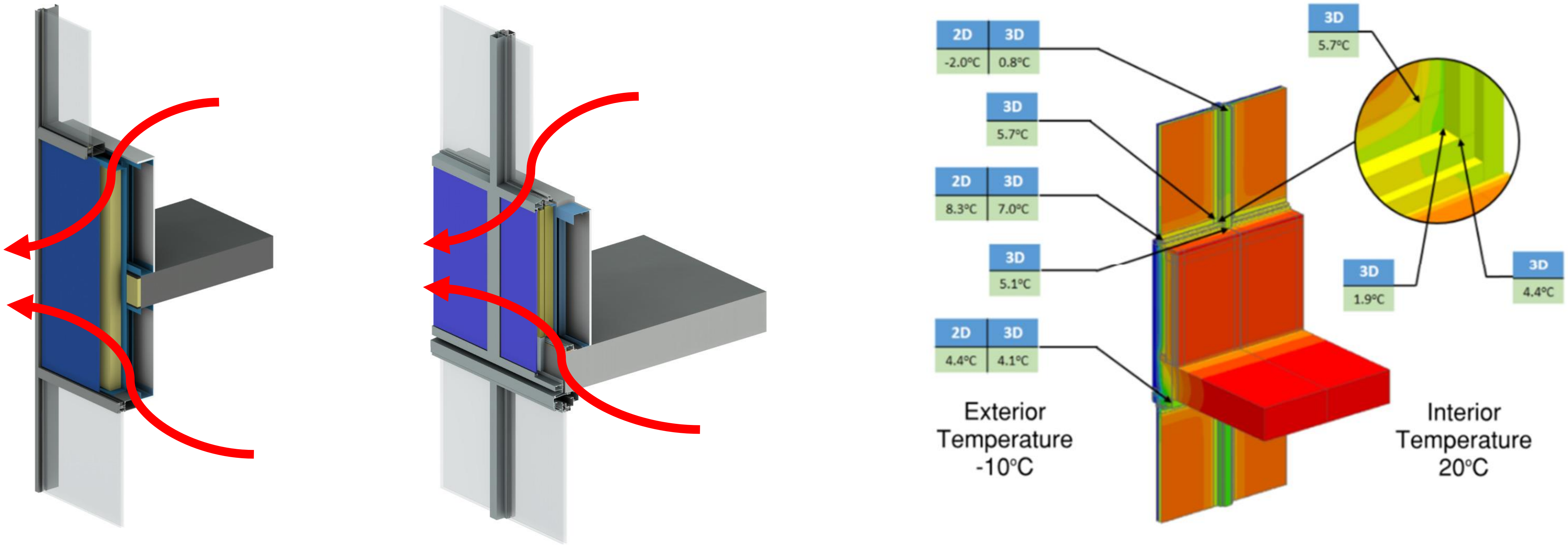
NFRC Spandrel
Product Evaluation

VS

Additional heat
flow from adjacent
components

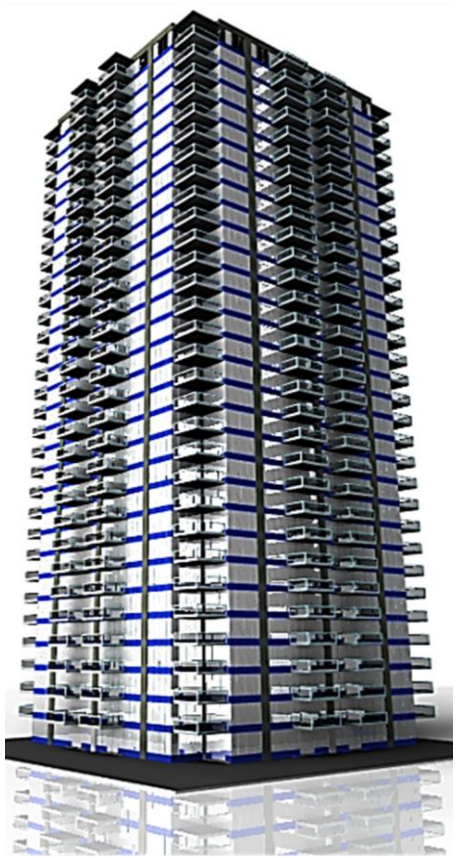
Nonrepresentative Conditions



Additional **heat flow** and increased **condensation** risk

CHARLES PANKOW FOUNDATION
Building Innovation through Research

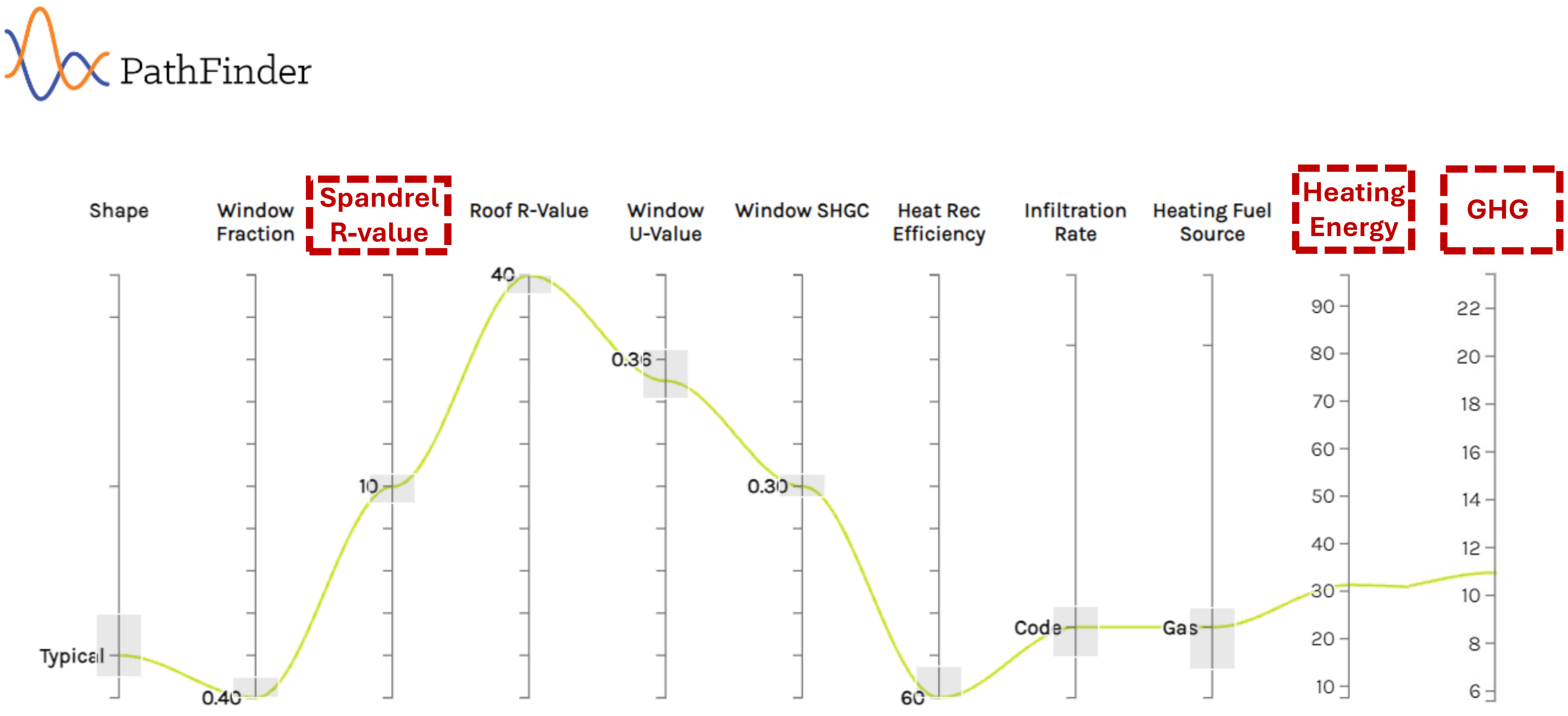
Building Energy Performance



Multi-unit
residential building

- Compact shape
- 40% window to wall ratio
- R-40 roof
- U-0.35 windows, 0.3 SHGC (Double glazed)
- HRV 60%
- Standard construction
- Gas heating

Impact of 2D NFRC vs. Reality

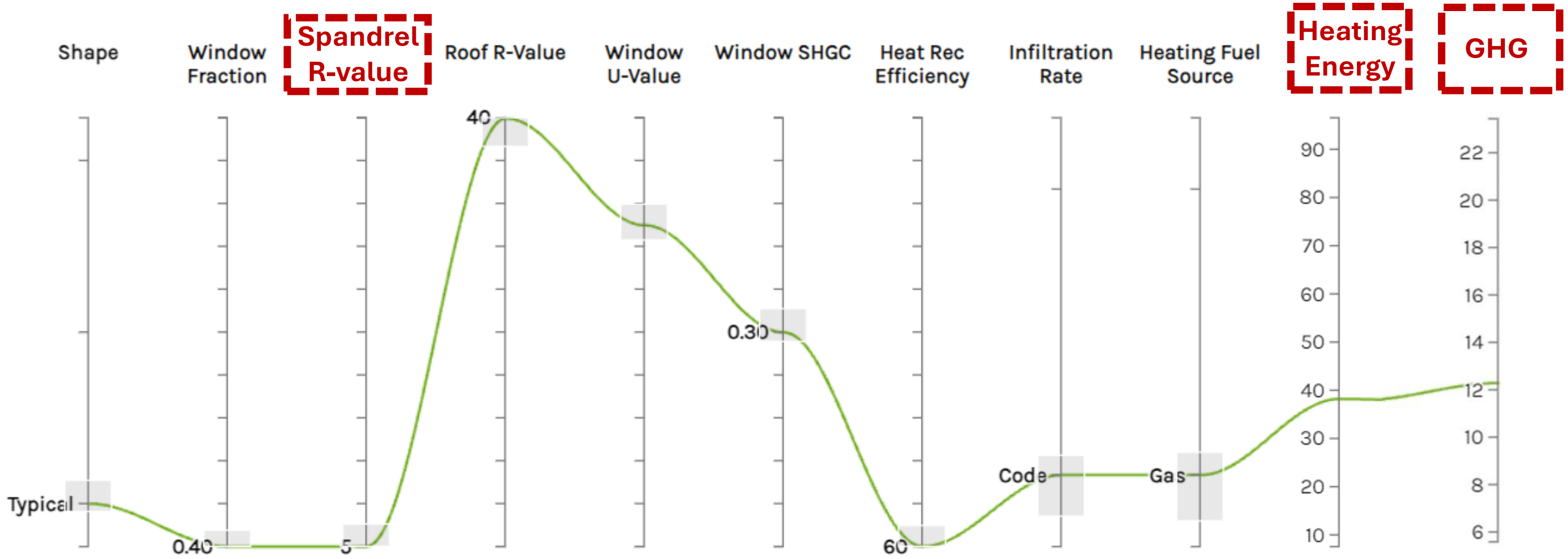


Climate Zone 4

Heating Energy	GHG
31.33	10.96

Impact of 2D NFRC vs. Reality

PathFinder



Climate Zone 4

22% Higher Heating Energy!

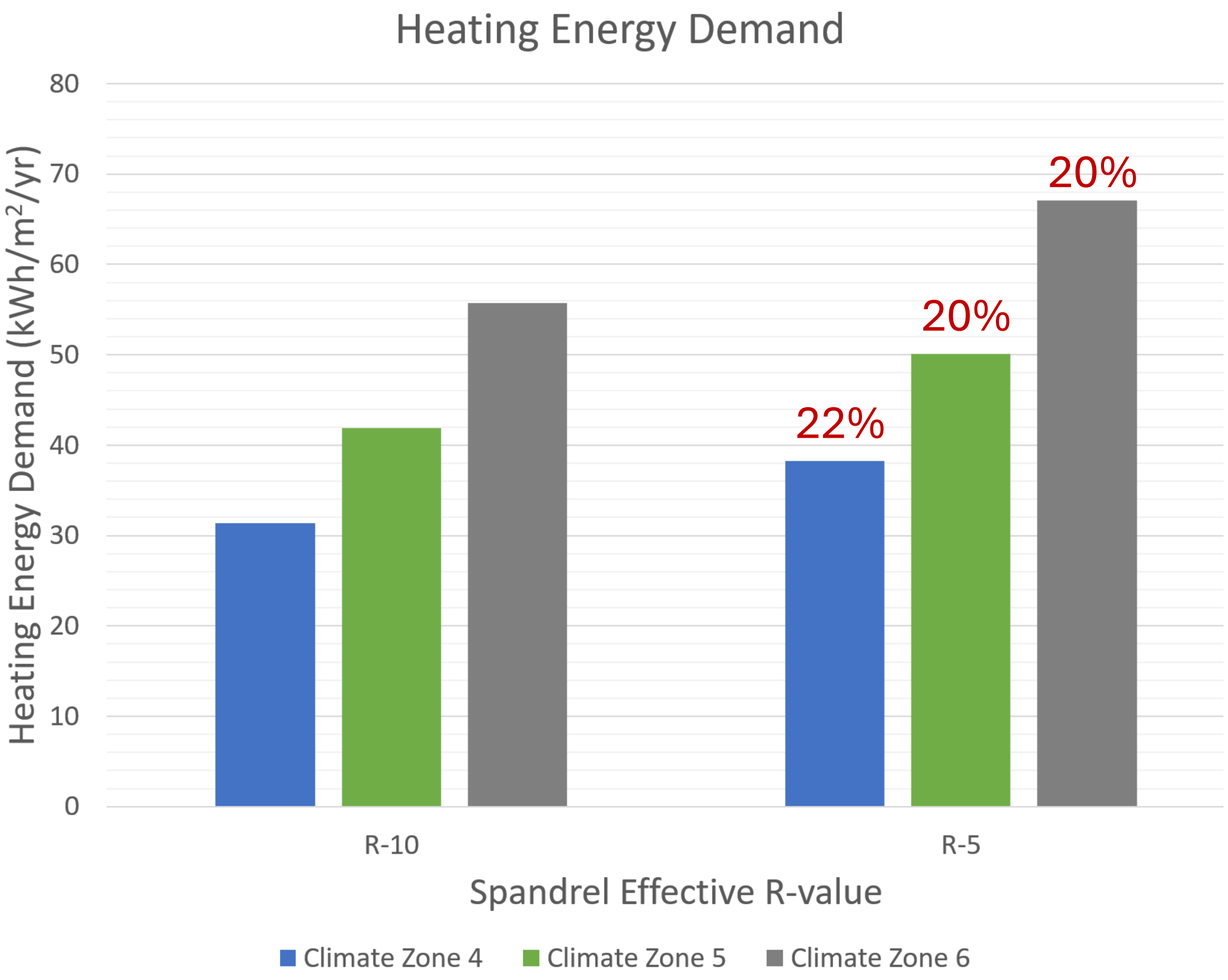
Heating Energy	GHG
38.26	12.29

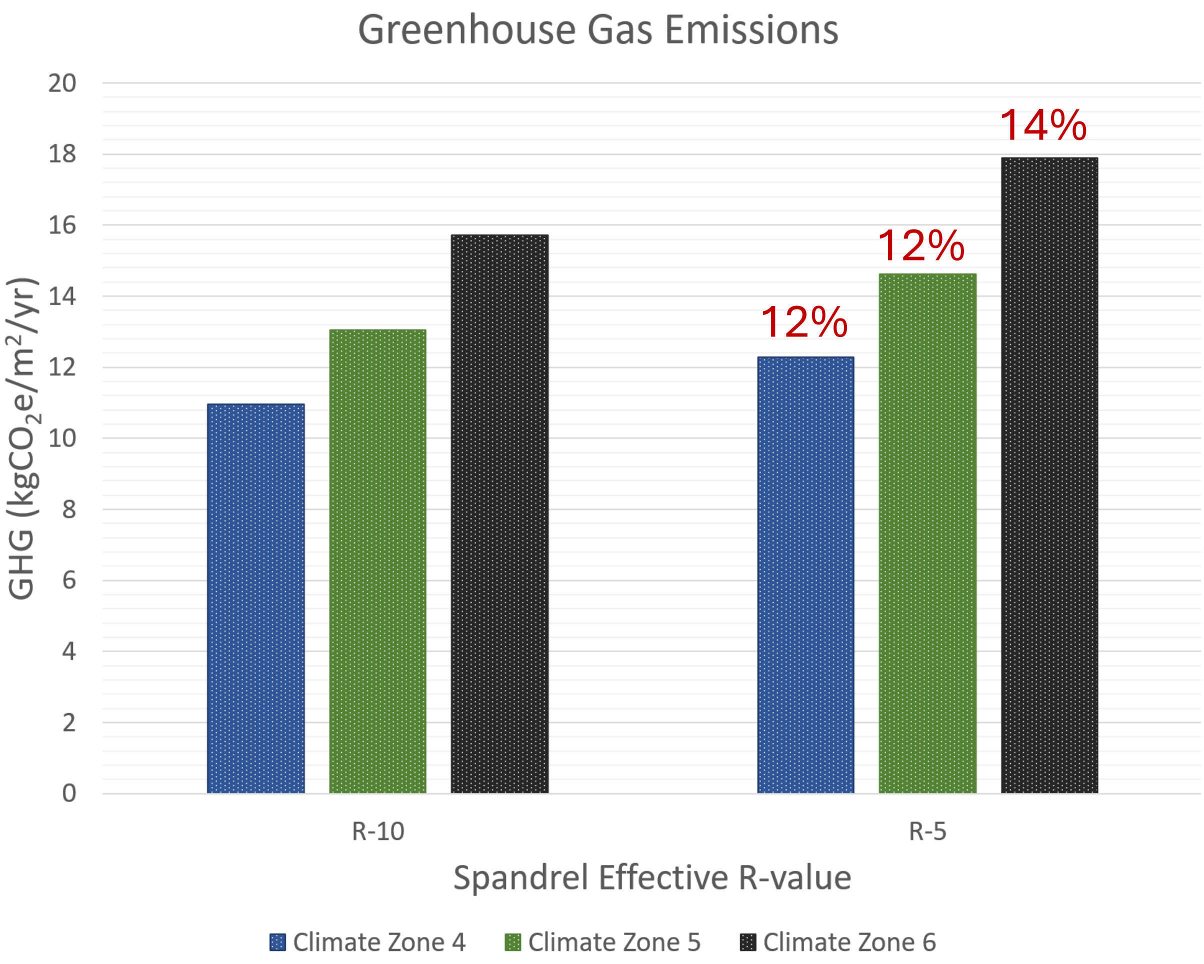
12% Higher Emissions!

Missed objectives

CHARLES PANKOW FOUNDATION
Building Innovation through Research

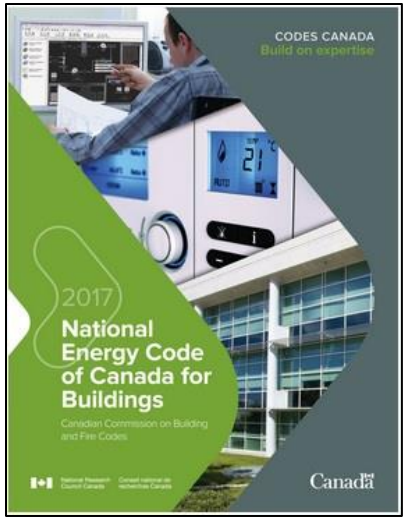
Impact of 2D NFRC vs. Reality

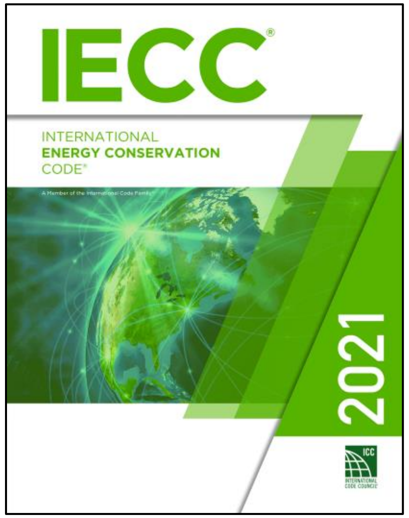


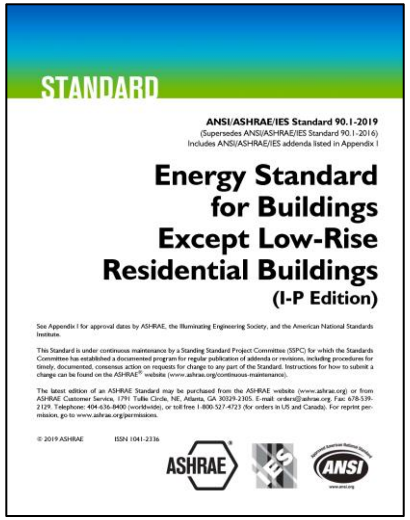


What does the future hold?

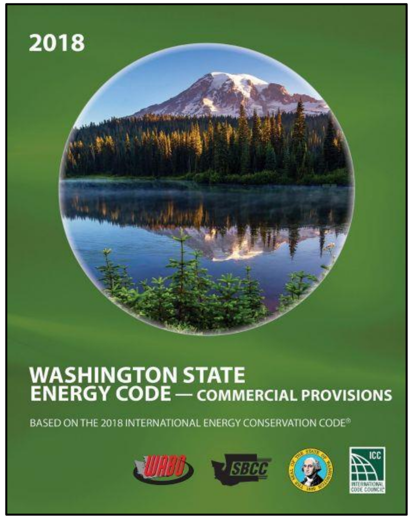
The Ugly

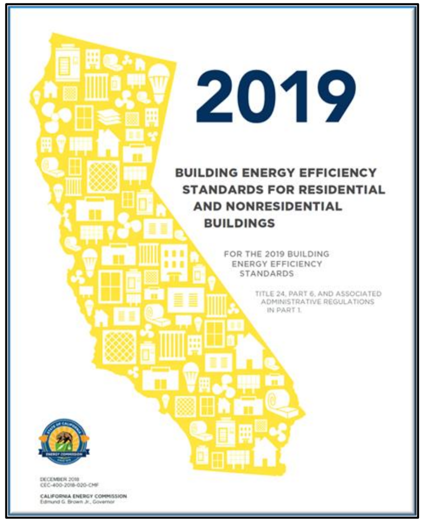


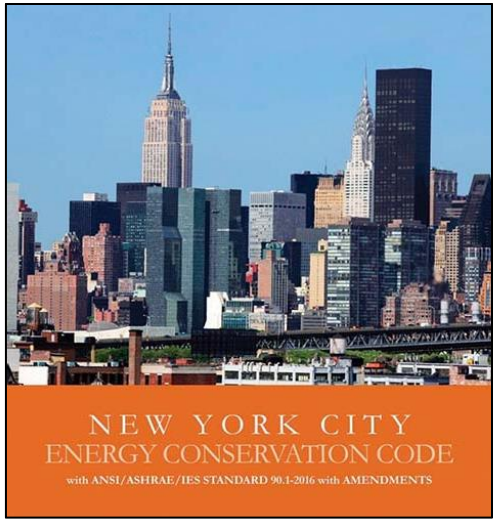


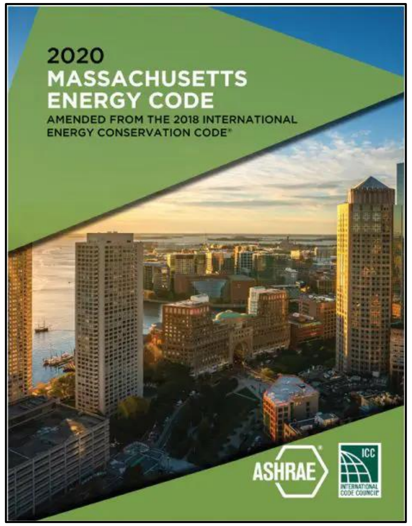


National Level









State Level

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Codes = Confusion

Classification

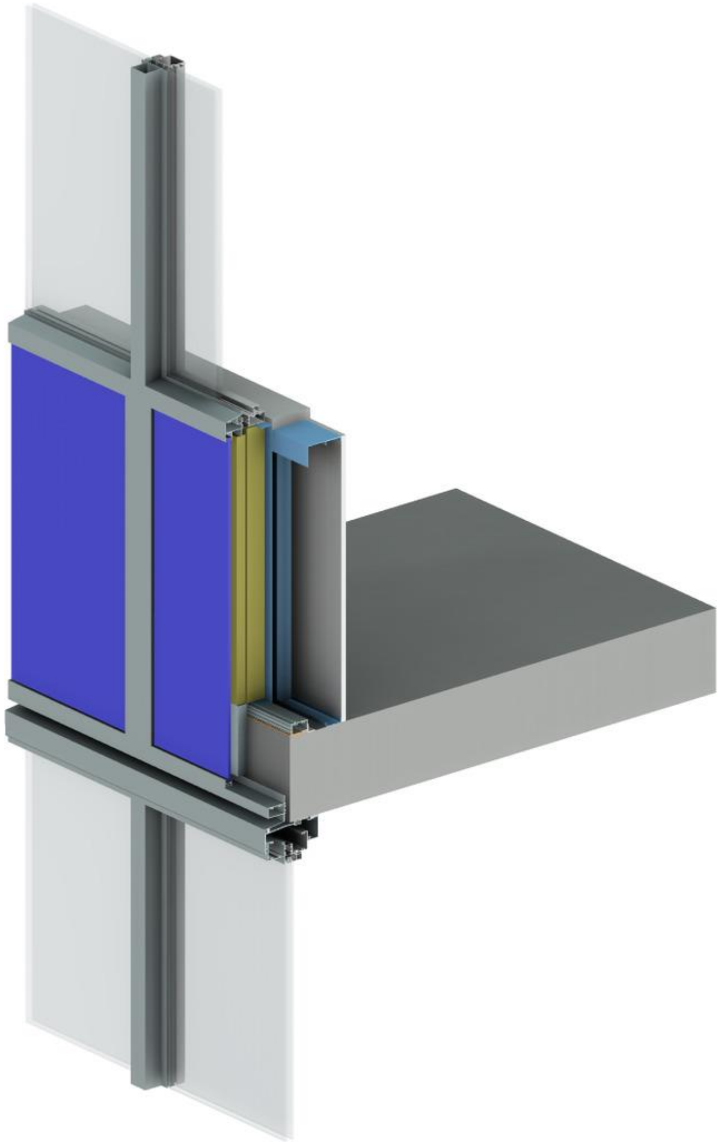
Opaque or Glazed?

Thermal Requirement

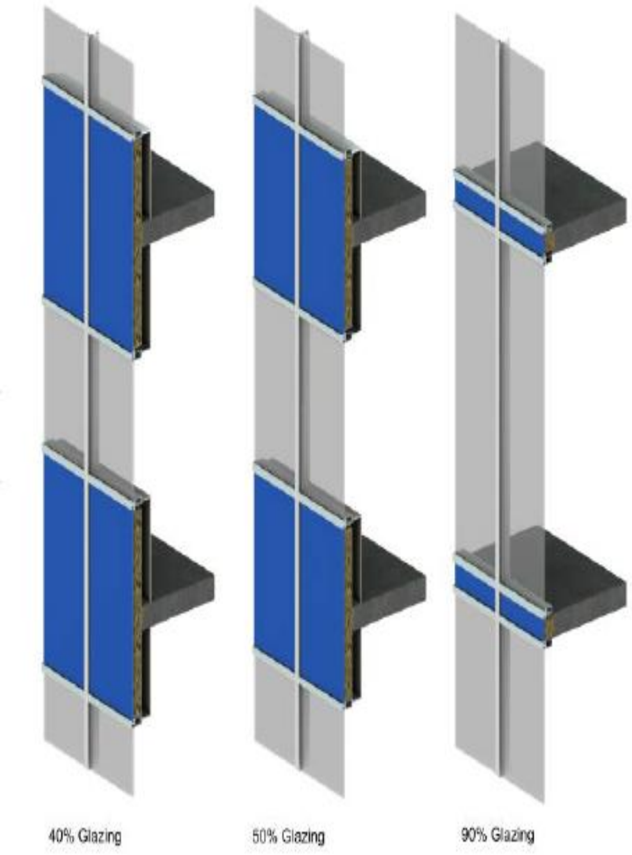
R-11 to R-30?

Calculation Method

Detailed analysis vs.
Tabulated values?



Spandrel Assemblies



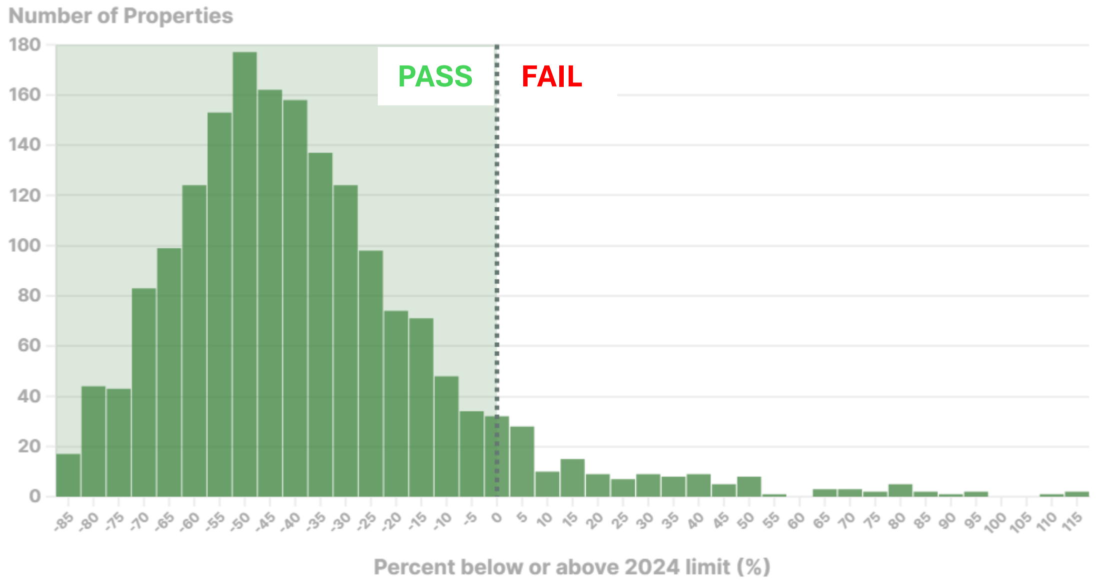
- Current systems = 20% to 40% worse than expected
- Current methods are inaccurate; no consensus on the appropriate method to use
- Thermal performance cannot be verified on-site
- Building energy use is higher than predicted during design, and so are the energy/carbon costs for Owners

How do you properly size AC and heating if you do not understand the performance of your system?

Penalizing Building Owners

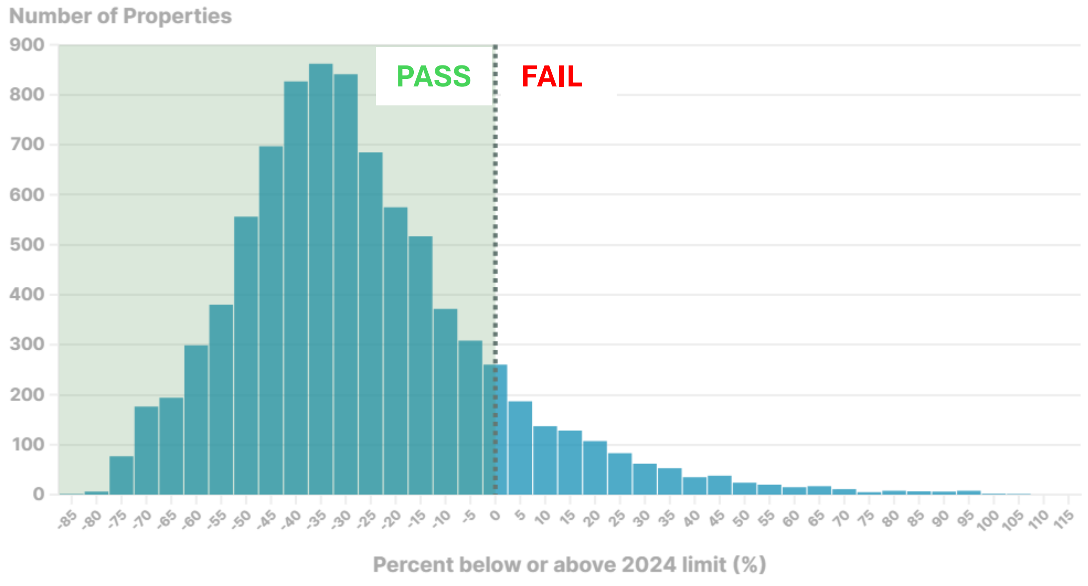
New York City's Local Law 97

Office



Data: LL84 filtered for data quality, emissions, and energy

Multifamily



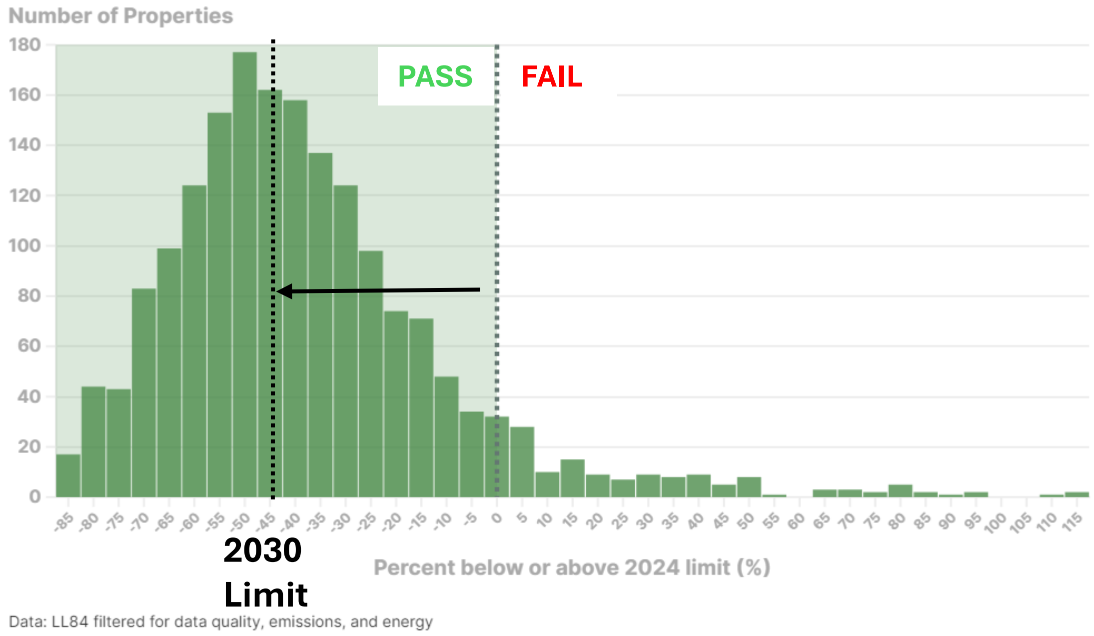
Data: LL84 filtered for data quality, emissions, and energy

CHARLES PANKOW FOUNDATION
Building Innovation through Research

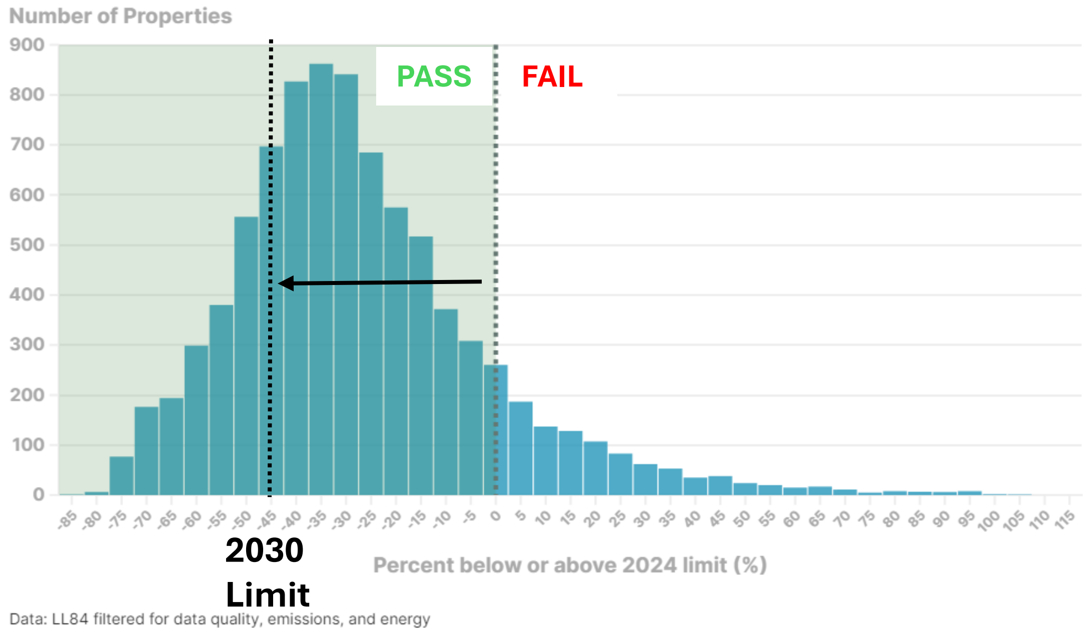
Penalizing Building Owners

New York City's Local Law 97

Office



Multifamily



Annual Fine* = \$268 / CO_2eq

*Assessed based on <u>energy bills NOT modeled energy</u>

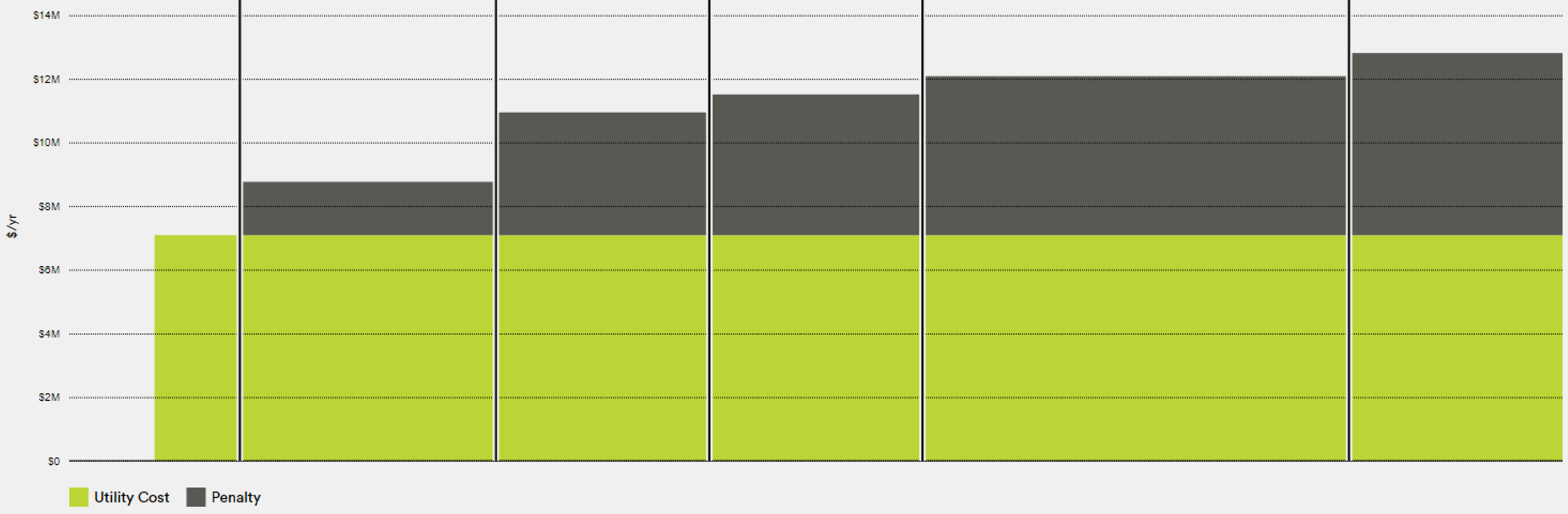
CHARLES PANKOW FOUNDATION
Building Innovation through Research

Penalizing Building Owners

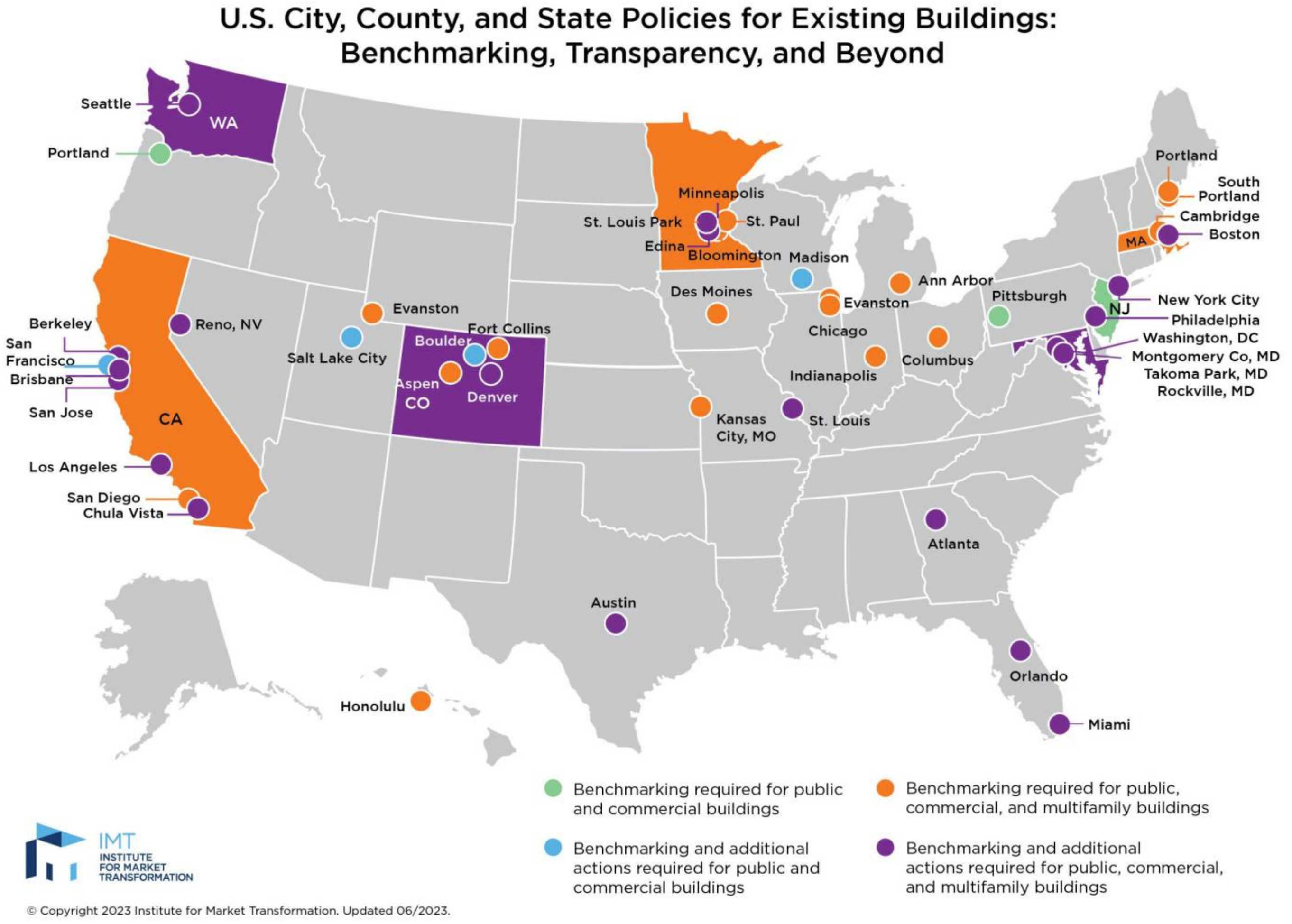
High-rise all curtain wall building in NYC built ~2010
(projected fines based on 2021 utility data)

Annual Cost Summary

	2024-2029	2030-2034	2035-2039	2040-2049	2050-
Utility Cost ($/yr)	$7,087,463	$7,087,463	$7,087,463	$7,087,463	$7,087,463
Est Penalty ($/yr)	$1,671,280	$3,852,136	$4,419,114	$4,994,812	$5,720,478
Total Cost ($/yr)	$8,758,743	$10,939,599	$11,506,576	$12,082,274	$12,807,941

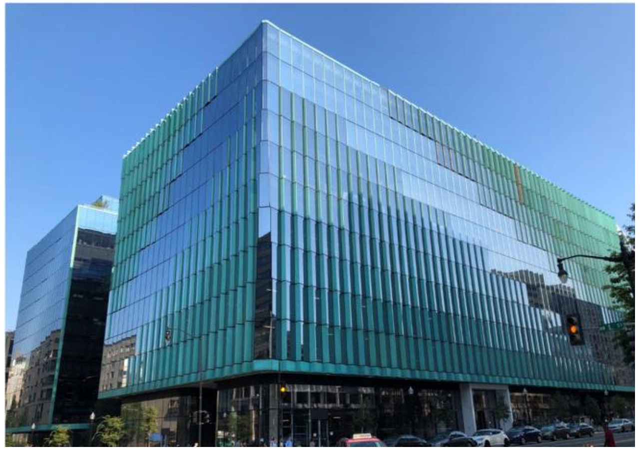


Existing Building Energy Disclosure Policies



Codes ⇆ Design


1960s -1970s

2010s

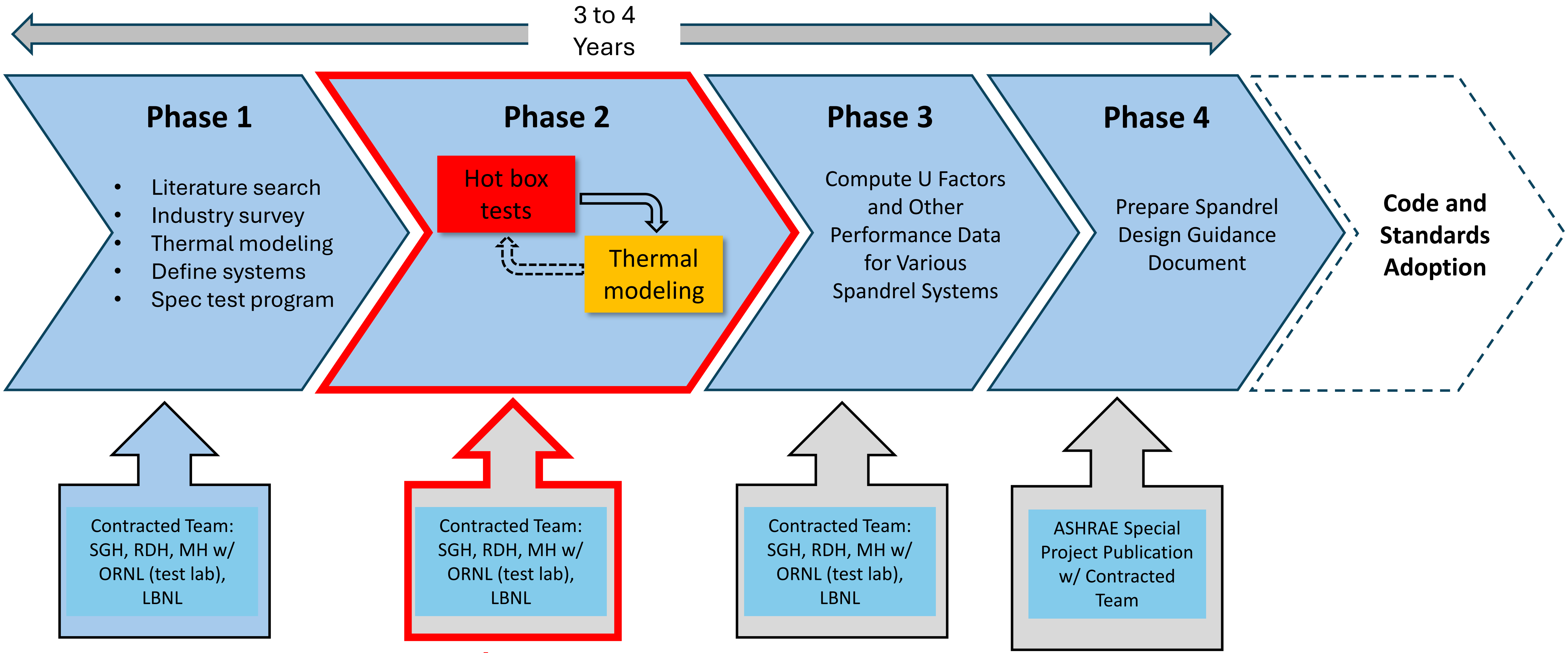
Industry Need

*A **reliable** and **consensus-based** thermal performance calculation **procedure** is required to:*

- *accurately assess current and new innovative spandrel designs.*
- *realize the objectives of the codes.*
- *not penalize well-intentioned Designers/Owners/Developers/Manufacturers.*

Reduce Operational Energy and
Carbon Footprint of Buildings

Research Timeline



Phase 2
Started Summer 2023

CHARLES PANKOW FOUNDATION
Building Innovation through Research

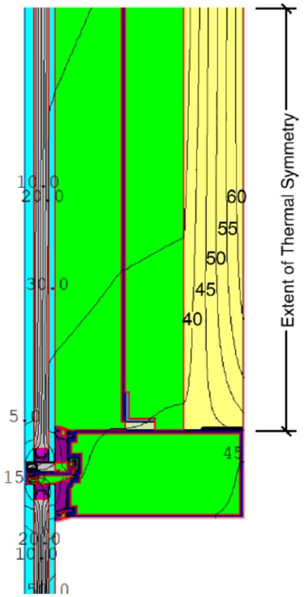
Close the Knowledge Gap

Physical thermal “hot box” testing

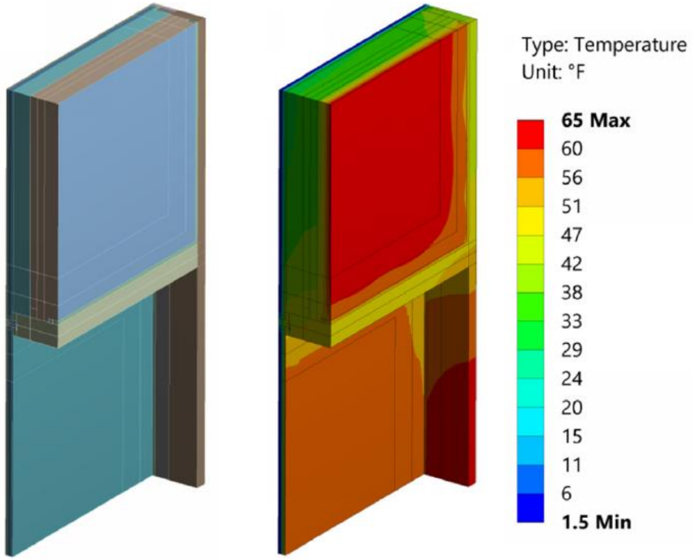
Oak Ridge National Laboratory

Result: detailed data set on heat flow through various components of spandrel assemblies

2-D modeling

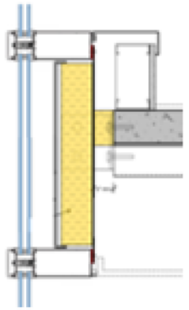
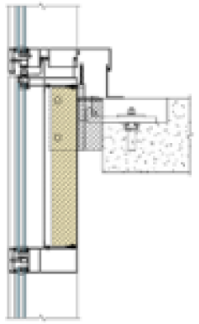
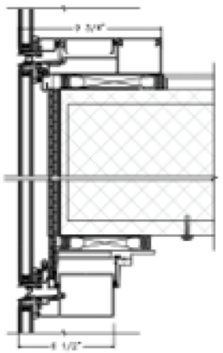
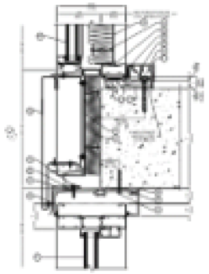
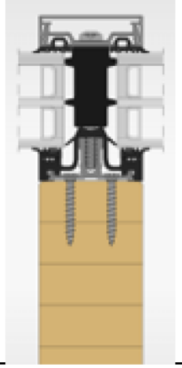
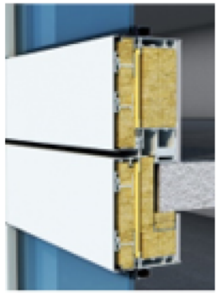


3-D modeling



CHARLES PANKOW FOUNDATION

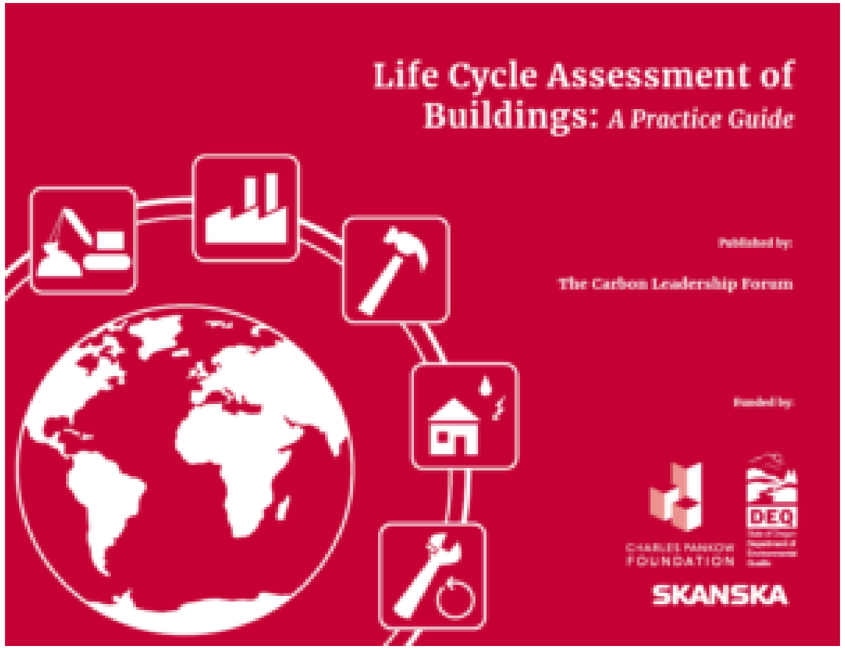
Building Innovation through Research

	**Stick-Built Curtain Wall** • Thermally-broken aluminum captured system • Commonly used in industry • Individual components installed on site		**Unitized Curtain Wall** • Thermally-broken aluminum structural glazed (SSG) system • Commonly used in industry • Prefabricated panels shipped to and assemblies on site
	**Window Wall (US)** • Thermally-broken aluminum captured system • Supported on slab edge, mullion above and below slab • Greater integration with intermediate floor slab, less space available for insulation leading to greater heat loss		**Window Wall (Canadian)** • Thermally-broken aluminum captured system • Significant integration with intermediate floor slab (more than US window wall system) • More space for insulation outboard of slab, but still high heat loss
	**Veneer System** • Captured system with wood or steel mullions • Alternative to typical curtain wall systems with potentially less heat loss • Individual components installed on site		**Nex Generation High Performance System** • Industry state of the art high performance systems • Thermally-broken aluminum systems with insulation (R-40+)

Test Article #1

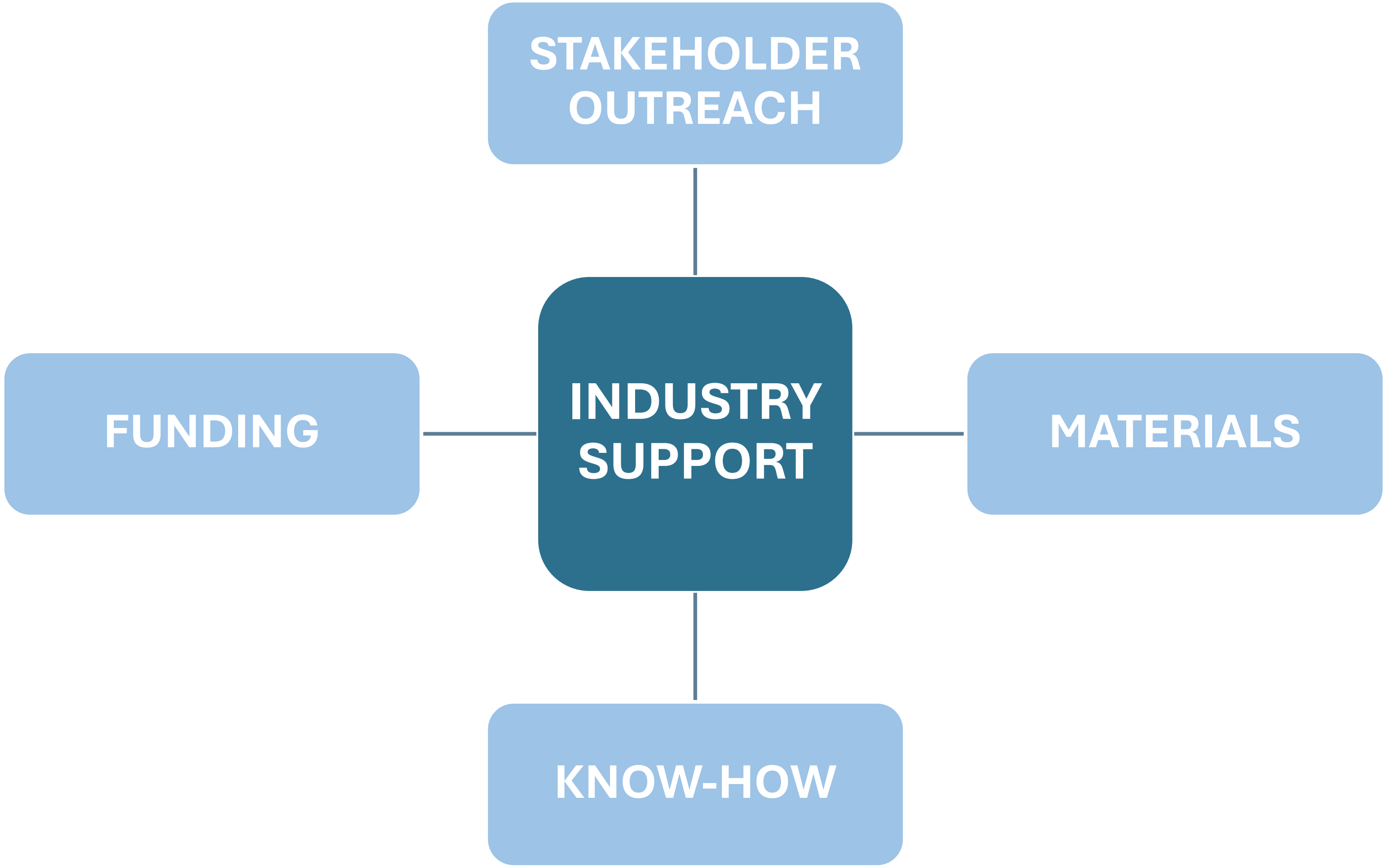
Whole-Life Carbon Study

- Construct whole-building **life cycle assessment models** of archetypal buildings in multiple locations.
- Compare low and high **embodied carbon curtain wall systems** to determine the impacts on global warming potential.
- Construct whole-building **energy models** of the same archetypal buildings in the same locations to determine impacts on **operational carbon emissions**.
- Compare the **carbon "investment" of higher performing spandrel systems** including trade-off between high and low embodied carbon systems on operational carbon.



CHARLES PANKOW FOUNDATION
Building Innovation through Research

Engagement Opportunities



Committed Donations!

TRI STAR
GLASS PRODUCTS

YKK ap®

WJE
ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

PERMASTEELISA
GROUP

NGA
NATIONAL GLASS ASSOCIATION with GANA

DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

Terracon
Consulting Engineers & Scientists

Leadership

- Letter of Support

Sustainable development opportunities

Investment

- Financial Support

Phase 1: Design Test Program

CHARLES PANKOW FOUNDATION

1 – Literature Review

2 – Industry Survey

3 – Current State of Use

4 – 3D CFD Modeling

5 – Test Program


CHARLES PANKOW FOUNDATION
Building Innovation through Research

THERMAL PERFORMANCE OF SPANDREL ASSEMBLIES IN GLAZED WALL SYSTEMS
Charles Pankow Foundation Research Grant RGA #04-22

Phase 1 Report
19 May 2023

PREPARED BY
Morrison Hershfield Corporation
RDH Building Science Inc.
Simpson Gumpertz & Heger Inc.

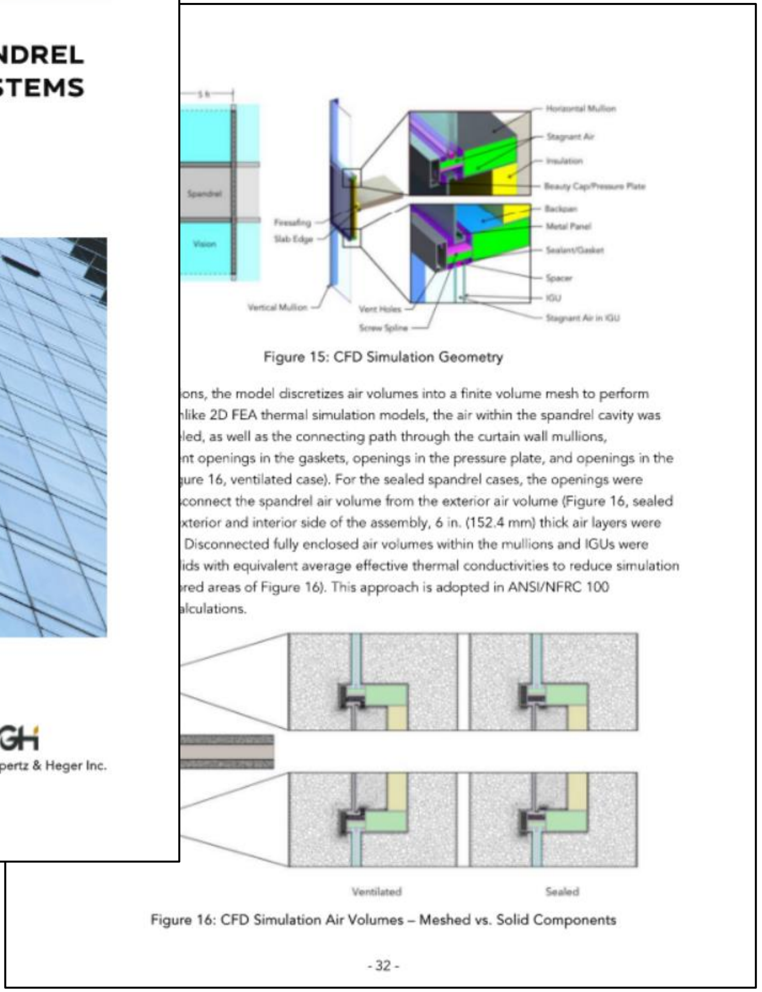


Figure 15: CFD Simulation Geometry

ons, the model discretizes air volumes into a finite volume mesh to perform
nlike 2D FEA thermal simulation models, the air within the spandrel cavity was
led, as well as the connecting path through the curtain wall mullions,
nt openings in the gaskets, openings in the pressure plate, and openings in the
ure 16, ventilated case). For the sealed spandrel cases, the openings were
connect the spandrel air volume from the exterior air volume (Figure 16, sealed
xterior and interior side of the assembly, 6 in. (152.4 mm) thick air layers were
Disconnected fully enclosed air volumes within the mullions and IGUs were
ids with equivalent average effective thermal conductivities to reduce simulation
red areas of Figure 16). This approach is adopted in ANSI/NFRC 100
lculations.

Figure 16: CFD Simulation Air Volumes – Meshed vs. Solid Components

- 32 -

Phase 1: Design Test Program

CHARLES PANKOW FOUNDATION

1 – Literature Review

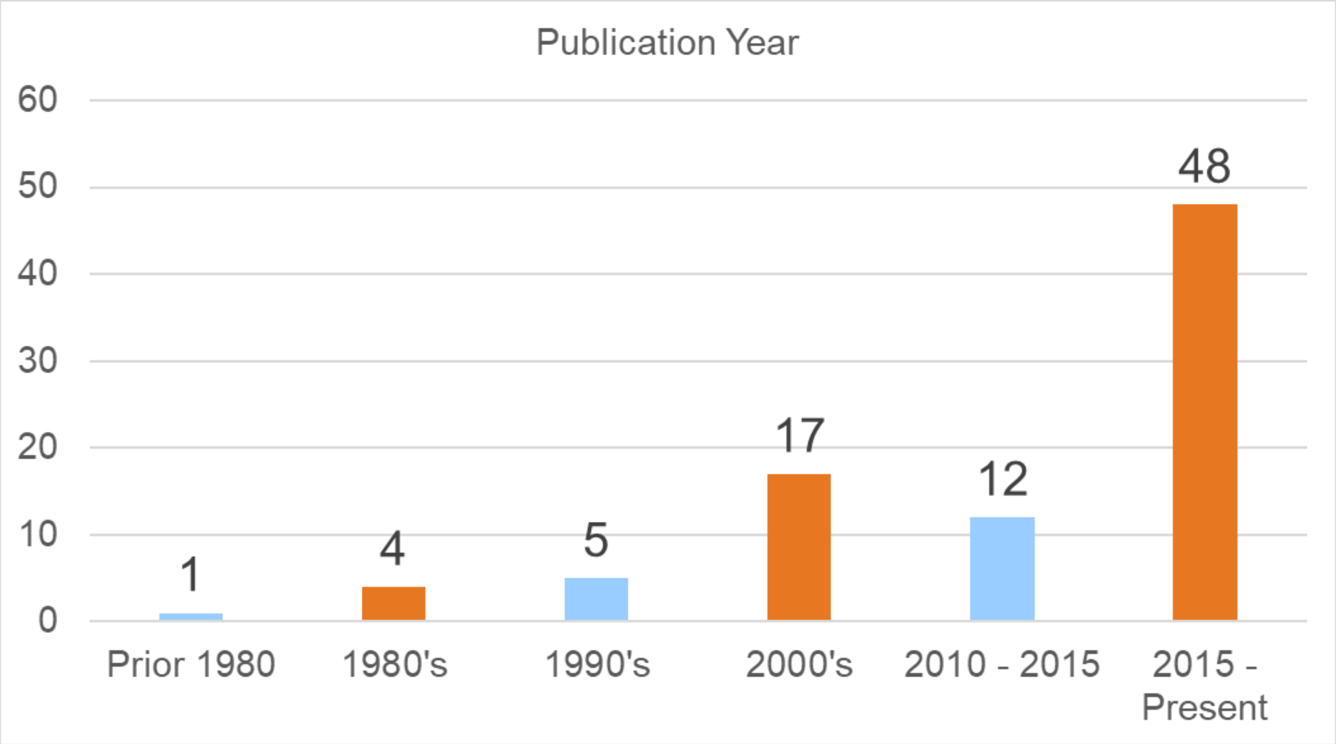
2 – Industry Survey

3 – Current State of Use

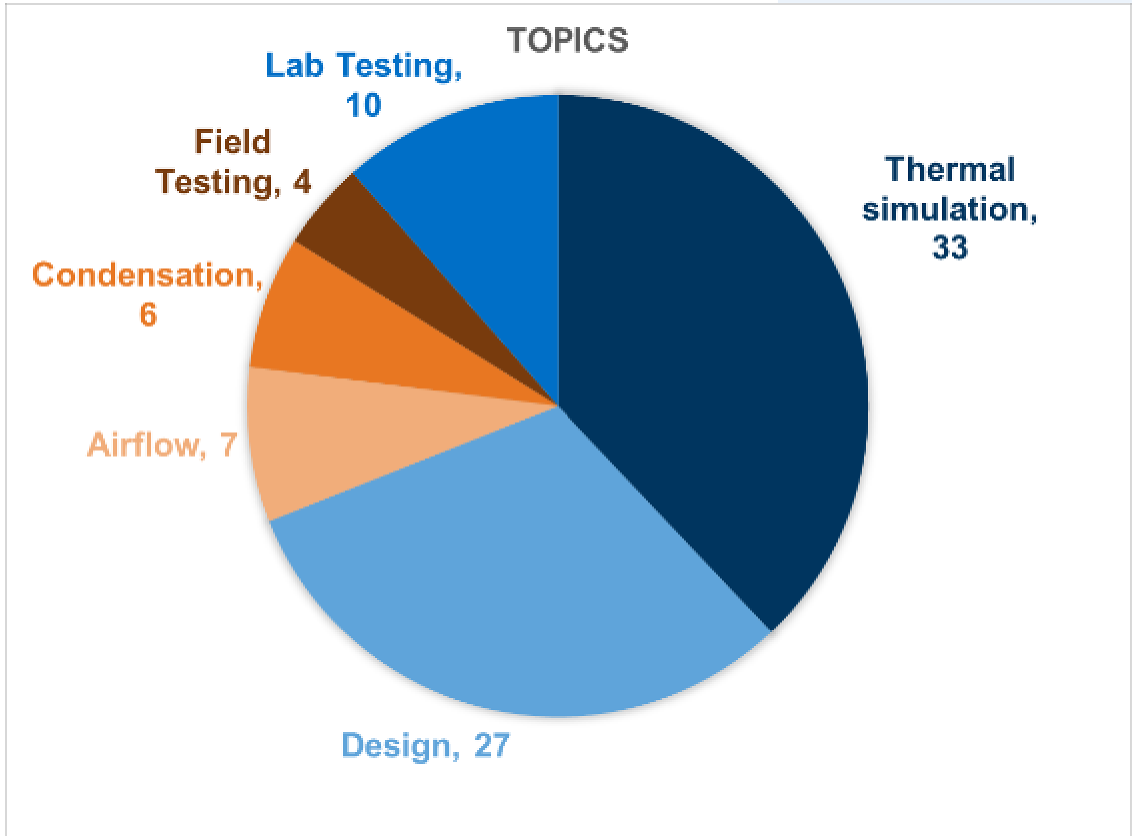
4 – 3D CFD Modeling

5 – Test Program

Literature Review



Breakdown of Reviewed Documents by Publication Year



Breakdown of Reviewed Documents by Topic

Literature Review – Gaps in Literature

- What are the impacts of contact resistance of components on thermal performance?
- How does size and configuration impact spandrel thermal performance?
- What are the impacts of various spandrel components on thermal performance?
- What is the impact of adjacent assemblies on spandrel thermal performance?
- How can the accuracy of 2D thermal simulation methods when compared to physical test results be improved?
- What is the accuracy of current industry standards and guidelines on simulating thermal performance compared to physical testing?