Building Energy Education | architects

Passive House High Performance Design

5.19.2022

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Providing effective energy strategies for buildings and communities

ICC Preferred Provider # 2396
ICC Course # 32260

AIA Illinois

ILLINOIS GREEN
A USGBC COMMUNITY

Stacey Pfingsten
Executive Vice President

Brian Imus
Executive Director

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Presenters:

Grant Mosey

Ryan Siegel

Presentation Education Credits

SEDAC is a Preferred Education Provider with the International Code Council (ICC). Credits earned on completion of this program will be reported to ICC for ICC members. Certificates of Completion will be issued to all participants.

ICC PREFERRED EDUCATION PROVIDER

This workshop is approved for 1.5 LU/HSW CES credits from the American Institute of Architects (AIA). Credits earned on completion will be reported for AIA members.

AIA Continuing Education Provider

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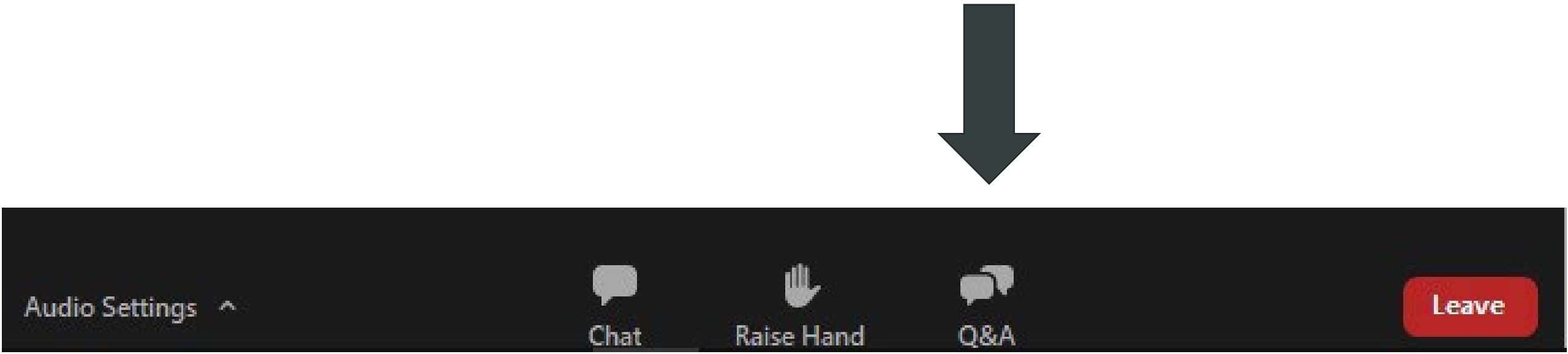
Questions



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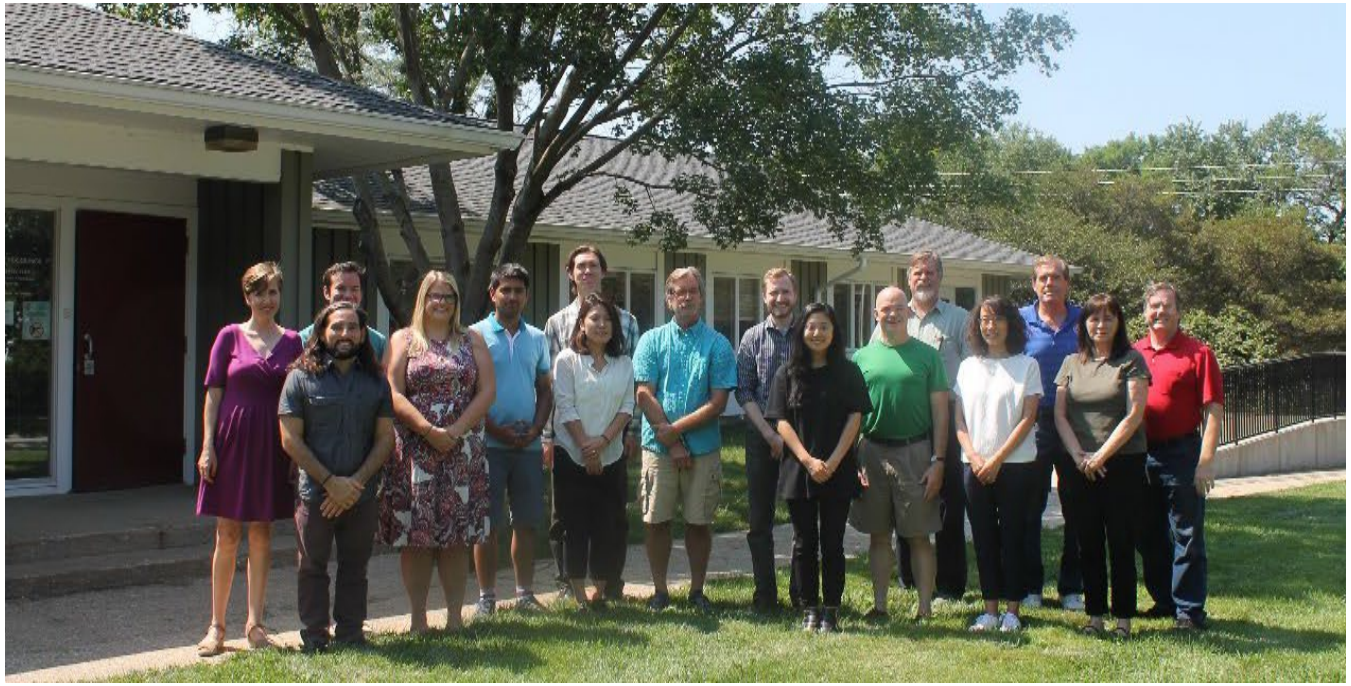
Who We Are

The Smart Energy Design Assistance Center (SEDAC) is an applied research program at University of Illinois.

Our mission: Reduce the energy footprint of Illinois and beyond.



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Building Energy Education | architects

Energy efficiency basics + advanced topics
Take your designs to the next level!

Building Energy Education Fundamentals

Renewables & Zero Code

Passive House

Training delivered by the University of Illinois Smart Energy Design Assistance Center (SEDAC) in partnership with the American Institute of Architects Illinois and the Illinois Green Alliance.

Webinars | Workshops | Online Modules

Resources | Technical Support

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https://learn.smartenergy.illinois.edu/
https://smartenergy.illinois.edu/bee_fundamentals/

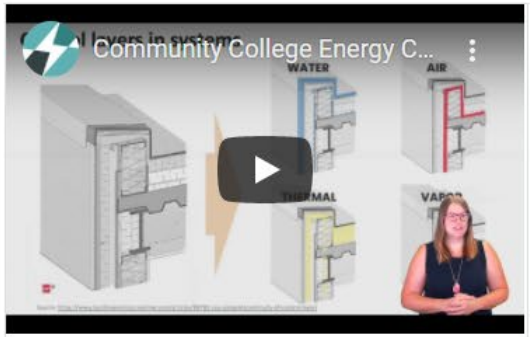
Building Energy Education | fundamentals

SEDAC's Building Energy Education (BEE) Fundamentals program offers **free** online energy code training that can be accessed anytime, anywhere. There is growing demand for skilled workers who know how to make buildings energy efficient. Today's professionals need training on energy efficiency best practices and how to meet energy code requirements for new and existing buildings. Join us for an exciting opportunity to bring energy code and building science basics to your students!

Check out our **Q&A**.

Intro Modules

1. Energy Efficiency Careers & Pathways
2. Building Energy Fundamentals
3. Introduction to Energy Codes & Standards
4. Navigating Energy Codes & Standards



Envelope Modules

5. Envelope & Insulation Fundamentals
6. Walls & Openings
7. Roofs & Ceilings
8. Foundations & Floors

Mechanical & Electrical Modules

9. Mechanical Equipment Sizing
10. Duct Design & Installation
11. Mechanical Ventilation
12. Lighting

Advanced Modules

13. Beyond Code
14. Net Zero Buildings
15. Existing Building Renovations

SEDAC Program Contacts

- Technical support

  energycode@illinois.edu

  800.214.7954
- Online resources at smartenergy.illinois.edu/
  - Blog Posts on current issues in efficiency and sustainability
  - Energy Smart Tips
  - Technical Notes

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smartenergy.Illinois.edu/energy-code/

TRAINING AND SUPPORT SERVICES

Workshops

Webinars

Online courses

Technical support

ENERGY CODE RESOURCES

What is the Illinois Energy Conservation Code?

Illinois Stretch Code

Frequently asked questions

Useful websites

Energy code smart tips

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SEDAC Building Energy Resources

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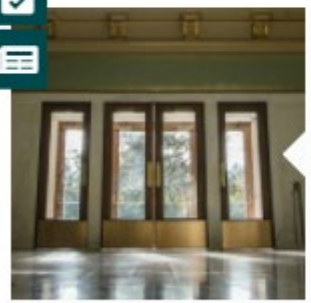
Energy Efficiency Basics

Home › Energy Efficiency Basics

A very good place to start



Opinion
Efficien
Importa

April 10,

By Patrick
Program
Working
energy ef
makes se
than ever

Top 10

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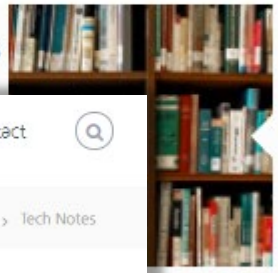
Facility Smart Tips

Home › Facility Smart Tips

Energy efficiency opportunities for specific facility types

Energy Smart Tips
for Wastewater



Libraries

May 11, 2017

This Smart Tip highlights SEDAC's most commonly recommended energy cost reduction measures for libraries. Libraries model sustainability by

as

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Tech Notes

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Energy saving technologies and strategies

Domestic Hot Water Recirculation

February 4, 2021

Can Domestic Hot Water Recirculation Systems Conserve Energy? The US Department of Energy estimates that more than 400 billion gallons [···]

Best Practices for Building Operations During COVID-19

July 13, 2020

Our understanding of how the coronavirus spreads is evolving at a rapid rate. What does this mean for HVAC systems [···]

COVID-19 and HVAC

Cleaning Condensing Units

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Learning Objectives

1. Develop knowledge of history and general principles of Passive House Institute
2. Discern the use cases for the Passive House Product Certification System
3. Comprehend the PHIUS certification process
4. Recognize analysis tools and supporting guides for passive building implementation

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History and Principles of Passive House

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Passivhaus vs Passive House

- Passivhaus is the original German high-performance home construction program founded in 1990's
- Passive House Institute US founded in 2003
  - First US Passive House was built in Urbana in 2012
- Climate-specific standards defined in 2015, updated on 3yr cycles

Image source: phius.org

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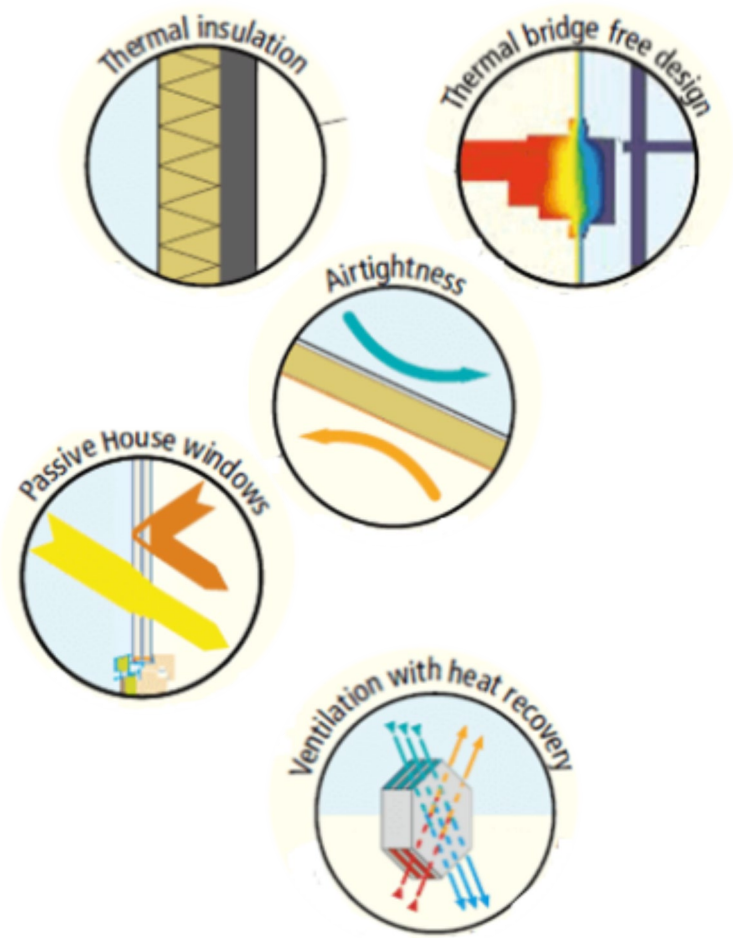
Core Principles of Passive House Design

- Thermal Control – build a tight, well-insulated envelope with no thermal bridges
- Air Control – provide a tight envelope coupled with balanced mechanical ventilation
- Radiation Control – Accept warm sunlight in winter, provide shade in the summer, and make use of daylighting
- Moisture Control – proper vapor and bulk water barriers, drying capability and interior humidity control

PHI Core Principles



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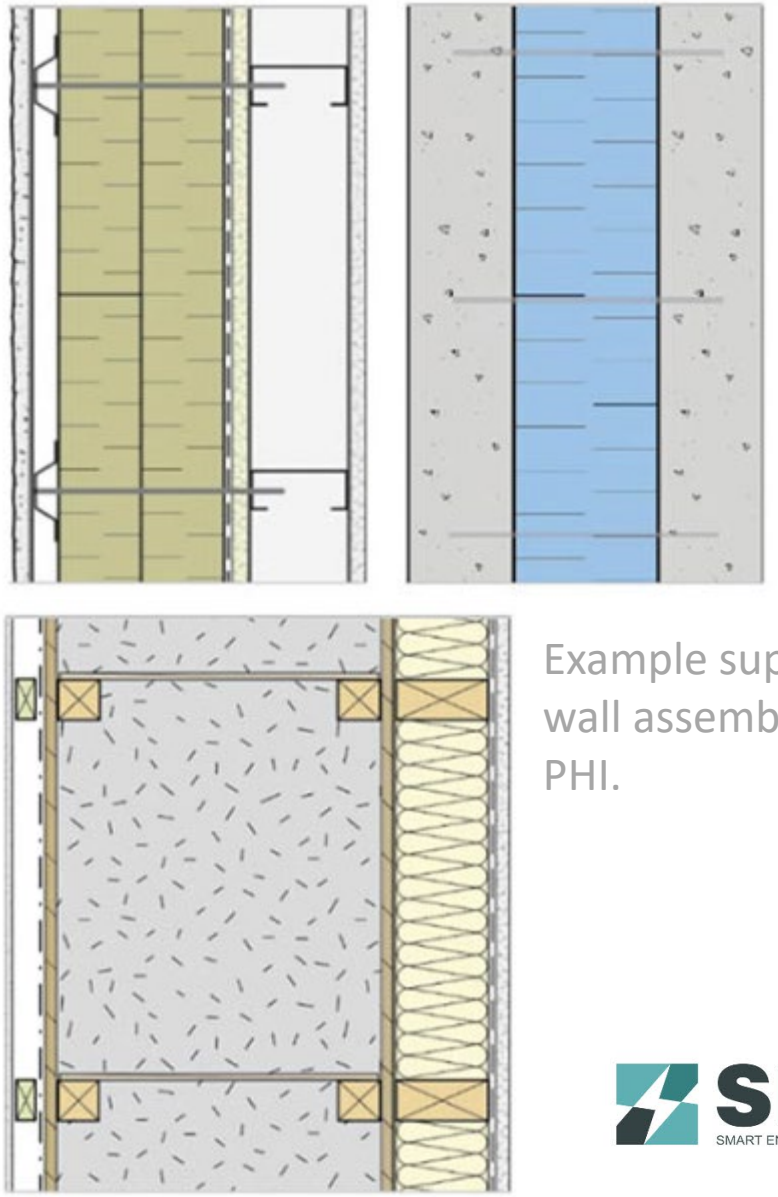
PHIUS – Thermal Control

Key Focus Points

- Add more, higher-quality insulation
- Better envelope performance ensures resiliency
- Avoid thermal bridging where possible

Insulation levels usually 2-3x's code minimum levels

Non-energy benefits of soundproofing, durability, and resiliency



Example super-insulated wall assemblies, courtesy PHI.

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PHIUS – Air-Tight Construction

Key Focus Points

- Ensure proper detailing of control layers
- Avoid switching between interior and exterior air control layers
- Field verification of air tightness required

Preventing uncontrolled leakage cuts heat loss/gain

Added benefits of improved humidity control, improved durability, and soundproofing

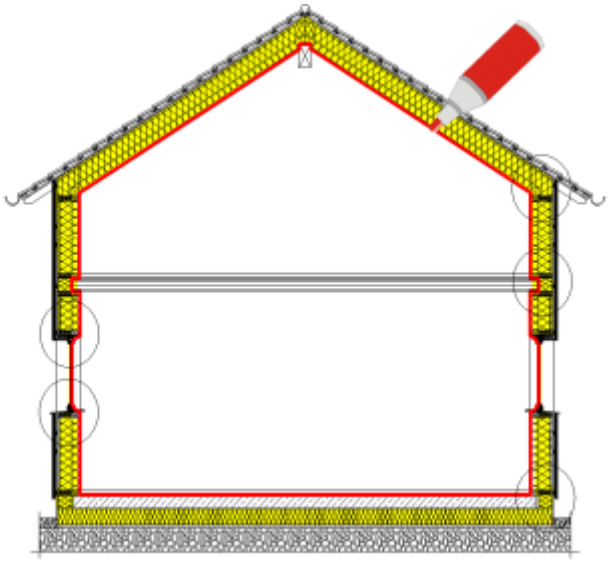

Image source: passipedia.org

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PHIUS – Radiation Control

Key Focus Points

- Use best-in-class fenestration and doors
- If using passive solar, pair with thermal massing
- Balance solar heat gain with heat losses through area and orientation of windows

Windows are the weakest part of an insulated envelope

Surface temperature/condensation risk is main concern in winter

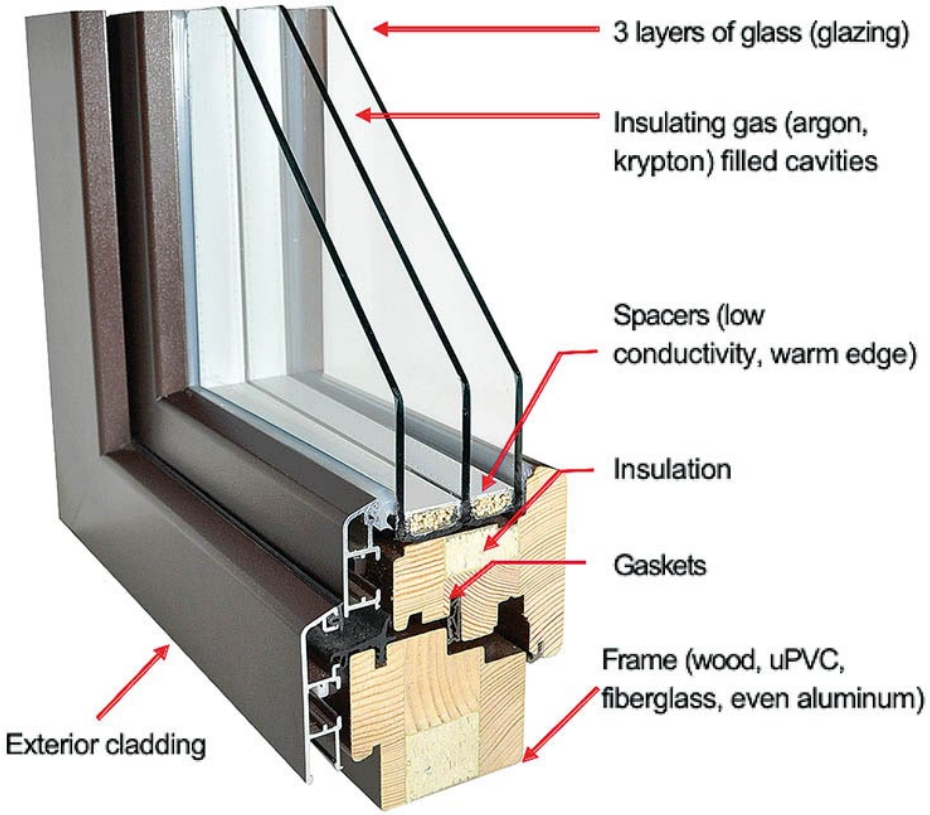

Image source: passivehouseaccelerator.com

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PHIUS – Balanced Ventilation

Key Focus Points

- Energy recovery
- Maintain indoor air quality
- Balanced exhaust and supply

Super-insulated, air-tight envelope restricts natural ventilation

Downsizes capacity of heating and cooling systems

Without heat recovery, fresh air would be dominant load in Passive Houses

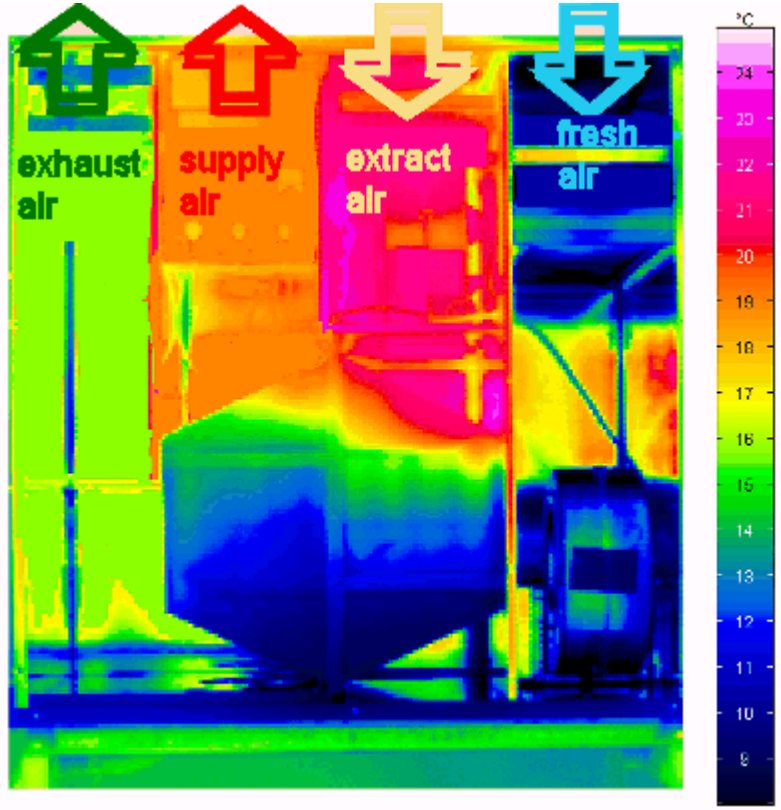

Image source: passipedia.org

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Passive House Product Certification

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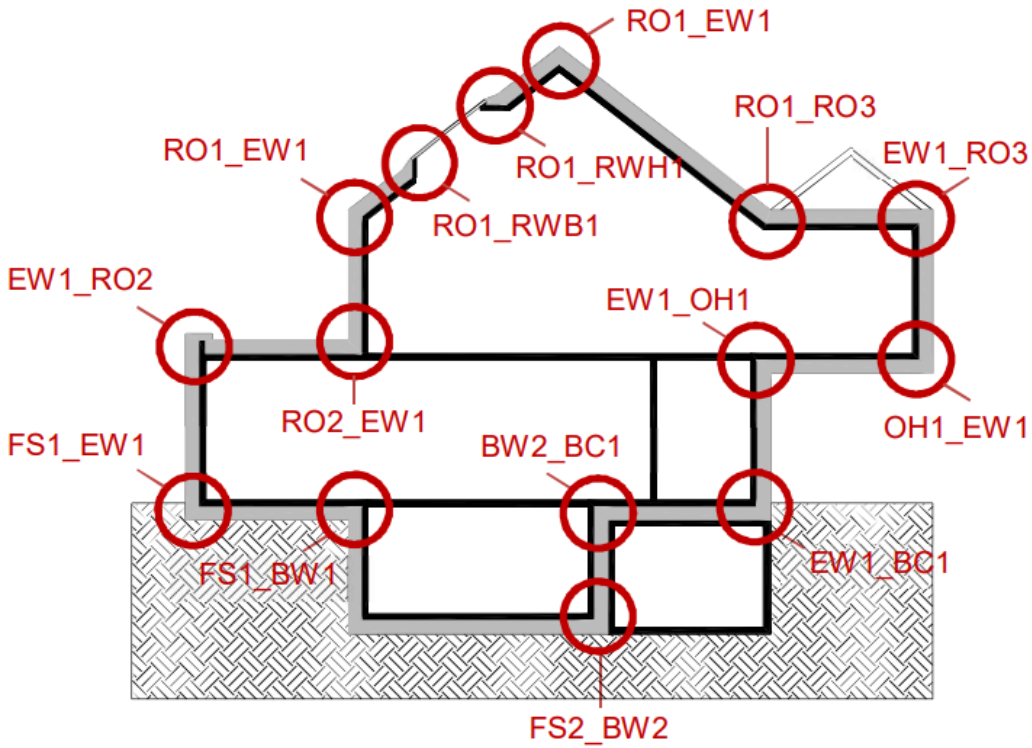
Passive House Certified Products

- Opaque Systems (wall, roof, foundation, floor)
- Windows
- Envelope Penetrations (doors, attic hatches)
- Recovery Ventilation Systems
- Heat Pumps (Germany only)

PHIUS Certified Opaque Systems

- Rates applicability of system to climate zone based on U-factor requirements
- Shows interior temperature of surfaces will remain above condensation temperature
- Shows assembly will not generate and hold interstitial moisture
- Must demonstrate air-tight detailing in drawings



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PHIUS Window Certification Factors

Climate Zone	Hygiene Criterion	Comfort Criterion	Efficiency Criteria			Moisture Criteria	
Criteria	$f_{Rsi=0.25} \geq$	Window U-value	Component $U*f_{R,\ PHI} \leq$	$f_{Rsi=0.25} \geq$	thermal bridge $\Psi \leq$	Condensation Evaporation	Max Accumulated Moisture Limit
Units	N/A	W/m^2K	W/m^2K	N/A	W/mK	N/A	g/m^2
4	0.65	1.05	0.25	0.82	0.010	by end of 12 months	200
5	0.55	1.25	0.50	0.74			

$$f_{Rsi=0.25} = \frac{\text{(minimum calc inside temperature-outside temperature)}}{\text{(inside-outside temperature)}} \quad (°C)$$

Converting Rsi to hr-sf-F/Btu: R-value = 5.678 * Rsi
Converting Usi to Btu/hr-sf-F: U-value = Usi/5.678

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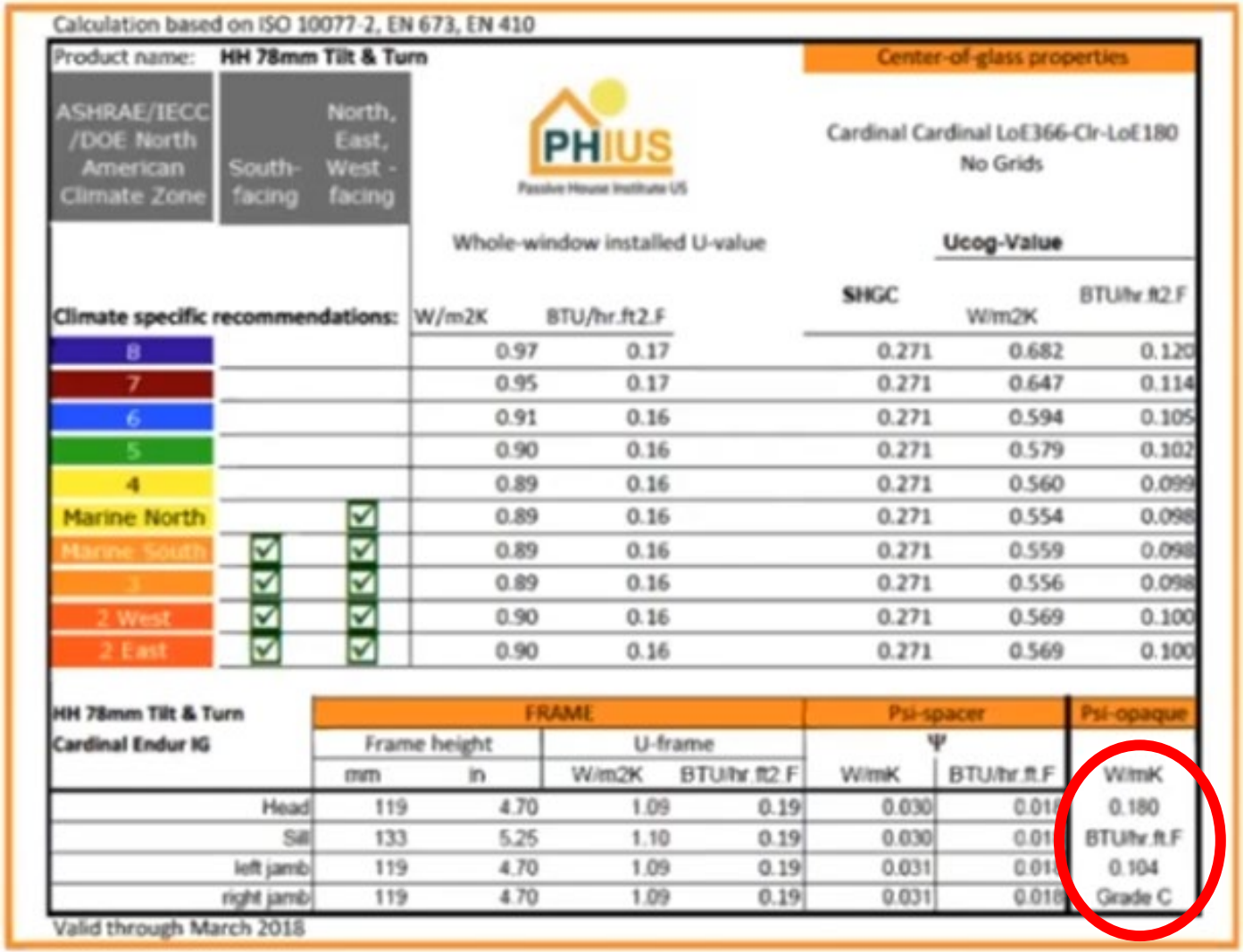
Certified Windows

- Certification provides climate zone-specific U-factors
- Ranks window applicability to climate zones
- Verifies window installation won't result in condensation
  - Must be at least Grade C for certification
- Easy reference for contractors



Calculation based on ISO 10077-2, EN 673, EN 410

Product name: **HH 78mm Tilt & Turn**

Center-of-glass properties: Cardinal Cardinal LoE366-Clr-LoE180, No Grids

PHIUS Passive House Institute US

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	Whole-window installed U-value BTU/hr.ft2.F	Ucog-Value SHGC	Ucog-Value W/m2K	Ucog-Value BTU/hr.ft2.F
Climate specific recommendations:							
8			0.97	0.17	0.271	0.682	0.120
7			0.95	0.17	0.271	0.647	0.114
6			0.91	0.16	0.271	0.594	0.105
5			0.90	0.16	0.271	0.579	0.102
4			0.89	0.16	0.271	0.560	0.099
Marine North		☑	0.89	0.16	0.271	0.554	0.098
Marine South	☑	☑	0.89	0.16	0.271	0.559	0.098
3	☑	☑	0.89	0.16	0.271	0.556	0.098
2 West	☑	☑	0.90	0.16	0.271	0.569	0.100
2 East	☑	☑	0.90	0.16	0.271	0.569	0.100

HH 78mm Tilt & Turn **Cardinal Endur IG**	FRAME: Frame height mm	Frame height in	U-frame W/m2K	U-frame BTU/hr.ft2.F	Psi-spacer Ψ W/mK	Psi-spacer Ψ BTU/hr.ft.F	Psi-opaque W/mK
Head	119	4.70	1.09	0.19	0.030	0.01[illegible]	0.180
Sill	133	5.25	1.10	0.19	0.030	0.01[illegible]	BTU/hr.ft.F
left jamb	119	4.70	1.09	0.19	0.031	0.01[illegible]	0.104
right jamb	119	4.70	1.09	0.19	0.031	0.01[illegible]	Grade C

Valid through March 2018

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Certified Opaque Systems

- Program verifies systems have low moisture risk (proper vapor control)
- Ensures panels have appropriate air, water, water vapor, and thermal control layers
- Minimal level of pest control/resistance is required
- Ensure different panel systems are appropriately joined for continuous barriers
- Verifies minimal thermal bridging

Image source: phius.org

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Certified Panel Sample Certificate

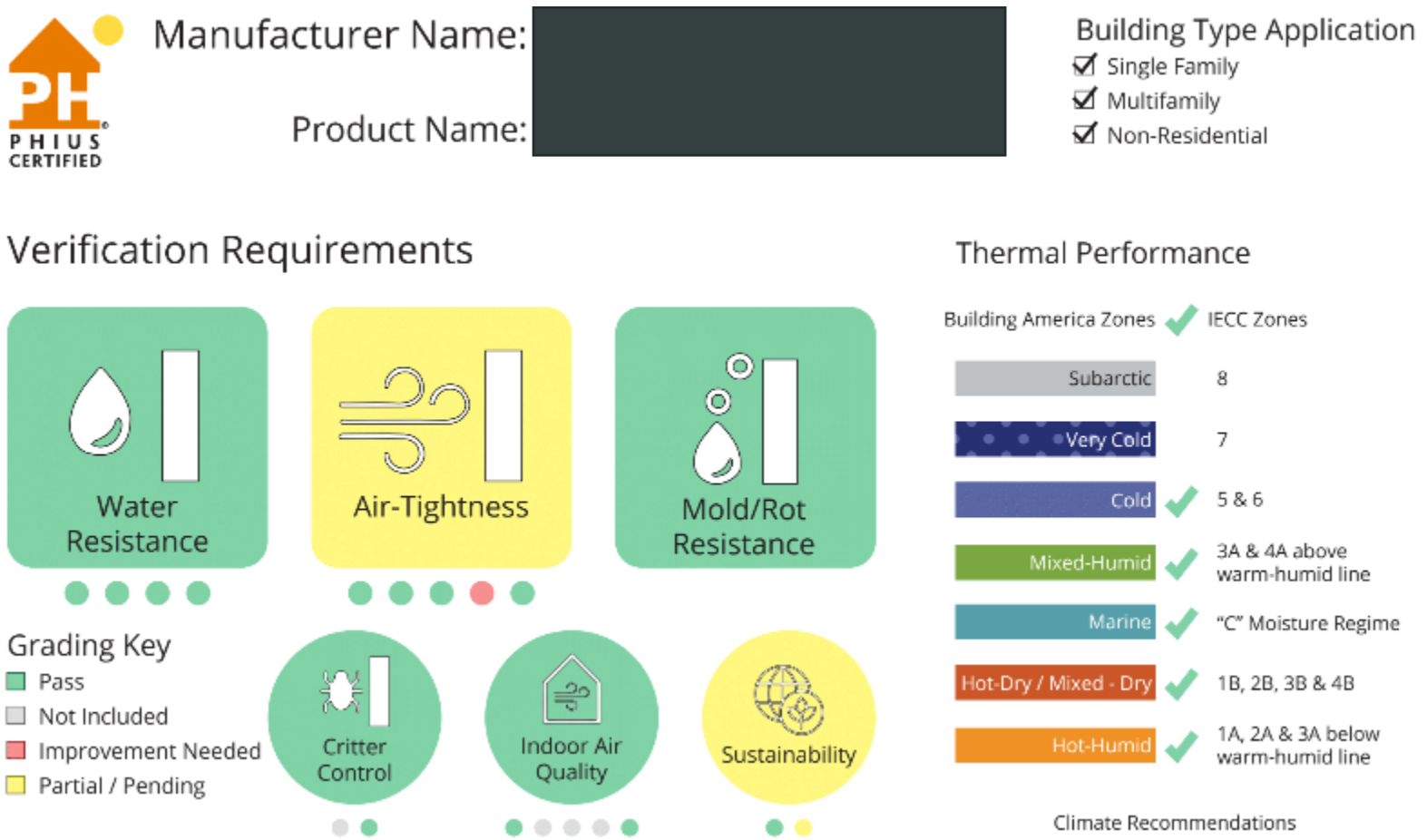

Image source: phius.org

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ERV Systems Certification

Certification Criteria	Required Specification
Speed control within 3 ranges	54% (set-back), 77% (normal) and 100% (boost)
Unit air tightness	No more than 3% leakage internally and externally to ERV
Recovery efficiency	@100 Pa, no less than 75% energy recovery between 32F and 50F
Power requirements	Stand-by energy of no more than 1W Fan energy of no more than 0.765W/CFM (frost protection disabled)
Sound limitations	No more than 25 dB(A) in occupied space. Unit can be up to 35 dB(A) if isolated and noise in space is no more than 25 dB(A)
Frost protection	Guarantee 12hr protection of exchanger @ 5F outdoor air using pre-heat coil Shutdown of post-heat hydronic coils if unit fails and outdoor air is <41F
Comfort ensured	Discharge no less than 62F when outdoor air @ 14F

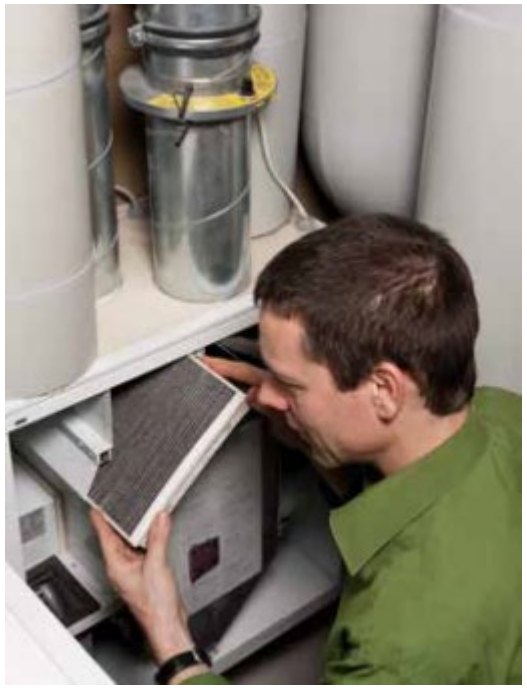

Image source: passivehouse.com

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Compact Heat Pump Certification – Germany Only

- Must supply air at 16.5 °C (61.7 °F), even if not actively heating down to -10 °C (14 °F)
- 75% heat recovery for passive heat recovery
- 0.45 Wh/m3 (0.76 W/cfm)
- Duct/unit air leakage ≤3% of average airflow rate of unit
- Primary energy demand of 55 kWh/m2 floor area (~5.1 kWh/sf)

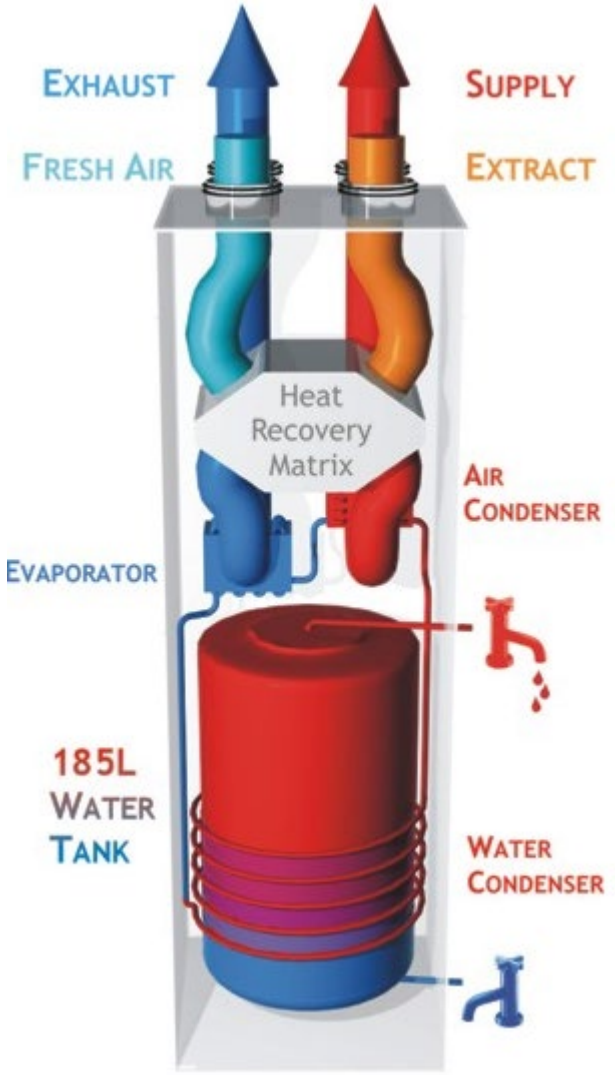

Image source: http://www.genvex.co.uk/genvexmp1.asp?pid=3436&cid=GENVEXmp1

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Standard Heat Pump Certification – Germany Only

- Indoor unit sound levels ≤25 dB(A), outdoor unit 55dB(A) in day and 40 dB(A) at night
- Demand of 15 kWh/m2 floor area (1.4 kWh/sf)
- Standby power draw of ≤1W
- Hygiene requirements include
  - Condensate drainage
  - Access to cooling/heating coils for cleaning

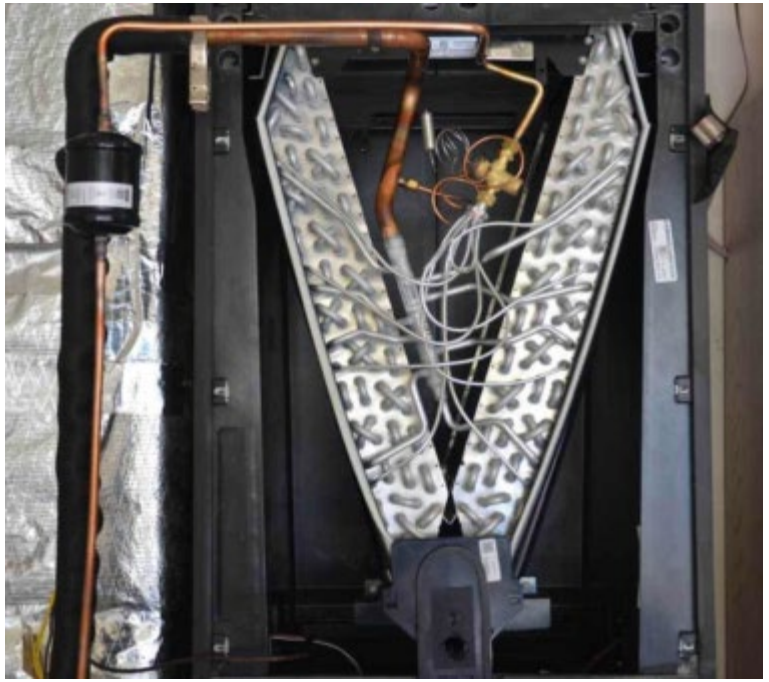

Image source: engineeringsadvice.com

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Passive House Certification Process

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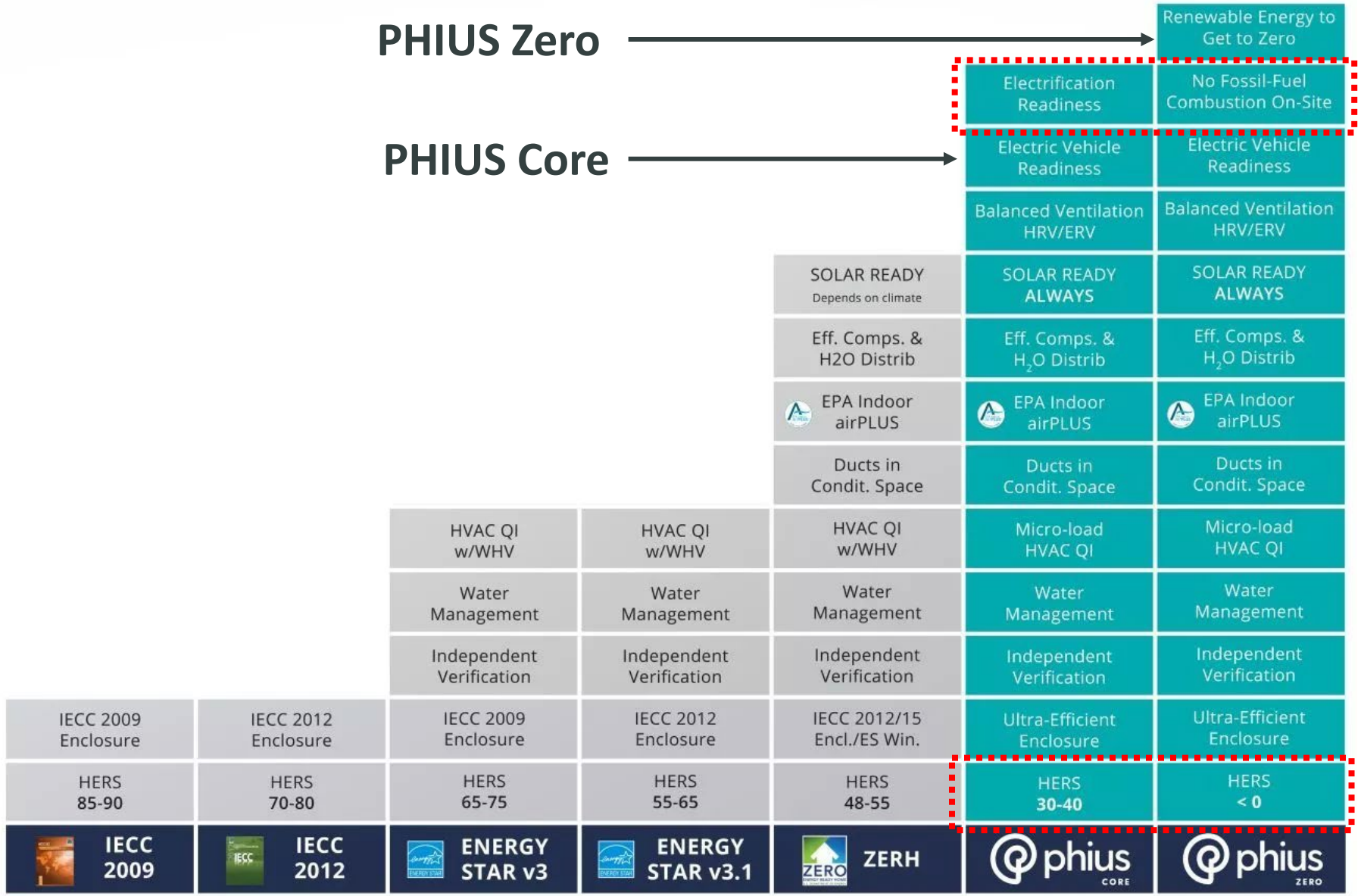
Levels of certification

- PHIUS
  - Minimum requirements of PHI program
  - Can allow for combustion appliances, but must be electrification ready

- PHIUS+/ZERH (Zero Energy Ready Home)
  - Add electrification requirements for HVAC equipment and appliances.

Levels of certification



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Referenced Standards

U.S. Department of Energy (DOE)

Zero Energy Ready Home

U.S. Environmental Protection Agency (EPA)

Indoor airPLUS label

U.S. Environmental Protection Agency (EPA)

ENERGY STAR

Residential Energy Services Network (RESNET)

Home Energy Rating System (HERS)

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Team Member Roles & Responsibilities

Phius Certified Consultant (CPHC)

- Recommended for All Project Types
- Works with project team throughout project to ensure requirements are met
- Completes WUFI Passive energy modeling

Phius Certified Building (CPHB)

- Sources, manages, and installs critical elements
- Documents construction process
- Tracks adaptations or alterations from project documents

Phius Certified Rater

- Required for single family detached; optional for attached/townhouses
- Responsible for site visits, testing, and verification
- A letter of intent is required for certification

Phius Certified Verifier

- Required for non-residential and multi-family projects; optional for single-family attached and townhouses
- Responsible for site visits, testing, and verification
- A letter of intent is required for certification

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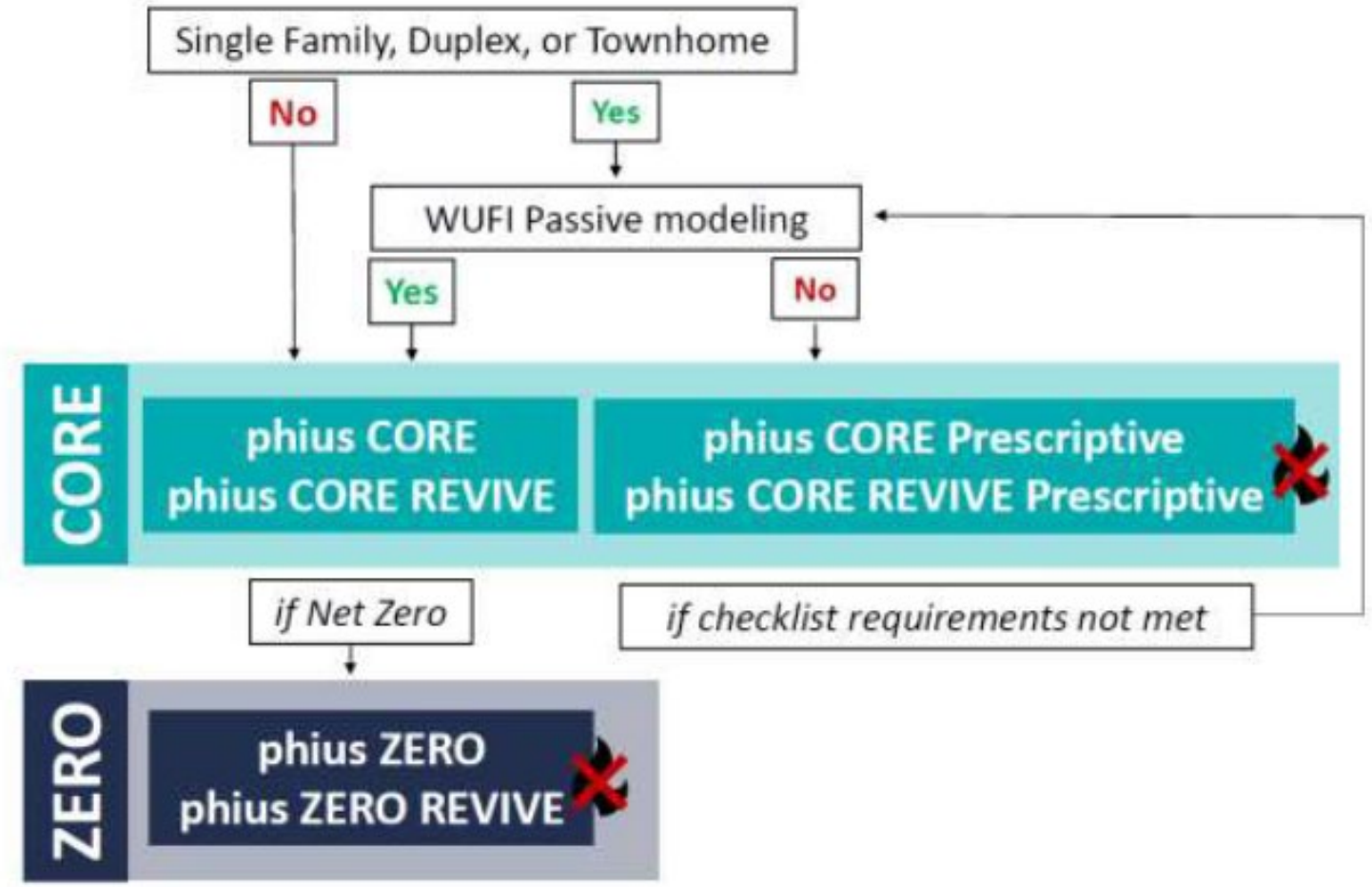
Compliance Paths

- Prescriptive
  - Building Components Directly Meet Requirements
  - Limited Scope
- Performance
  - Building Meets Overall Requirements
  - Any project may certify



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Scope Requirements and Limitations

Path	Performance		Prescriptive
New Const.	CORE	ZERO	CORE Prescriptive
Retrofit	CORE REVIVE	ZERO REVIVE	CORE REVIVE Prescriptive
Scope	All Building Types		Single-family Detached Residences Duplexes Townhomes
Combustion Limitations	N/A	No fossil-fueled combustion on-site.	
Design Limitations	N/A		• No indoor pools or jetted tubs. • Limit on the ratio of floor area to bedrooms. • Limits on fenestration area and orientation.

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Airtightness Requirements

Performance			Prescriptive		
Building Type	**50 Pa**	**75 Pa**	**Building Type**	**50 Pa**	**75 Pa**
≥5 Stories & Non-combustible*	$q \leq 0.080$ CFM_{50}/ft^2	$q \leq 0.110$ CFM_{75}/ft^2	**Single-family detached, attached and townhomes**	$q \leq 0.040$ CFM_{50}/ft^2	$q \leq 0.053$ CFM_{75}/ft^2
All other buildings	$q \leq 0.060$ CFM_{50}/ft^2	$q \leq 0.080$ CFM_{75}/ft^2			
**Non-combustible in this sense is construction that is not subject to mold and rot. This would mean no wood-based framing members or sheet goods, and no wood-based or paper-based insulation.*					

- Whole-building air-tightness test must be performed
- Gross enclosure surface area is measured as the exterior thermal boundary, including ground-contact surfaces
- Testing can take place at either 50 Pa or 75 Pa of pressure
- Can be “missed” if “extra” leakage is “non-assembly-threatening”
  - Certification Staff may allow element to be taped off
  - Un-taped test results must be used for energy model

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Active Conservation Requirements

Performance		Prescriptive
CORE	ZERO	CORE
The performance path uses a source energy target to limit overall energy use.		The prescriptive path uses individual appliance and equipment efficiency measures to limit overall energy use.
Net Source Energy Demand[5,6] ≤ E	Net Source Energy Demand[6,7] ≤ 0	Relevant sections of the Prescriptive Checklist: 8. Mechanical Systems[7] 9. Lighting, Appliances & Water Heating[8]
Refer to the Phius 2021 Criteria Calculator to determine specific limit for the project.		Refer to the Phius CORE Prescriptive Checklist to determine criteria for the project.

- In addition to passive conservation strategies limiting heating and cooling, overall building performance must be addressed
- Includes all non-heating-and-cooling end uses
- Net Source Energy Demand
  - Residential Occupants equal to no. bedrooms plus one; one occupant for studios
  - Non-residential uses floor area

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Active Conservation Requirements: Performance Path

Performance		
Tier	**CORE**	**ZERO**
Mixed-Use Buildings[12]	The residential SE limit applies if the building has common spaces and conditioned spaces that are not dwelling units, but that primarily serve the residents.[11]	
	For non-residential spaces designed to mainly serve non-resident clientele, an additional SE allowance may be calculated using the Non-Residential limits, based on the iCFA of those spaces.[13]	No additional SE allowance provided for spaces serving non-resident clientele.
Unfinished Spaces	No source energy allowance for unfinished spaces and no source energy impact associated with the internal gains. See Section 1.5.5.	
Off-grid Buildings	Process load allowance is provided for indoor water supply and/or wastewater treatment[14]. Residential = 800 kWh/person/yr for Non-Residential = 14 kWh/kgal	No process load allowance given.

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Active Conservation Requirements: Performance Path

Performance						
Tier	**CORE**			**ZERO**		
Net Energy Accounting	Source Energy demand is calculated as the annual usage *net of* renewable energy that is *produced and used directly on-site*. Renewable energy production that is exported from the site or generated off-site is not credited.			Source Energy demand is calculated as the annual usage *net of* all on-site & off-site renewable energy procured.		
Residential Buildings[8]	Net Source Energy Demand[6,9] ≤ E (kWh/yr/person)			Net Source Energy Demand[6] ≤ 0 (kWh/yr/person)		
Non-Residential Buildings[10]	Net Source Energy Demand[7]			Net Source Energy Demand[7]		
	kBTU/ft²/yr	kWh/ft²/yr	kWh/m²/yr	kBTU/ft²/yr	kWh/ft²/yr	kWh/m²/yr
	≤ 24.5	≤ 83.6	≤ 7.8	≤ 0	≤ 0	≤ 0
	Process load[11] allowances may increase the source energy limit. Phius will determine the source energy allowance on a case-by-case basis.			Process load allowances do not increase the source energy limit.		

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Renewable Energy Requirements

Performance		Prescriptive
CORE	**ZERO**	**CORE**
Renewable energy is not required, but some on-site renewable energy is credited.	The adjusted renewable energy provided to the project must be equal to or greater than the modeled energy use of the building.	Renewable energy is not required, nor credited as offsets.

Location	Renewable Energy Source	Renewable Energy Adjustment Factor	
		CORE	ZERO
On-Site	On-Site Renewable Energy System	Varies[39]	1.00
Off-Site	Directly Owned Off-Site Renewable Energy System	N/A	0.75
Off-Site	Community Renewable Energy System	N/A	0.75
Off-Site	Virtual PPA	N/A	0.75
Off-Site	Green-e RECs	N/A	0.20

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Moisture Design Requirements

Opaque Assemblies

Three compliance paths:

- Prescriptive Control Guidelines
- WUFI Hydrothermal Analysis
- Moisture-engineered design by qualified PE

Fenestration

fRsi must be met using one of the following:

- General Frame Type U-Value
- U-Frame (Uf) inferred from U-Window (Uw) and U-Center of Glass (Ucog)
- AAMA 1503 Condensation Resistance Factor (CRF)
- NFRC 500-2020 Condensation Resistance
- CAN/CSA A440.2 Temperature Index
- fRSI method

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Envelope Requirements

Area	Requirement
Air Barrier Integrity	Air barrier is contiguous including behind stairs, porch roofs, fireplaces, showers/tubs, attic knee walls, walls/ceilings adjacent to vented attics, and floors over unconditioned basements and crawlspaces.
Air Sealing	All penetrations between conditioned and unconditioned spaces sealed, service chases capped at exterior, exterior doors to garages weather-stripped, rough window/door openings sealed, etc.
Insulation Quality Check	All insulated assemblies have achieved a RESNET Grade I Cavity Insulation or Grade II Continuous Insulation Level.
Window Performance	Windows are ENERGY STAR certified and/or triple-glazed with thermally broken spacers.
Vented Attic Reduced Thermal Bridging	Vent baffles installed in bays with soffit vents to prevent wind washing, insulation over top places and under attic walkways/platforms R-21 to R-30 depending on climate zone.
Slab Edge Insulation	In select climate zones, slab-on-grade edge insulated to R-5 to IECC specified depth.
Above Grade Walls Reduced Thermal Bridging	Above grade walls achieve at least one of the strategies for Reduced Thermal ridging listed in Section 3 of the ENERGY STAR Rater Field Checklist.
Other Thermal Bridging/Mitigation Strategy Identification	Other meaningful thermal bridges and mitigation strategies should be identified and noted.

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Select Mechanical Requirements

Area	Requirement
Balanced Ventilation	A whole-building mechanical ventilation system must be provided. Said system must be balanced (i.e. with total measured supply and exhaust airflows within 10% of one another).
Ventilation Defrost	A pre-heat defrost is required for ERV's meeting certain requirements, as opposed to relying on re-circulation defrost.
Heating/Cooling Equipment	Exterior locations for cooling equipment are designated and offer natural drainage for condensate and dedicated branch circuits for heat pumps.
Heating/Cooling Distribution	Return air passes through a MERV filter, humidity control is maintained, bedrooms are pressure balanced with doors closed, and ducts and air handlers are entirely within the conditioned environment.
Combustion Safety and Condensation Management	All combustion heating and water heating systems within the building pressure boundary are sealed combustion, direct-vent appliances. Fireplaces are not draft type, not unvented, and have combustion air inlet connected to firebox.
Domestic Hot Water	Hot water heaters have adequate space, dedicated circuits, and do not feature continuous, time, or temperature based recirculation systems.
Lighting	80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps in 80% of sockets.
Appliances	All appliances are ENERGY STAR qualified and clothes drying and cooking equipment have dedicated 240-volt outlets.

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Select Other Requirements

Area	Requirement
Water/Moisture Managed Site/Foundation	Slabs are underlain by aggregate or sand and positive drainage away from foundations is secured. Drainage tile is provided at basements.
Water Managed Wall/Roof	All wall openings are flashed and gutters/downspouts are provided.
Water Managed and Low Emitting Building Materials	Building materials are moisture resistant and certified low emission.
Radon, Pest, and Combustion Pollution Management	Radon features are installed as required and rodent screens are provided.
Electric Vehicle Charging Infrastructure	Up to one space per dwelling unit of electric vehicle charging is provided.
Combustion Equipment	No natural draft fireplaces are permitted and fossil fuel combustion fireplaces are not permitted for renovations, ZERO, or CORE prescriptive paths
Electric Readiness	Electrification readiness is provided for all non-electric equipment.

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Prescriptive Calculator/Checklist

Phius 2021
Performance Criteria Calculator v2

言語 / LANGUAGE:	ENGLISH
Units	METRIC (SI)
Building Function	RESIDENTIAL
Project Type	NEW CONSTRUCTI
PREFECTURE	AICHI
CITY	HAMAMATSU
Envelope Area (m²)	3,750
iCFA (m²)	1,500
Dwelling Units (Count)	1
Total Bedrooms (Count)	4

Space Conditioning Criteria

Annual Heating Demand	8.5	kWh/m²yr
Annual Cooling Demand	31.2	kWh/m²yr
Peak Heating Load	8.8	W/m²
Peak Cooling Load	8.2	W/m²

Source Energy Criteria

Phius CORE	8637	kWh/person.yr
Phius ZERO	0	kWh/person.yr

PHIUS+ 2021 Prescriptive Calculator

State	GEORGIA
City	ATLANTA HARTSFIELD INTL
ASHRAE Climate Zone	3A
iCFA (ft²)	2646
Number of Bedrooms	3
	*iCFA and bedrooms per dwelling unit
Number of Stories	2

4. SOLAR PROTECTION

4.1.1 Maximum Whole Window SHGC		0.25
4.4.1 Projection Factor for Fixed Overhangs		NR

5. HEAT TRANSMISSION

5.1.1a Fenestration/Openings	Maximum U-Value	0.26	(BTU/h.ft².°F)
5.1.1b Walls & Overhang Floors	Minimum Effective R-Value	31	(ft².°F.h/BTU)
5.1.1c Roofs, Ceilings	Minimum Effective R-Value	61	(ft².°F.h/BTU)
5.1.1d Floors	Minimum Effective R-Value	20	(ft².°F.h/BTU)

6. MOISTURE RISK LIMITATION

6.2.1 Fenestration Condensation Resistance, Minimum fRsi		0.64

7. MECHANICAL VENTILATION

7.1.1 Minimum Sensible Recovery Efficiency, Heating Mode		66%
7.1.3 Minimum Total Recovery Efficiency, Cooling Mode		60%
7.1.5 Maximum Length of Fresh Air Duct to Outside		15 ft each

8. MECHANICAL SYSTEMS

Select System Type: Single-Package ASHP

8.2 System Efficiency	Minimum HSPF	9.6
	Minimum COP @ 5F	NR
	Minimum SEER	18
	Minimum EER	12.5

9. LIGHTING

	Average brightness	800	Lumens/Lamp
	Number of Lamps	(Bed+1) x 5	
9.1.1.1a Minimum Average Required Efficacy		0.0	Lumens/Watt

*NR = No Requirement

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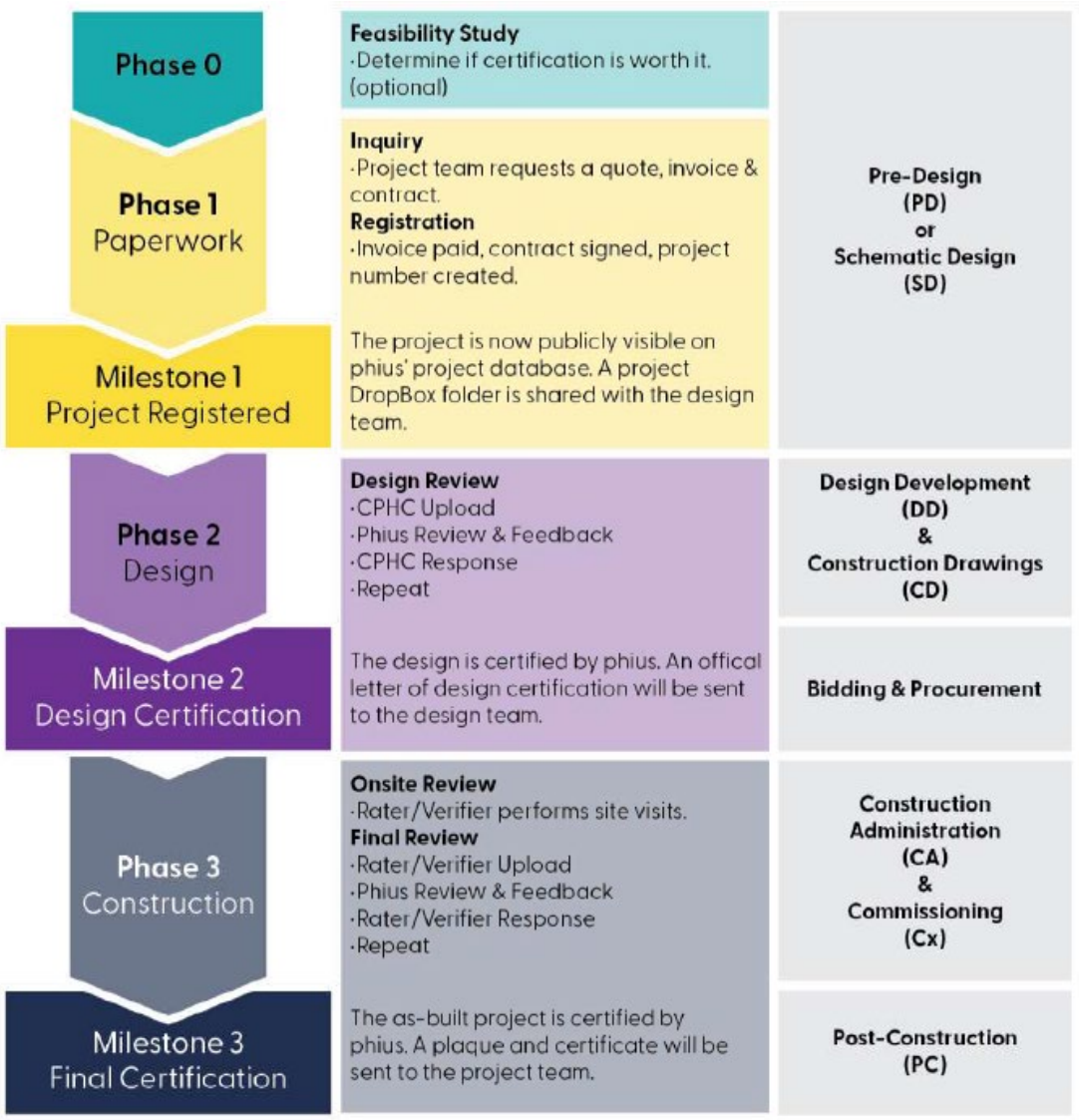
Review Process



Phase 0
Optional Feasibility Study

Phase 1
Paperwork including quote, invoice, and contract concluding with project registration.

Phase 2
Design documentation is created and reviewed concluding with design certification.

Phase 3
Construction is undertaken and reviewed/verified concluding with final certification.

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Certification Tools and Guides

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Limits

Zone	Heating kBtu/SF/yr	Heating Peak BTU/SF/h	Cooling kBtu/SF/yr	Cooling Peak BTU/SF/h	Air Tightness cfm50/sf envelope
4A	4.8	6.3	5.3	6.4	0.05-0.08
5A	6.0	6.5	3.2	6.2	

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Thermal Control - Prescriptive References

Opaque Component R-Value Ranges
[hr.sf.F/Btu]

Climate Zone	0 & 1	2	3A/B	3C	4A/B	4C	5A/B	5C	6	7	8
Walls & Overhanging Floors (Above Grade)	R 16 - 28	R 24 - 32	R 24 - 40	R 28 - 32	R 32 - 48	R 28 - 44	R 32 - 52	R 36 - 48	R 40 - 56	R 48 - 84	R 52 - 132
Roofs	R 48 - 56	R 52 - 60	R 56 - 68	R 56 - 60	R 64 - 80	R 60 - 76	R 64 - 80	R 64 - 80	R 72 - 84	R 76 - 120	R 80 - 164
Walls & Floors (Below Grade)	R 1 - 16	R 8 - 16	R 8 - 20	R 8 - 16	R 16 - 24	R 12 - 24	R 16 - 32	R 8 - 28	R 20 - 36	R 24 - 60	R 32 - 80
Ceilings (Unconditioned Basement / Crawlspace)	R 7 - 22	R 14 - 22	R 14 - 26	R 14 - 22	R 22 - 30	R 18 - 30	R 22 - 38	R 14 - 34	R 26 - 42	R 30 - 66	R 38 - 86

Fenestration U-Value Ranges
[Btu/hr.sf.F]

Climate Zone	0 & 1	2	3A/B	3C	4A/B	4C	5A/B	5C	6	7	8
Windows & Doors (Whole-Window)	0.5 - 0.29	0.5 - 0.23	0.47 - 0.19	0.39 - 0.25	0.23 - 0.16	0.37 - 0.18	0.24 - 0.13	0.27 - 0.2	0.19 - 0.11	0.22 - 0.09	0.19 - 0.08

Fenestration Solar Protection Ranges

Climate Zone	0 & 1	2	3A/B	3C	4A/B	4C	5A/B	5C	6	7	8
Maximum SHGC* (Whole-Window)	0.25	0.25	0.25	0.30	0.40	NR					
Minimum South Overhang (Projection Factor)	0.06 - 0.59	0.42 - 0.58	0.53 - 0.71	0.6 - 0.67	NR						
Adequate Exposure Diversity (AED)	Varies**										
Net Heat Gain	NR				Varies	NR	Varies	NR	Varies		NR

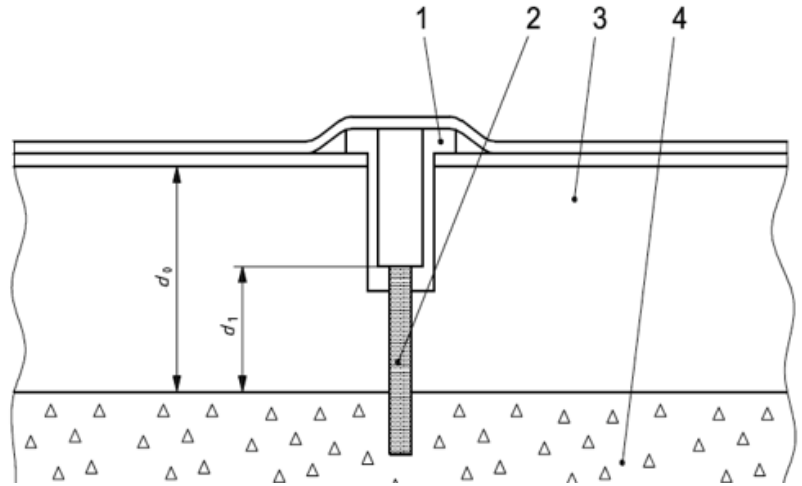
Thermal Control - Tools

Fastener Correction Calculator		PHIUS Notes/Instructions
*Results in green		*enter information into orange cells
Adjusted R-Value (hr.ft2°F/BTU)	**32.82**	Adjusted R-value after fastener reduction taken into account. Modeled assembly should match this overall R-value.
Recessed Fasteners?	FALSE	TRUE/FALSE - Recessed fasteners start below the surface of the exterior insulation.
Fastener Material	Aluminum	Thermal conductivity of fastener influences calculation.
Assembly Area (ft2)	67.5	Area of assembly being assessed
Fastener Count	40	Number of Fasteners
nf (#/ft2)	0.593	Fastener density based on wall area and number of fasteners
Af (in2)	0.053	Cross sectional area of one fastener
d0 (in)	11.875	Thickness of the insulation layer containing fasteners
d1 (in)	9.125	Length of the fastener that penetrates the insulation layer. d1 can be greater than the thickness of the insulation layer if the fastener passes through it at an angle.
R1 (hr.ft2°F/BTU)	34.38	Thermal resistance of the insulation layer penetrated by the fasteners. In the case of a recessed fastener, d1 is less than the thickness of the insulation layer and R1 is equal to d1 divided by the thermal conductivity of the insulation.
RTh (hr.ft2°F/BTU)	46.5	Total thermal resistance of the component ignoring any thermal bridging. Add the resistance layer, including air films, but ignoring framing etc..

Material	Thermal conductivity (W/mK)
Aluminum	160
Mild Steel	50
Stainless Steel	17
Solid plastic (typical)	0.21

per ISO 6946:2007(E), section D.3

No correction shall be applied in the following cases: a) where there are wall ties across an empty cavity; b) when the thermal conductivity of the fastener is less than 1 W/m.K.



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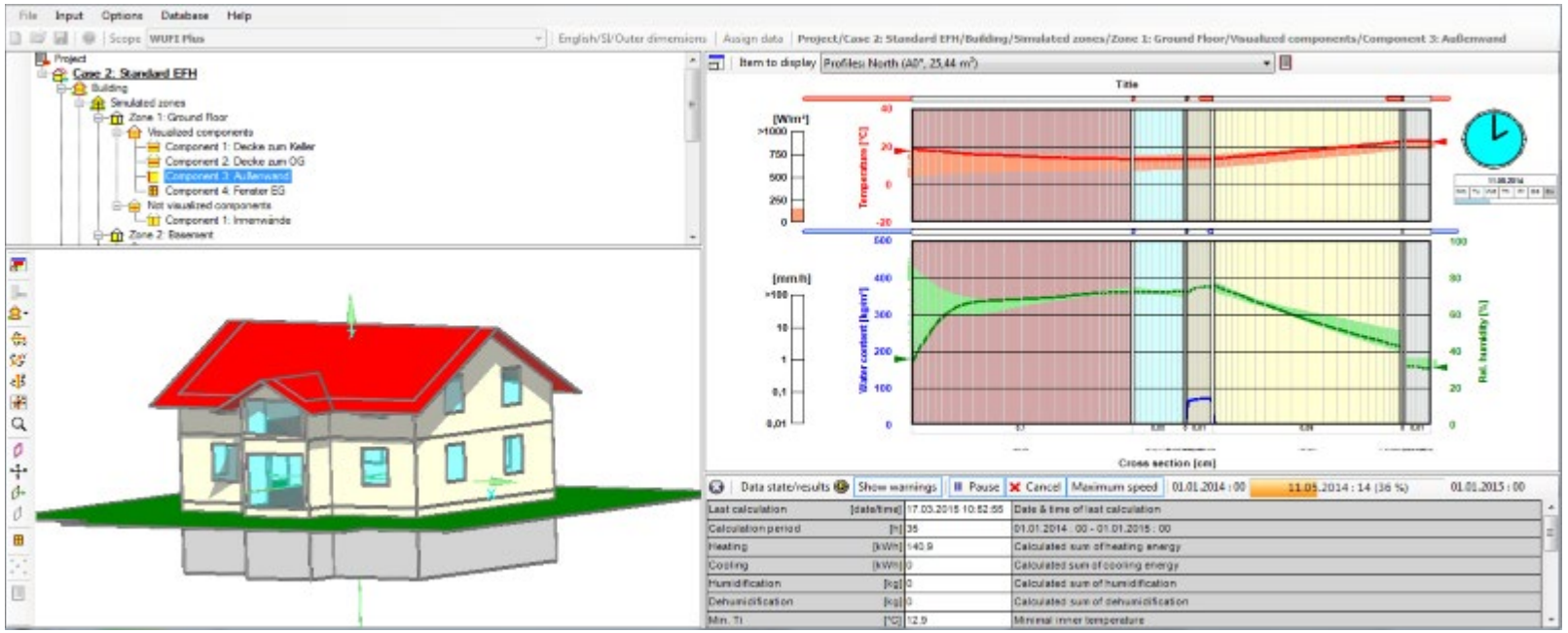
WUFI Hygrothermal Analysis



Multiple variations of WUFI

PHI uses custom program, WUFI Passive

Hygrothermal analysis can document hygiene requirements met for components or whole home

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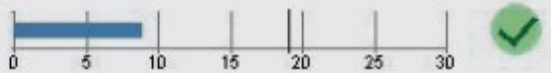
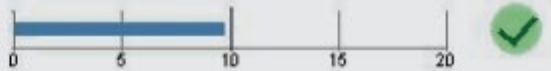
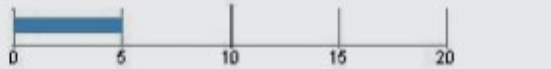
WUFI PHI Compliance Analysis

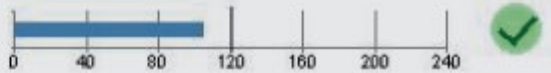
PASSIVEHOUSE REQUIREMENTS

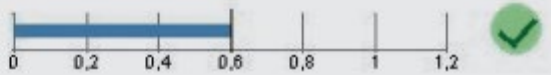
Certificate Criteria:	**European**	
Heating Demand		
specific:	**10,9**	kWh/m²a
total:	938	kWh/a
peak:	4	kWh/m²
Cooling Demand		
specific - sensible:	**8,9**	kWh/m²a
total - sensible:	217	kWh/a
peak - sensible:	1,7	kWh/m²
latent:	6,4	kWh/m²a
Heating Load		
specific:	**9,8**	W/m²
total:	847	W
Cooling Load		
specific:	**5,1**	W/m²
total:	440	W
Primary Energy		
specific:	**105**	kWh/m²a
total:	9088	kWh/a
Air Tightness ACH50	**0,6**	1/h











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FAQs

- Is Passive House just for Residential?
- Do tight buildings cause mold?
- What is the cost premium?
- How long does it take?
- What are the benefits beyond energy?

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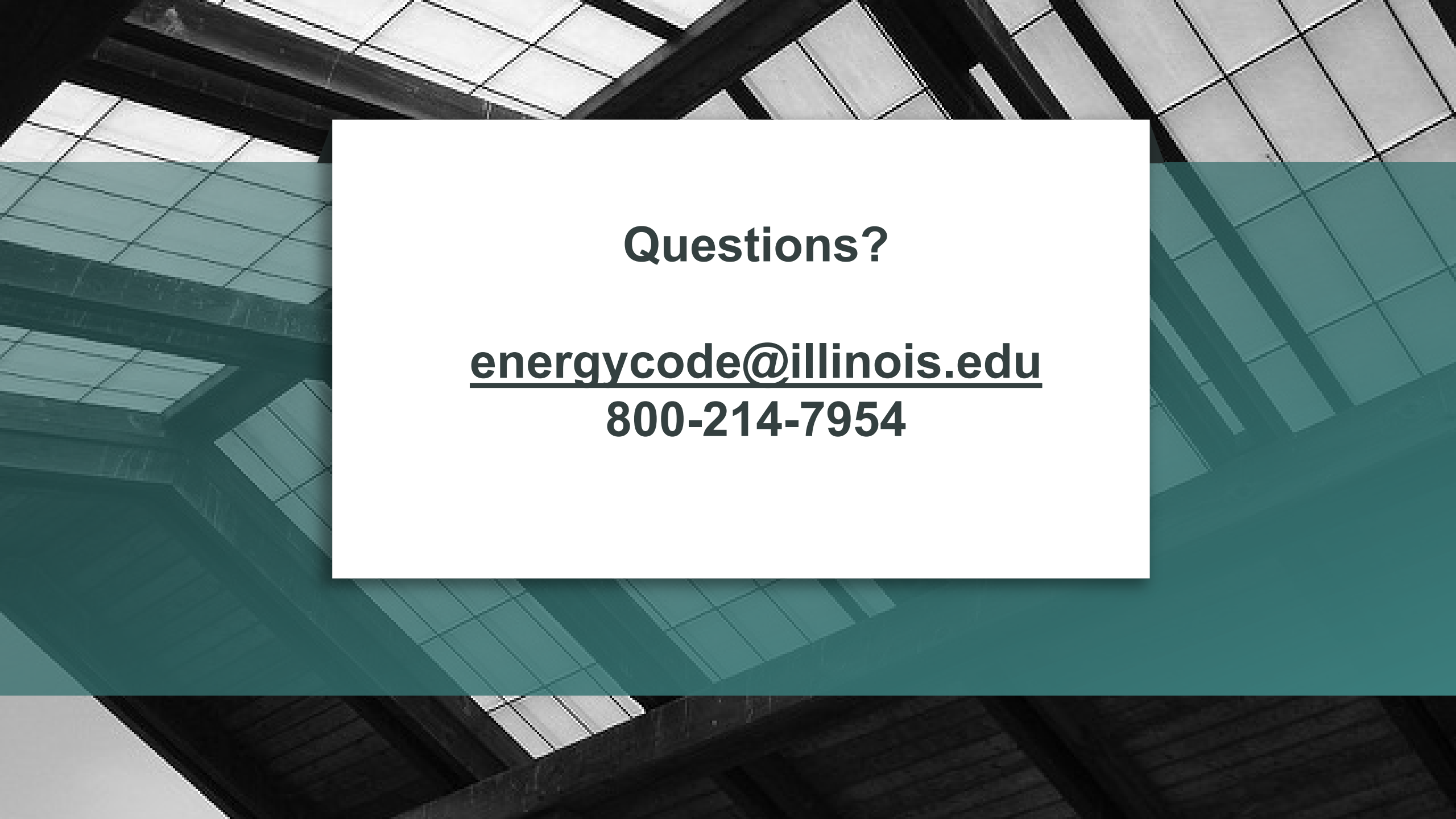

Questions?

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