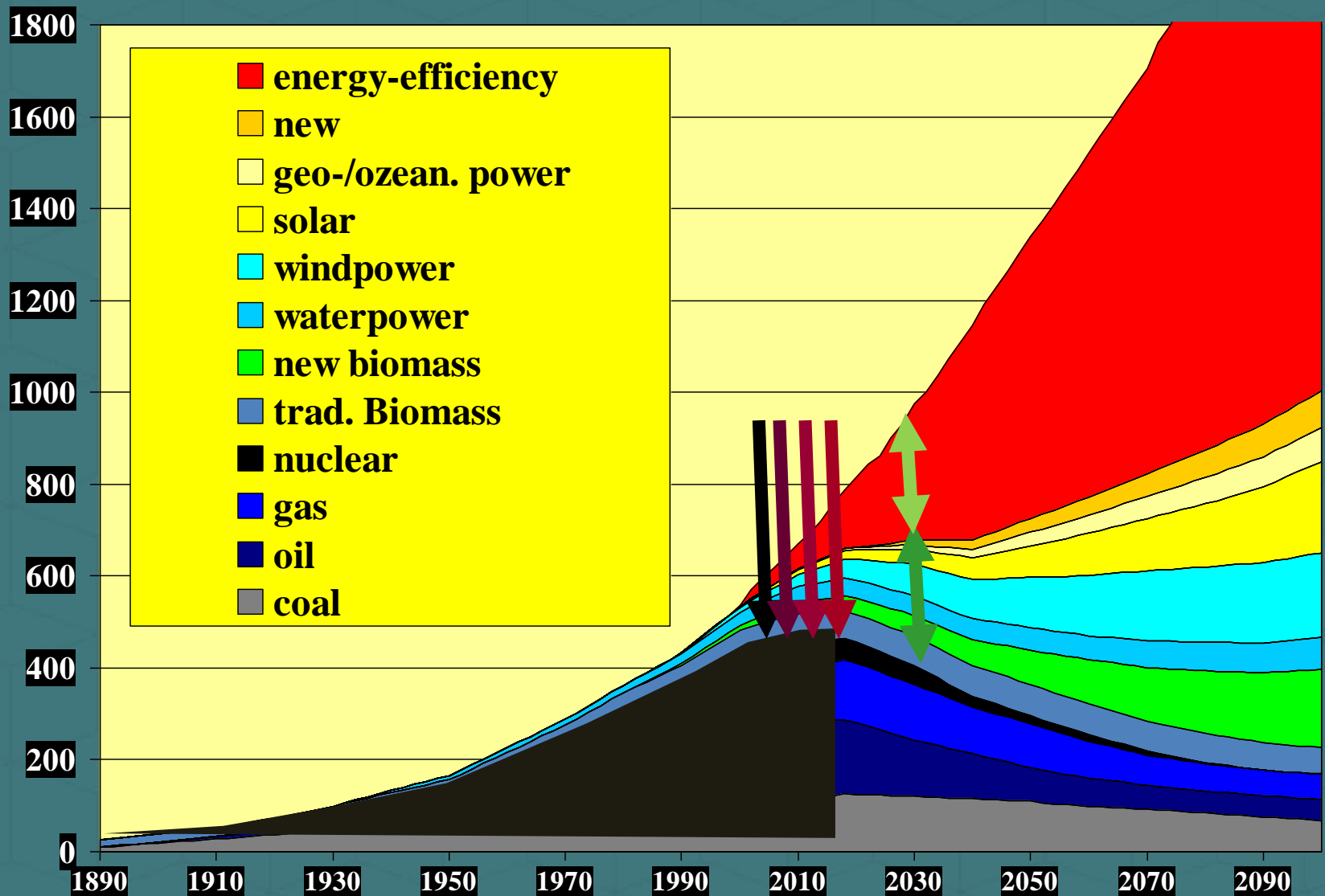


MULTIFAMILY PASSIVE BUILDINGS: EVALUATION OF MEASURED PERFORMANCE

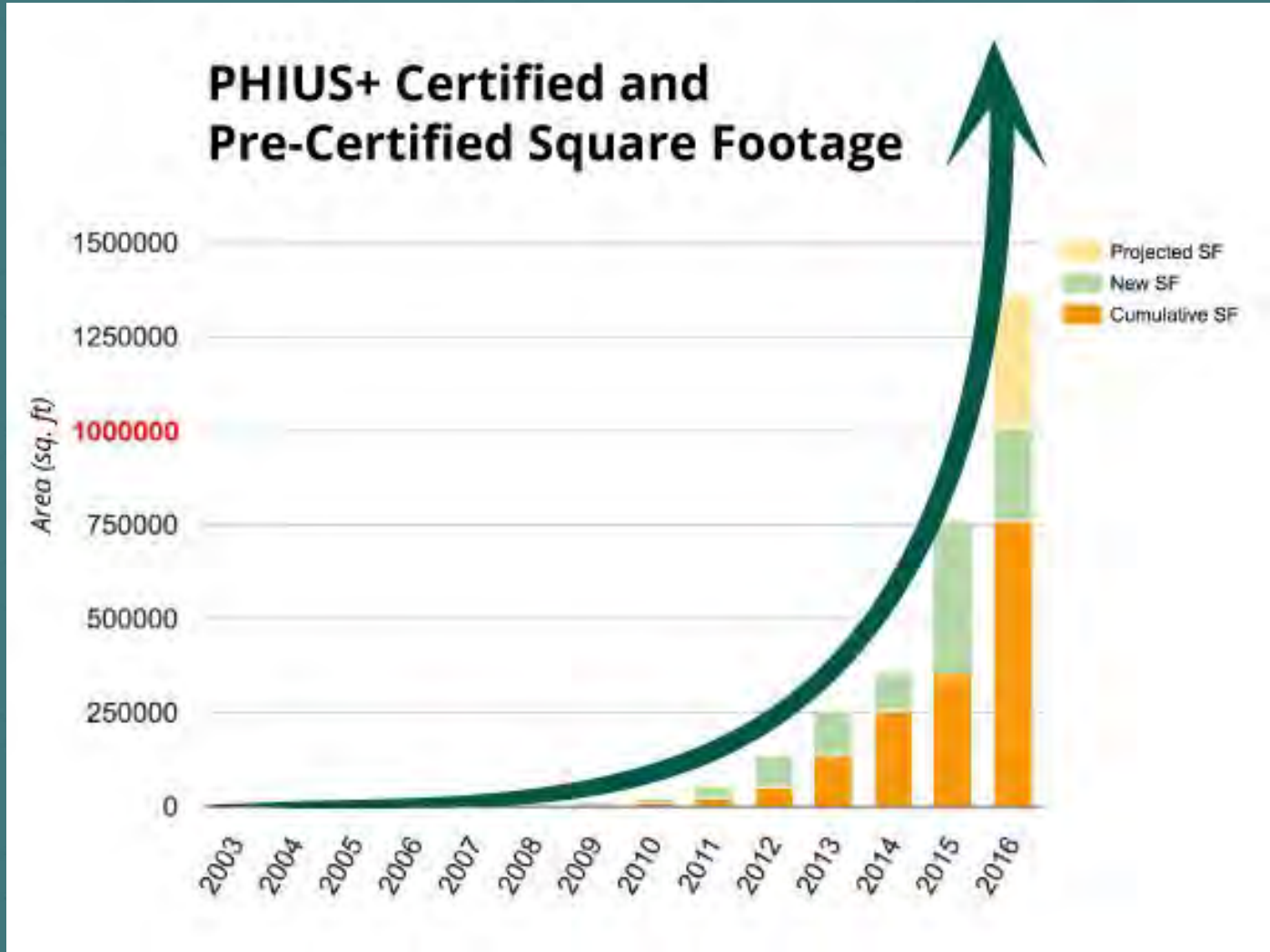


FUTURE WORLDWIDE TRANSITION



Reference: Shell-Study (till 2005), Scenario with high efficiency and regenerative usage of energy

PASSIVE HOUSE US DATABASE



Source: www.phius.org

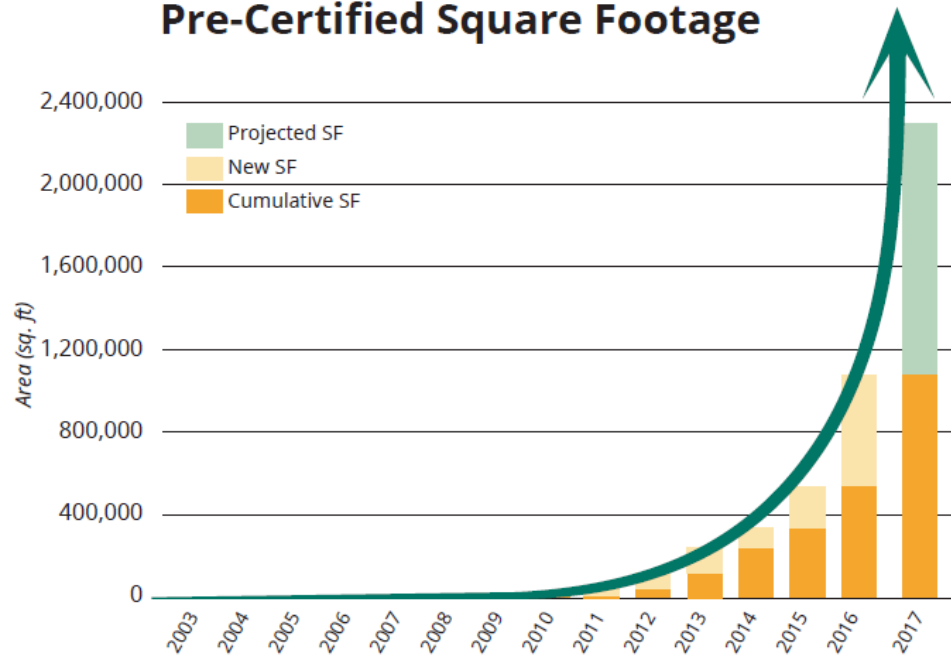


PHIUS CERTIFIED PROJECTS

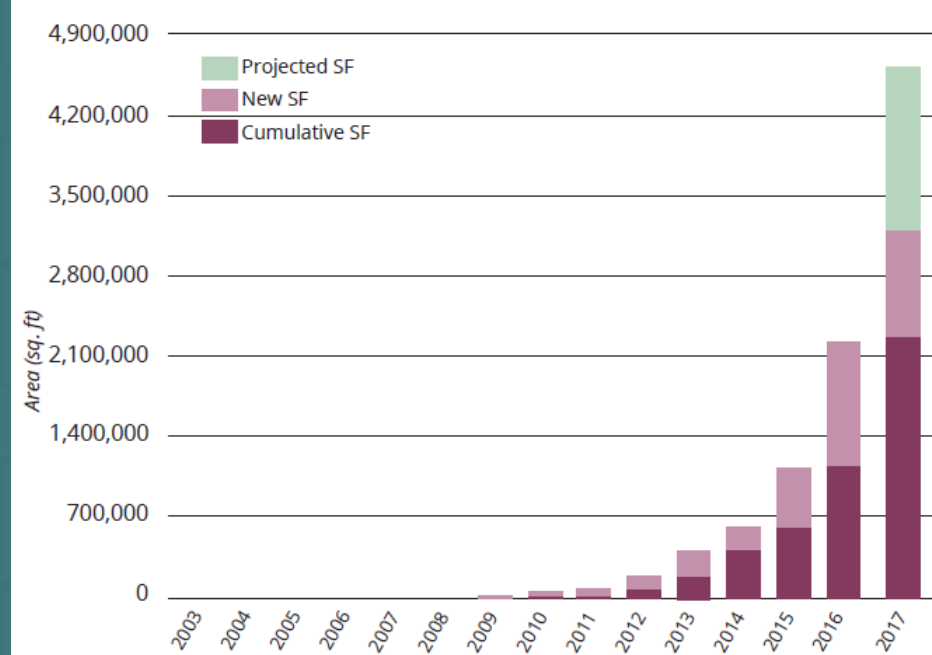
PHIUS+ TRENDS FOR 2017

Source: www.phius.org

PHIUS+ Certified and Pre-Certified Square Footage

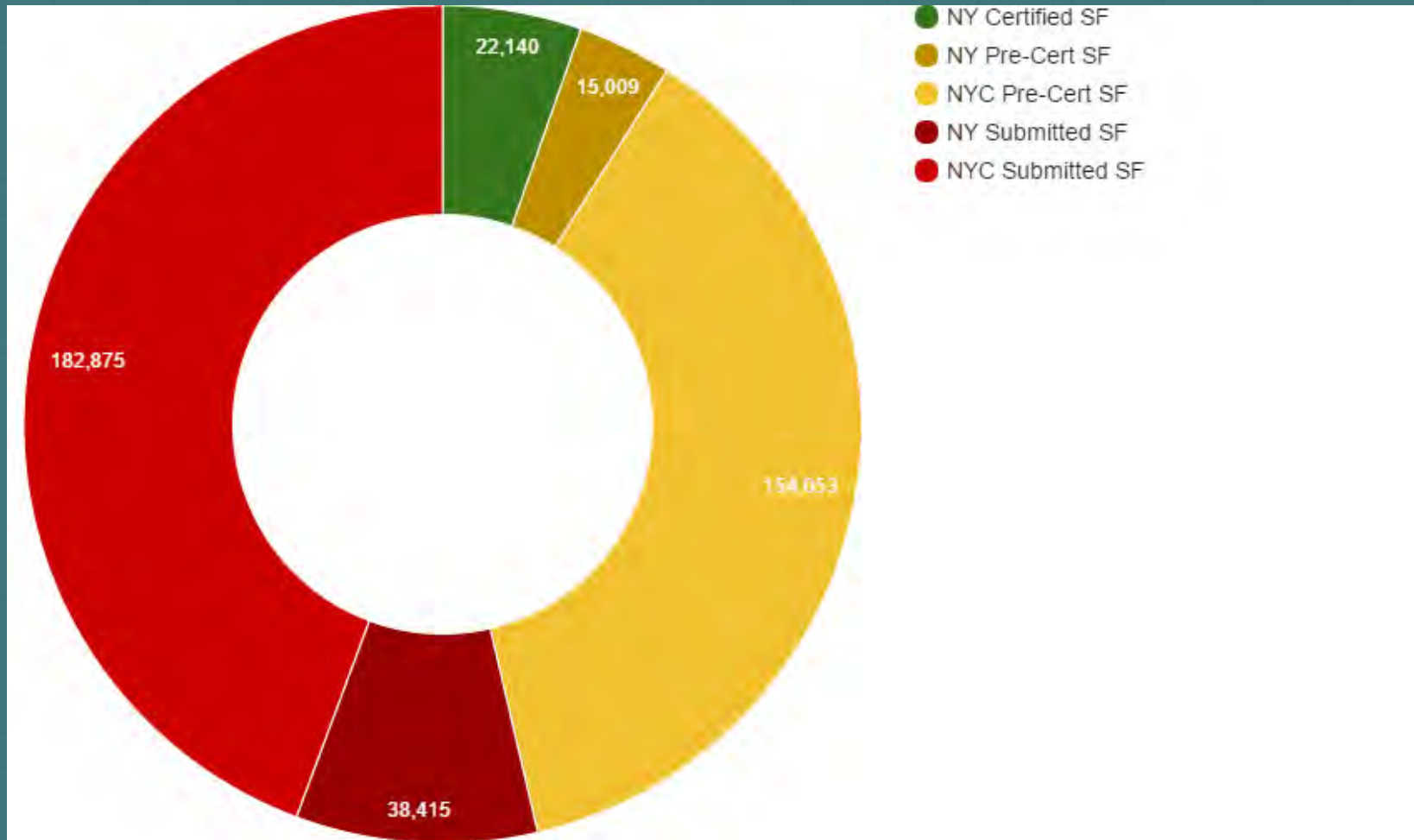


PHIUS+ Total Square Footage



95% of total certified and pre-certified passive building construction in NA

NY STATE AND CITY SQFT OCTOBER 2016 PHIUS+ PROJECTS



410,000 SQ FT TOTAL DOCUMENTED SUBMISSIONS

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**PASSIVE HOUSE FOR
MULTIFAMILY BUILDINGS**

WHOLE BUILDING ENERGY BALANCE

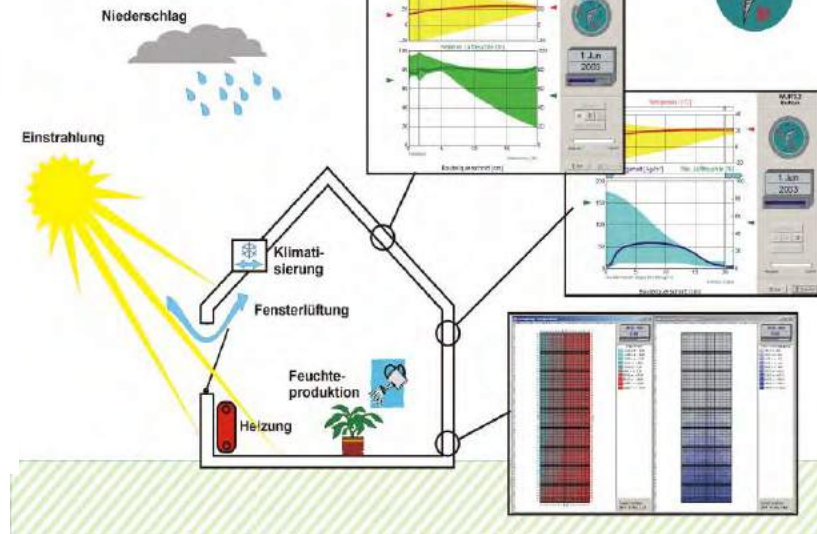


WUFI® Passive



PHPP

WUFI® Plus



TERMINOLOGY

Demands, Peaks, Site & Primary Energy

Annual Demand [kBTU/yr.ft²]: Space conditioning energy consumed over the course of the year, delivered by the equipment to the space.

Peak Load [BTU/hr.ft²]: Space conditioning requirement during the peak climate conditions (average over the worst 24 hours). Determines the size of the mechanical system.

Site Energy [kWh/person.yr] OR [kBTU/yr.ft²]: Total energy consumed over the course of the year, including space conditioning, hot water, plug loads, lighting, appliances, systems, etc. (Excludes electrical vehicle charging energy, and lighting energy specific to vehicle parking areas)

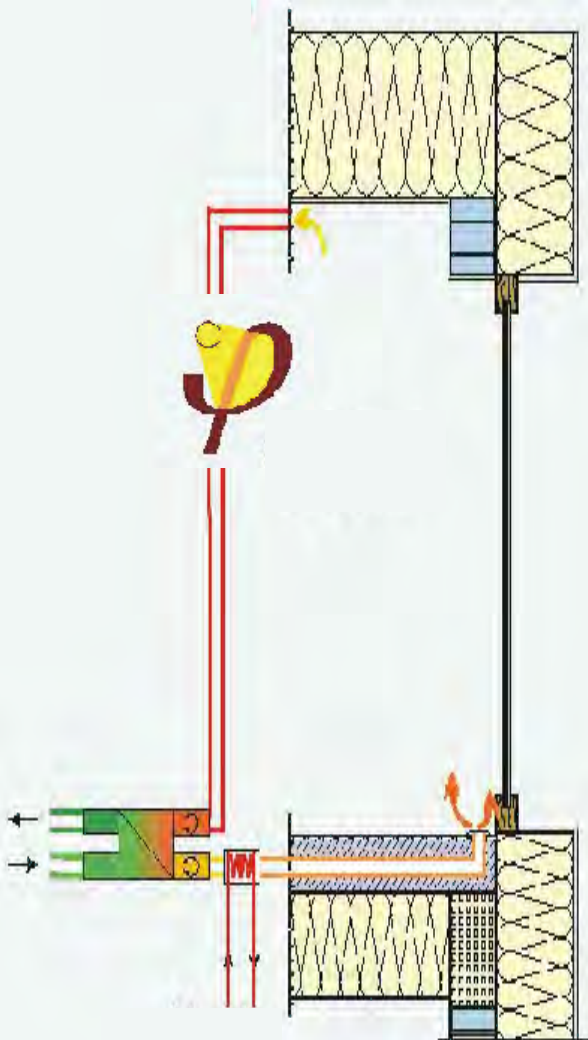
*No requirement for PHIUS+ Certification

Source (Primary) Energy [kWh/person.yr] OR [kBTU/yr.ft²]: Site energy as described above, multiplied by the source/primary energy factor for the specific fuel type used.

Ex: Electricity has a PE factor of 3.16 kWh/kWh (generation at the source vs use on site)

EUROPEAN

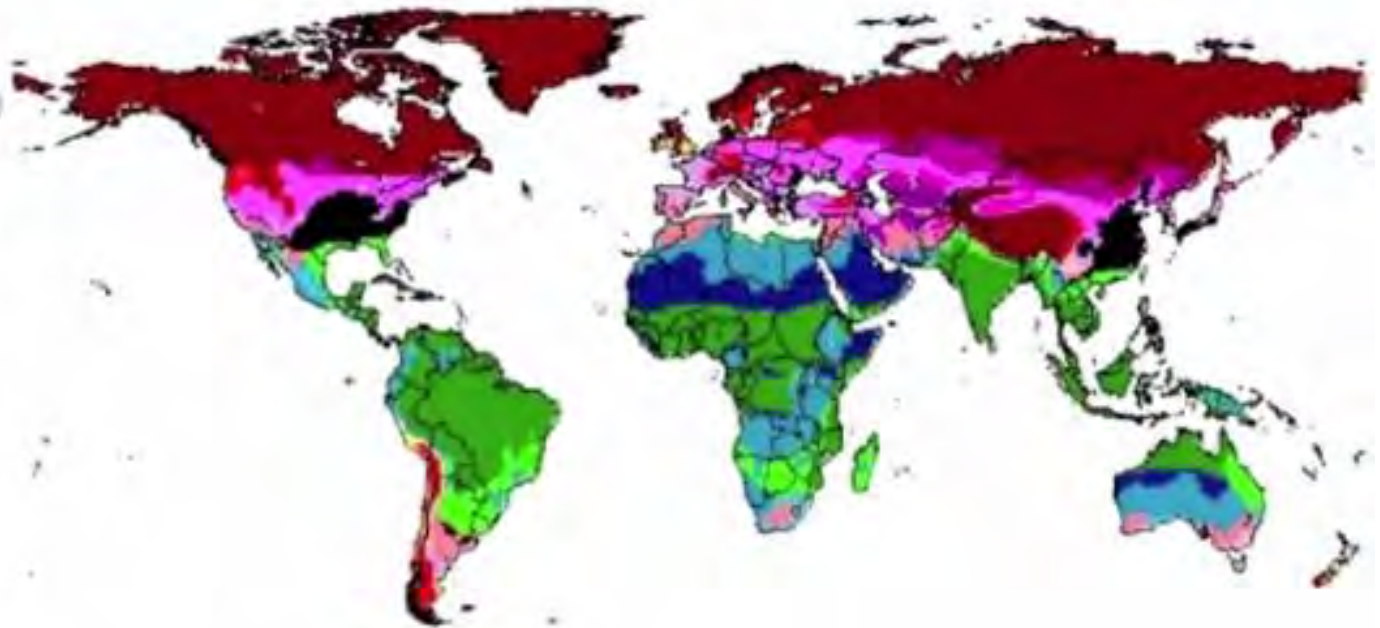
PASSIVHAUS CRITERIA



Primary Energy	kBTU/ft ² /yr	38
Airtightness	ACH ₅₀	0.6
Annual Heat Demand	kBTU/ft ² /yr	4.75 (+ allowance for latent)
Annual Cooling Demand		
Peak Heat Load	BTU/ft ² .hr	3.14
Peak Cooling Load		
Ventilation	% efficiency	75%
	W/cfm	≤ 0.76
Thermal Envelope	nr. U-F/BTU	≥ 1.5
	BTU/hr. ft ² °F	≤ U-0.026
Thermal Bridge Free	BTU/ hr. ft °F	Ψ ≤ 0.006
Windows Installed	BTU/hr. ft ² °F	U _{w-install} ≤ 0.15
SHGC	%	≈ 0.50 - 0.55

PHIUS+2015: CLIMATE SPECIFIC DESIGN

- 1. Only Heating (very HHD)
- 2. Only Heating (HHD)
- 3. Only Heating (MHD+LHD)
- 4. Heating and Cooling (very HHD+LCD)
- 5. Heating and Cooling (HHD+MCD)
- 6. Heating and Cooling (HHD+LCD)
- 7. Heating and Cooling (MHD+MCD)
- 8. Heating and Cooling (MHD+LCD)
- 9. Heating and Cooling (LHD+MCD)
- 10. Heating and Cooling (LHD+LCD)
- 11. Only Cooling (very HCD)
- 12. Only Cooling (HCD)
- 13. Only Cooling (LCD+MCD)
- 14. Cooling and Dehum (very HCD)
- 15. Cooling and Dehum (HCD)
- 16. Cooling and Dehum (LCD+MCD)
- 17. Heating, Cooling, Dehum



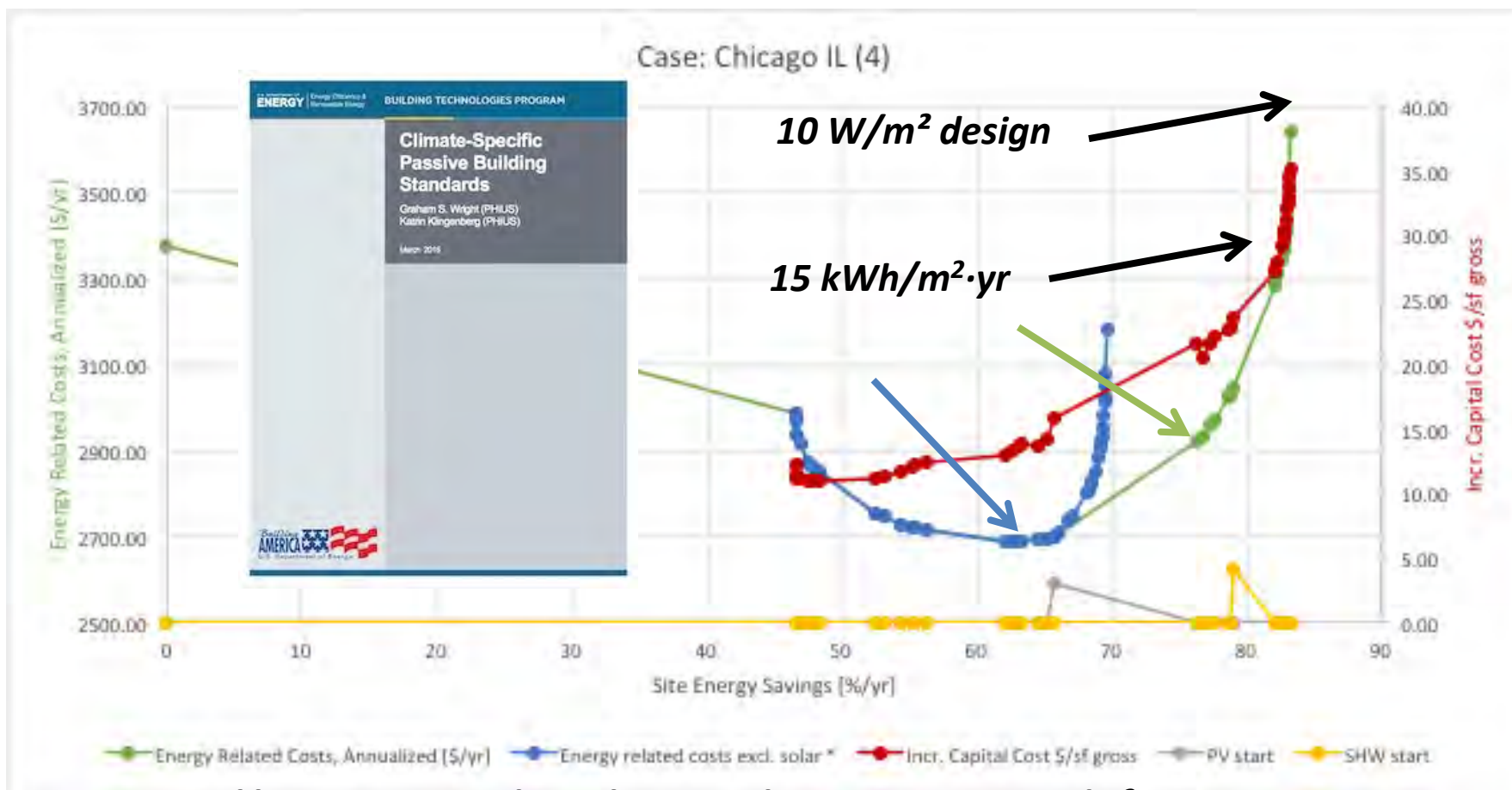
Graph Courtesy of Global Buildings Performance Network

PHIUS+ 2015 PASSIVE BUILDING CRITERIA

Primary Energy	kBTU/ft ² /yr	(Bedrooms+1 * (6200 kWh *3.412 kBTU/kWh))/iCFA
Airtightness	cfm/ft ²	0.05 cfm/gross ft ² shell @ 50 pa 0.08 cfm/gross ft ² shell @ 75 pa
Annual Heat Demand	kBTU/ft ² /yr	1.0 - 12.0
Annual Cooling Demand		1.0 - 21.4
Peak Heat Load	BTU/ft ² .hr	0.8 - 5.4
Peak Cooling Load		1.8 - 8.9

Ventilation	% efficiency	53% - 95%
	W/cfm	0.27 - 2.23
Thermal Envelope	hr. ft ² °F/BTU	≈ R-25 - R-80
	BTU/hr. ft ² °F	≈ U-0.04 - U-0.0125
Thermal Bridge Free	BTU/ hr. ft °F	Ψ ≤ 0.006
Windows Installed	BTU/hr. ft ² °F	Uw-install 0.41 - 0.08
SHGC	%	≈ 0.27 - 0.61

NEW STANDARDS IDENTIFY US ECONOMIC OPTIMUM TAKING PV COST INTO ACCOUNT

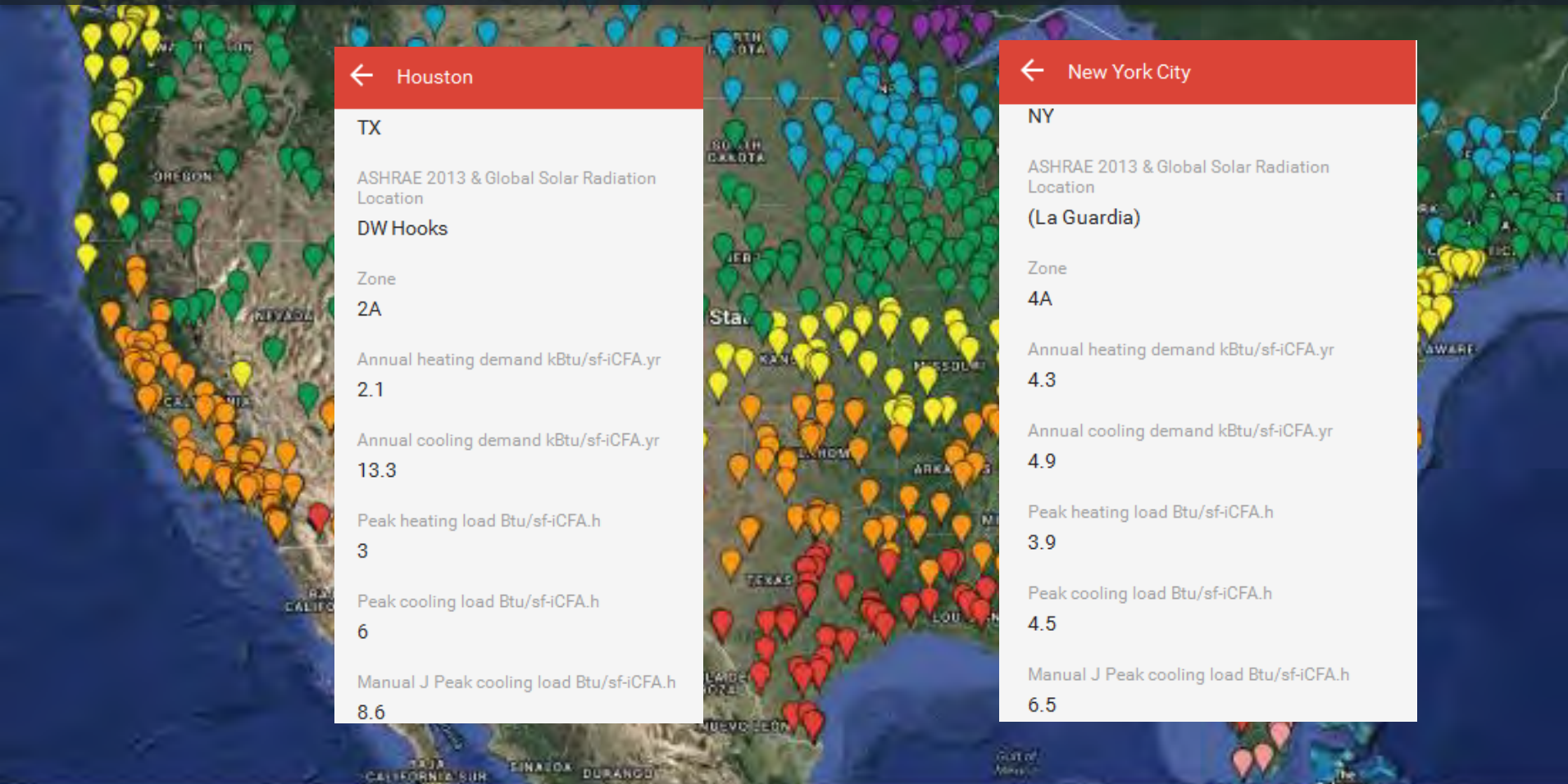


<http://www.nrel.gov/docs/fy15osti/64278.pdf> 15 kWh/m²·yr

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CLIMATE SPECIFIC METRICS

PASSIVE STANDARDS IN VARYING CLIMATES



PERFORMANCE CRITERIA DIFFERENCES

Annual Demand, Peak, Source & Air-tightness







PHI CERTIFICATION – does not require US industry standards

- One annual demand target for space conditioning for all climates with an additional allowance for dehumidification based on climate
- Targets not cost-optimized by location
- No mandatory climate specific peak load target to assure thermal comfort
- Source energy target per square foot for residential and commercial & PER based on German conversion factors
- Air-tightness measured relative to building volume
- Standard applied to residential and commercial, separate & less stringent standard for retrofit projects

PHIUS+2015 – requires US industry standards (DOE ZERH, ES, Indoor AIR Plus)

- Climate specific annual demand targets for all space conditioning
- Targets cost-optimized by location
- Mandatory peak load targets to assure thermal performance & resilience
- Source energy target per person for residential, square foot for commercial based on US conversion factors
- Air-tightness measured relative to opaque envelope area
- Standard applied to all building types including retrofits with an additional allowance for existing thermal bridging

DOE PERFORMANCE STAIRCASE

							Source Zero Renewable Energy System
							Balanced Ventilation HRV/ERV
							Balanced Ventilation HRV/ERV
							SOLAR READY ALWAYS
							SOLAR READY ALWAYS
							Eff. Comps. & H ₂ O Distrib
							Eff. Comps. & H ₂ O Distrib
							Eff. Comps. & H ₂ O Distrib
							EPA Indoor Air Package
							EPA Indoor Air Package
							EPA Indoor Air Package
							Ducts in Condit. Space
							Ducts in Condit. Space
							Ducts in Condit. Space
							Micro-load HVAC QI
							Micro-load HVAC QI
							Water Management
							Water Management
							Water Management
							Independent Verification
							Independent Verification
							Independent Verification
							Ultra-Efficient Enclosure
							Ultra-Efficient Enclosure
							Ultra-Efficient Enclosure
							HERS 35-45
							HERS 35-45
							HERS < 0
							HERS < 0
							HERS < 0
 IECC 2009	 IECC 2012	 ENERGY STAR v3	ENERGY STAR v3.1	 ZERH	 PHIUS+	 PHIUS+ SourceZero	

CERTIFICATION PROTOCOL DIFFERENCES

Internal Gains, TFA and iCFA, Occupancy & MELs

PHI –

- Unrealistically low internal gain default assumptions
- Treated Floor Area (TFA) energy reference area – *EUIs are not directly comparable!*
- Occupancy assumption by fixed square foot per person
- Different MEL and lighting assumptions
- Source EUI – based on German conversion factors – *not directly comparable!*

PHIUS+2015 –

- 80% of RESNET internal gain assumptions
- Interior conditioned floor area (iCFA) energy reference area – *EUIs are not directly comparable!*
- Occupancy calculated bedrooms +1
- Different MEL and lighting assumptions
- Source EUI – based on US conversion factors – *not directly comparable!*

Three Case Studies



	<i>Uptown Lofts</i>	<i>Knickerbocker Commons</i>	<i>Orchards at Orenco Phase 1</i>
<i>Location</i>	Pittsburgh, PA	Brooklyn, NY	Hillsboro, OR
<i>Square Footage (iCFA)</i>	2,3994 ft ²	31,903 ft ²	48,035 ft ²
<i>Number of Units</i>	24	24	57
<i>Modeled Occupancy</i>	27 (PHIUS+) 48 (PHIUS+ 2015)	72 (PHIUS+) 72 (PHIUS+ 2015)	113 (PHIUS+) 131 (PHIUS+ 2015)
<i>PHIUS+ Project #</i>	1188	1274	1203

Three Case Studies



	<i>Uptown Lofts</i>	<i>Knickerbocker Commons</i>	<i>Orchards at Orenco Phase 1</i>
<i>Climate Zone</i>	4A	4A	4C
<i>Location</i>	Pittsburgh, PA	Brooklyn, NY	Hillsboro, OR
<i>*Annual Heating demand target (kBtu/sf)</i>	4.5	4.6	5.1
<i>*Annual Cooling demand target (kBtu/sf)</i>	5.4	3.9	1
<i>*Peak Heating load (Btu/sf)</i>	4.2	3.9	3.7
<i>*Peak Cooling load (Btu/sf)</i>	4.7	4.2	3.9

*PHIUS+ 2015 Climate Specific Targets

Uptown Lofts



Things to keep in mind

- Site Energy analyzed
- All electricity monitored together (includes all HVAC, hot water usage, lighting and MELs)
- Heat pumps (heating/cooling) in apartments
- Direct Electric baseboards in stairs
- HRV
- Direct Electric WH