Tool

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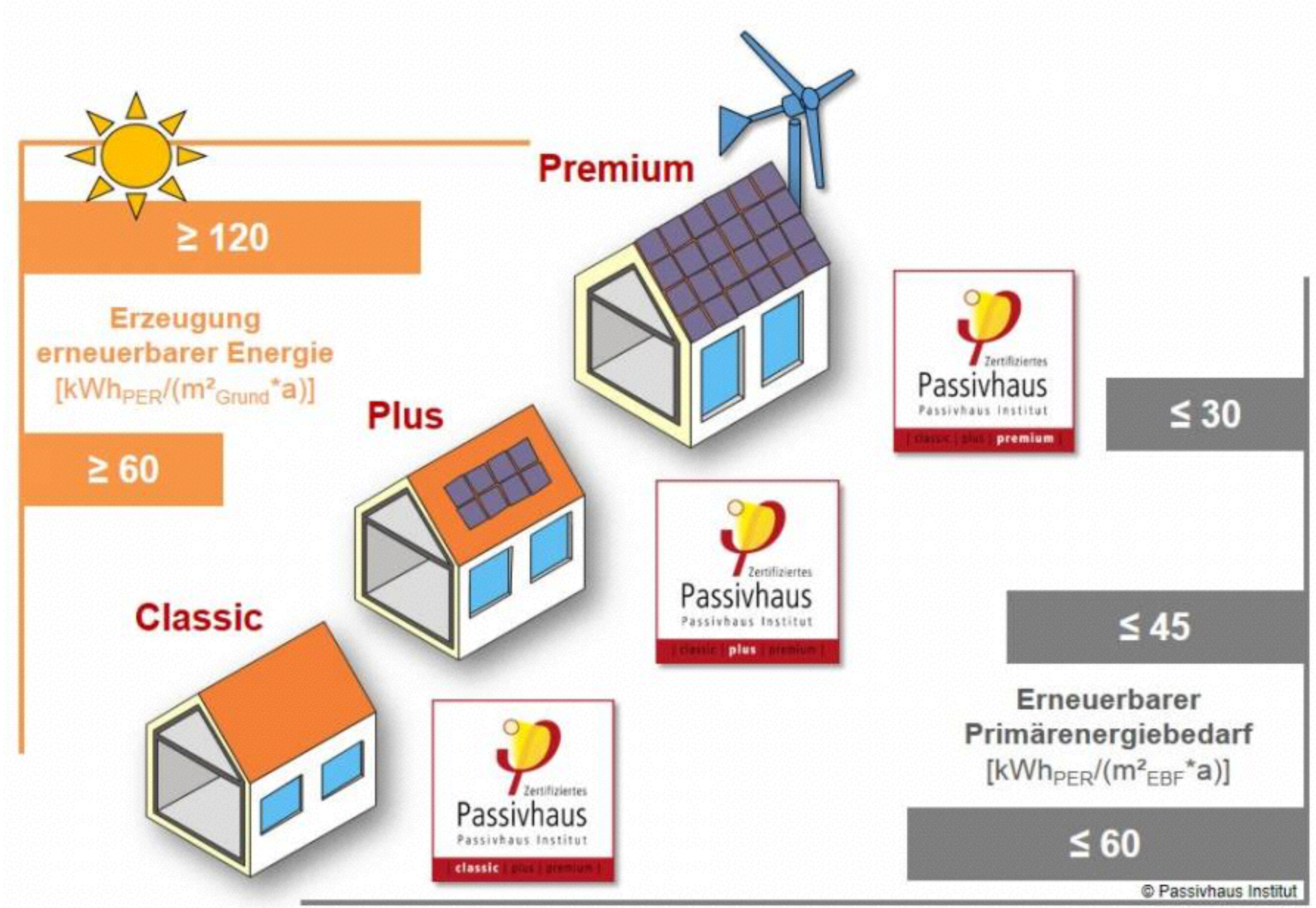
The Path to Ultimate Sustainability



Global Climate Specificity

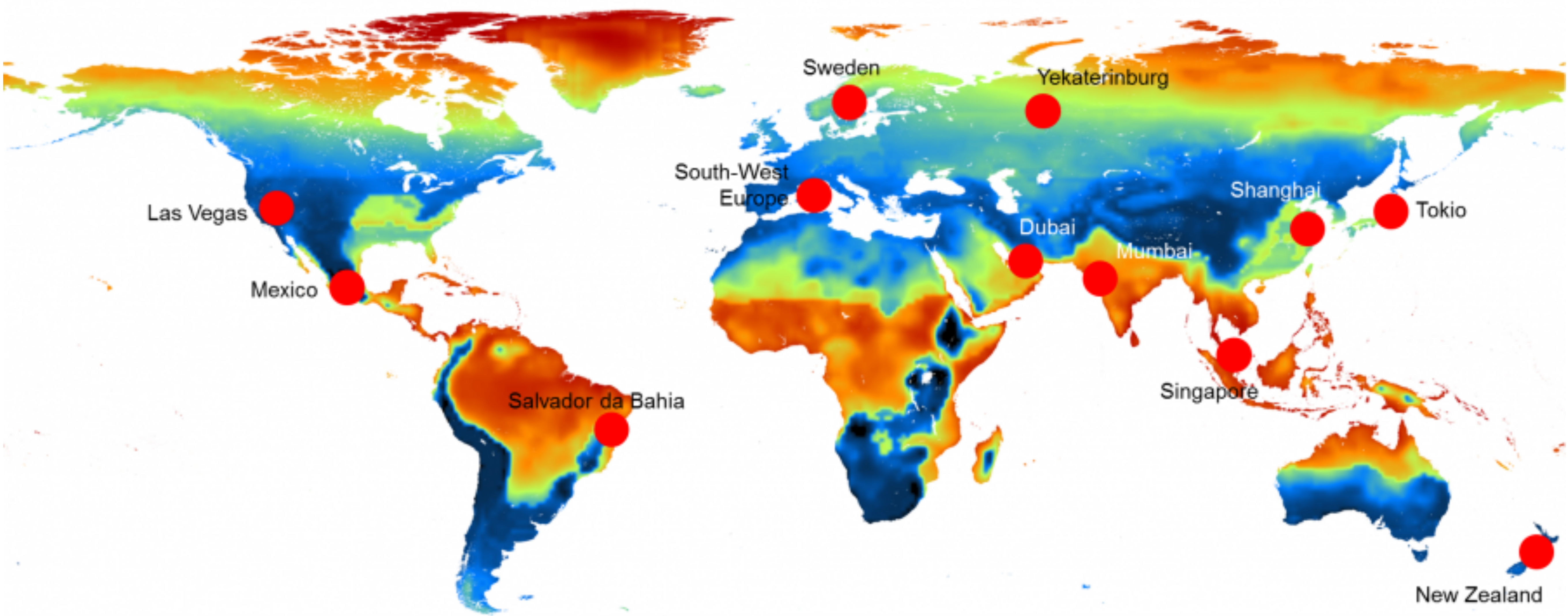


Illustration © Passive House Institute

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Climate-Specific Requirements

Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]			Glazing[5]	Solar load[6]		
	Insulation	Exterior insulation	Interior insulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)			Solar heat gain coefficient (g-value)	Max. specific solar load during cooling period	Min. heat recovery rate[7]	Min. humidity recovery rate[8]
	Max. heat transfer coefficient (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Determined in PHPP from project specific heating and cooling degree days against ground.	0.09	0.25	-	0.45	0.50	0.60	$U_g - g*0.7 \le 0$	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	$U_g - g*1.0 \le 0$		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	$U_g - g*1.6 \le 0$		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	$U_g - g*2.8 \le -1$		75%	-
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	-
Hot		0.50	0.75	Yes	1.25	1.30	1.40	-		-	60 % (humid climate)
Very hot		0.25	0.45	Yes	1.05	1.10	1.20	-		-	60 % (humid climate)

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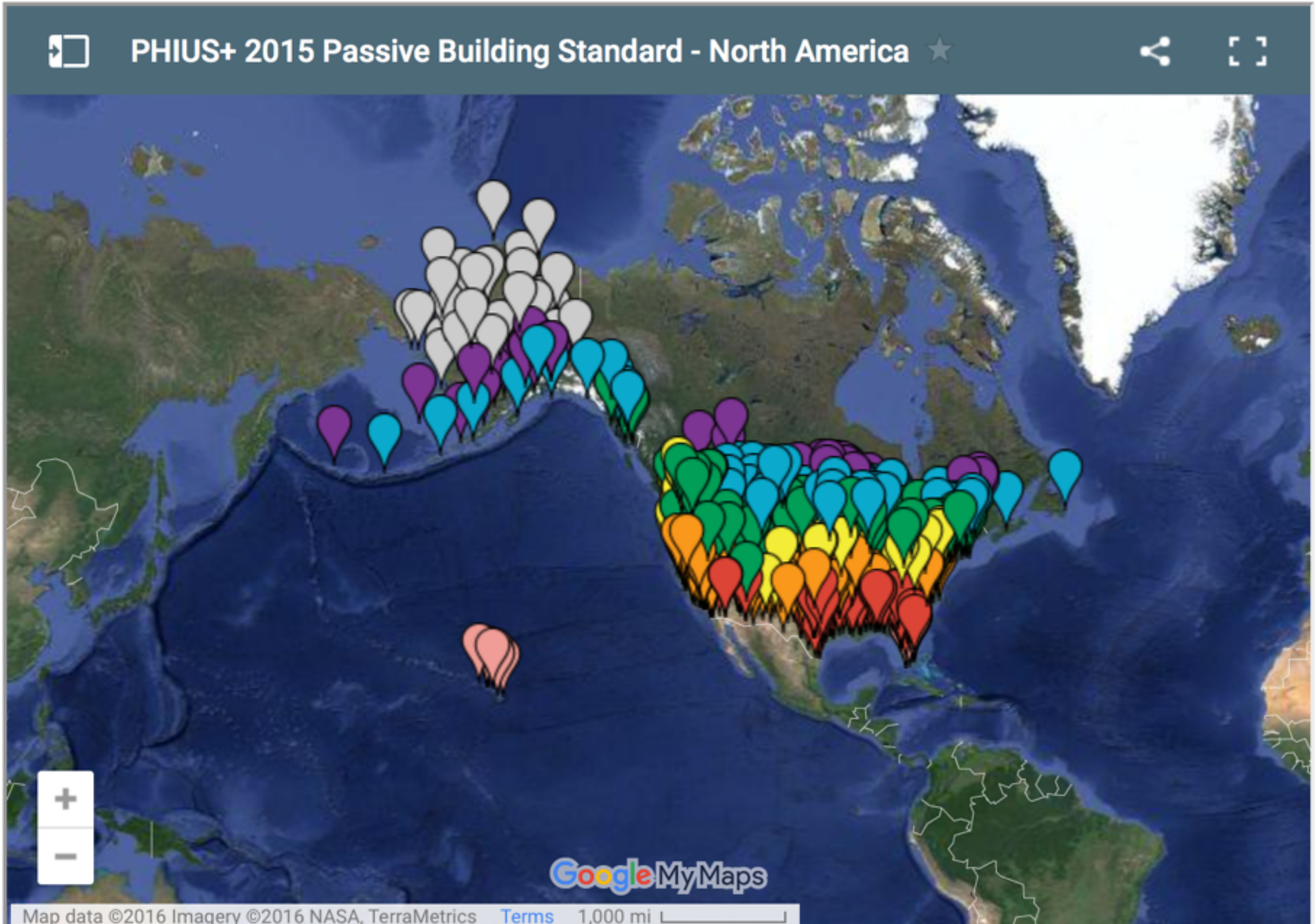
PHIUS+

United States

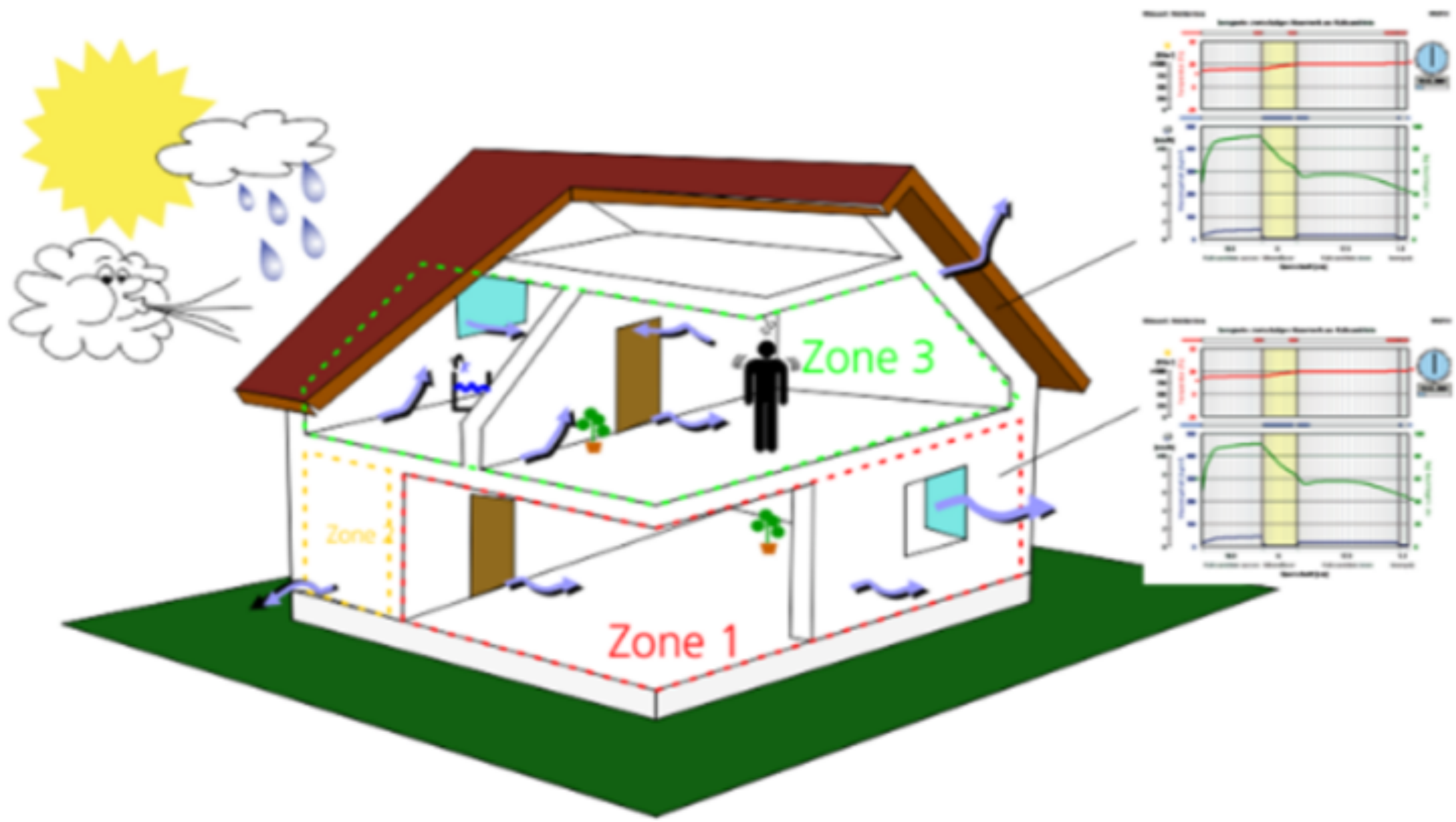
- Passive House Institute U.S., Chicago, Il
- Local raters and tie-in with other certifications
- New sovereign standard for the U.S.
- Climate zone specific

U.S. Climate Specificity



Energy Modeling

WUFI® Passive



Passive House in 90 Seconds

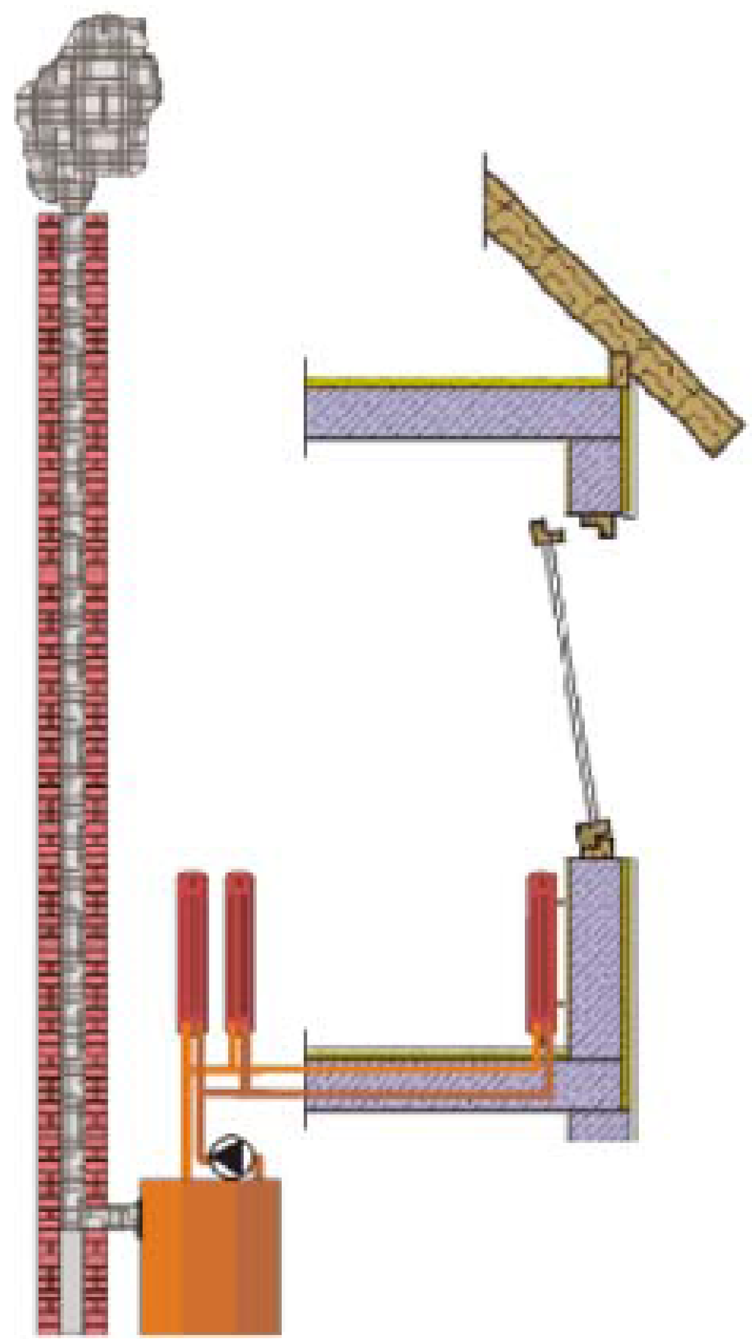
Basic Concept

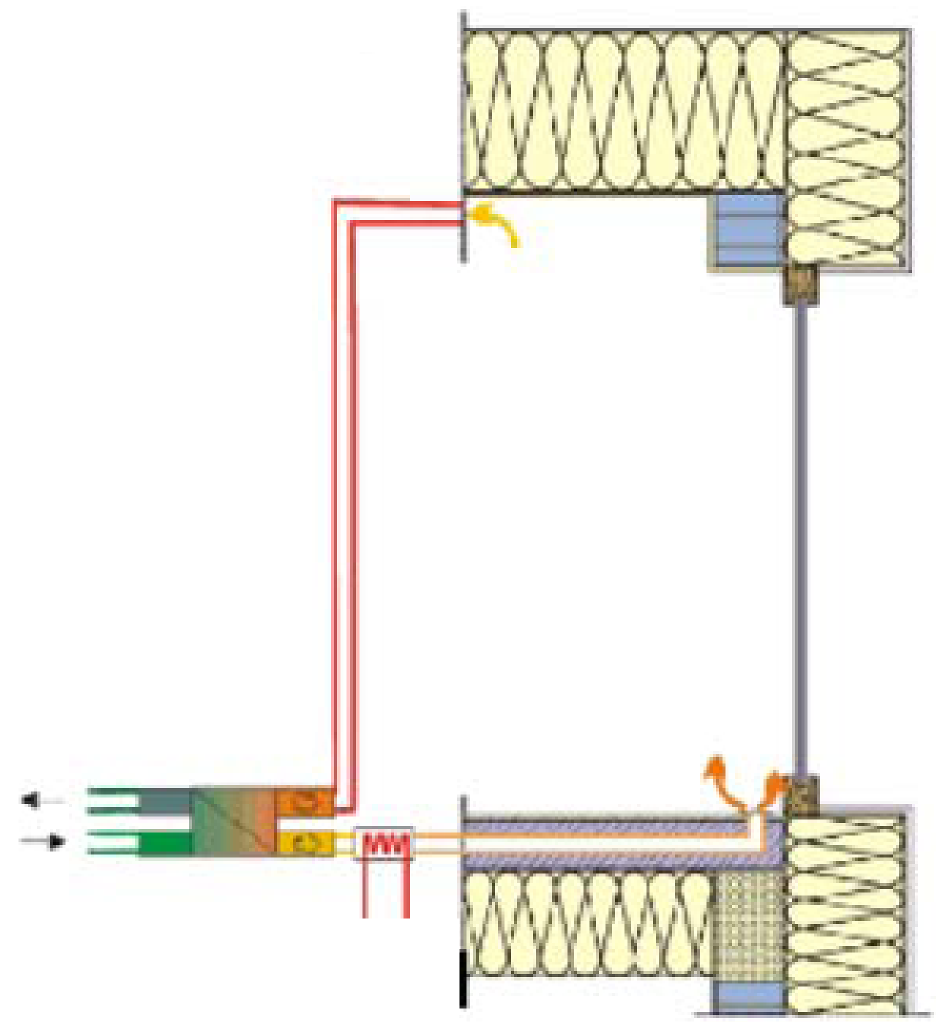
Conservation first

➡ Minimize losses

➡ Maximize (free) gains

Active vs. Passive





Active: 25-125 kBtu/(sf yr)

85 - 450 kWh/(m^2 a), typically found in the U.S.

Passive: 4.75 kBtu/(sf yr)

15kWh/(m^2 a), maximum target

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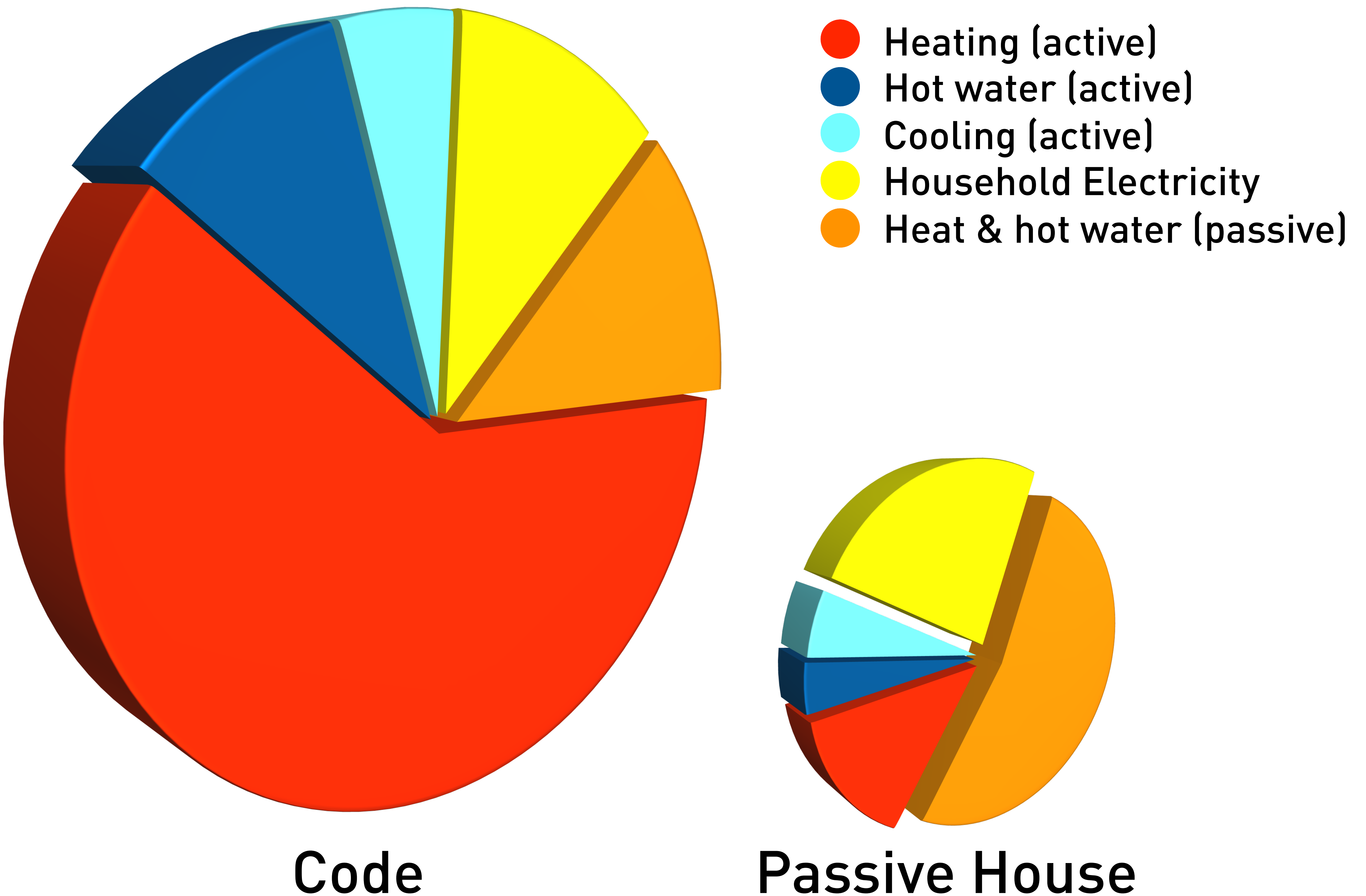
Source: Krapmeier & Drössler 2001

Energy Footprint



- ➡ up to 95% less heating energy
- ➡ 50 to 75% less total energy

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Learning from the BioHaus

Waldsee BioHaus, North America's first certified Passive House

Average energy use since 2006: 33kWh/(m^2 yr), or 10,500 Btu/(sf yr)

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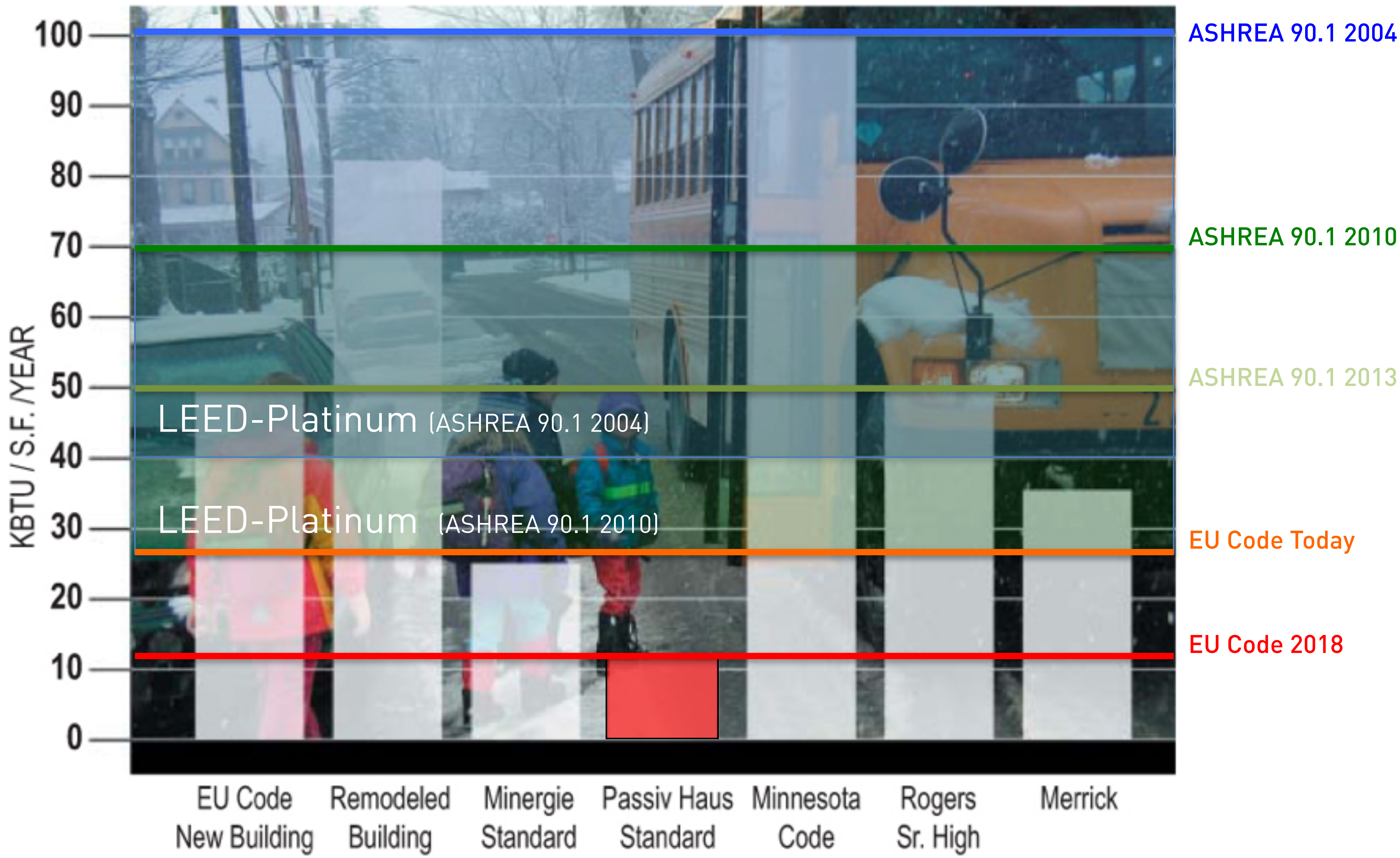
Performance Comparison



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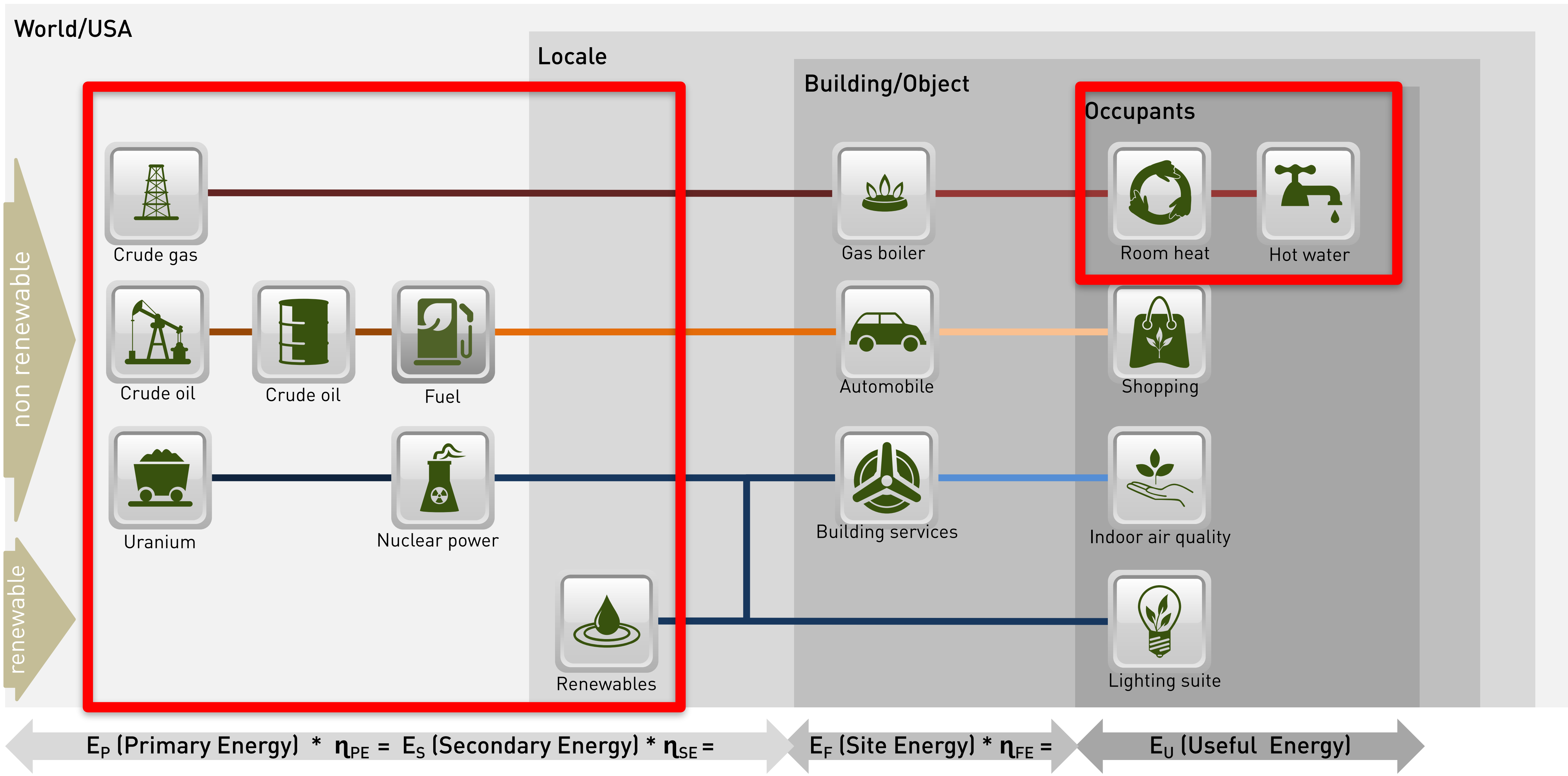
Understanding Energy Flow



120 kWh/ (m^2 a) or 38.1 kBtu/(sf yr) • Passive House Target • 15 kWh/ (m^2 a) or 4.75 kBtu/(sf yr)

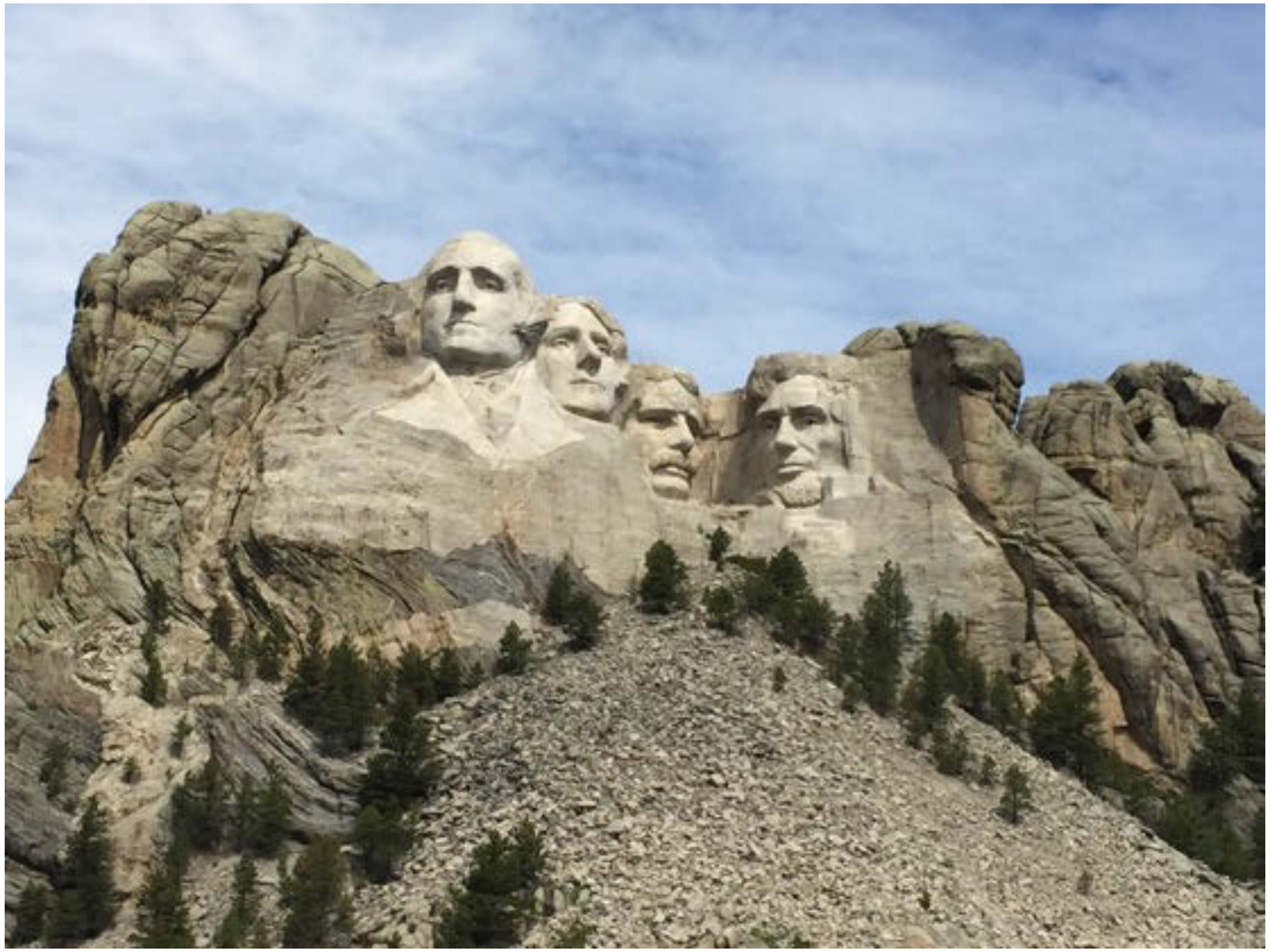
Understanding Energy Flow

Passive House takes care of energy performance.
Other systems and certifications are recommended to control:

- Environmentally and people friendly use of resources
- Operation, facility management
- Indoor environmental quality

Case Study 1
Impact of the Passive House Standard

State of South Dakota, 2013/14



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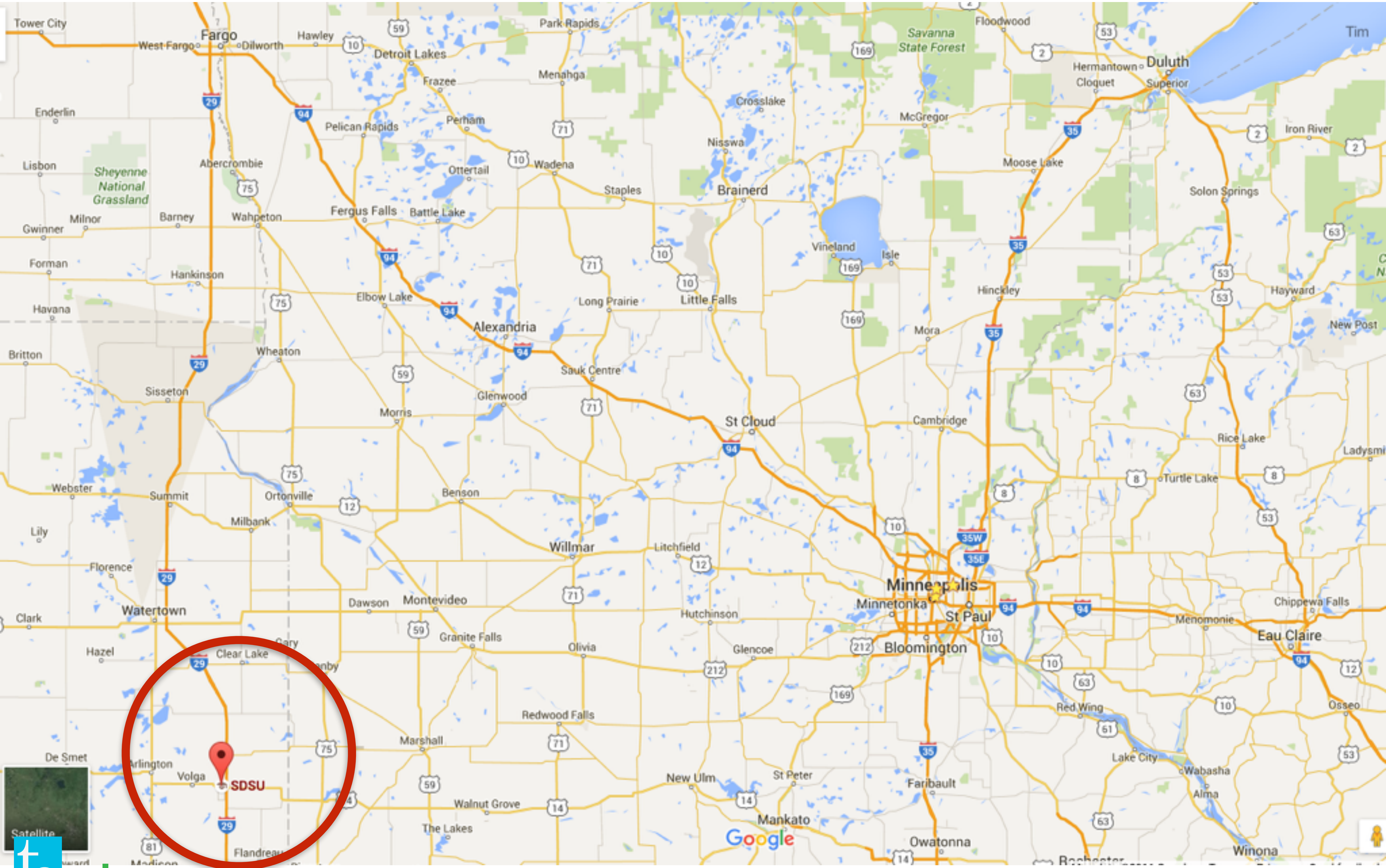
SDSU, Brookings, South Dakota



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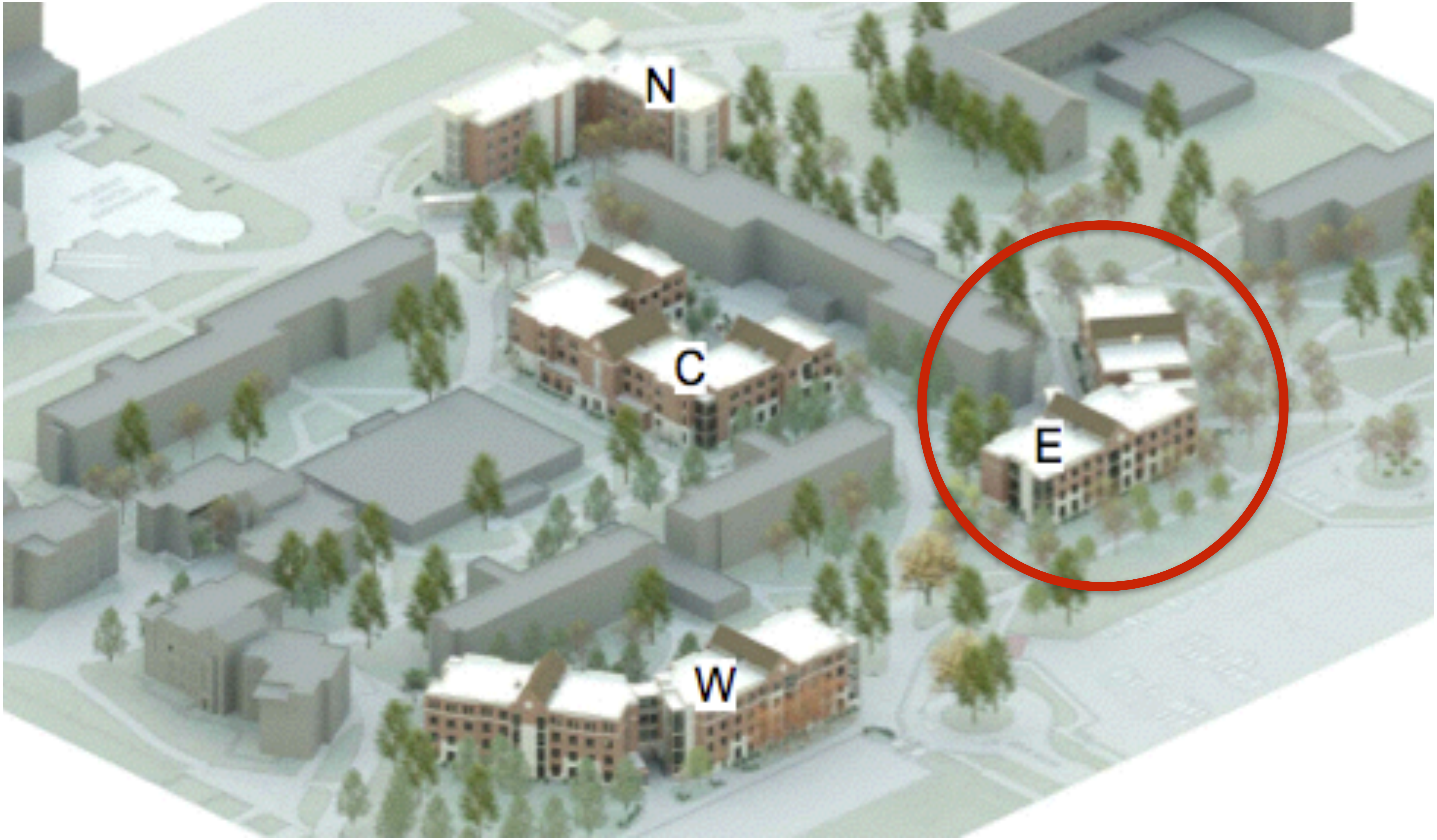
Jackrabbit Grove Residence Hall



South Dakota State University campus in Brookings, South Dakota
Building E, 2012
LEED Silver, 95 rooms, 190 tenants

Jackrabbit Grove Residence Hall

Project

- Analysis of the design and construction of the Base Building
- Analysis of the construction cost of the Base Building
- Creation of a Passive House version of the Base Building
- PHPP energy modeling
- Life cycle costing
- Evaluation and Recommendations
- Conclusion and Benefits

High-Performance Building Envelope

	Base Building	Passive House Building
Exterior Walls	R-16 (h sf °F/ Btu)	**R-34 (h sf °F/ Btu)**
Roof	R-70 (h sf °F/ Btu)	R-70 (h sf °F/ Btu)
Slab	R-3 (h sf °F/ Btu)	**R-27 (h sf °F/ Btu)**
Windows, Ext. Doors	U- 0.41 (Btu/ h sf °F) SHCG-0.27	**U- 0.12 (Btu/ h sf °F)** **SHCG-0.50**
Thermal Bridges	Significant	**Free**
Airtightness	ACH_{50}: 3.0 1/h (est.)	**ACH_{50}: ≤ 0.6 1/h (field tested)**
Ventilation w/ HR	51% HR-Efficiency 0.45 Wh/ m^3 Electr. Eff.	**87% HR-Efficiency** 0.45 Wh/ m^3 Electr. Eff.
Heating/ Cooling	District heating/cooling	District heating/cooling

➡ Opportunity for on-site HVAC system

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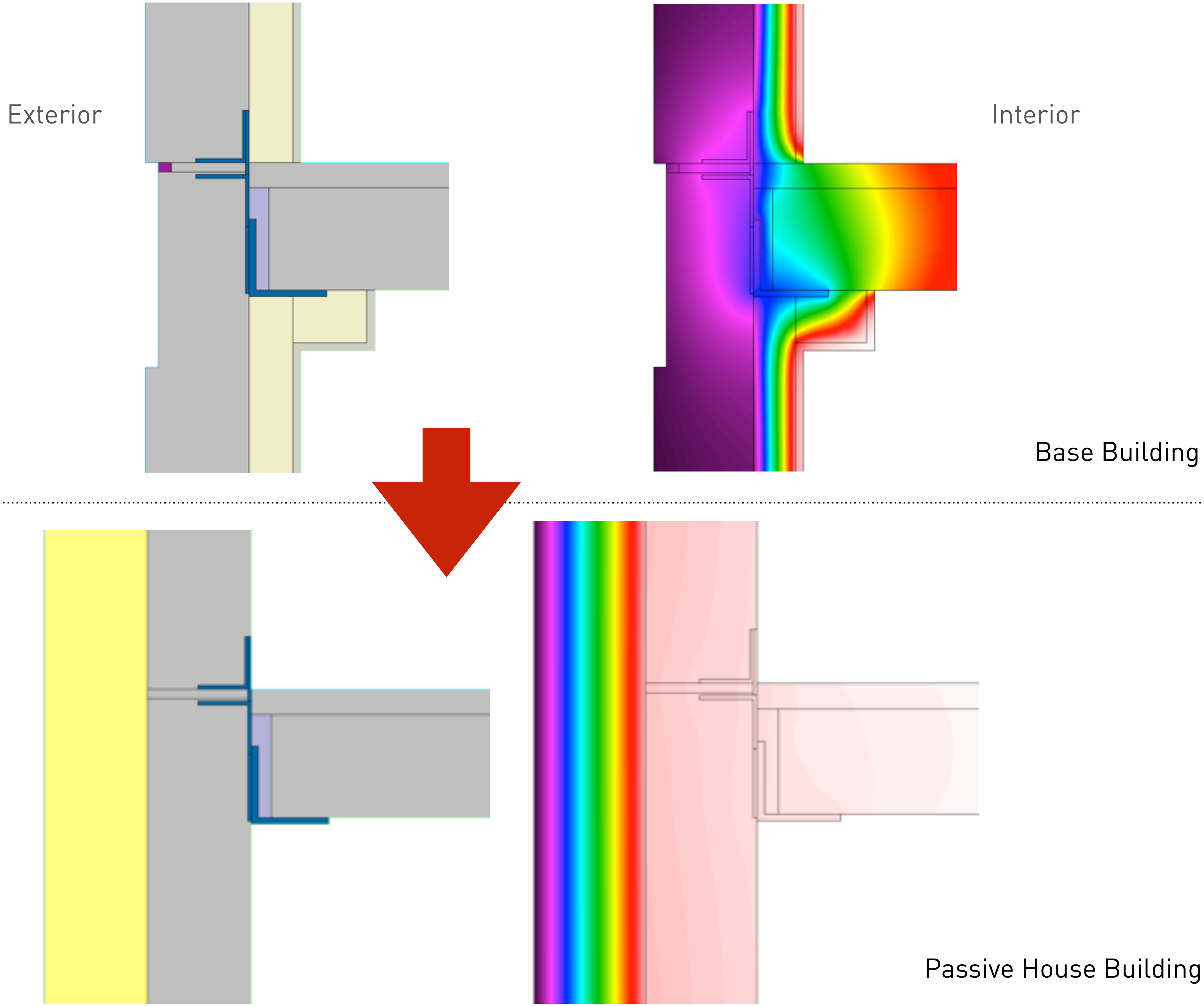
Thermal Bridge Free Assemblies



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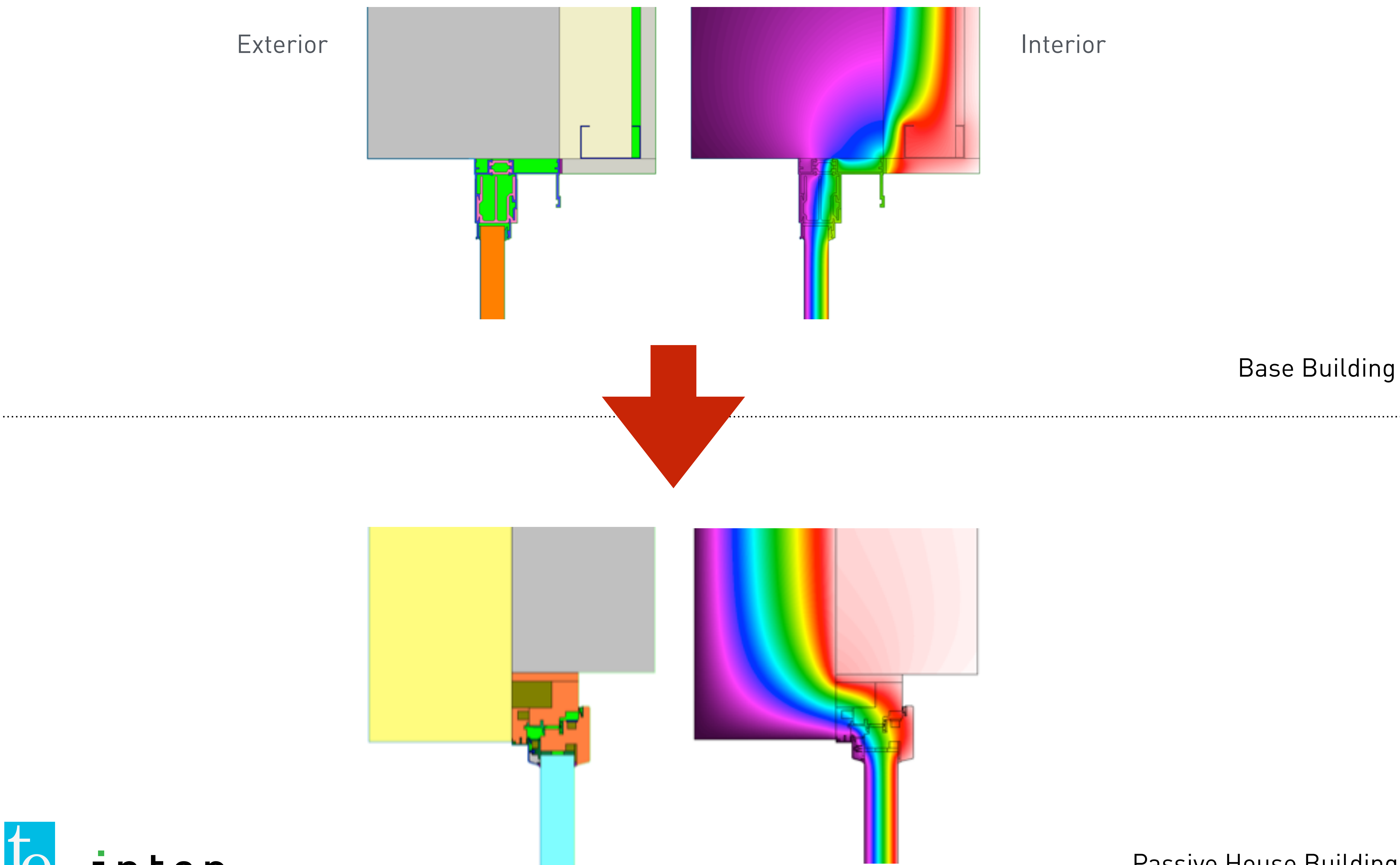
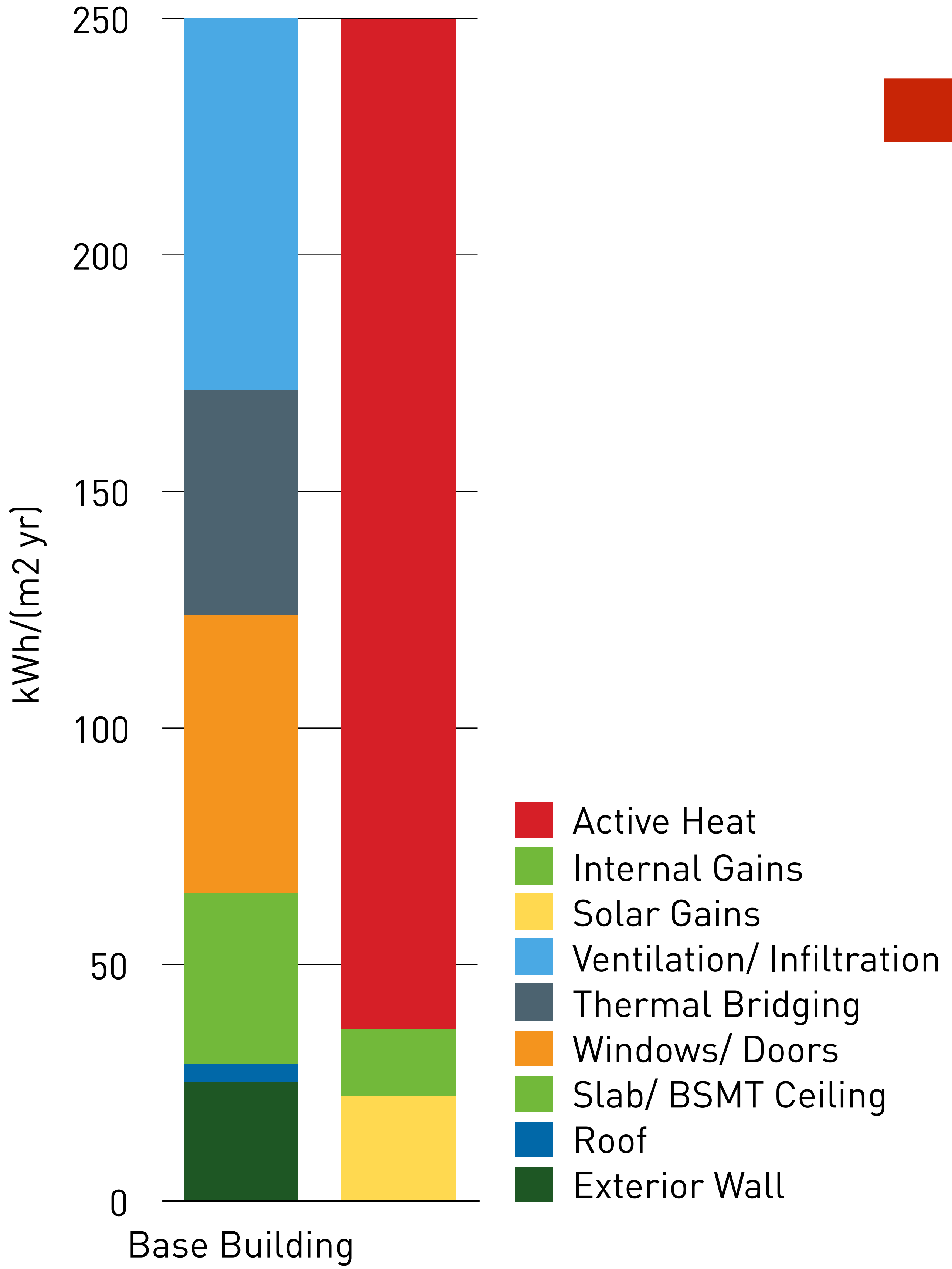
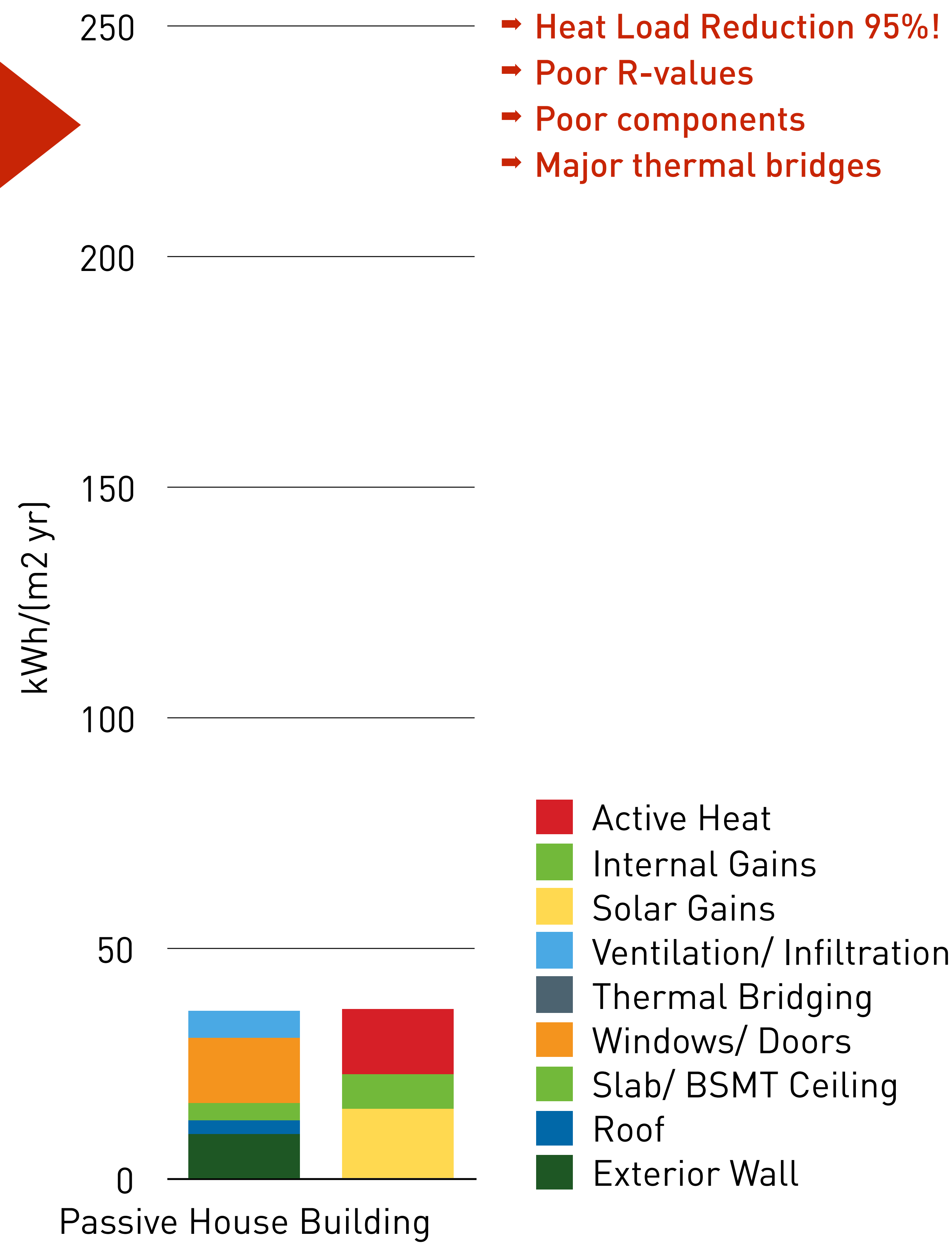
Thermal Bridge Free Details



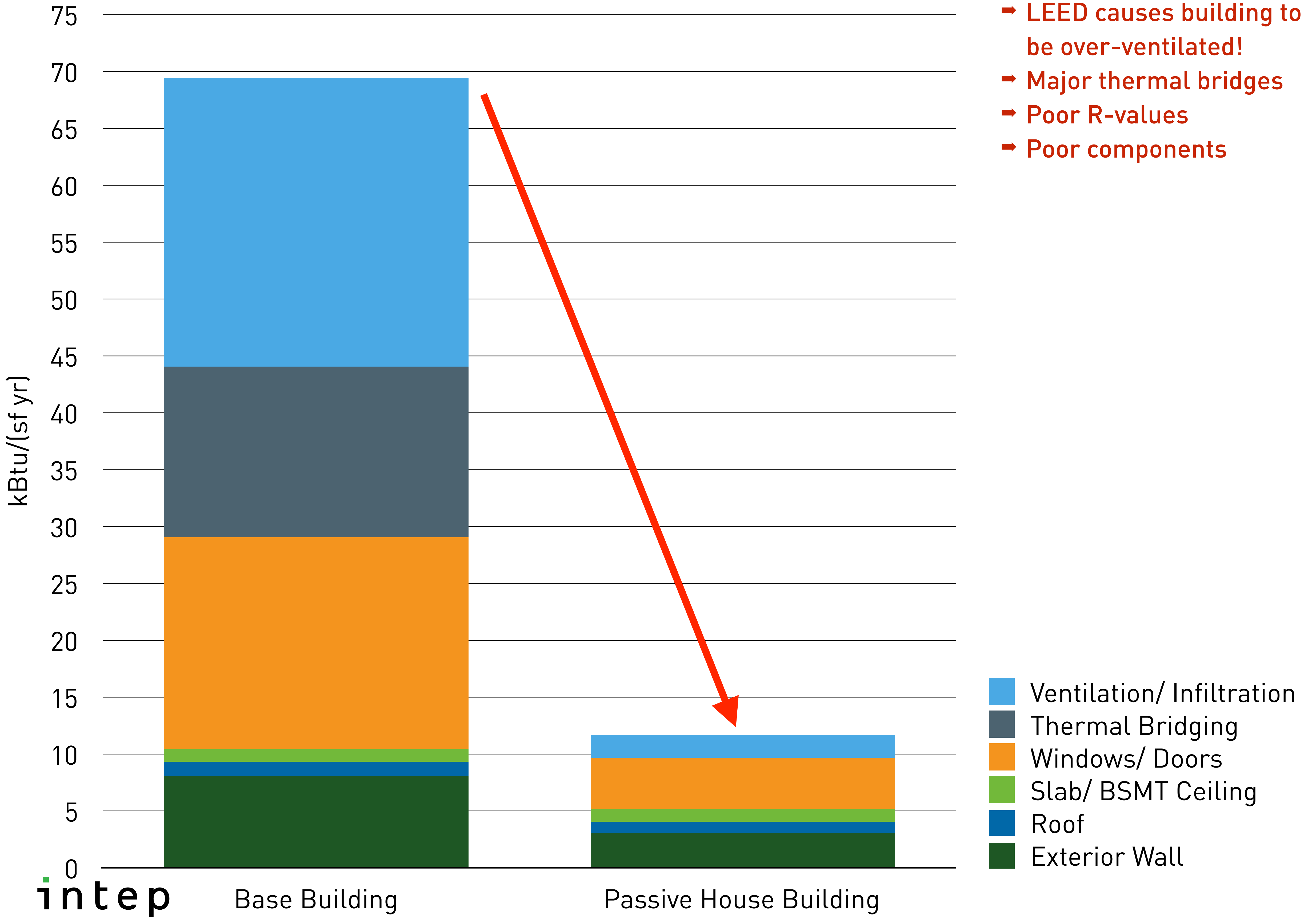
Heat Flow Comparison





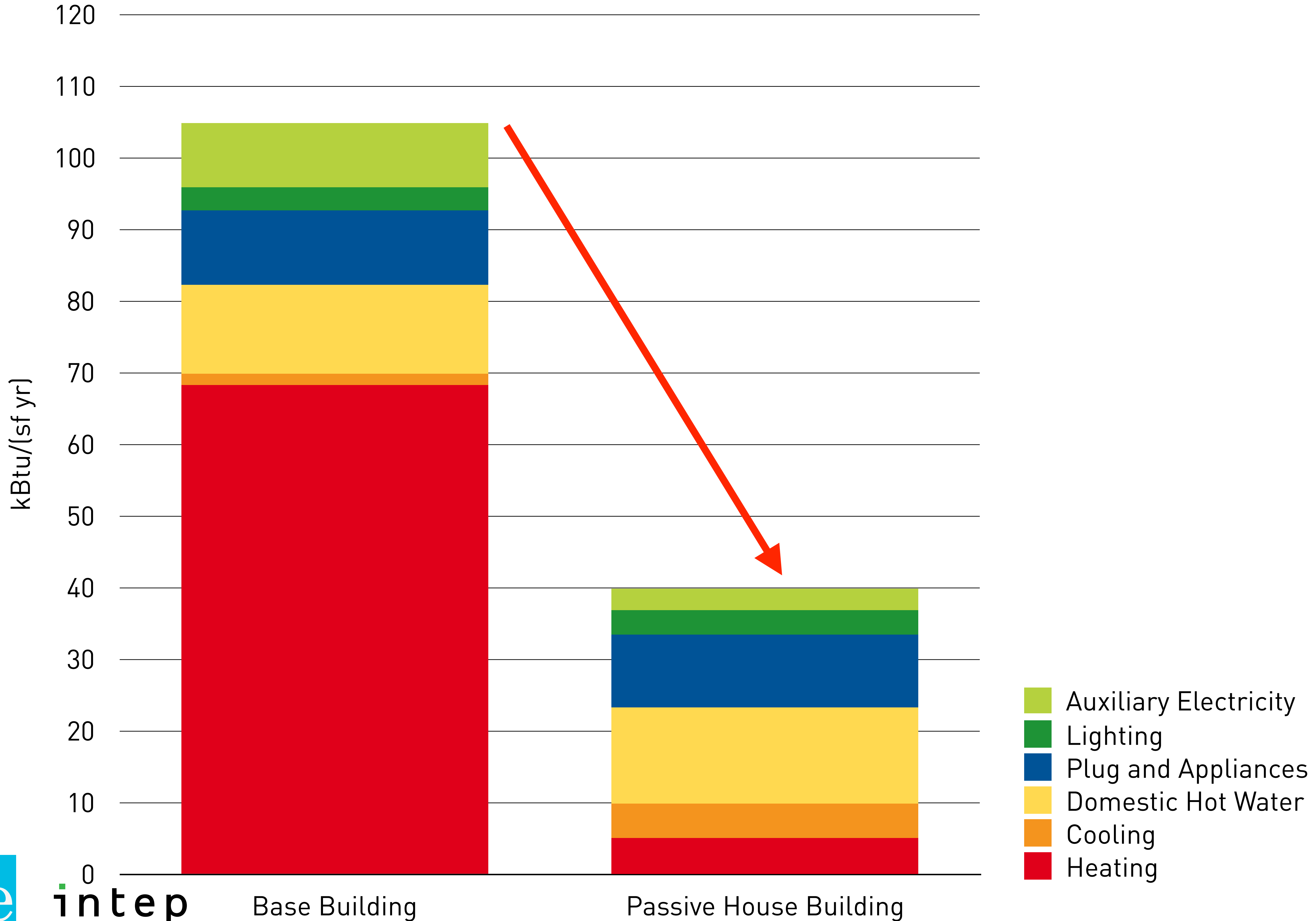
- Heat Load Reduction 95%!
- Poor R-values
- Poor components
- Major thermal bridges

Heat Loss Comparison

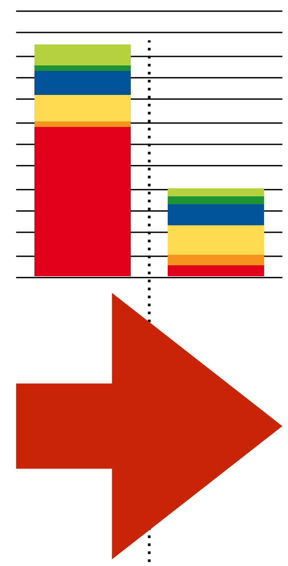


- LEED causes building to be over-ventilated!
- Major thermal bridges
- Poor R-values
- Poor components

Energy Consumption Comparison

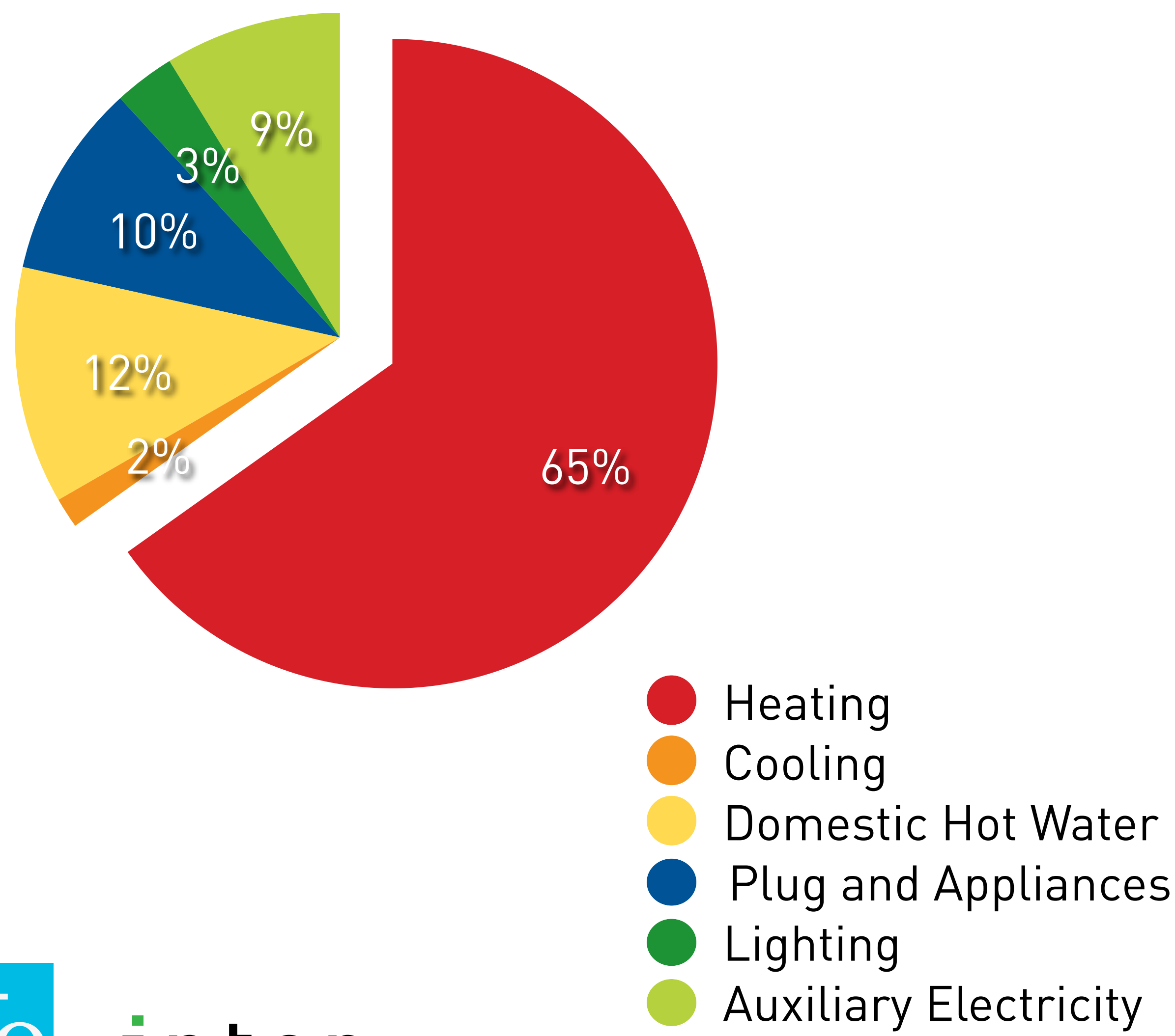


Energy Flow Comparison

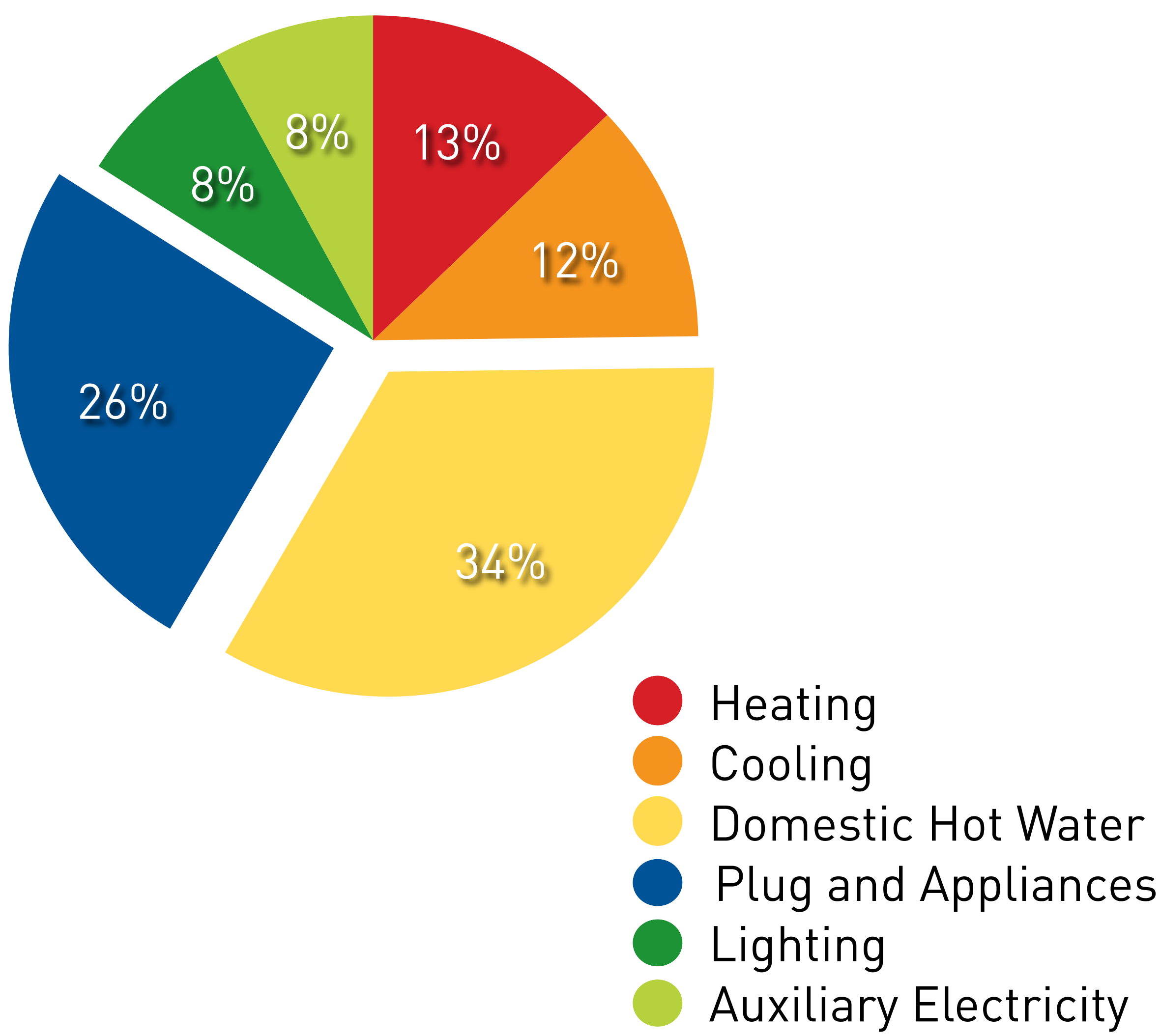


- ➡ Focus on plug loads
- ➡ Focus on domestic hot water

Base Building



Passive House Building



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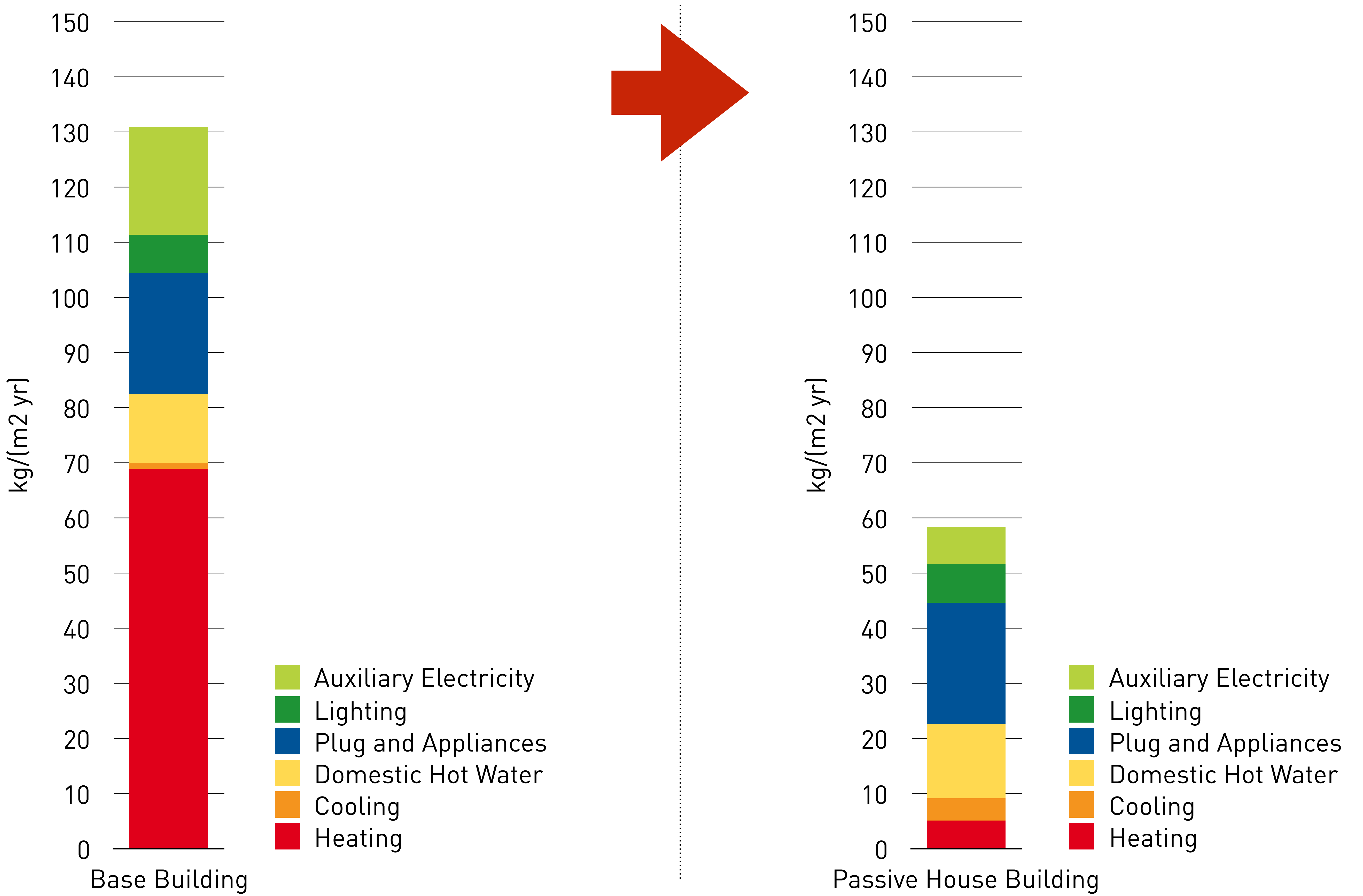
Carbon Emissions Comparison



Cost Comparison

Building Component	Base Building	Passive House Building	Difference
Structural Building Concrete + Steel + Masonry Systems	$2,015,796	$2,015,796	$0
Rough + Finish Carpentry	$230,339	$230,339	$0
Roofing, Moisture & Thermal Protection	$334,957	+$634,957	+$300,000
Glass & Glazing/ Door + Hardware	$611,076	+$1,067,076	+$456,000
Drywall Steel Stud Framing	$587,489	$587,489	$0
Interior Finishes	$451,441	$451,441	$0
Specialties & Accessories	$84,406	$84,406	$0
Elevators	$95,000	$95,000	$0
Plumbing Systems + Fire Suppressions System	$762,800	$762,800	$0
HVAC Systems	$518,650	$468,650	($50,000)
Electrical Systems	$683,675	$683,675	$0
Earthwork Excavation	$122,590	$122,590	$0
Building Investment Cost Total	**$6,498,219**	**$7,196,046**	**$697,827**

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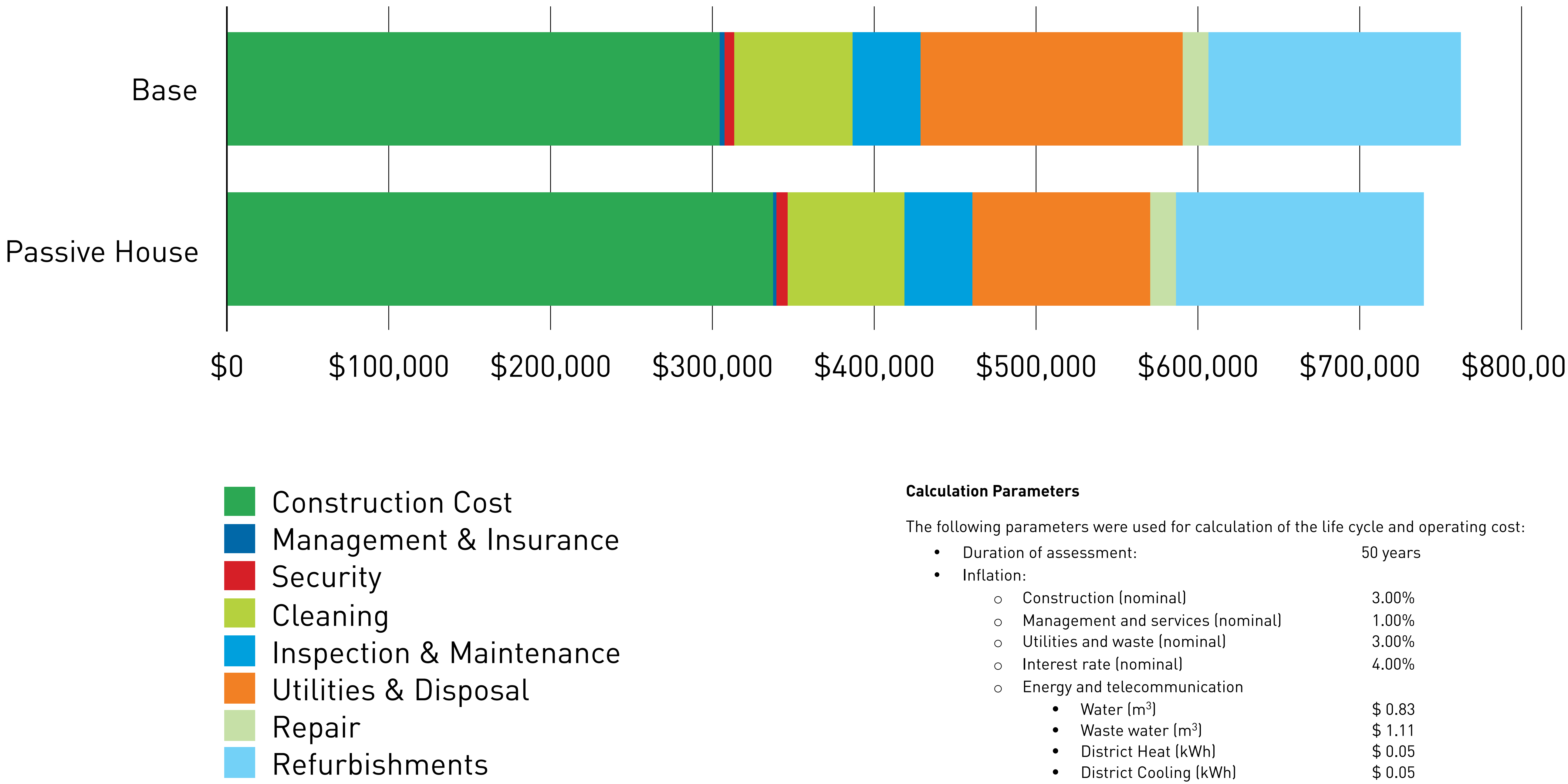
➡ Construction cost increase of approx. 10.5%

Life Cycle Cost Comparison

Annual Annualized Cost Comparison w/o HVAC system reduction



Calculation Parameters

The following parameters were used for calculation of the life cycle and operating cost:

- Duration of assessment: 50 years
- Inflation:
  - Construction (nominal) 3.00%
  - Management and services (nominal) 1.00%
  - Utilities and waste (nominal) 3.00%
  - Interest rate (nominal) 4.00%
  - Energy and telecommunication
    - Water (m^3) $ 0.83
    - Waste water (m^3) $ 1.11
    - District Heat (kWh) $ 0.05
    - District Cooling (kWh) $ 0.05
    - Electricity (kWh) $ 0.07

➡ Annual Annuitized Cost Reduction of approx. 3%