ENERGY DESIGN
conference & expo

Ultra-Efficient Housing

The Solution for a Sustainable Future

DESIGNER
CERTIFIED
PASSIVE HOUSE
DESIGNER

Tim Eian, Dipl.-Ing.
Certified Passive House Planner & Consultant

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In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors code/ energy** continuing education requirements."

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Tanner

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Building Performance, Measured Results

Learning Objectives

1. The Passive House building energy standard
2. Energy efficiency
3. Climate efficiency
4. Life Cycle Cost efficiency
5. Moving from standard construction to Passive House
6. New construction multi-family affordable housing
7. Retrofit multi-family affordable housing
8. The tangible and intangible benefits of ultra-efficiency

“Passivhaus” - Passive House

EnerPHit ✓

Quality-Approved
Energy Retrofit with
Passive House Components
Dr. Wolfgang Feist

PHI **Low Energy** Building

“A rigorous, voluntary building energy standard focusing on highest energy efficiency and quality of life at low operating cost.”

Passive House in 90 Seconds

Video: Hans-Jörn Eich

Global Standard

Think globally, build locally.

Since 1991

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Climate Zone Specificity

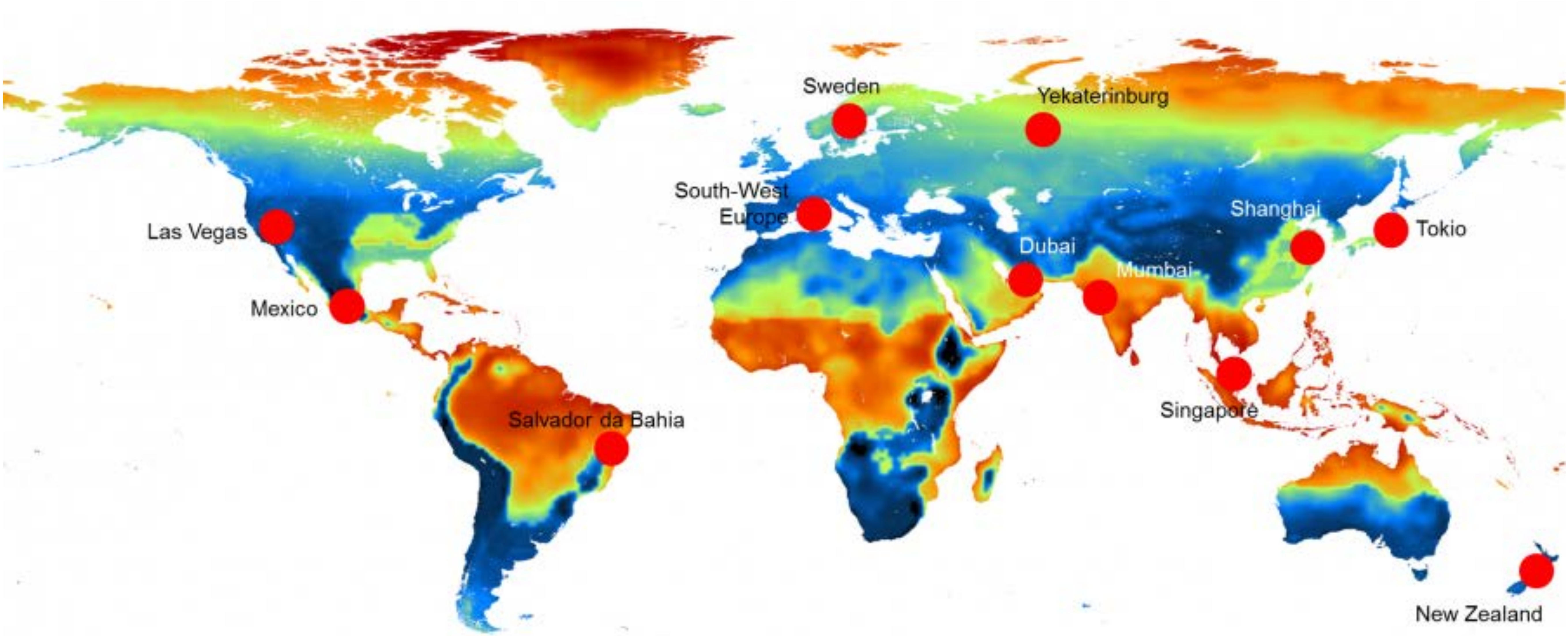
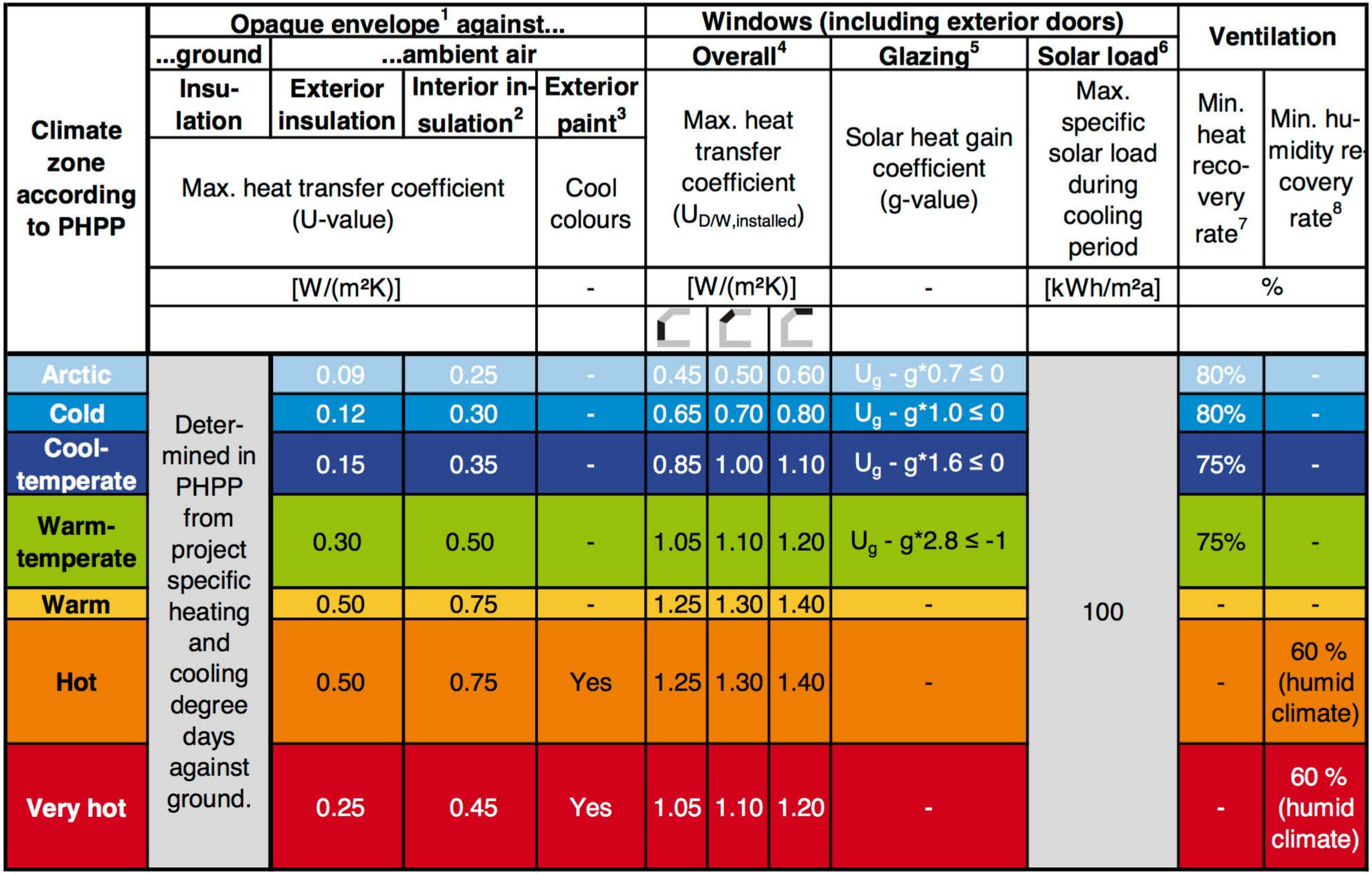


Illustration © Passive House Institute

Climate Zone Targets



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	$U_g - g*0.7 \leq 0$	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	$U_g - g*1.0 \leq 0$		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	$U_g - g*1.6 \leq 0$		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	$U_g - g*2.8 \leq -1$		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)

Third-Party Certified

Certification Documentation

This building has been awarded the Certified Passiv
by the Passive House Institute.

This certification is based solely on the design data and sp
House Institute by the client for the purpose of certificatio
checked and approved the building's energy balances ac

This certification does not cover quality assurance c
implementation. The Passive House Institute hereby ta
the above.

Certificate-ID: 9689_PHI_PH_20141017_AM

Passive House Institute
Dr. Wolfgang Feist
Rheinstr. 44/46
64283 Darmstadt
Germany

Passive House Institute

Certificate

**The Passive House Institute awards the seal "Certified Passive House"
to the following building**

24th Street Passive House #1, 749 24th St. North, La Crosse, WI 54601, USA

Client: **Western Technical Collage
400 7th St. North, La Crosse, WI 54602, USA**

Architect: **Integrated Planning LLC
901 23rd Ave NE, Minneapolis, MN 55418, USA**

Building Services: **Integrated Planning LLC
901 23rd Ave NE, Minneapolis, MN 55418, USA**

Certified Passive House
Passive House Institute

This building was designed to meet Passive House criteria as defined by the Passive House Institute. With appropriate on-site implementation, this building will have the following characteristics:

- Excellent thermal insulation and optimised connection details with respect to building f
  demand or heating load will be limited to
  15 kWh per m² of living area and year or a heating load of 10 W/m²
- When outdoor temperatures are high, thermal comfort can be ensured with pas
  minimal energy demand for cooling and dehumidification according to the location-
  requirements.
- A highly airtight building envelope, which eliminates draughts and reduces the h
  The air change rate through the envelope at a 50 Pascal pressure difference, as ve
  ISO 9972, is less than
  0.6 air changes per hour with respect to the building's volume
- A controlled ventilation system with high quality filters, highly efficient heat re
  consumption, ensuring excellent indoor air quality with low energy consumption
- A total primary energy demand for heating, domestic hot water, ventilation and
  during normal use of less than
  120 kWh per m² of living area and year

This certificate is to be used only in combination with the associated certificatio
the exact characteristics of the building.

Passive Houses offer high comfort throughout the year and can be heated
example, by heating/cooling the supply air. Even in times of cold outdoor tem
of a Passive House is evenly warm on the inside and the internal surface temp
air temperatures. Due to the highly airtight envelope, draughts are elim
ventilation system constantly provides fresh air of excellent quality. Energy co
comfort in a Passive House are very low. Thanks to this, Passive Houses off
and future rises in energy prices. Moreover, the climate impact of Passive H
use, thereby resulting in the emission of comparatively low levels of carbon

**issued:
Darmstadt, 17.10.2014**

Wolfgang Feist

Dr. Wolfgang Feist

Certificate-ID: 9689_PHI_PH_20141017_AM

Certified
Passive House

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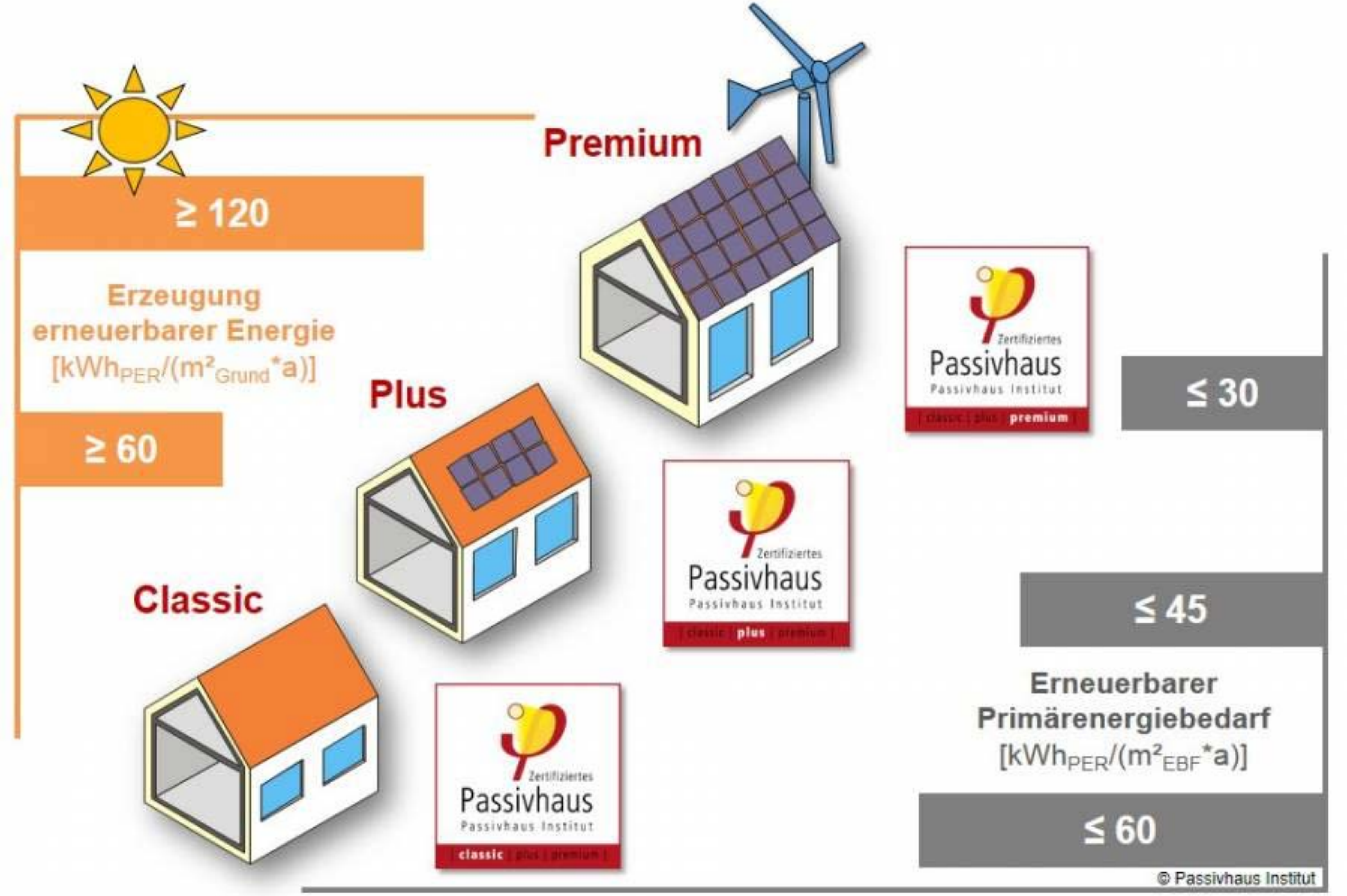
Tool for Sustainable Design

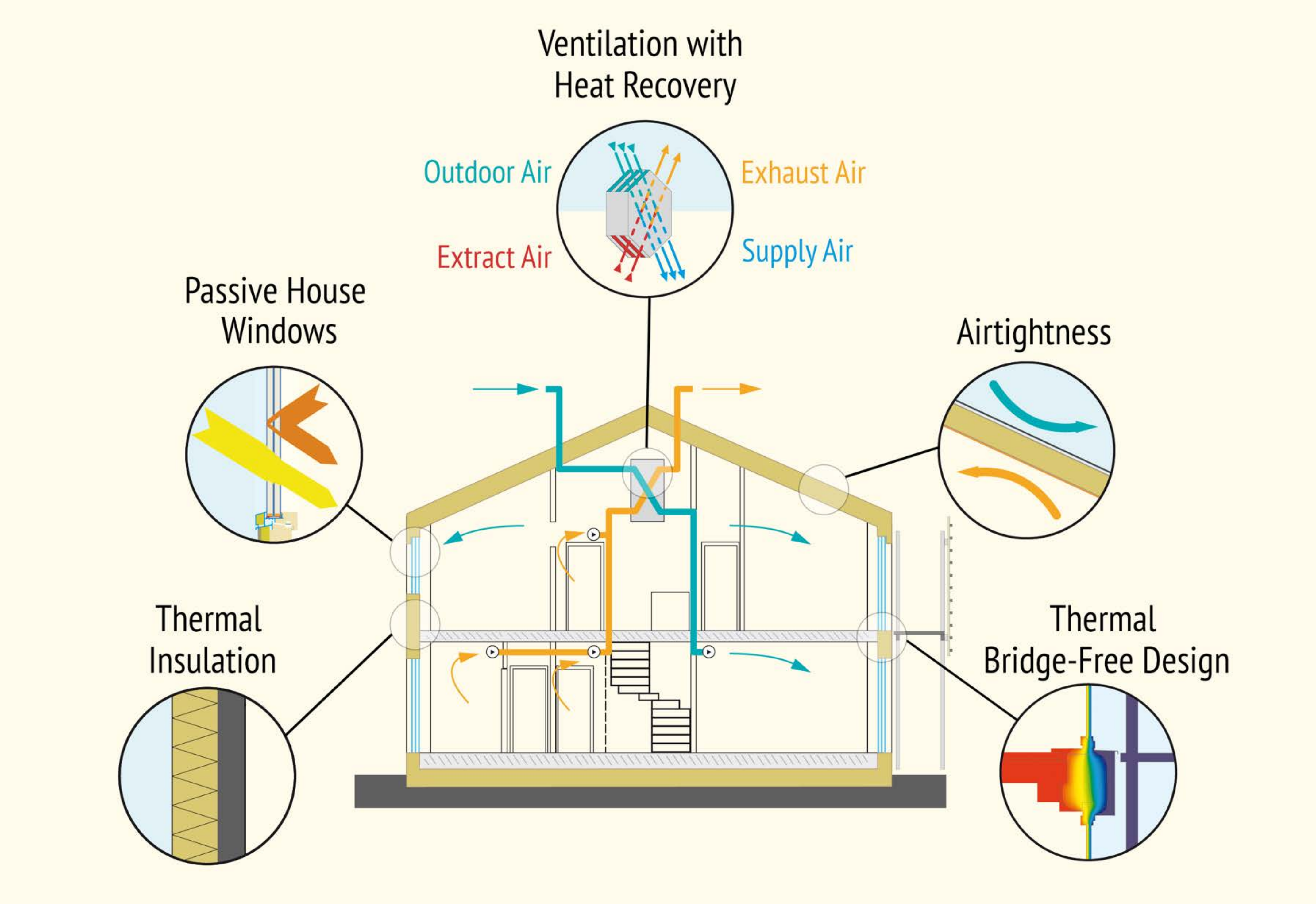
Path to Sustainability



Basic Concept

- Conservation first
- Minimize losses
- Maximize (free) gains

The 5 Principles



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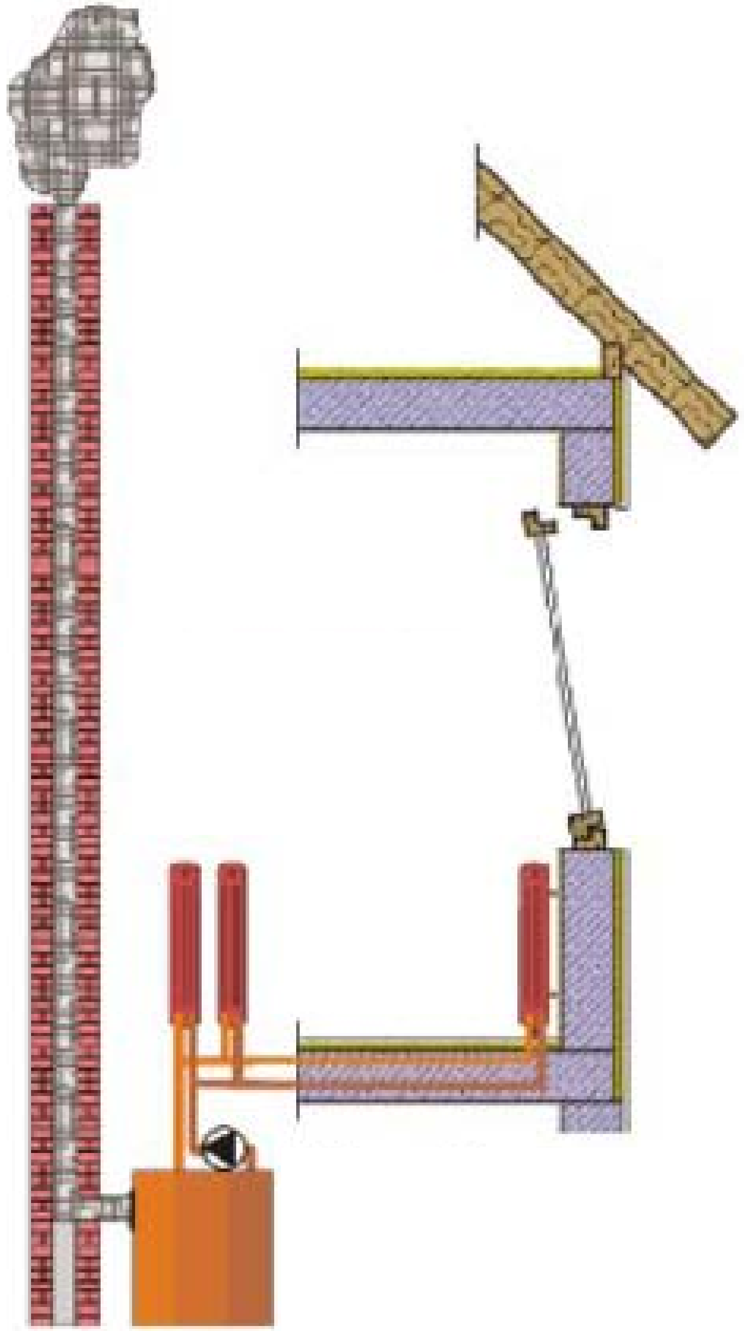
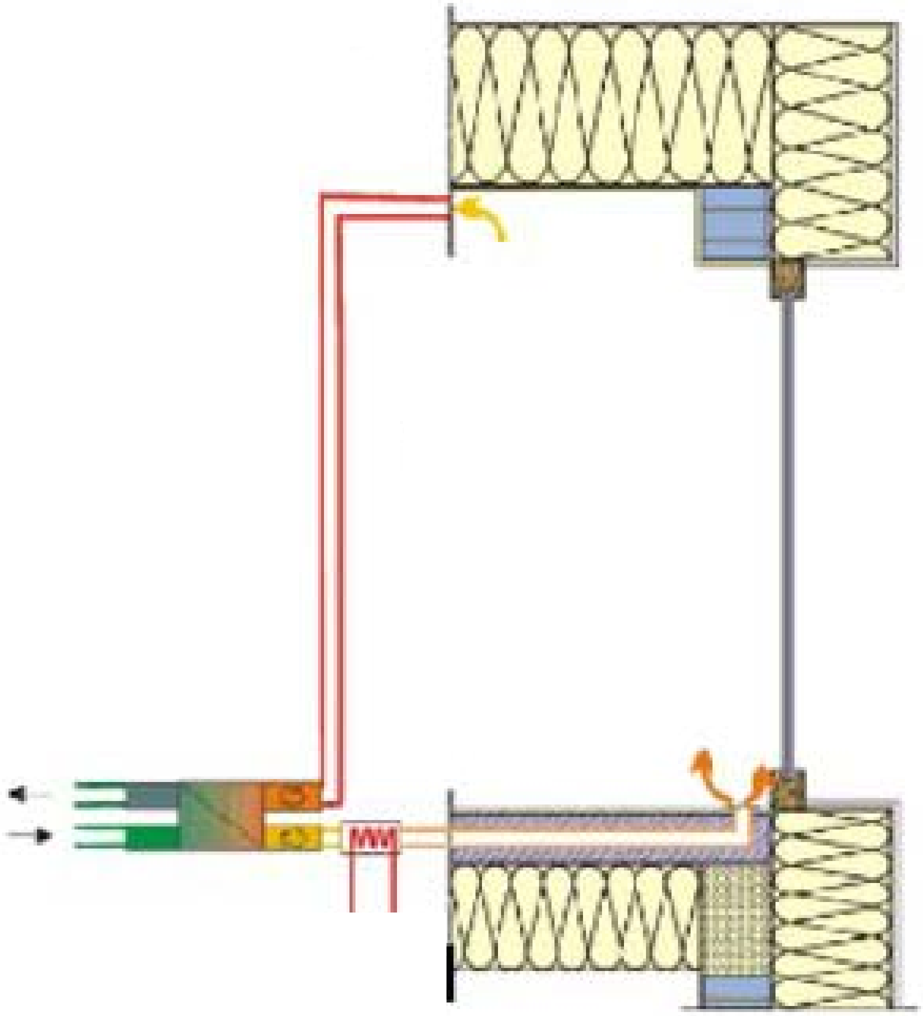
Active versus Passive



Active: 25-125 kBtu/(sf yr)

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

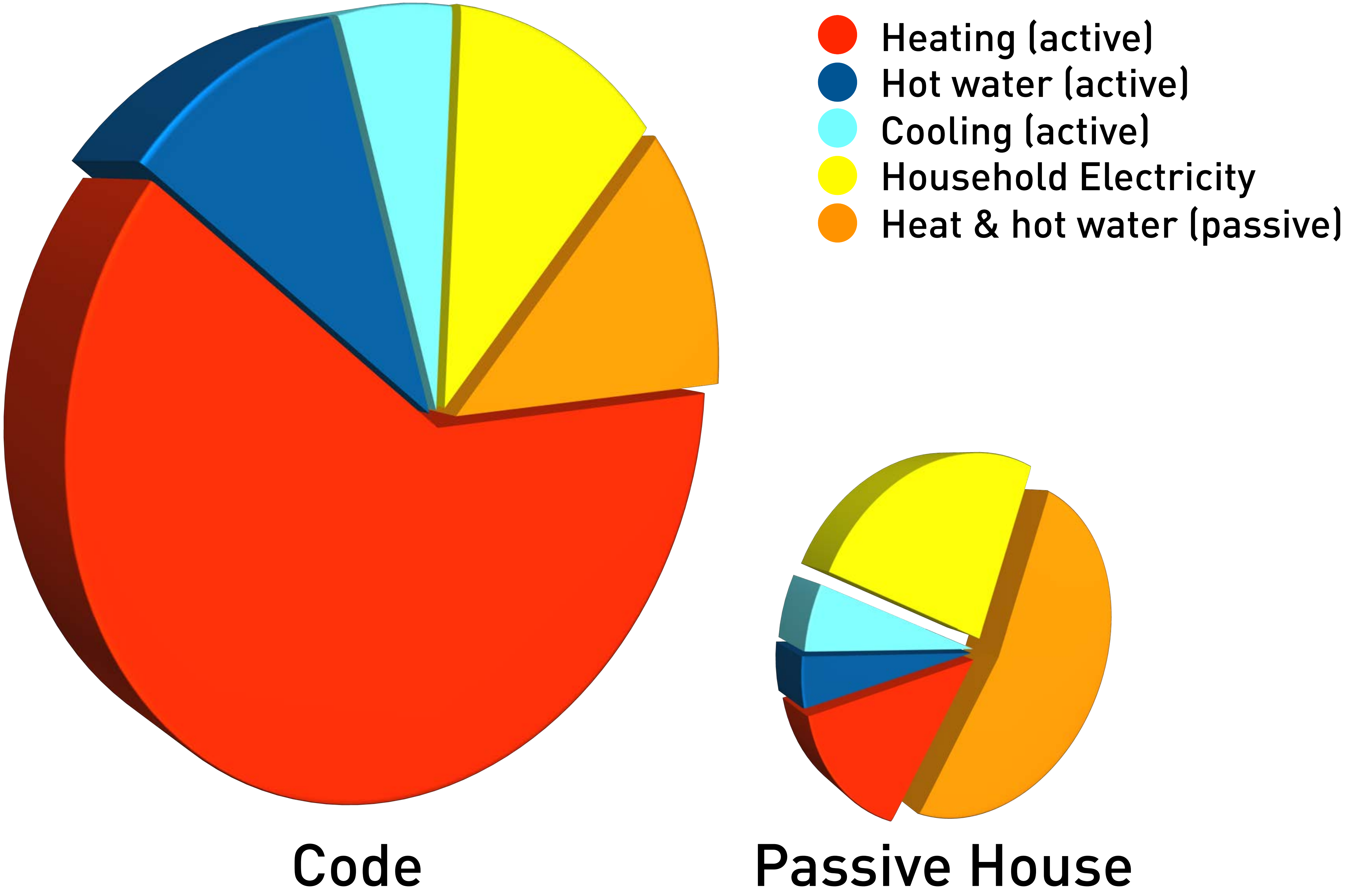


Passive: 4.75 kBtu/(sf yr)

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

Source: Krapmeier & Drössler 2001

Energy Footprint Comparison



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

Metrics

Energy per Square Foot and Year

Gas mileage for buildings.

Heating/ Cooling Energy Targets

PHI Low Energy Building Entry Level	≤ 9.5 kBtu/(sf yr)	≤ 30kWh/(m^2 a)
EnerPHit Quality-Approved Energy Retrofit with Passive House Components Dr. Wolfgang Feist Retrofit	≤ 7.9 kBtu/(sf yr)	≤ 25kWh/(m^2 a)
New Construction	≤ 4.75 kBtu/(sf yr)	≤ 15kWh/(m^2 a)

Source Energy Targets

PHI Low Energy Building

≤ 38 kBtu/(sf yr)

$\leq 120 \text{kWh}/(\text{m}^2\ \text{a})$

EnerPHit ✓

Quality-Approved Energy Retrofit with Passive House Components

Dr. Wolfgang Feist

varies

$\leq 120\ \text{kWh}/(\text{m}^2\ \text{a}) + ((QH - 15\ \text{kWh}/(\text{m}^2\ \text{a})) * 1.2)$

Suggested Heat Load Target

≤ 3.17 Btu/(h sf)

$\leq 10\text{W/m}^2$

Heating energy can be supplied through ventilation system.

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Airtightness Target

≤ 0.6 ACH$_{50}$

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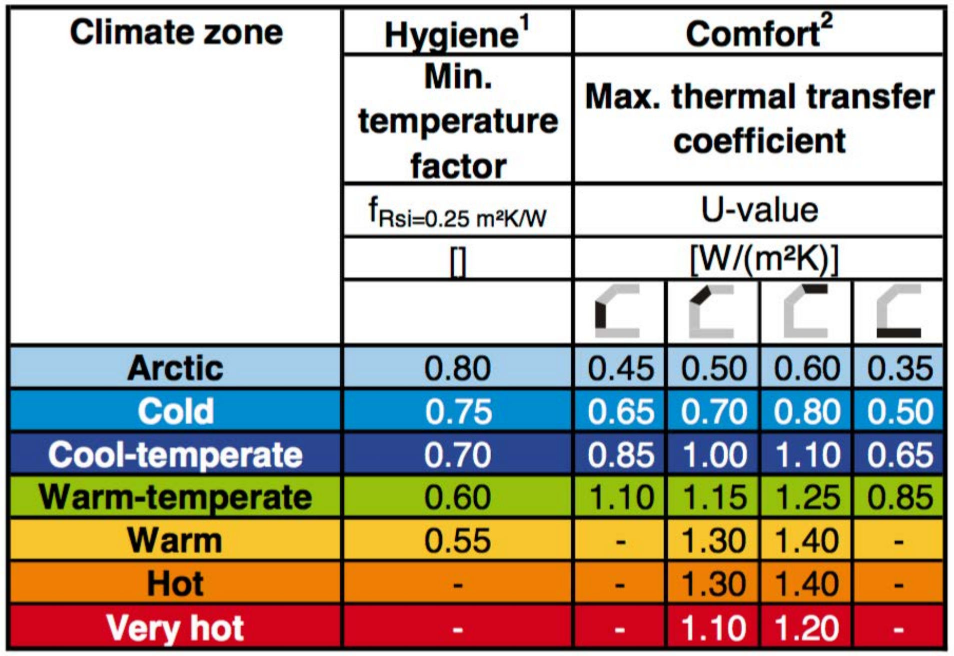
≤ 1.0 ACH$_{50}$

Measured with a blower door in the field.

Component Targets



Climate zone	Hygiene[1]	Comfort[2]			
	Min. temperature factor	Max. thermal transfer coefficient			
	$f_{Rsi=0.25\ m^2K/W}$	U-value			
	[]	$[W/(m^2K)]$			
Arctic	0.80	0.45	0.50	0.60	0.35
Cold	0.75	0.65	0.70	0.80	0.50
Cool-temperate	0.70	0.85	1.00	1.10	0.65
Warm-temperate	0.60	1.10	1.15	1.25	0.85
Warm	0.55	-	1.30	1.40	-
Hot	-	-	1.30	1.40	-
Very hot	-	-	1.10	1.20	-

- Maximum U-values
- Minimum R-values
- SHGC requirements
- Minimum heat-recovery rates

EnerPHit offers a Component Track.

Energy Modeling


PHPP

Passive House Planning Package

Version 9 (2015) © Passive House Institute

Definition of Ultra-Efficiency

- Energy efficiency
- Climate efficiency
- Life cycle cost efficiency

Energy Efficiency Principles

PHI **Low Energy** Building

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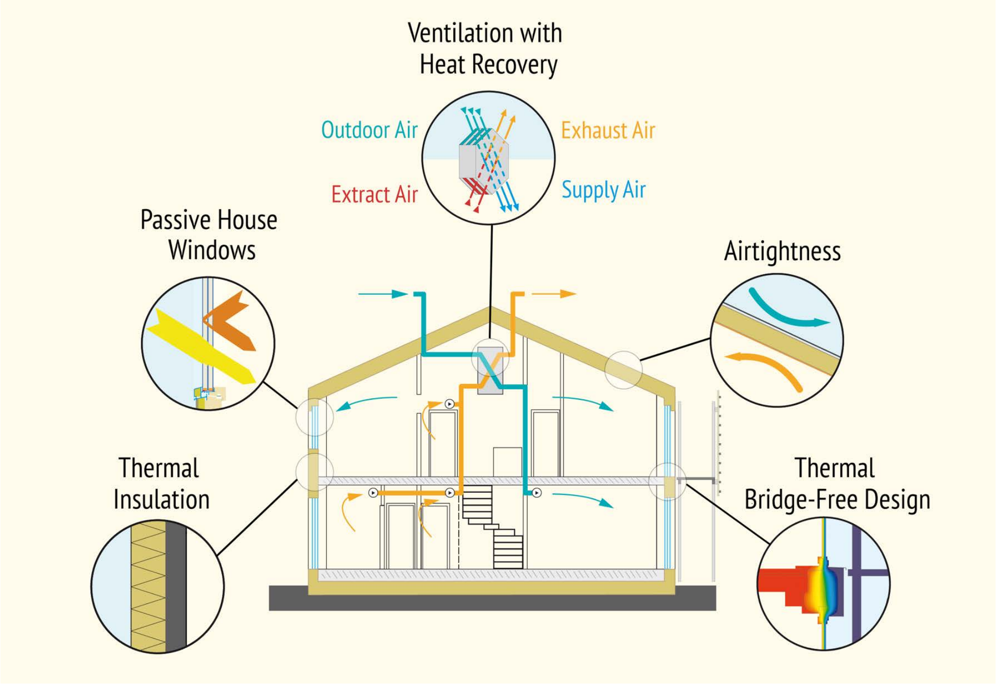
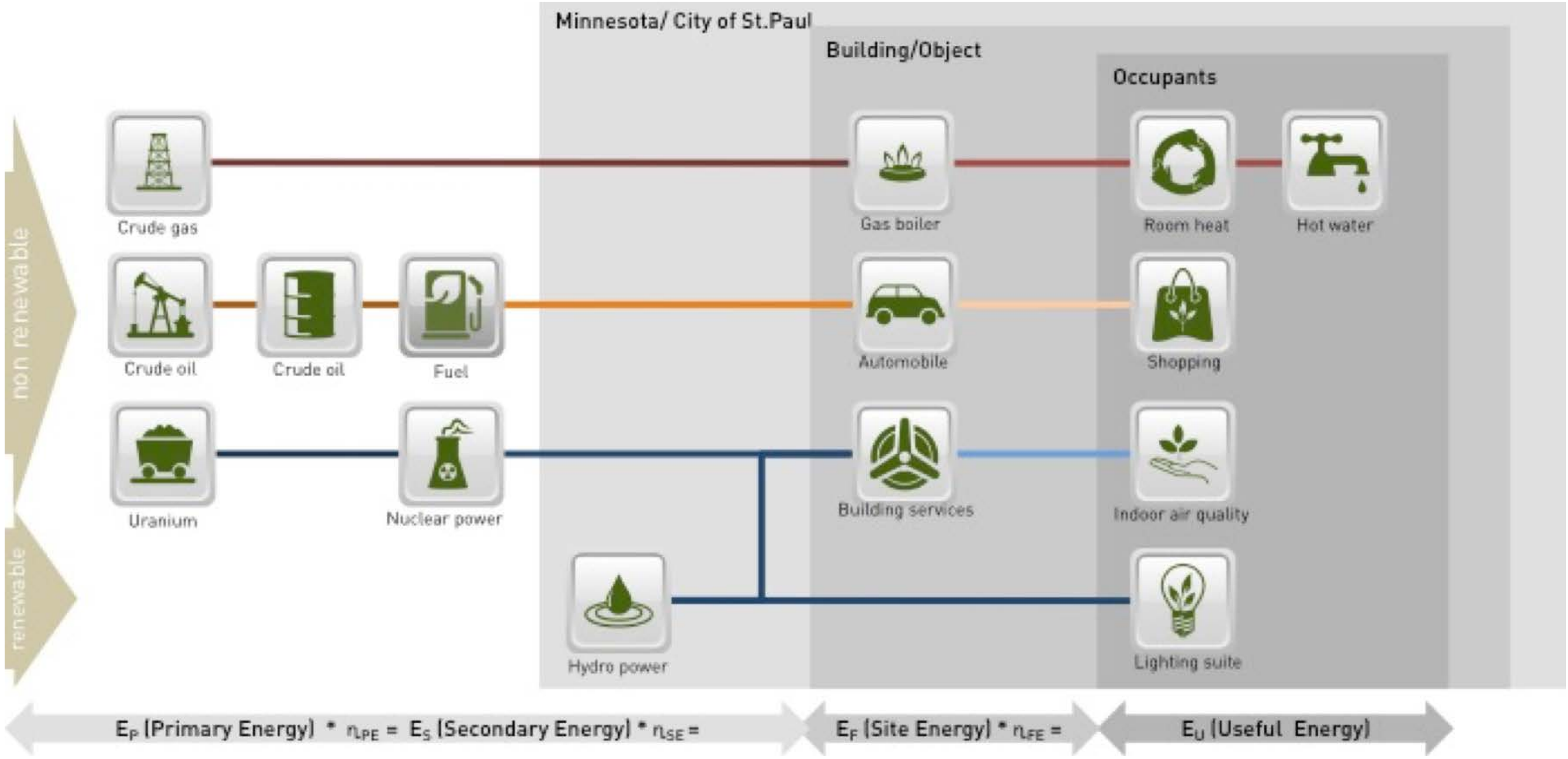


PHPP

Passive House Planning Package

Version 9 (2015) © Passive House Institute

Climate Efficiency Principle



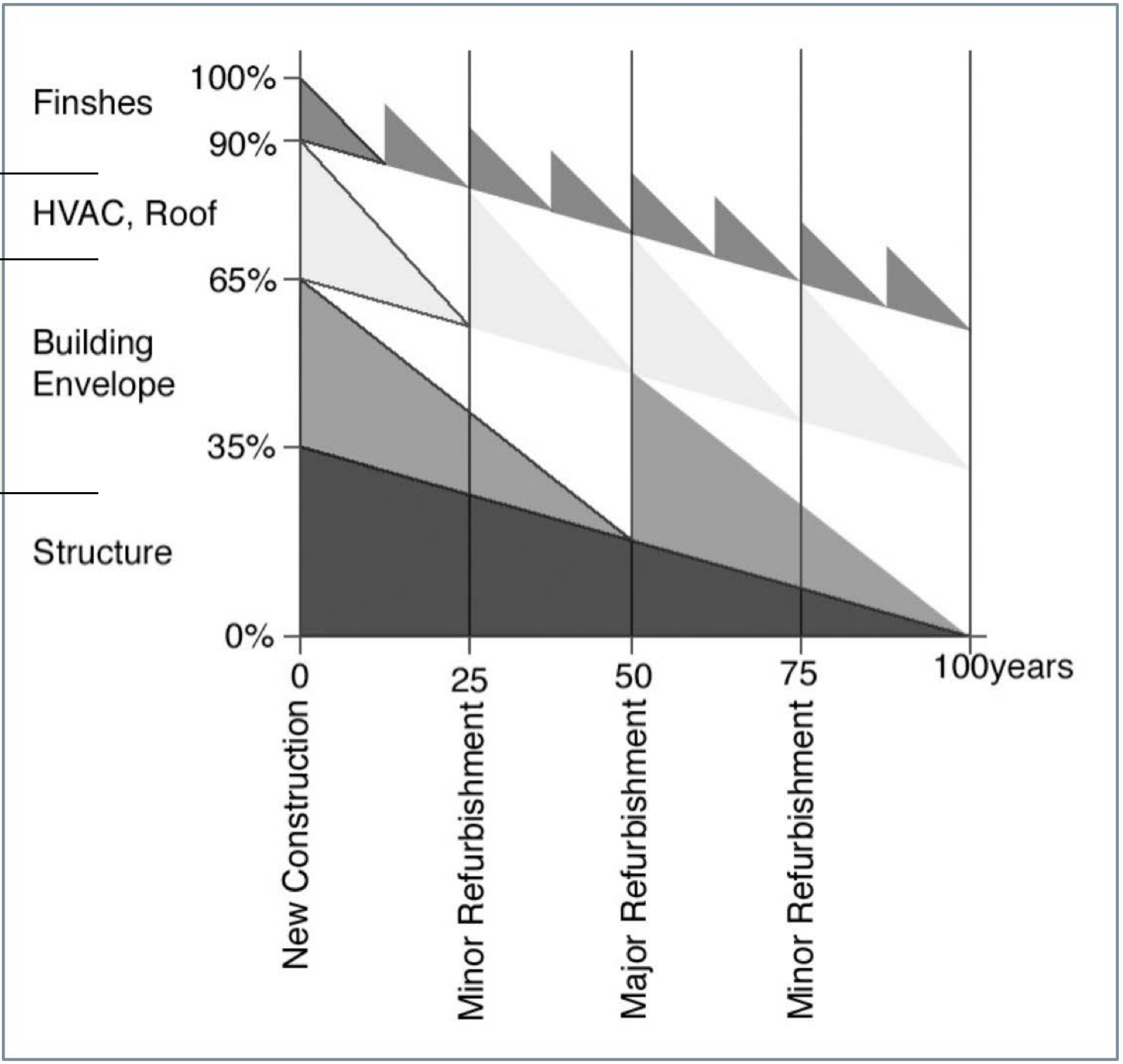
To Improve Here

Reduce here

Life Cycle Cost Efficiency Principles

To Save Here ›

Invest here ›



Ultra-Efficiency Priorities

1. Building Envelope: Energy avoidance and comfort through use of “passive” measures
2. Mechanical Systems: Healthy and efficient operation through use of adequately sized “active” systems
3. Electrical Systems: Energy-efficient operation through use of current technology
4. Renewable Energy and Storage Systems: Sustainable energy generation

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5. Fresh Water: Reducing the amount of potable water used on site
6. Stormwater: Managing stormwater responsibly
7. “Green” Building Materials: People and earth-friendly materials and construction

The Passive House Upgrade

Student Housing - State of South Dakota

Pierre, SD - 2012/14

Project

Using the Passive House Standard for State projects, what changes?

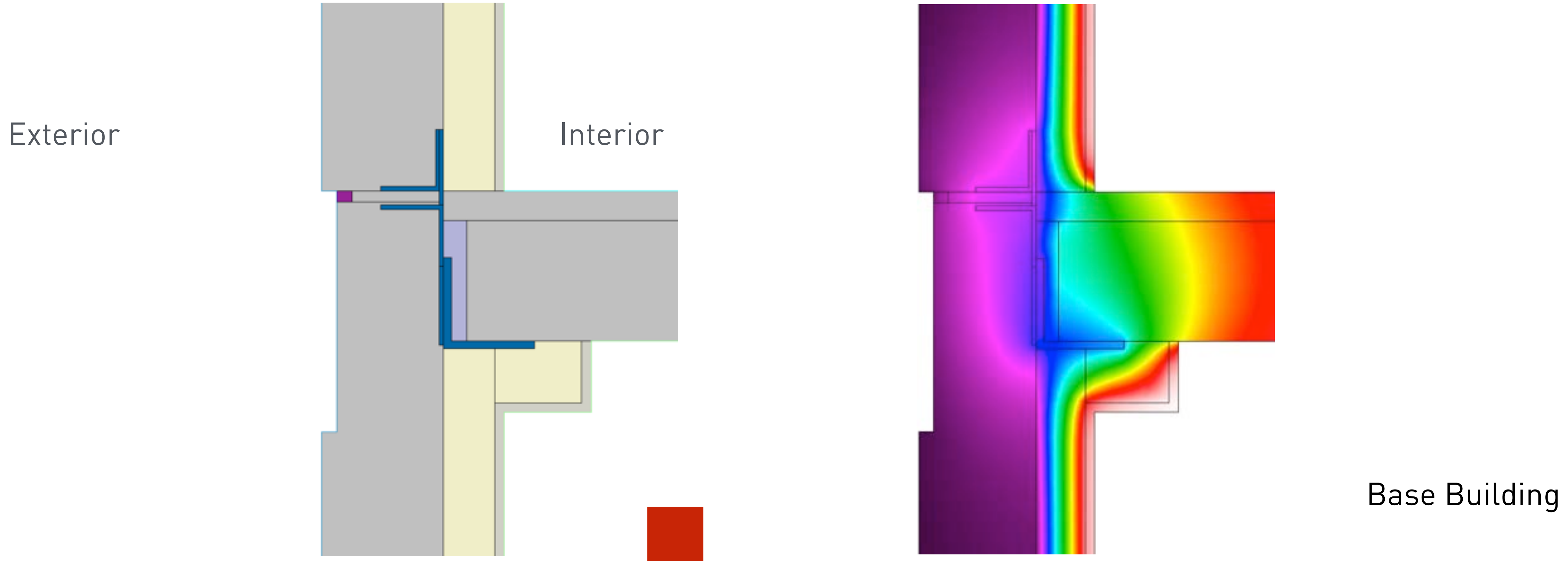
- Differences for the Building Envelope
- Thermal Bridge Free Design
- Heat Flow and Loss Comparisons
- Energy Consumption and Flow Comparisons
- Carbon Emissions Comparison
- First Day and Life Cycle Cost Comparison
- Key Conclusion and Benefits

Building Envelope Comparison

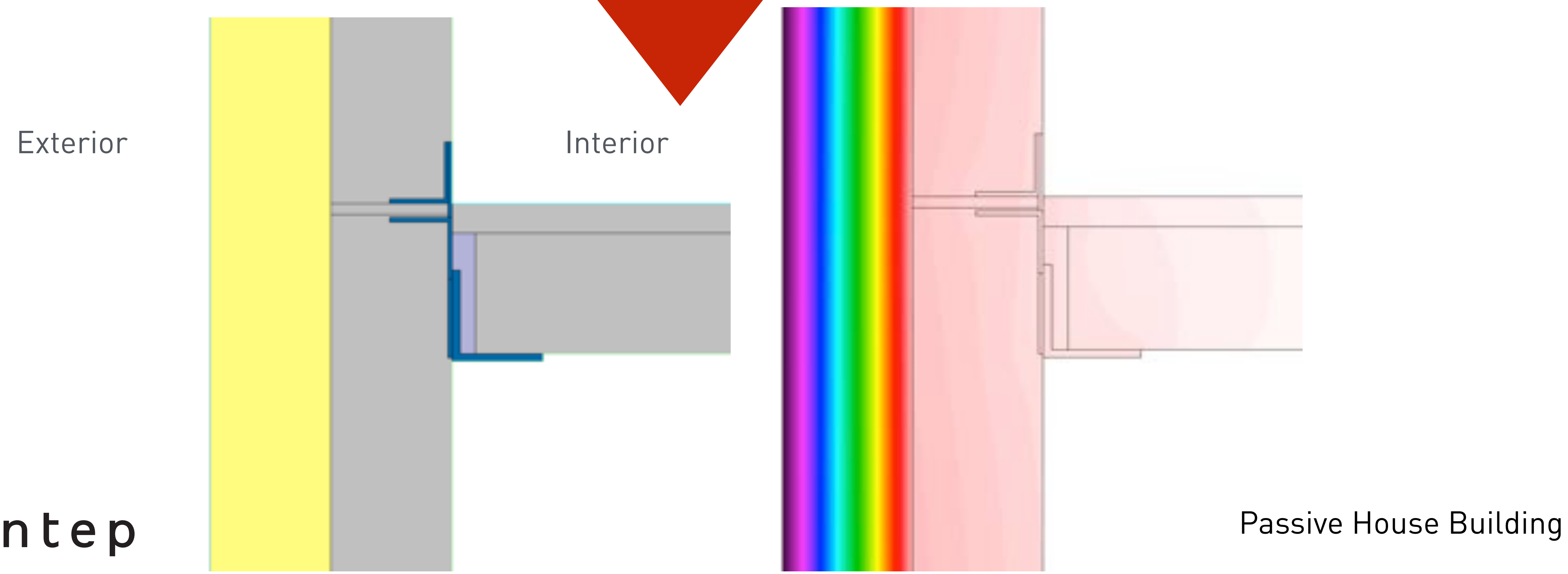
Component	Base	Passive House
Exterior Walls	R-16 (h sf °F/ Btu)	**R-34 (h sf °F/ Btu)**
Roof	R-70 (h sf °F/ Btu)	R-70 (h sf °F/ Btu)
Slab	R-3 (h sf °F/ Btu)	**R-27 (h sf °F/ Btu)**
Windows, Ext. Doors	U- 0.41 (Btu/ h sf °F) SHCG-0.27	**U- 0.12 (Btu/ h sf °F)** **SHCG-0.50**
Thermal Bridges	Significant	**Free**
Airtightness	ACH_{50}: 3.0 1/h (est.)	**ACH_{50}: ≤ 0.2 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

Thermal Bridge Comparison

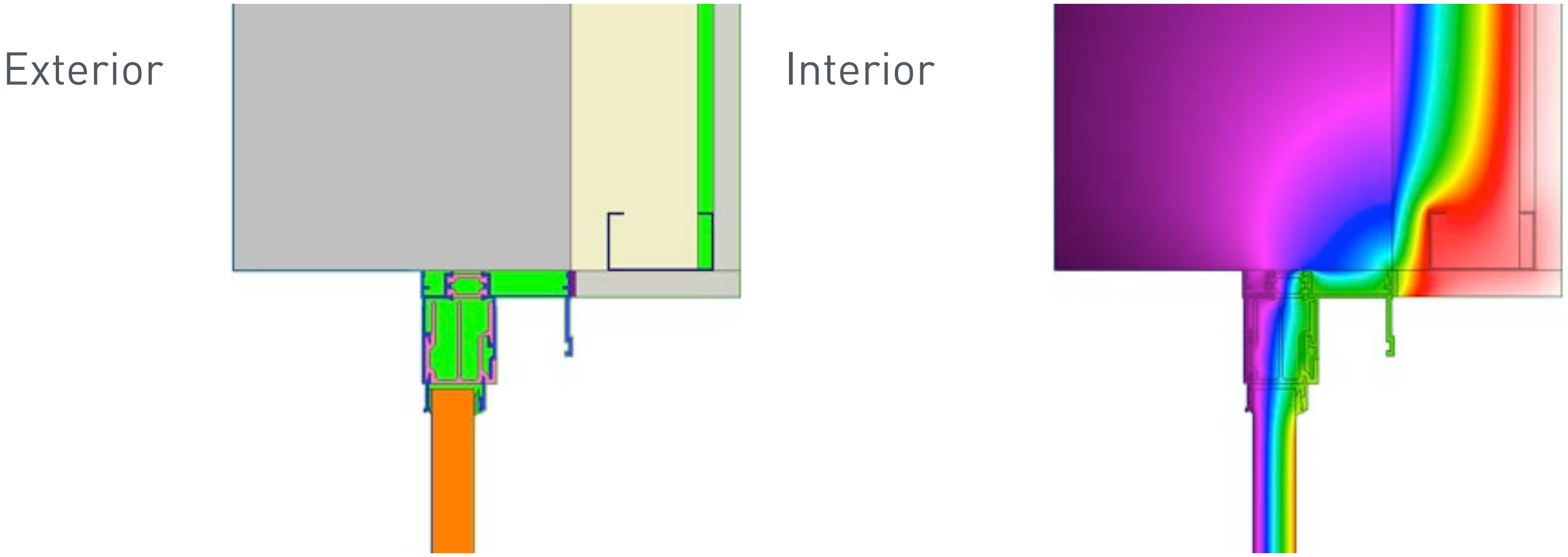


Base Building

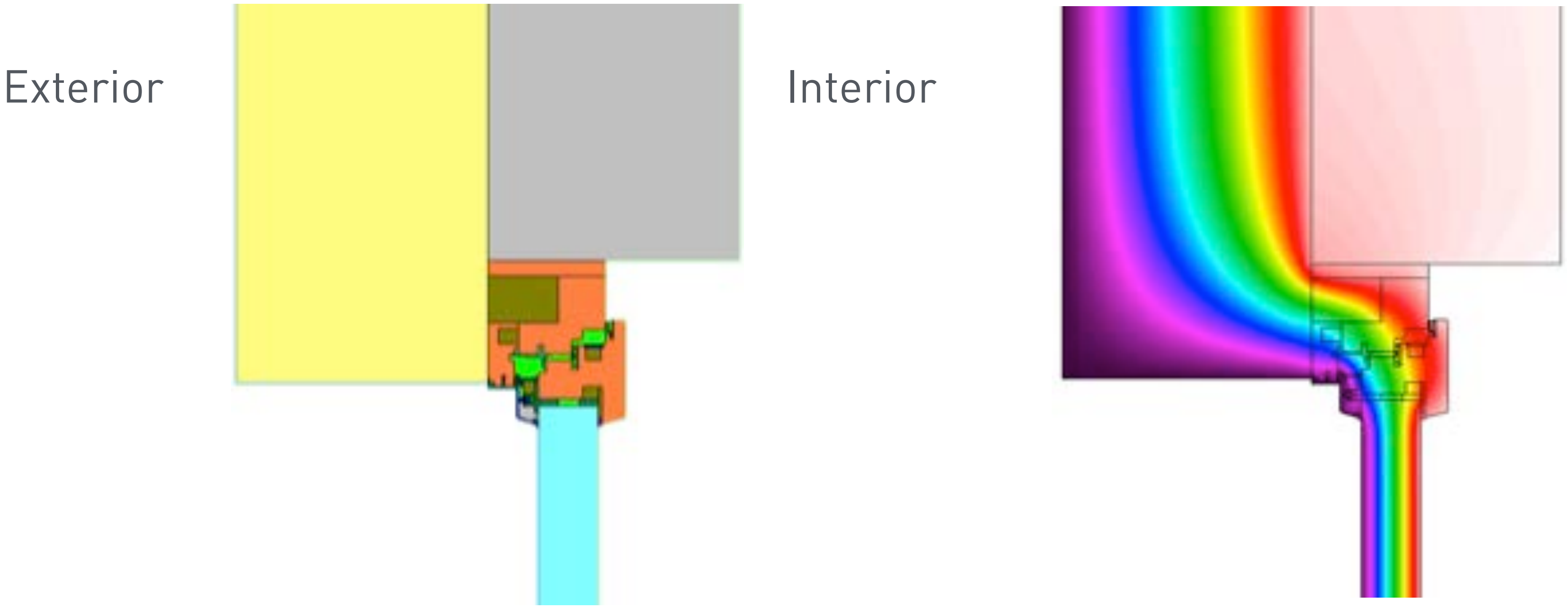


Passive House Building

Thermal Bridge Comparison

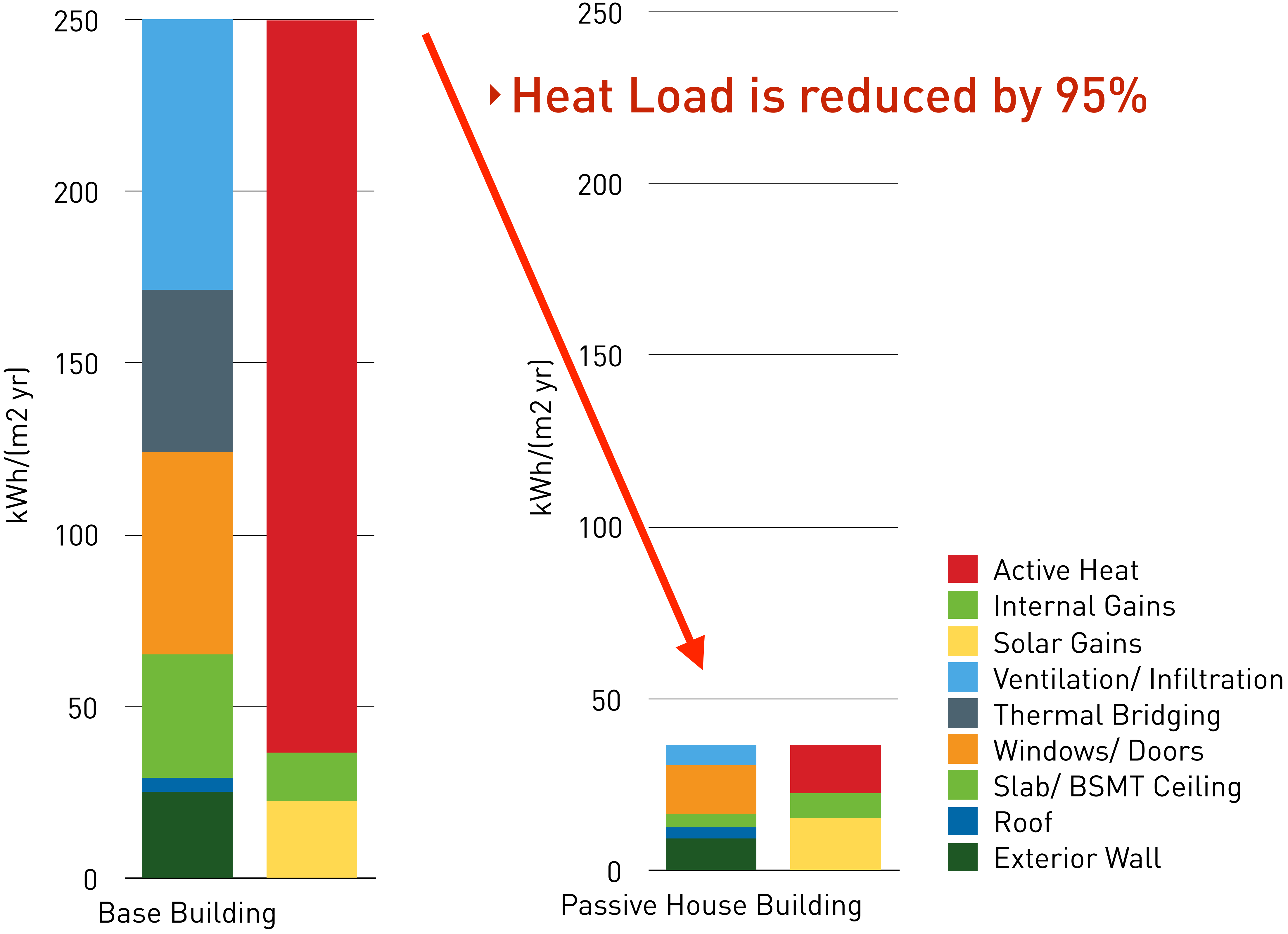


Base Building



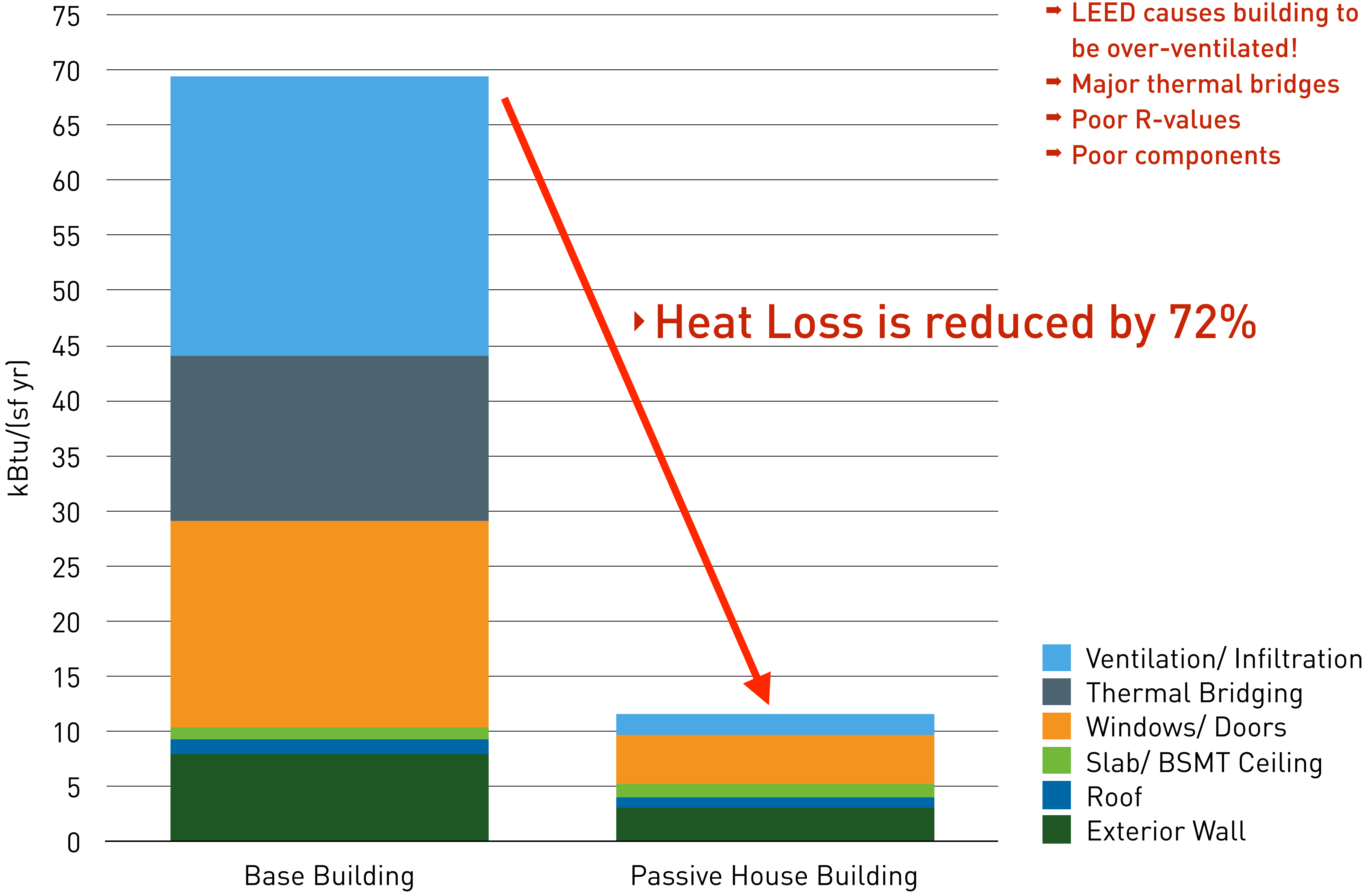
Passive House Building

Heat Flow Comparison



- Heat Load is reduced by 95%

Heat Loss Comparison



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

- ‣ Heat Loss is reduced by 72%

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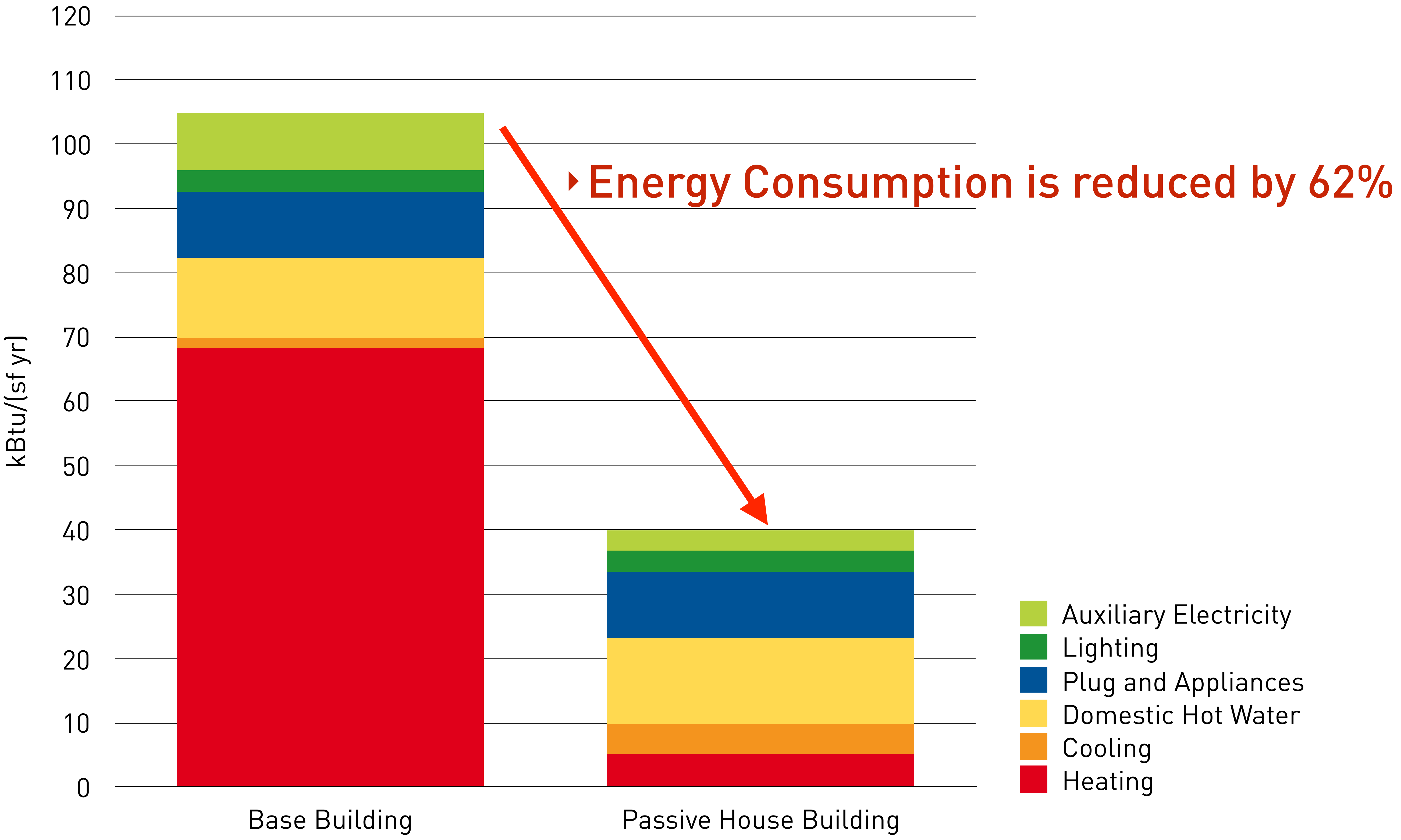
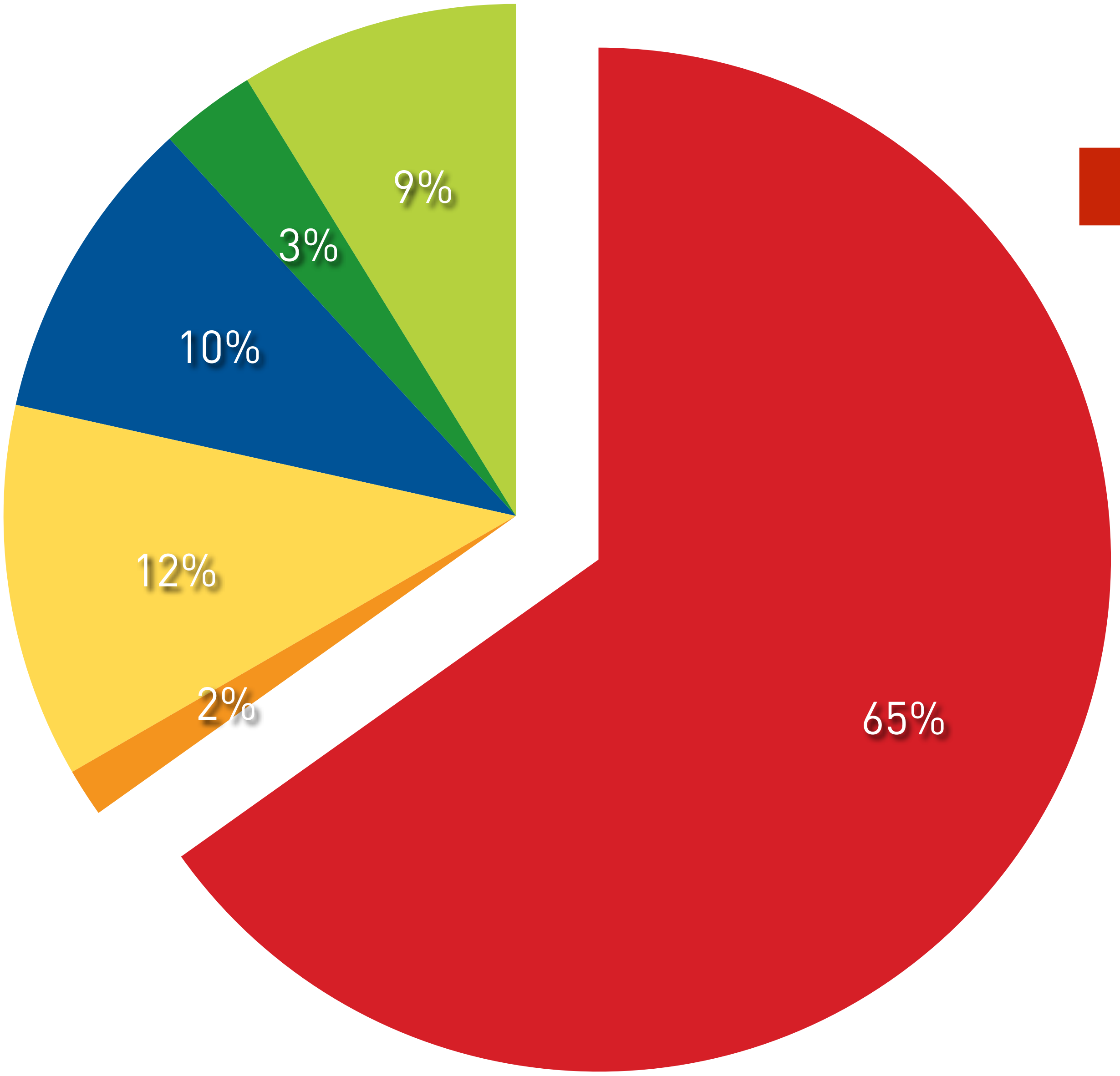
Energy Consumption Comparison



- Energy Consumption is reduced by 62%

Energy Flow Comparison

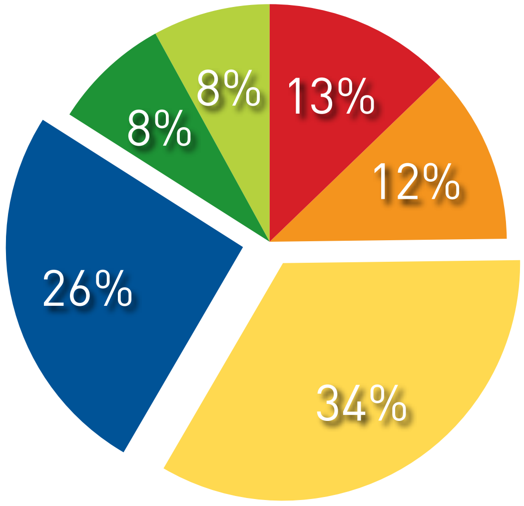
Base Building



➡ **Focus on heating load**

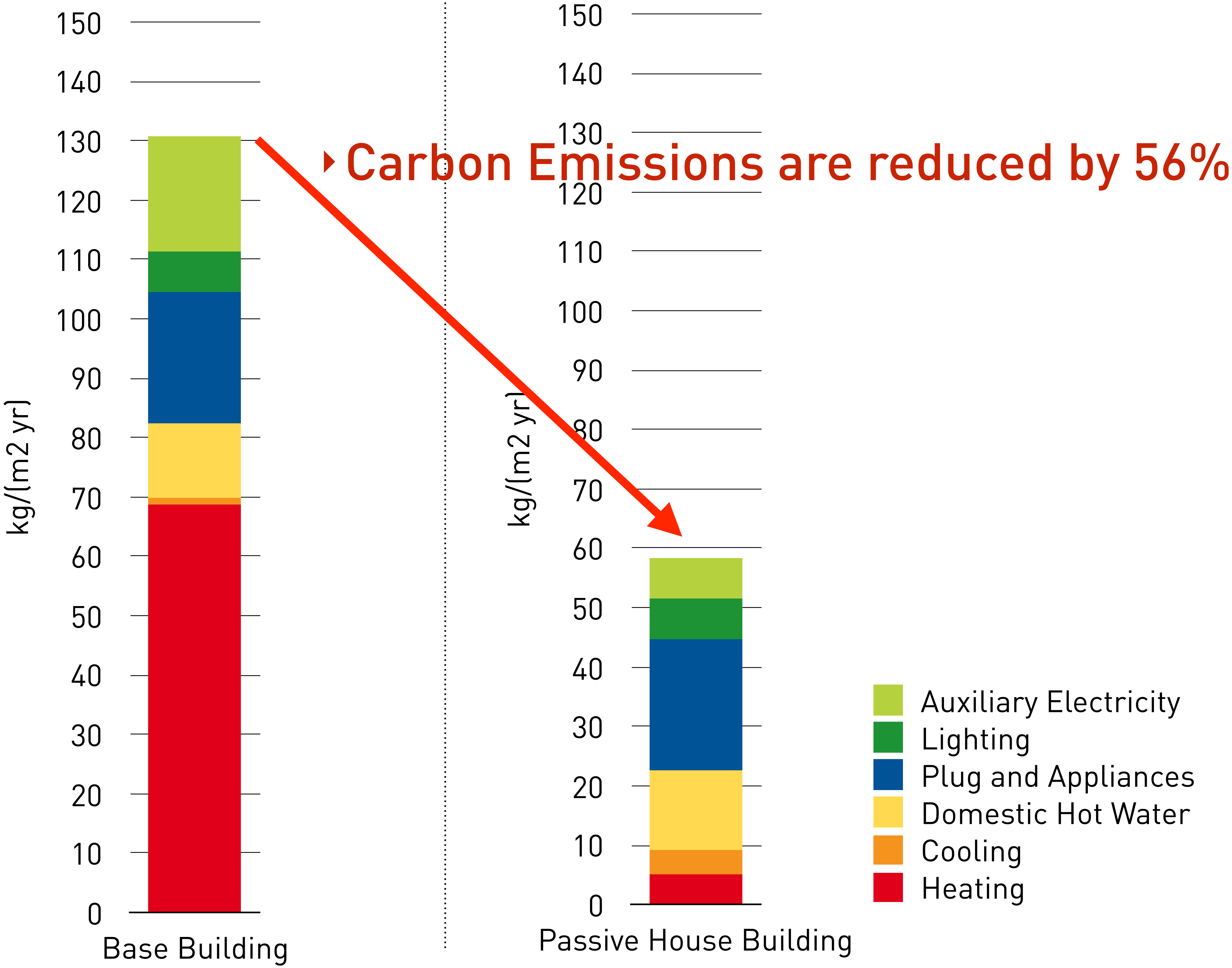
- 🟥 Heating
- 🟧 Cooling
- 🟨 Domestic Hot Water
- 🟦 Plug and Appliances
- 🟩 Lighting
- 🟩 Auxiliary Electricity

Passive House Building



➡ **Focus on plug loads and domestic hot water**

Carbon Emissions Comparison



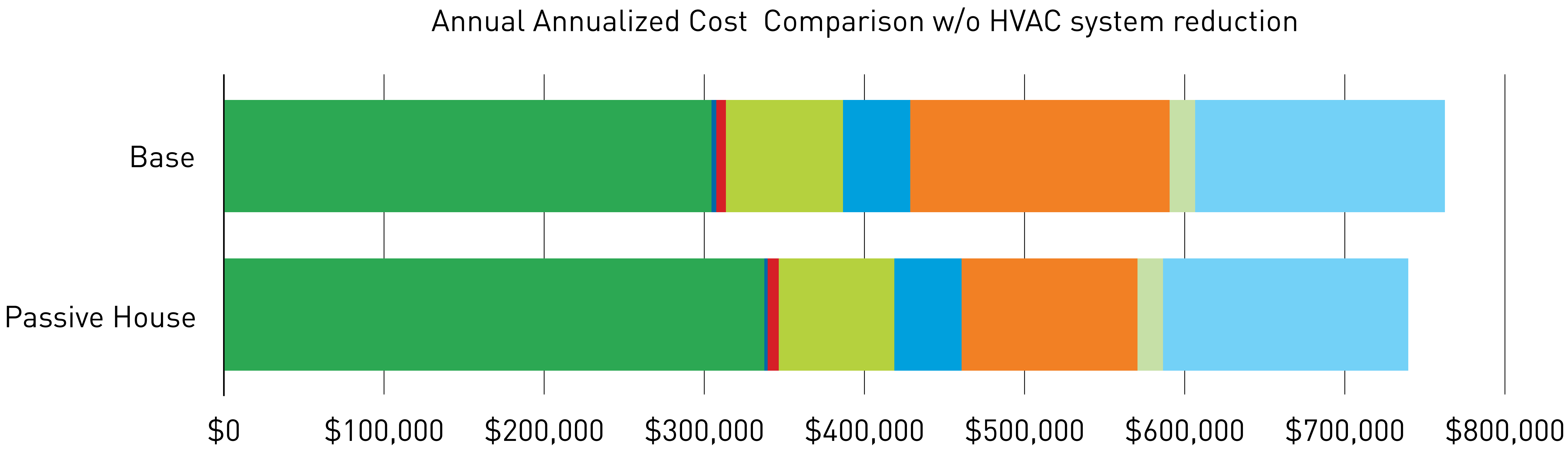
- Carbon Emissions are reduced by 56%

First-Day Cost Comparison

Building Component	Base	Passive House	Difference
Structure: Concrete, Steel, Masonry	$ 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**

- Construction cost increase approx. 10.5%

Life Cycle Cost Comparison


Annual Annualized Cost Comparison w/o HVAC system reduction

- 🟩 Construction Cost
- 🟦 Management & Insurance
- 🟥 Security
- 🟩 Cleaning
- 🟦 Inspection & Maintenance
- 🟧 Utilities & Disposal
- 🟩 Repair
- 🟦 Refurbishments

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%

Multifamily New Construction

Hook & Ladder Apartments - Affordable Housing

Minneapolis, MN - 2016/18

Project

59-unit, affordable multi-family housing project. 61,000 sf on 5-stories.

- Differences in Construction
- Differences in Systems
- First Day Cost Comparison
- Life Cycle Cost Comparison
- Site and Source Energy Comparison
- Carbon Comparison
- Conclusion and Benefits

Building Envelope Comparison

Building Envelope	**Base**	**Passive House**
Exterior Walls	R-22 (h sf °F)/Btu	R-45 (h sf °F)/Btu
Roof	R-40 (h sf °F)/Btu	R-65 (h sf °F)/Btu
Slab	R-10 (h sf °F)/Btu	R-25 (h sf °F)/Btu
Windows	U-Factor: 0.30 Btu/(h sf °F) SHGC: 30%	U-Factor: 0.14 Btu/(h sf °F) SHGC: 26%
Thermal Bridges	No consideration	Thermal bridge free design
Airtightness	No consideration	ACH_{50}: 0.2 $^{1}/_{h}$ (Preset and field-measured)

HVAC & DHW System Comparison

System	Base	Passive House
Ventilation	Assumed bypass inside “magic pack” heating and cooling system in combination with individual bathroom exhaust fans.	Balanced whole-house heat recovery ventilation system with Passive House recovery efficiency: 87% Electric efficiency: 0.45 Wh/m^3 Automated controls based on air quality
Heating/ Cooling	Individual apartment “magic pack” units with ducted distribution (gas furnace heat, electric air-conditioning)	Single, whole-house air-source electric heat-pump with individual apartment indoor units and ducted distribution (electric heating and air-conditioning)
Domestic Hot Water	Central gas-fired domestic hot water boilers with circulation line	Summer: heat recovery from air-conditioning to domestic hot water system; summer and winter: gas-fired backup boiler with circulation line

Site Energy Comparison

	Heating Energy (kBTU/ yr)	Total Energy (kWh/ yr)	Total Energy (kBTU/ yr)	Energy Use Index (kWh/ gsf)	Energy Use Index (kBTU/ gsf)
US existing					78.8
Base	116,360	581,254	1,983,795	9.5	32.6
Passive House	3,792	196,024	669,021	3.2	6.6
Passive House Savings Potential	-112,568 (-97%)	-385,230	-1,314,774	-66%	-66% (-92% vs. existing)

- Site Energy Demand is reduced by 66%, or more

Source Energy Comparison

	Total source energy (kWh/ yr)	Source Energy Use Index (kWh/ gsf)	Source Energy Use Index (kBTU/ gsf)
US existing			127.9
Base	1,106,432	18.2	62.0
Passive House	401,686	6.6	22.5
Passive House Savings Potential	**-704,746**	**-64%**	**-64%** **(-82% versus existing)**

- Source Energy Demand is reduced by 64%, or more

Carbon Comparison

	Total CO_2 Impact (tons CO_2 equ.)	CO_2 Impact Index (kg CO_2 equ./ gsf)
Base	184	3.03
Passive House	109	1.79
Passive House Savings Potential	**-75**	**-41%**

- **Carbon Emissions are reduced by 41%, or more**

Energy Cost Comparison

	Cost Index ($/ gsf)
Base	0.482
Passive House	0.328
Passive House Savings	**-32%**

- **Energy Cost are reduced by 32%, or more**

First-Day Cost Comparison

Based on predesign analysis, the first day investment cost for the Passive House building is between 7.5 and 17% above the cost for the base building (MN code).

This is the first project of its kind in the region and the developer and build teams are new to Passive House making this a pilot project.

Life Cycle Cost Comparison

Annual annuitized cost difference in percent.

	60 years	50 years	40 years	30 years	20 years	10 years
Passive House savings potential (high)	6.36%	7.03%	3.95%	3.13%	1.31%	-5.40%
Passive House savings potential (low)	11.95%	12.87%	9.00%	8.63%	6.05%	-0.08%

- **Life Cycle Cost are cheaper than conventional building.**

Multifamily Retrofit

Elliot Tower - Affordable Housing Retrofit

Minneapolis, MN - 2017

Project

88-unit, affordable multi-family housing project retrofit. 48,000 sf on 14-stories.

- Differences in Construction
- Differences in Systems
- First Day Cost Comparison
- Life Cycle Cost Comparison
- Site and Source Energy Comparison
- Carbon Comparison
- Conclusion and Benefits

Ultra-Efficiency: Paradigm Shift

Building Envelope Updates

Building Envelope	Elliot Existing (h sf °F)/Btu	Elliot Retrofit (h sf °F)/Btu
Exterior Walls	R-4	R-45
Roof	R-3	R-50
Slab	R-1	R-10
Windows	U-0.30 SHGC: 30%	U-0.14 SHGC: 30%
Thermal Bridges	No consideration	Minimal
Airtightness	No consideration	ACH$_{50}$: 0.2

Ventilation System Updates

System	Elliot Existing	Elliot Retrofit	Multifamily Building New
Ventilation	Outside air supplied to central corridors on each floor. Post heat via central boiler system. Post cooling and dehumidification via window air conditioners in apartments. Exhaust via bath fan stacks on roofs. No heat recovery.	Balanced, whole-house heat recovery ventilation system with Passive House certified recovery efficiency of around 85%. No need for post heat, or post cooling and dehumidification.	Balanced, whole-house heat recovery ventilation system with Passive House certified recovery efficiency of around 85%. No need for post heat, or post cooling and dehumidification.

HAC System Updates

System	Elliot Existing	Elliot Retrofit	Multifamily Building New
Heating/ Cooling	Heating: Gas-fired hot-water system with unit base boards Cooling: Window air conditioner	Air, or ground-source VRF system with central heat pump units and split heads in apartments; option for summer heat recovery to the domestic hot water system	Air, or ground-source VRF system with central heat pump units and split heads in apartments; option for summer heat recovery to the domestic hot water system

Domestic Hot Water System Updates

System	Elliot Existing	Elliot Retrofit	Multifamily Building New
Domestic Hot Water	Central, gas-fired, tanked domestic hot water boilers with circulation line; uninsulated piping	Air, or ground source heat pump system with gas-fired backup boiler; insulated pipework; option for summer heat recovery	Air, or ground source heat pump system with gas-fired backup boiler; insulated pipework; option for summer heat recovery
Distribution	Uninsulated fresh water piping	Continuously insulated fresh water piping	Continuously insulated water piping

Savings Potential

Project	Heating Energy (kWh/ yr)	Cooling Energy (kWh/ yr)	Domestic Hot Water (kWh/ yr)	Auxiliary and Plug Loads (kWh/ yr)
Existing	992,600	53,800	268,100	357,500
Ultra-Efficiency	57,400	37,600	106,900	223,100
Ultra-Efficiency Savings Potential	**94% less**	**30% less**	**60% less**	**38% less**

- Heating Energy can be reduced by over 90%

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Savings Potential continued

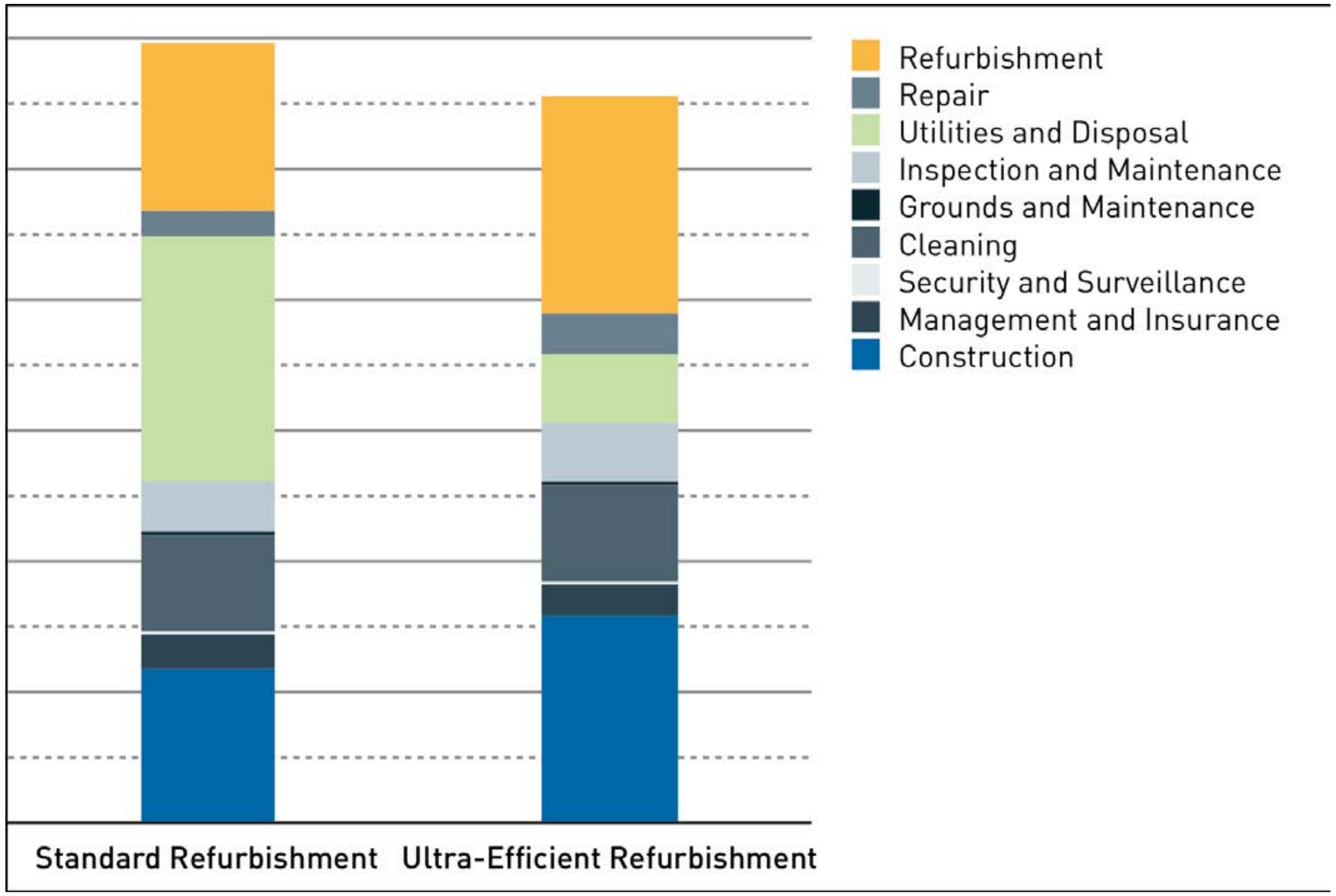
Project	Site Energy (kWh/ yr)	Site Energy Cost ($/ yr)	Total CO_2 Impact (tons CO_2 equ.)
Existing	1,672,000	88,700	390.4
Ultra-Efficiency	425,000	36,100	167.0
Ultra-Efficiency Savings Potential	**75% less**	**59% less**	**57% less**

- Site Energy can be reduced by 75%, cost by about 60% and CO2 by over 57%.

Investment Cost

Item	Cost (low)	Cost (high)
Pilot Project Cost Estimate	$9,903,600	$10,703,600
Unit Cost (without Main Floor Improvements)	**$105,000**	**$115,000**

Life Cycle Cost Advantage



	60 years	50 years	40 years	30 years	20 years	10 years
Savings Potential	7.8%	**6.9%**	3.8%	4.9%	2.5%	-9.5%

- Life Cycle Cost are cheaper than “just fixing” the building.

Key Benefits

Highest Comfort

Superior Indoor Environmental Quality

Resource Efficiency

Image Source: dreamstime.com

Cheapest Life Cycle Cost

Image Source: dreamstime.com

Climate Action

Key Findings

- Differences in construction and systems are manageable but require diligent, experienced design team—particularly for energy modeling and detail design
- Ultra-Efficiency costs "different" on day 1
- Life Cycle cost are cheaper (not putting any cost value on human benefits)
- Energy performance is entirely different; heating is no longer a major consumer of energy; domestic hot water production and plug loads need to be managed and reduced
- Fits the paradigm of a sustainable building

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Thank You!

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