Up-scaling and mainstreaming sustainable building practices in western China

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Design and construction - of sustainable buildings
可持续建筑的设计和建造

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Things people worry about
人们所担心的问题

- It is too technical and complicated
- 太过技术化，难以理解
- It will not work form a thermal comfort perspective
- 未能考虑热舒适性角度
- It will use a lot of energy (at least more than calculated)
- 将耗用大量能源（至少超过计算出的数值）
- They cannot open windows and cannot breathe
- 不能打开窗户，不能呼吸新鲜空气
- There will be mould
- 将发生霉变
- The design will be lacking
- 将缺乏设计
- Costs will explode
- 成本会激增
- It will not be cost effective
- 它将不符合成本效益
- I will not make any money for the extra work
- 额外工程不能带来任何收益

State of the Art technologies
先进的技术

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Most used technologies
使用最广泛的技术

- Superinsulation 超级保温
- Triple glazed windows 三重玻璃窗
  - (U = 0.8 W/m²K)
- Heat Recovery Systems 热回收系统 > 90%
- Hybrid Ventilation 混合通风
- Demand Ventilation 按需通风
- Heat pumps (w/w) 热泵 (w/w)
- Floor heating 地板采暖
- LED Lighting LED照明
- PV (+ Battery) 光伏(+ 电池)
- Class A+++ Appliances A+++类电器

资料来源: Frauenhofer IBP

Cost Effectiveness of Measures
成本效率及优先性

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	Cost effective 成本效益	Niche 利基市场	R & D 研发
Hot Climate 炎热的气候			
Advanced roofs 先进的屋顶（综合设计/BIPV）		✔	
Very low SHGC 非常低的得热系数（或动态窗户）	✔		
Reflective Walls 反射墙体	✔		
Cool Roofs 降温屋顶	✔		
Exterior Shading 外部遮阳及建筑物遮阳	✔		
Optimised ventialtion 优化的自然式/机械式通风	✔		
Phase change Materials 相变材料			✔
Cold Climate 寒冷的气候			
Passive heating gain 被动式供暖增益	✔		
Optimised insulation 优化的隔热	✔		
Super insulation 超级保温		✔	
No Thermal Bridges 无热桥	✔		
Air Sealing 气密封性	✔		
Window Films 玻璃贴膜	✔		
Highly insulated windows 高度保温的窗户		✔	
Passivhaus performance 被动房性能		✔	

资料来源：国际能源署、bigEE

Low Energy Building (LEB)
Easy approach to reach energy efficiency
低能耗建筑
达到节能的简单方法

- Compact building form and adequate orientation 紧凑的建筑形式和合适的朝向
- East-West orientation of building 东西朝向
- Usage of passive solar gains 被动获得太阳能
- Avoidance of thermal bridges 避免热桥
- Effective external shading elements to avoid summer overheating 有效外遮阳夏季降温
- Highly energy-efficient building envelope 高效围护结构
  - including high performance windows, 包括高性能窗
  - insulation and 保温
  - air tightness 气密性
- Highly energy-efficient heating and/or cooling technologies 高性能供暖和供冷技术
- Highly energy-efficient units for ventilation and domestic hot water production 高性能风扇和热水供应
- Highly energy-efficient lighting and appliances 高性能照明和设备

(the users are responsible for this but the developer should provide guidance to them 用户主导，开发商需提供指南)

- Quality surveillance of construction work and 建筑过程的质量监督
- Occupant's briefing and building energy management 住户指导和能源管理

40-60% 的节能率

Ultra low Energy Building (ULEB)
Advanced approach to reach energy efficiency
超低能耗建筑（ULEB）
达到节能的先进方法

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Further improvement from the LEB concept:
从低能耗建筑概念进一步改进

- Extraordinarily good thermal insulation (e.g. 10 to 40 cm insulation thickness for roof and outer walls, depending on climate zone)
  更好的保温 （比如，根据气候区不同10－40cm 屋顶和墙隔热）
- Windows: 窗户
  Triple (U_{Window}-values less than 0.8 W/m²K for cold and temperate climate zones) respectively double (U_{Window} < 1.3 W/m²K for hot climate zones) low-e-glazing
  三层玻璃（寒冷和温暖地区u值小于0.8 W/m²K ），low-e双层（热气候区u值小于1.3 W/m²K ）
- Energy efficient heating / cooling backup system for covering the residual heating / cooling energy demand if necessary
  节能供暖 / 供冷后备系统
- In addition to energy efficiency actions: Use of local renewable heat sources to the best extent possible (solar radiation, ambient and geothermal energy, sustainable biomass)
  尽可能使用当地的可再生能源（太阳能，空气和地热能，可持续生物能）

60%至80%的节约率

Zero / Plus Energy Building (ZPEB)
Advanced approach to reach energy efficiency
零/正能耗建筑（ZPEB）
达到节能的先进方法

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Based on the Ultra-low Energy Building concept
基于超低能耗建筑概念

- In addition to the highly energy-efficient building performance, *on-site* power or heat generation from renewable energy sources or from combined heat and power (CHP)
  除了高效节能建筑性能外，还包括从可再生能源或热电联产获得的发电或热量
- “Zero Energy Building” if amount of produced energy (converted in primary energy equivalent!) is roughly identical with annual primary energy demand
  如果产生的能量（从一次能源等效转换！）大致相同于年度一次能源需求量，则为“零能耗建筑”。
- “Plus Energy Building” if it exceeds the demand
  如果超过需求，则为“正能耗建筑”

80 % and beyond 大于80 % 节能

Retrofit Apartment building Freiburg
改造弗赖堡公寓大楼

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Freiburg, Germany - 德国弗莱堡

Location	Germany
地点	德国
Type of building	Social Housing
建筑类型	社会保障房
Treated floor area (TFA)	ca. 7200 m²
处理的楼层面积 约	7200 m²
Surface/Volume ratio 0,26 m-1	
表面积/体积比	0.26 m-1
Number of apartments	before 90
公寓数量	之前为 90
	after 139
	之后为 139
Year of completion	1968
落成年份	1968
Year of refurbishment	2009
改造年份	2009

Source: Freiburger Stadtbau Verbund

- **Large energy savings are possible in practice with an 80% lower energy demand achieved by a well designed building and a holistic approach.**

- **通过精心设计的建筑和整体性方法，在实践中有可能获得80%的较低能源需求，节省大量能源。**

Retrofit Apartment building Freiburg
改造弗赖堡公寓大楼

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Building Services - 建筑设备

- Total Primary Energy (incl. elec.) 112 kWh/m2/年

一次能源总量（包括电力能源）：约112 kWh/m2/年

- Heating Consumption ca. 15 kWh/m2/a (reduced from 68 kWh/m2/a)

采暖消耗：约15 kWh/m2/a（从68 kWh/m2/年减少）

  - 100 % through a CHP unit (gas) for district heating (PE-Factor 0,4)

  100%通过热电联产机组（燃气）进行区域供暖（PE系数0,4）

- Ventilation system with heat recovery (83%）热回收通风系统（83%）
- Photovoltaics on the roof ca. 25 kWp 屋顶光伏量：25 kW

Building Envelope - 建筑围护

- Triple Glazing U-Value ca. 0.7 W/m2K 三层玻璃传热系数：约0.7W/M2K
- 200 mm Façade Insulation U-Value ca. 0.15 W/m2K 200mm厚的立面保温传热系数：约0.15W/M2K

Costs and Energy Consumption - 成本和能源消耗

- The total building costs amount to €13,440,000 建造成本总额：€13,440,000欧元
  - per m2 € 1,680 /m² (€ 600 /m² energy saving measures)

  按每平方米计算：€1,680/平方米（节能对策：€600/平方米）

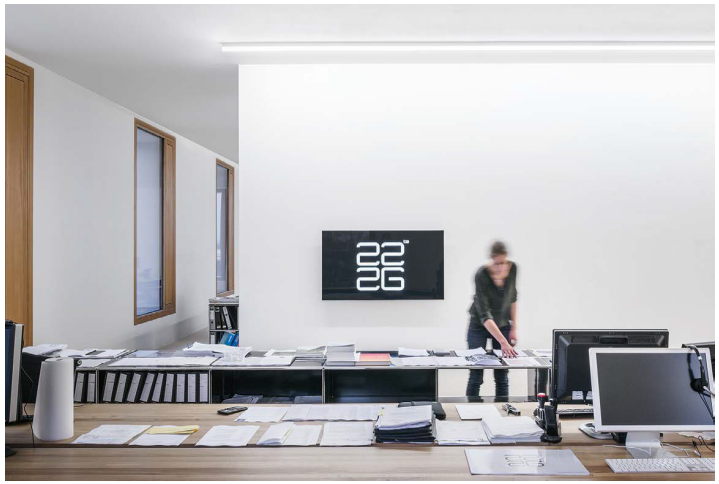
- Subsidies by programme „Social City“ and credit at reduced interest 推行“社会城市”项目补贴，发放降息贷款

Source: Freiburger Stadtbau Verbund

Office building 2226
A building without a heating or cooling system
写字楼2226号
未配备采暖或冷却系统的大楼

Lustenau, Austria - 奥地利卢斯特瑙

Location	Austria
地址	奥地利
Type of building	Office
建筑类型	写字楼
Treated floor area (TFA)	ca. 2421 m²
经处理后的楼面面积	约2421 m²
Building volume	ca. 13824 m³
建筑体积	约13824 m³
Year of completion	2013
竣工年份	2013
Interior Temperature	22°C – 26°C
室内温度	22°C – 26°C



Source: Baumschlager Eberle, Architektur + Technik

Office building 2226
A building without a heating or cooling system
写字楼2226号
未配备采暖或冷却系统的大楼

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Building Services - 建筑设备

Heating Consumption = 0 kWh/m2/a.　采暖能耗 = 0 kWh/m2/a

The heat sources in the building are: 建筑内部热源：

- People with 80 W/person　人散发的热量：80W/人
- Office Appliances　办公电器

Temperature stability through thermal mass 通过蓄热体控制温度稳定性

Ventilation through windows via smart monitoring 智能监控窗户通风

Building Construction - 建筑结构

U-Value Wall	0.13 W/m²K (76 cm brickwork)
墙体传热系数	0.13 W/m2K (76 厘米厚的砌砖)
U-Value Window	0.63 W/m²K
窗户传热系数	0.63 W/m2K
Room heights of at least	3.70 m
房屋高度至少	3.70米

Costs and Energy Consumption - 成本和能源消耗

Costs 1000 m² (average costs for Austria)

1000平米成本（奥地利平均成本）

Source: Baumschlager Eberle, Architektur + Technik

LCT One
Passive House Wood-Hybrid Pre-Fab Building System
木建筑系列
被动式房屋轻木-混合结构组合式建筑系统

Voralberg, Austria - 奥地利福拉尔贝格

Type of building	Office
地址	奥地利
Treated floor area (TFA)	ca. 1765 m²
楼面面积	约1765m²
Building volume	ca. 8074 m³
建筑容积	约8074 m³
Year of completion	2012
竣工年份	2012

Source: Photo: Norman Müller, Hermann Kaufmann ZT GmbH
资料来源：照片：Norman Müller, Hermann Kaufmann ZT 股份有限公司

LCT One
Passive House Wood-Hybrid Pre-Fab Building System
木建筑系列
被动式房屋轻木-混合结构组合式建筑系统

Building Services - 建筑设备

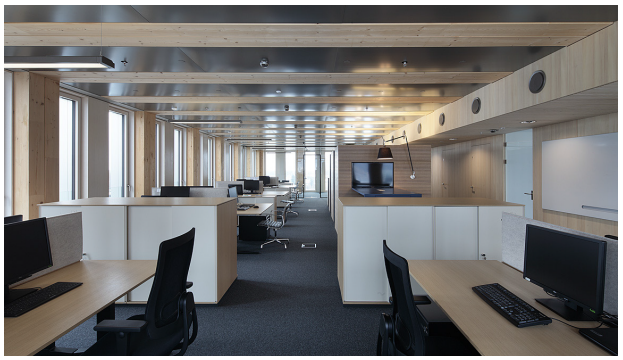
Primary Energy consumption 117 kWh/m2/a
一次能源消耗：117 kWh/m2/a
Heating Consumption 11 kWh/m²/a.
采暖消耗：11 kWh/m2/a
Ventilation system with heat recovery
热回收通风系统

Building Construction - 建筑结构

U-Value Wall	0.11 W/m²K
墙体传热系数	0.11 W/m²K
U-Value Window	0.76 W/m²K
窗户传热系数	0.76 W/m²K

Costs and Energy Consumption - 成本和能源消耗

Costs 1417 EUR/m² 成本：每平方1417 欧元
The total project costs amounts to 2,5 million Euros.
项目总成本达250万欧元



资料来源：Photo: Norman Müller, Hermann Kaufmann ZT GmbH

Passive House Bruck
A Passive House in China
布鲁克被动式房屋
一种中国特色的被动式房屋

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Changxing County, Zhejiang Province
浙江省长兴县

Location	China
地址	中国
Type of building	Hotel/ Apartment
建筑类型	酒店/公寓
Treated floor area (TFA)	ca. 2200 m²
楼面面积	约2200 m²
Number of apartments	50
公寓套数	50
Year of completion	2013
竣工年份	2013

资料来源：Peter Ruge Architekten

Passive House Bruck
A Passive House in China
布鲁克被动房:在中国的被动房

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Building Services - 建筑设备

Total Primary Energy (incl. Elec.) 109 kWh/m²/a.
一次能源消耗（包括电力能源）：109 kWh/m²/a.
Heating Consumption < 15 kWh/m2/ through a heat pump
通过热泵进行采暖的消耗：小于15 kWh/m2
Mechanical ventilation with:机械通风：

HRV 75% heat recovery rate,	全热回收率75%
60% humidity recovery rate	湿度回收率60%
Dehumidification is 12g/kg if needed	如有需要，除湿负荷12g/kg

Hot water through a solar water heater 25 Units with an area of 81.75m²
通过太阳能热水器热水， 25个单元/81.75m²

Building Envelope - 建筑围护

Exterior Wall U-Value	0.163 W/m²K
外墙传热系数	0.163 W/m²K
Roof U-Value	0.110 W/m²K
屋顶传热系数	0.110 W/m²K
Window U-Value	0.85 W/m²K
窗户传热系数	0.85 W/m²K

资料来源:Peter Ruge Architekten

Thank you for your attention

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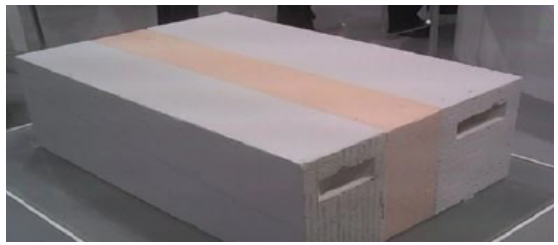
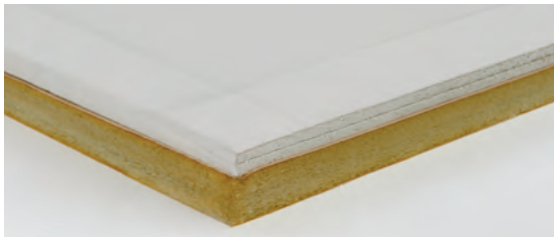
High Performance Insulation
隔热

Polystrol with Graphite Thermal transmittance = 0,030 W/(mK)
石墨聚苯乙烯 传热系数= 0.030 W/(mK)

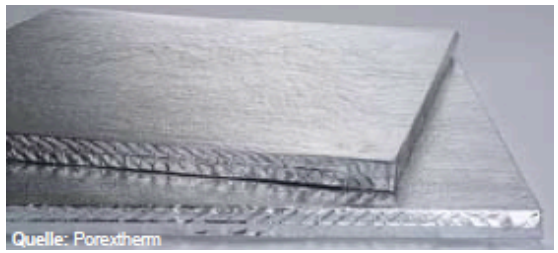
Rigid foam epoxy resin Thermal transmittance = 0,022 W/(mK)
环氧树脂硬质泡沫 传热系数= 0.022 W/(mK



Aerowool Thermal transmittance = 0,019 W/(mK)
Aerowool隔热材料（岩棉和气凝胶的合成物）
传热系数= 0.019 W/(mK)

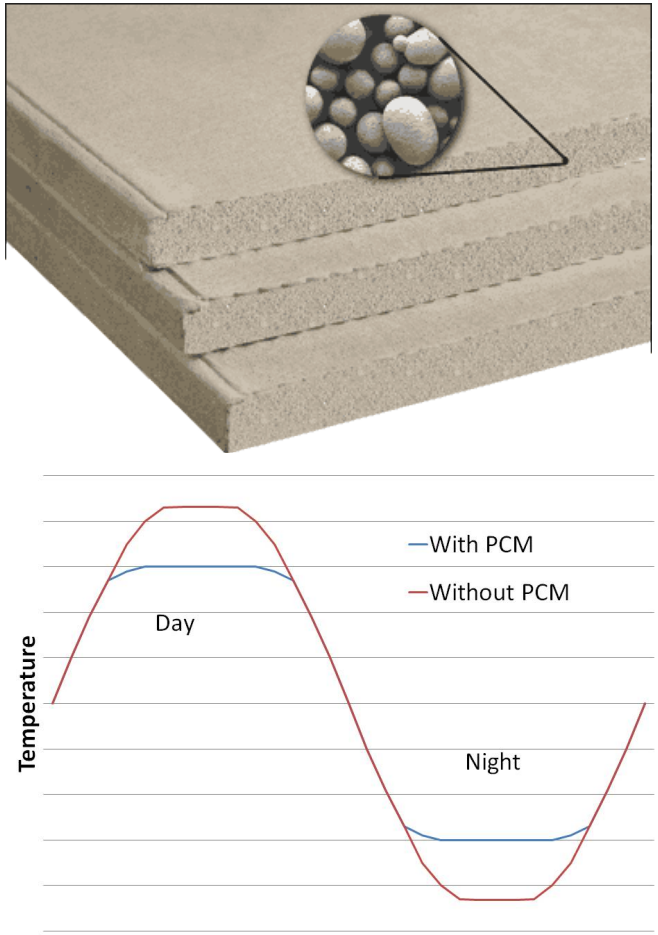


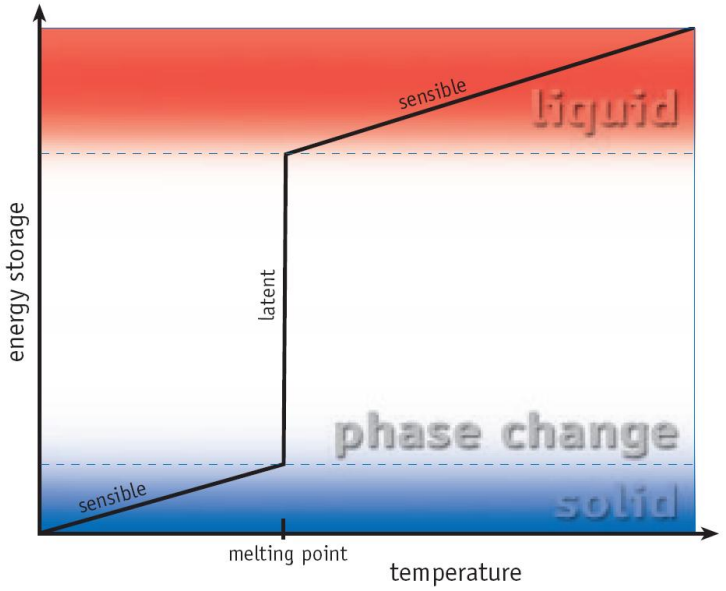
Vacuum Insulation
Thermal transmittance = 0,006 W/(mK)
(factor 10 - 1 cm =10 cm conventional insulation)



资料来源: Frauenhofer IBP, Rockwool

Phase Change Materials
相变材料





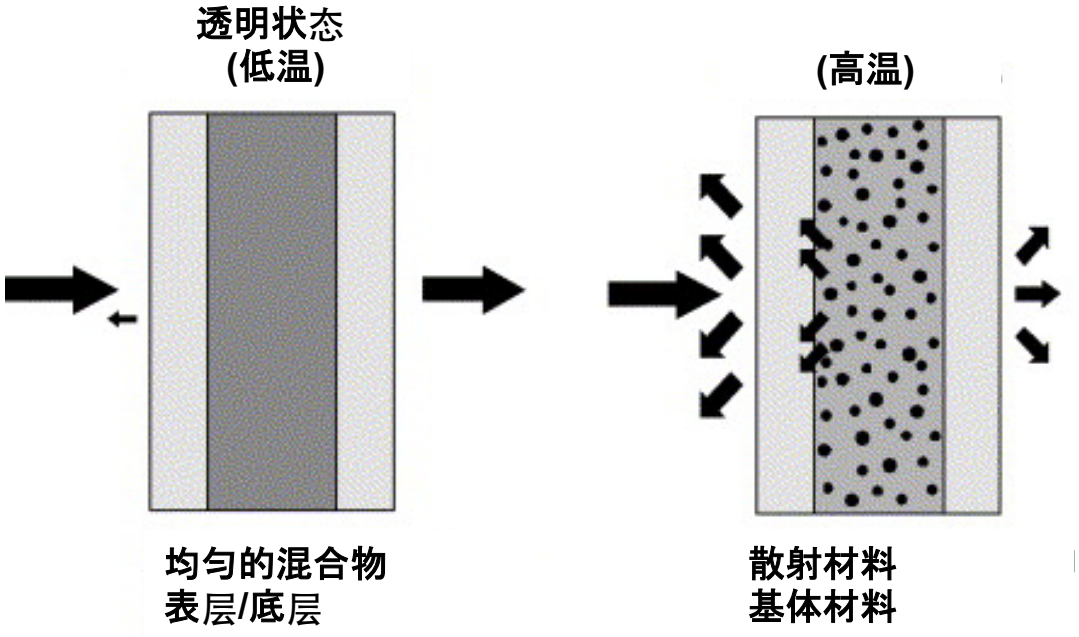
资料来源: Climate Tech Wiki, Enob, Bine

High Quality Windows - Triple Glazing
三层玻璃

- U-Value < 0.8 W/m²K
- U值< 0.8 W/m²K
- Double low-E coating
- 低辐射双涂层
- Argon filled
- 氩气填充
- Low conductivity spacers
- 低导热性隔离物
- Double gasket (for airtightness)
- 双密封垫（为气密性）
- Frames „thermally broken“
- 框架“断热”
- U_F = 0.57 W/m²K
- U_F = 0.57 W/m²K
- Spacers ψ = 0.03 W/mK
- 隔离物 ψ = 0.03 W/mK

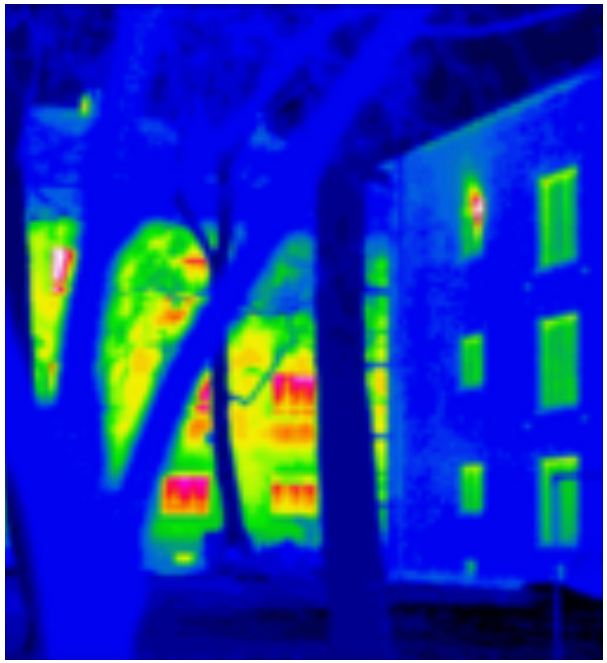
资料来源：被动式房屋研究所（Passive House Institute）

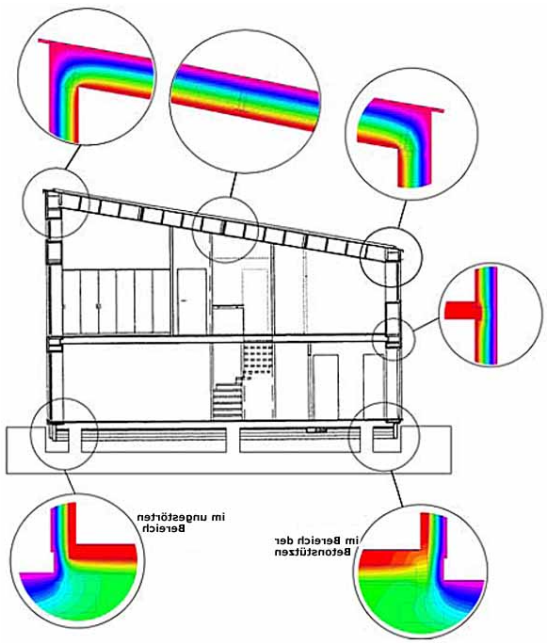
Thermotropic Shading Systems
热致遮阳系统



资料来源：Frauenhofer IBP

Thermal Bridges
热桥





资料来源：被动式房屋研究所（Passive House Institute）

Air-Tightness
气密性

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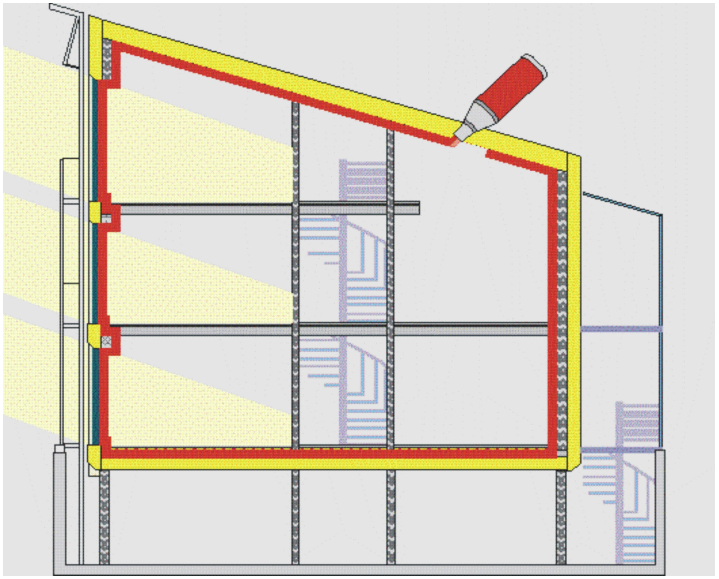
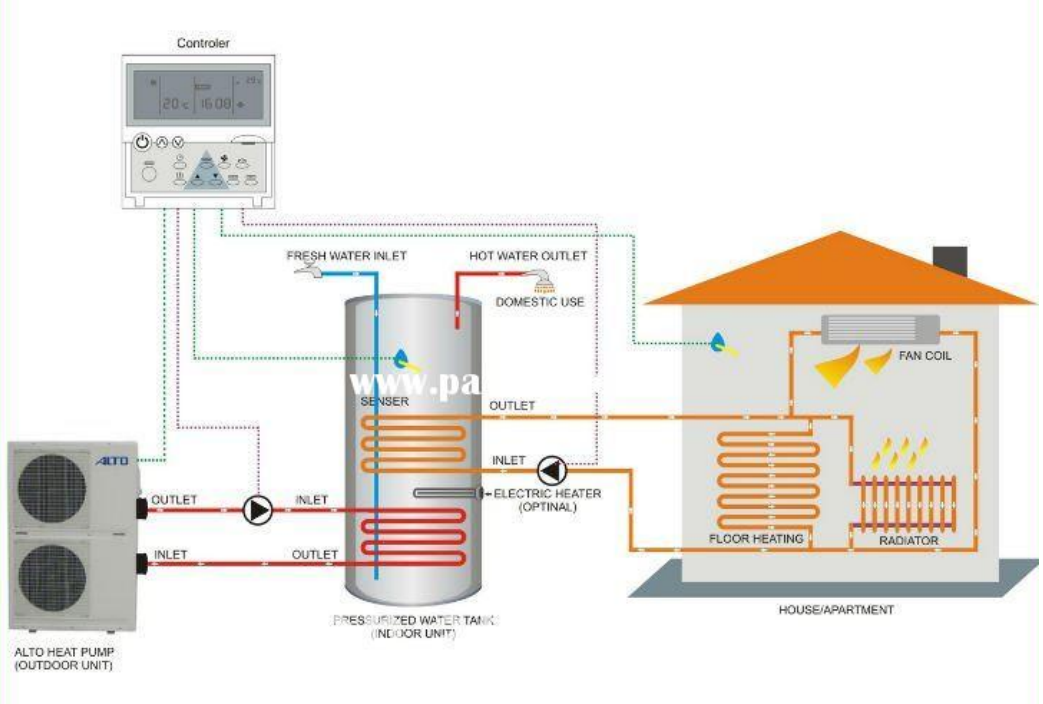


资料来源: Lutz Weidner, 被动式房屋研究所 (Passive House Institute)

Heat Pumps
热泵



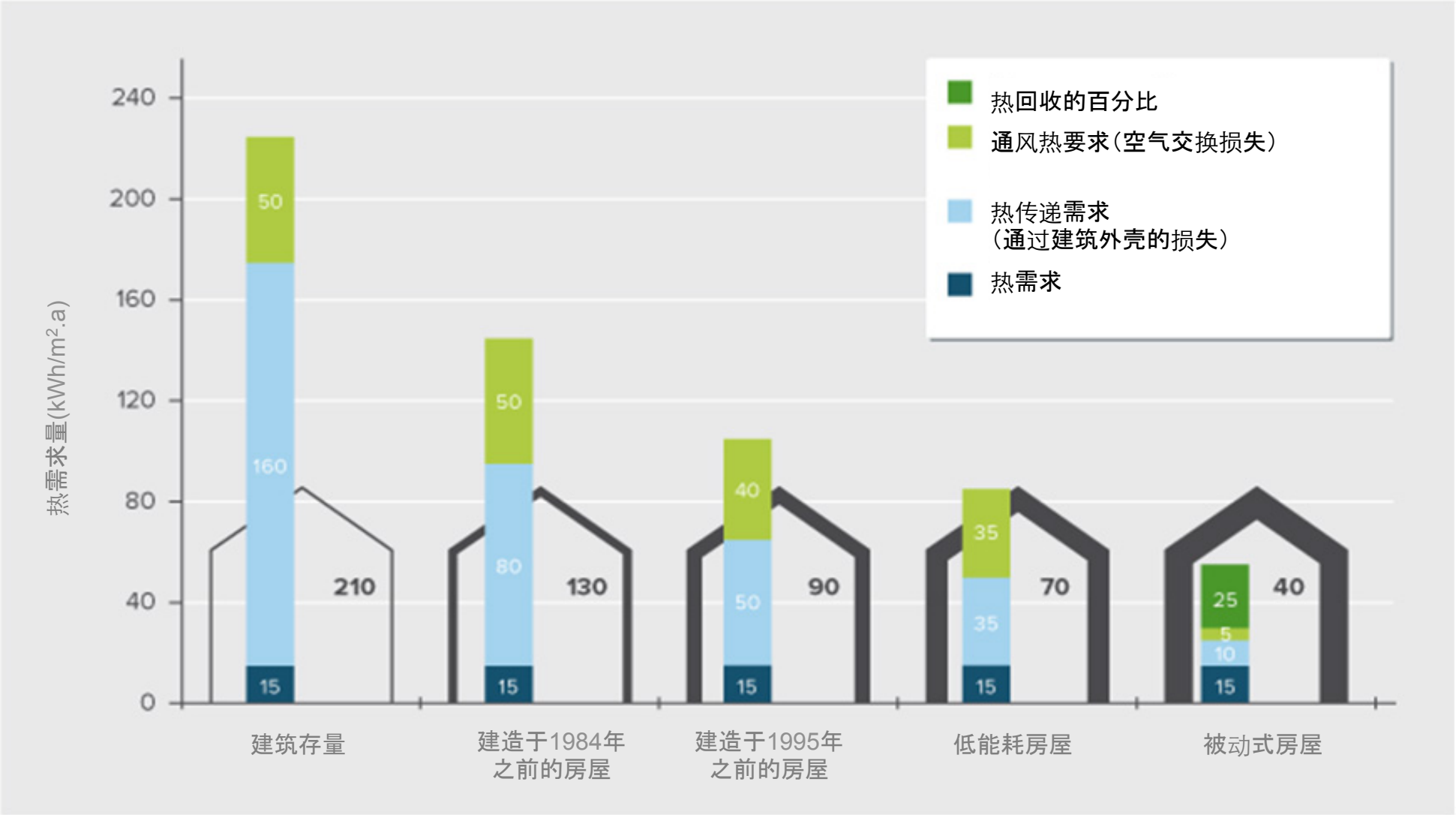
资料来源：FPH（2012), Viessmann

HRV Systems
外幕墙HRV

HRV System and casement window

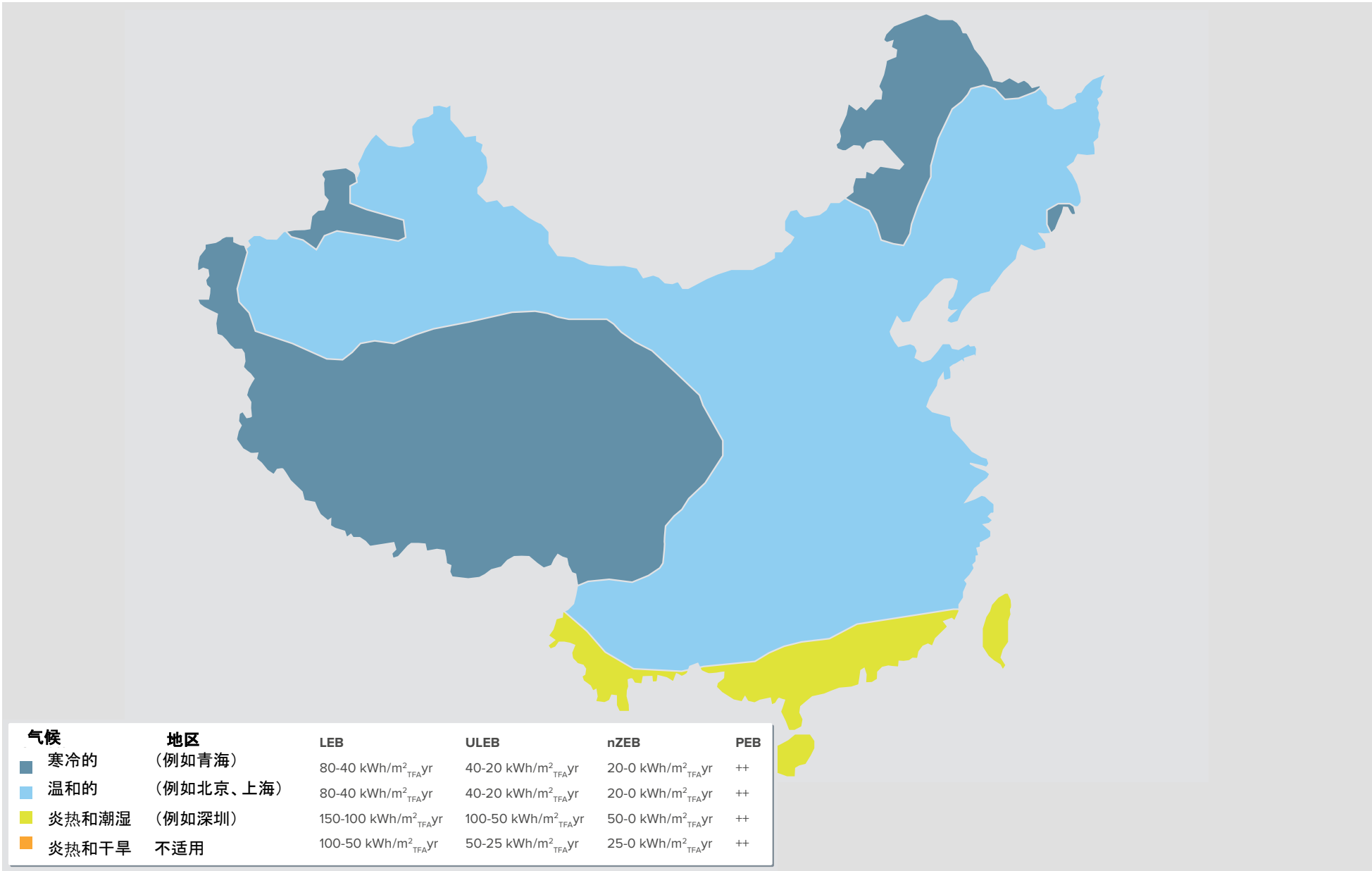
资料来源：被动式房屋（Passive House

Importance of heat recovery
热回收的重要性



资料来源：Händel，2011

bigEE Climate Zones for China
节能水平



Source: bigEE

Back-up

Examples of EU low energy building levels
欧洲低能耗建筑水平的例子

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Austria	Annual heating energy consumption below 60-40 KWh/m²
奥地利年度采暖能耗低于60-40KWh/m²	
Belgium	Low Energy Class 1 for houses: 40 % lower than standard levels,
	Very low Energy class: 60 % reduction for houses,
比列时第1类低能耗房屋：低于标准水平40%	
极低能耗类：减少60%	
Denmark	Low Energy Class 1 = 50% lower than standard levels
丹麦第1类低能耗房屋低于标准水平50%	
Finland	Low energy standard: 40 % better than standard buildings
芬兰：低能耗标准：低于标准水平40%	
France	New dwellings: less than 50 kWh/m² (in primary energy).
	(40 kWh/m² to 65 kWh/m²
法国新住宅：50 kWh/m²（一次能源）	
（40 kWh/m²至65 kWh/m²）	
Germany	Between 60kWh/(m²•a) and 40 kWh/(m²•a)
	Passive House = ca. 40 kWh/(m²•a)
德国：60kWh/(m2.a)和40 kWh/(m2.a)之间	
被动式房屋 = 约为40 kWh/(m2.a)	

Ultra-Low-Energy Buildings
超低能耗建筑

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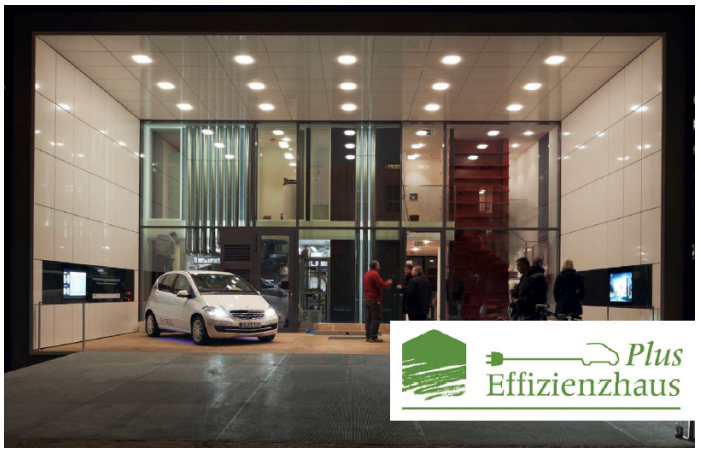
Germany (among others)
德国（及其他）

PassivHaus（被动式房屋）	PHI	1991
Plusenergiehaus（正能耗房屋）	Disch	1994
Nullenergiehaus（零能耗房屋）	BUW	2008
Niedrigstenergiehaus（低能耗房屋）	EPBD	2010
Effizienzhaus Plus（正能耗房屋）	DENA	2011



资料来源：被动式研究所

Comparison of U-Values
U值比较

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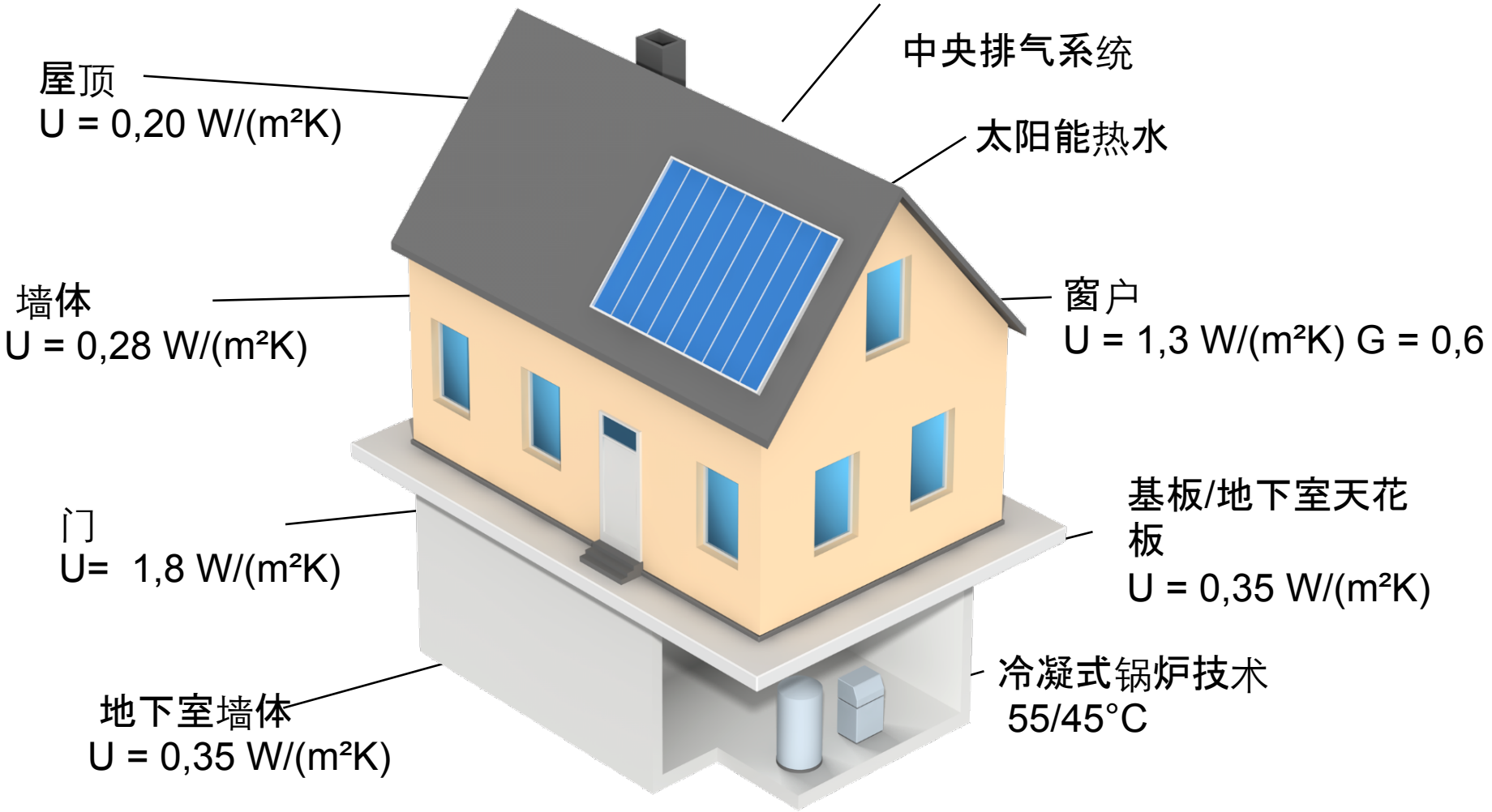
	EnEV 2014	节能房屋 70	节能房屋 55	被动式房屋
屋顶U值 (W/m^2K)	≤ 0.20	≤ 0.18	≤ 0.15	≤ 0.12
窗户U值 (W/m^2K)	≤ 1.1	≤ 0.90	≤ 0.90	≤ 0.80
墙体U值 (W/m^2K)	≤ 0.28	≤ 0.24	≤ 0.21	≤ 0.15
示例系统	冷凝式锅炉 + 太阳能热水器	热泵 + 太阳能热水器	热泵/颗粒 + 太阳能热水器	热泵/颗粒 + 太阳能热水器
通风	窗户通风的气密性试验	机械通风的气密性试验	机械式热回收通风的气密性试验	机械式热回收通风的气密性试验

Reference building according to EnEV 2014
- Residential buildings
节能条例2014参考建筑
- 住宅建筑



Source: Energieagentur NRW

Reference building according to EnEV 2014 - Non-Residential (Troom≥ 19°C)

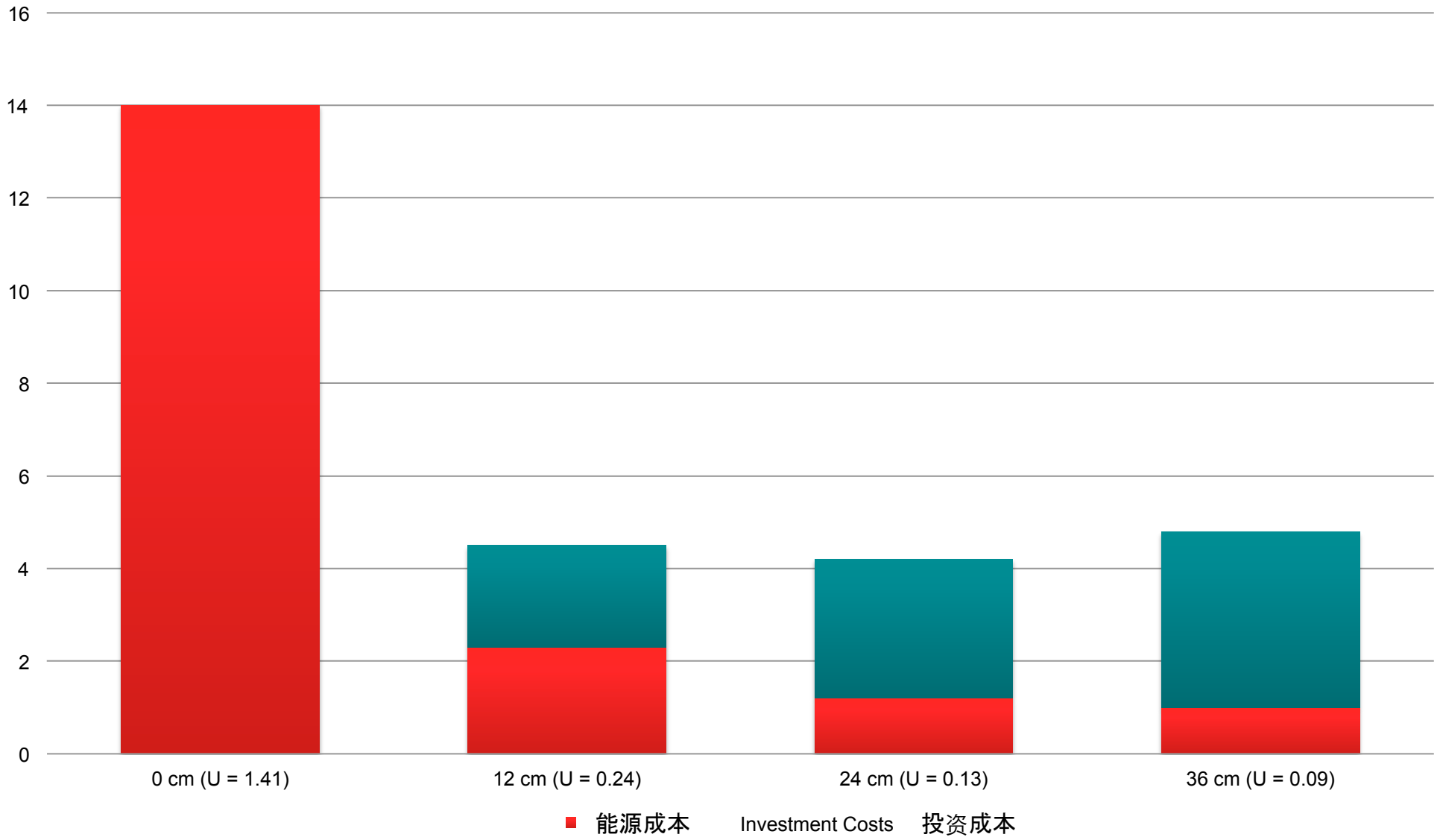
节能条例2014参考建筑 - 非住宅建筑（室内温度≥ 19°C)

屋顶	U = 0,20 W/(m²K)
墙体	U = 0,28 W/(m²K)
地下室墙体	U = 0,35 W/(m²K)
Cellar Ceiling (unheated)	U = 0,35 W/(m²K)
Window	U = 1,3 W/(m²K)
	g = 0,6

空调和制冷技术(根据使用中的系统)
太阳能光热系统(在热水需求高的情况下)
直接／间接照明
现存监测
恒照明控制
55/45°C冷凝式锅炉技术

Source: Energieagentur NRW

Insulation cost effectivity
隔热成本的有效性



资料来源：被动式房屋研究所（Passive House Institute）

Air Tightness
气密性

资料来源：Pro Clima

Cost effectivness and priority
成本效率及优先性

	成本效益	利基市场	研发
寒冷的气候			
被动式设计			
优化被动式设计	✔		
被动式供暖增益	✔		
先进的外壳			
优化的隔热	✔		
超级隔热		✔	
无热桥	✔		
气密封性	✔		
双层玻璃，低辐射窗户	✔		
玻璃贴膜	✔		
高度隔热的窗户		✔	
先进的技术			
热泵	✔		
太阳能（水）	✔		
被动式房屋等效性能		✔	

资料来源：国际能源署、bigEE

Cost effectiveness and priority
成本效率及优先性

	成本效益	利基市场	研发
炎热的气候			
被动式设计			
优化被动式设计	✔		
减少制冷负荷	✔		
外部遮阳及建筑物遮阳	✔		
反射墙体	✔		
先进的技术			
有空调建筑的隔热	✔		
相变材料			✔
先进的屋顶（综合设计/BIPV）		✔	
非常低的得热系数（或动态窗户）	✔		
优化的自然式/机械式通风	✔		

资料来源：国际能源署、bigEE

Energy Consumption Levels
节能水平

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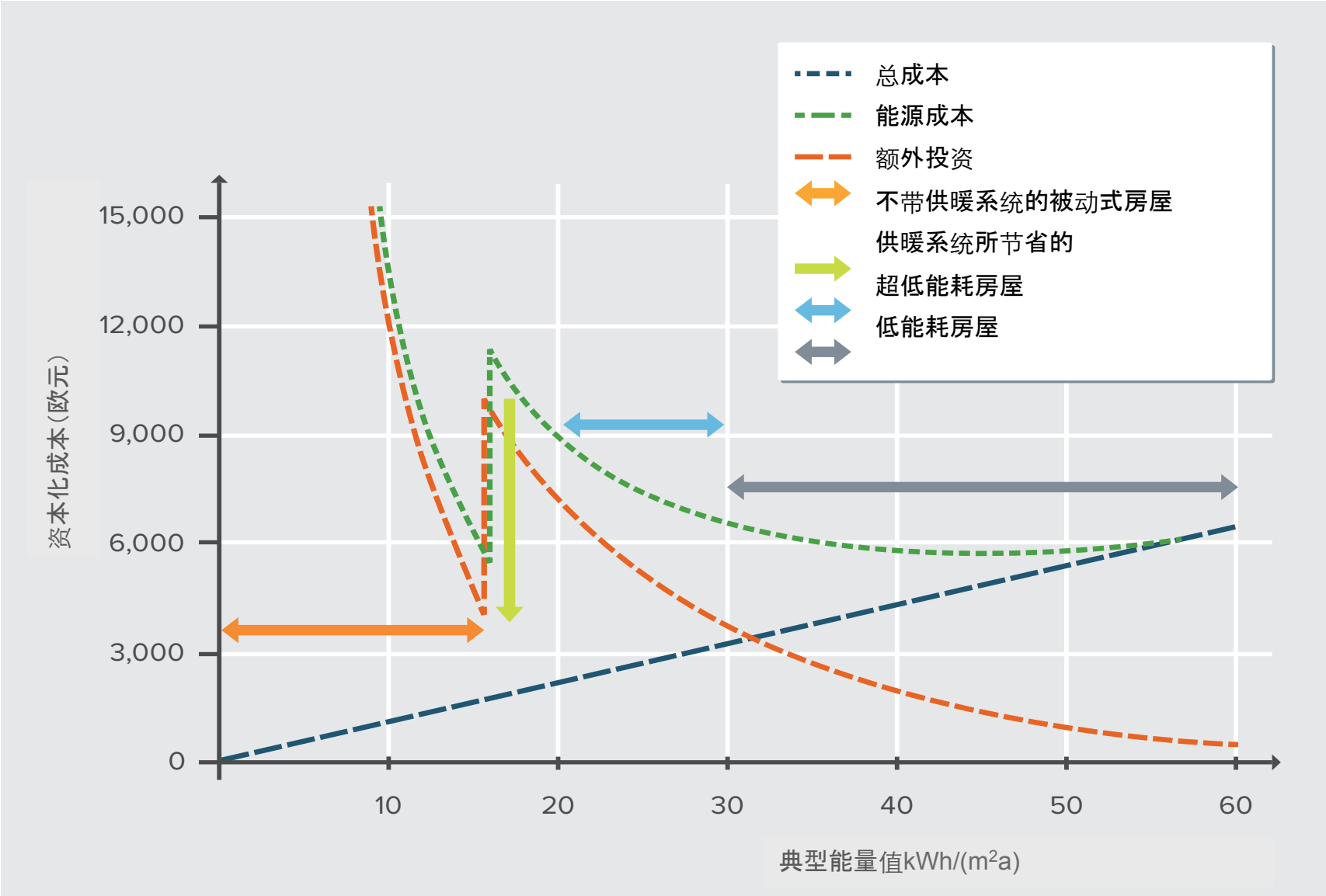
	寒冷的	温和的	炎热和潮湿	炎热和干旱
	例如青海	**例如北京/上海**	**例如深圳**	
	kWh/m^2_{TFA}yr	kWh/m^2_{TFA}yr	kWh/m^2_{TFA}yr	kWh/m^2_{TFA}yr
LEB	40 – 80	40 – 80	100 – 150	50 – 100
ULEB	20 – 40	20 – 40	50 – 100	25 – 50
nZEB	0 – 20	0 – 20	0 – 50	0 – 25
PEB	++	++	++	++

（TFA：处理的楼层面积）

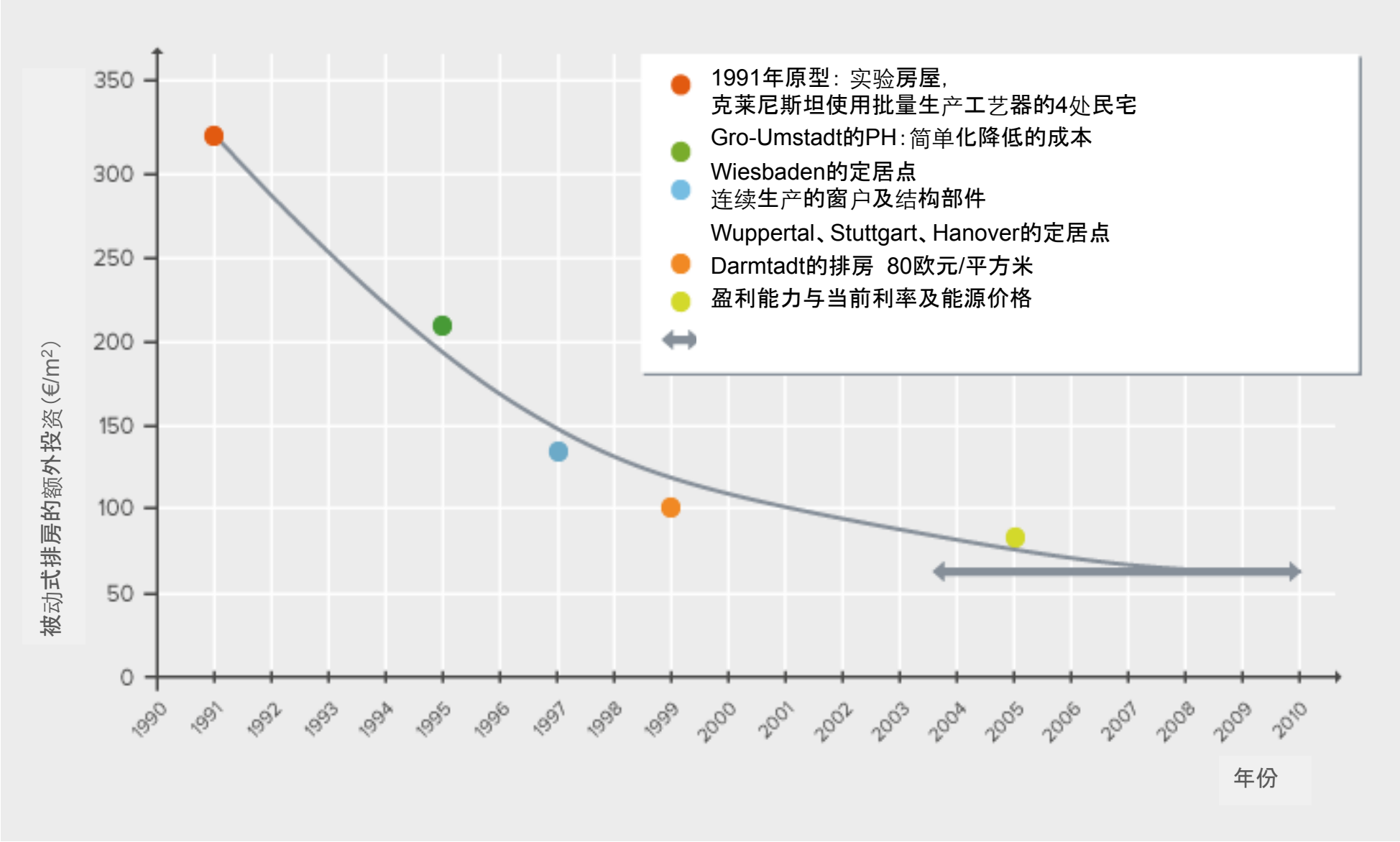
Recommended primary energy consumption ranges for heating, cooling, dehumidification, ventilation, and domestic hot water in new residential buildings

Costs of energy efficient buildings
节能建筑的成本



资料来源：被动式房屋研究所（Passive House Institute）

Cost Optimality
成本优化



资料来源: 被动式房屋研究所（Passive House Institute）

Solar Village Freiburg
弗赖堡太阳能村庄

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Plus Efficiency House

“正能耗房屋”

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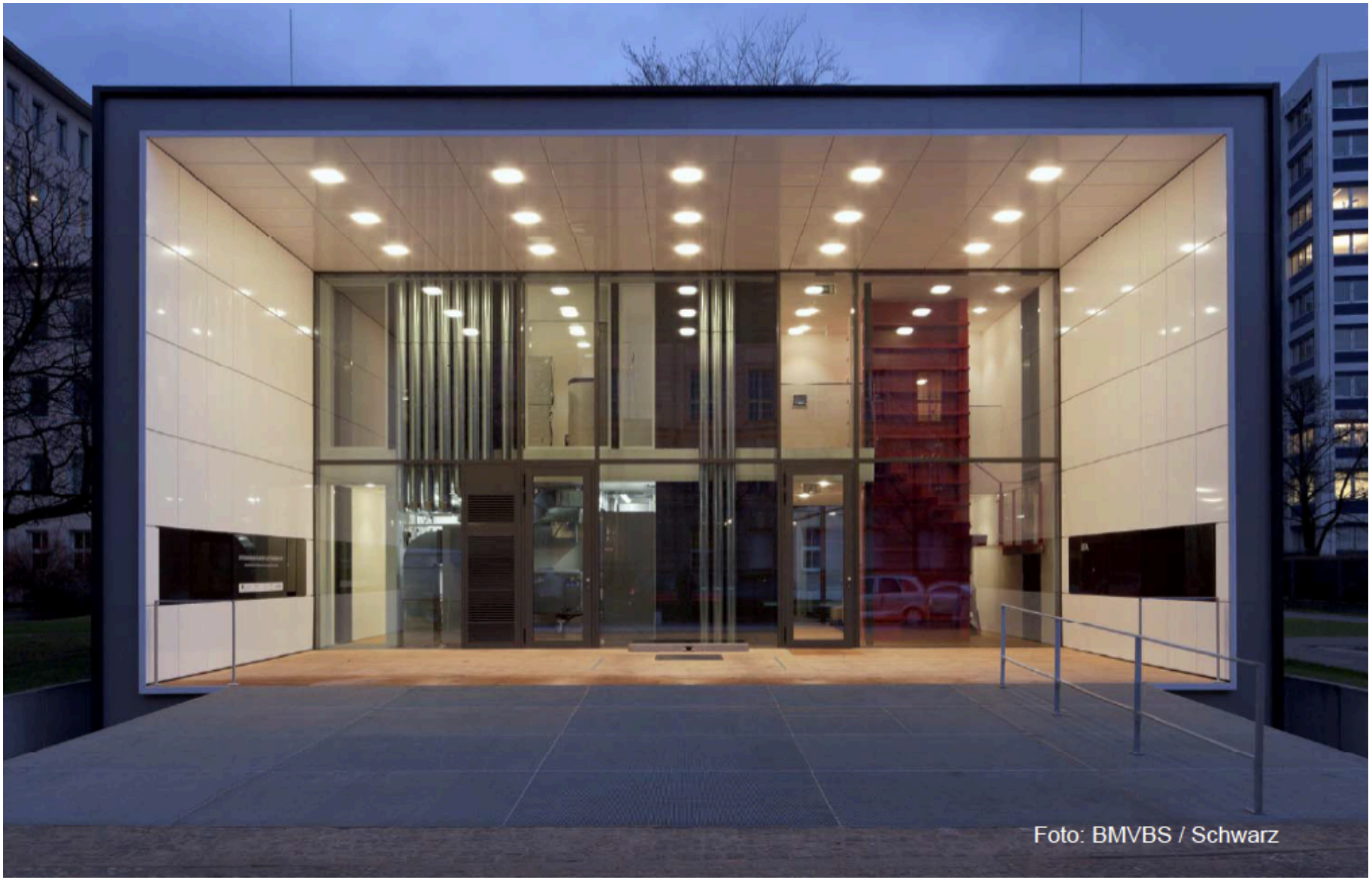

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