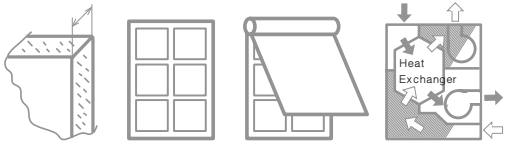
BROAD TOWN BUILDING THERMAL
INSULATION RETROFITTING CASES

FROM ONE COMMUNITY TO ONE PLANET

Melting Ice at the North Pole
Shot by BROAD Chairman Zhang Yue in May, 2009

BUILDING THERMAL INSULATION CAN SAVE THE EARTH

Building contributed to 40% global CO_2 emission. With only 4 simple measures, we can save energy by 4~10 times



Chilly areas like Moscow, Harbin

uninsulated wall, single-paned window → CO_2

10 cm insulated wall, double-paned window → CO_2

30 cm insulated wall, four-paned window, heat recovery fresh air → CO_2

Cold winter and hot summer areas like New York, Shanghai

uninsulated wall, single-paned window → CO_2

5 cm insulated wall, double-paned window → CO_2

20 cm insulated wall, triple-paned window, external solar shading, heat recovery fresh air → CO_2

Hot areas like Hongkong, Dubai

uninsulated wall, single-paned window → CO_2

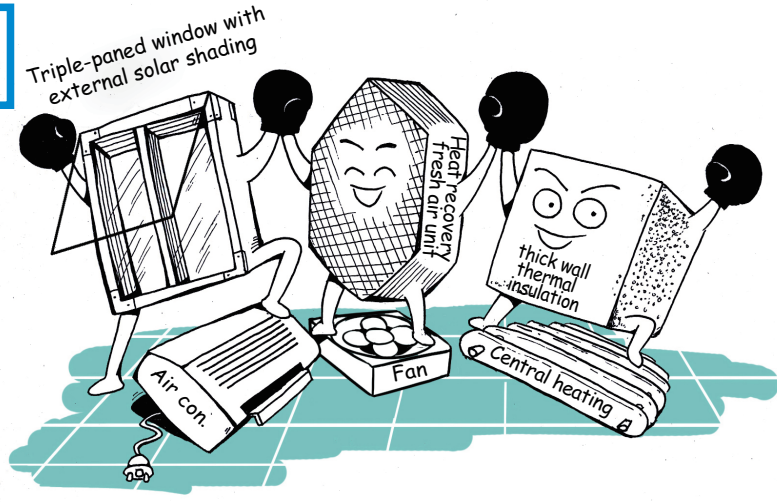
2 cm insulated wall, double-paned window → CO_2

8 cm insulated wall, triple-paned window, external solar shading, heat recovery fresh air → CO_2

EXPERIENCE OF BUILDING THERMAL INSULATION AT BROAD TOWN —— WE EXPECT THE WORLD TO FOLLOW

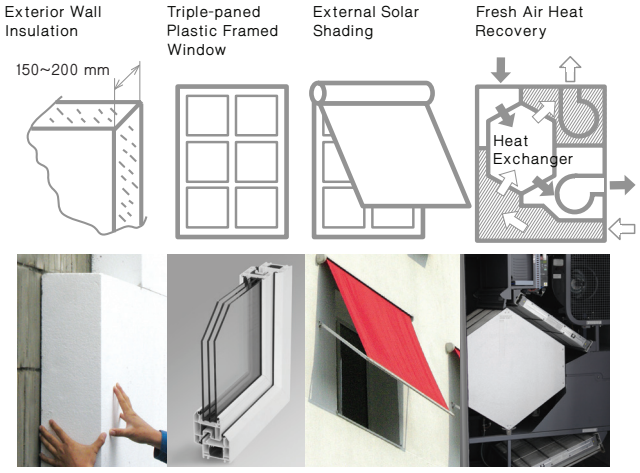
With over 20 years' central air conditioning serving experience in 80+ countries, we realized that uninsulated buildings have caused the most widely energy waste in the world, which is far beyond anyone's imagination. Starting from 2008, we decided to retrofit the buildings at BROAD Group H.Q. in BROAD Town, to explore for the humankind a full set of experience of using less air conditioning. Now by sharing what we've discovered, we hope you can follow us and do thermal retrofitting by yourselves

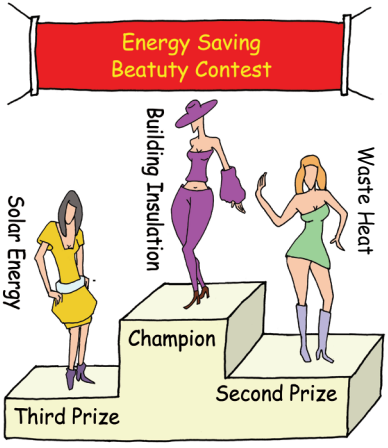
TECHNO-LOGY	Very Simple	We learn and practise on-site, design and construct by ourselves	Everyone can learn well
ECONOMY	Very Cost -effective	All retrofitting investments can have a 3-year payback	
EFFECT	Very Striking	80% energy can be saved (air quality can also be improved drastically)	
QUALITY	Indoor environment is much more comfortable than before		



* BROAD Town is located on the outskirts of Changsha, South China. Changsha (N 28° , E113°), has 4-5 cold months and 5-6 hot months, the lowest temperature is -10℃ and the highest 43℃. Only 1-3 months in a year can be free from air conitioning. This kind of climate is very typical globally, as in Shanghai, Osaka, Washington, D.C., Rome, etc.

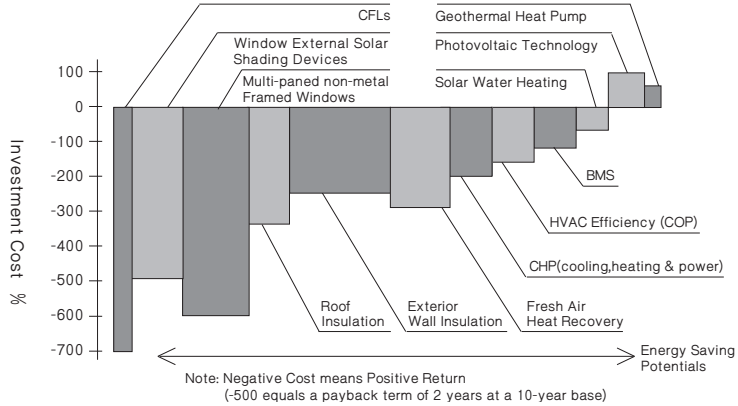
FOUR TYPICAL RETROFITTING MEASURES AT BROAD TOWN — BUILDING INSULATION





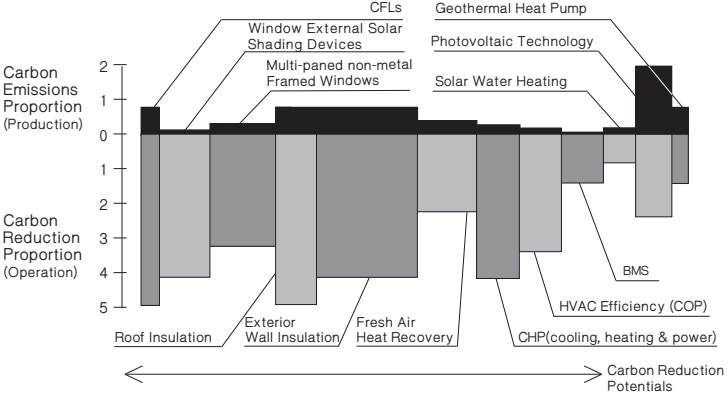
COMPARISONS AMONG VARIOUS BUILDING ENERGY-EFFICIENT RETROFITTING MEASURES

Typical Payback Comparisons



Note: Negative Cost means Positive Return
(-500 equals a payback term of 2 years at a 10-year base)

Lifecycle Carbon Balance Comparisons



Sources: Mckinsey & Company *Unlocking Energy Efficiency in the U.S. Economy*, BROAD Building Energy Efficiency Company


Big Villa P17
Big Villa P15
Apartment P9
Office Building P5
Teaching Building P25
Villa P21
Villa P20
Dorm P12
Dorm P11
Hotel P23
Club P13
Office Building P24
Villa P19
Villa P22

BROAD QUALITY MANAGEMENT BUILDING

Building usage: Office
Designed occupants: 400
Usage area: 4,212 m^2
Built in 1994 Retrofitted in 2008
Energy consumption before retrofitting: 294 kWh/m^2·a
Energy consumption after retrofitting: 61.2 kWh/m^2·a
Retrofitting expense: 217,000 USD
Energy saving rate: 80%
Payback: 2.9 years

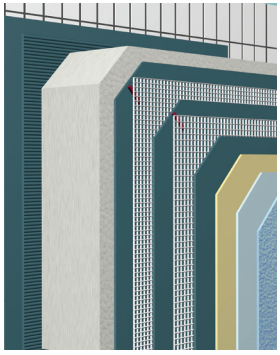
Before Retrofitting

* kWh indicates primary energy, equals to 0.1kg of oil equivalent (the same applies to the following cases)
1kWh electricity equals to 4 kWh primary energy.

Wall Insulation

Thickness of polystyrene foam board: 150 mm, reducing heat transfer by 8 times
(Multi-gridding and mortar in cracks, extremely durable)
Exterior thermal insulation technology is very easy to learn and can be executed by ordinary workers after 1 week training.

Original Wall:
Ceramic tile without insulation



Triple-paned Plastic Framed Window

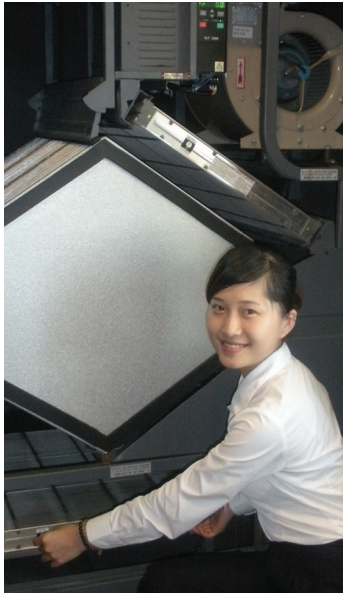
Reduces heat transfer by 8 times

Original Window:
Single-paned aluminum window

Heat Recovery Fresh Air Unit

Heat recovery efficiency is about 70% in summer, 90% in winter
Air flow: 12,000 m^3/h

Before Retrofitting:
Ventilation through open window



Exterior Solar Shading

Swing arm, cloth shade;
Each window reduces roughly 1.5 kW of heat transfer

Original Window:
Interior blinds

A/C Equipment

Cooling capacity 140 kW (40 USRT), gas-fired (2 units of BCT70 on the roof). Reduce cooling load by 6 times and reduce heating load to 0

Auto Revolving Door

Each revolve just loses 0.1 ~ 0.4 kWh of heat
Annual energy saved equals to 5 ton oil

Original Door:
Single-layer
auto door

INVESTMENT PAYBACK LIST OF ENERGY-EFFICIENT BUILDING RETROFITTING

Thick exterior thermal insulation

Thickness of polystyrene foam board: 150 mm
Heat transfer coefficiency: 0.24 W/m^2 K
(Original wall without insulation: 2.1 W/m^2 K)
Energy saved : 110 kWh/m^2.a (equals 11L oil)
Annual total energy saved: 25.7 t.o.e
Payback: 3.3 years

Labor: 40 workers/35 days
Material and construction cost: USD 28/m^2
Construction process:

1. Base treatment	2. Interfacial agent
3. Binding Mortar	4. 150 mm PE board
5. Anti-crack mortar finishing	6. 1st gridding
7. Anti-crack mortar embedded	8. 2nd gridding
9. Anti-crack mortar finishing	
10. Flexible, waterproof putty	
11. Sealing lacquer	12. Topcoat

Triple-paned plastic framed window

Heat transfer coefficiency: 1.65 W/m^2 K
(Original single-paned aluminum window: 13 W/m^2 K)
Annual energy saved per square meter: 690kWh (equals 69L oil)
Annual total energy saved: 20.9 t.o.e
Payback: 1.3 years

Panes: 4 mm×3 layers inert gas filled
Window frame: 60 mm PVC
Labor: 5 workers / 5 days
Material and installation cost: USD 70/m^2

Exterior solar shading

Effective solar shading time: 677 hrs/a (west windows)
Annual energy saved by each board: 355 kWh
Annual total energy saved: 2.1 t.o.e
Payback: 3.9 years

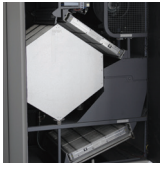
Control principle:
motor cloth shade auto control & protection
1. Optical sensor: Solar shading will be activated if luminance is ⩾ 7 klux (auto solar shading)
2. Temperature sensor: Solar shading will be foldedup if temperature is <18℃ (auto lighting)
3. Wind sensor: Solar shading will be folded up if wind velocity is ⩾ 30 km/h (avoids damage)

Solar shading area: 124 m^2 (71 pcs in total)
Labor: 5 workers/7days
Material and installation cost: USD 62/m^2

Fresh Air Heat recovery

Heat exchanging time: 2,700 h/a
Enthalpy difference: 10 W/m^3
Annual total energy saved: 21.2 t.o.e
Payback: 3.7 years

Note: t.o.e is short for ton of oil equivalent



Working principle:
Dirty air from indoor is exchanged with fresh air from outside through heat exchanger so that fresh air temp can be either increased or decreased.
Heat recovery efficiency: about 70% in summer, 90% in winter
Labor: 8 workers/15 days
Heat recovery fresh air units and air ducts cost: USD 72,616

BUILDING ENERGY EFFICIENCY QUICK CALCULATION SHEET

Building Name: Quality Management Building
Location: No. 1, Flag Raising Ceremony Square, BROAD Town, No. 3, BROAD Road, Changsha, Hunan, PRC
Building Usage: Office, 400 Occupants
Design Institute: BROAD Energy Efficiency Institute
Designer: Deng Peng
Design Date: October, 2008

Scope of Energy Consumption (check✓)

- ☑ Heating / Cooling Equipment Energy Consumption (Electricity and Fuel)
- ☑ Heating / Cooling Transmission and Distribution System (Water Pump, Fan)
- ☑ Air Conditioning Terminal Electricity Consumption
- ☑ Ventilation

Note: 1. This *Quick Calculation Sheet* is a basis for retrofitted building energy efficiency level appraisal
2. The upright letters are standard format which can not be changed; the italics are design values

Please fill in this sheet before starting the retrofitting design. With basic heat transfer knowledge and building information, this sheet can be easily completed in several hours or 1 to 2 days

Basic Information

Construction Date: *April, 1994*				Building Use Area: *4,212* m²			A
Rennovation Date: *October, 2008*				Building Envelop Area: *4,220* m²			B
Occupution rate *42%*			C	Climate Zone: *Chilly Hot Area(C1H2)*			D
Solar Radiation *39* W/m²			E				
Indoor–Outoor Temperature Difference Limit	Winter *23*℃		G	Average Interior-Exterior Temperature Differnece	Winter *15*℃		J
	Summer *11*℃		H		Summer *8*℃		K
Annual AirConditioning Operation Hours	Winter *200*		L	Annual Ventilation Operation Hours	*6,240*		p
	Summer *1,350*		M				

Incoming Envelope Load Energy Consumption

Category	Material	Thickness mm	Heat Transfer Coefficient W/m²K	Area m²	Heat Transfer W/℃	
Exterior Wall	*Polystyrene Board*	*150* *100*	*0.24* *0.35*	*1,220* *1,584*	*293* *554*	Q
Roof	*Extrusion Plate*	*100*	0.23	1,222	*281*	
Window	*Triple-Paned Plastic Framed*	*4+9+4+ 9+4*	*1.65*	*124 (71Fans)*	*205*	
Other *(including doors, parapet, galss room)*			*1.8*	70	*128*	

(Sum of Heat Transfer)

Radiant Heat: *124* m² × E = *4,836* W — R

Winter: L × Q × J ÷ A ÷ 1,000 = *1* kWh/m² per year — S
Summer: (M × Q × K + *677* × R) ÷ A ÷ 1,000 = *4.5* kWh/m² per year — T

Ventilation Load Energy Consumption

Season	Ventilation m³/m²	Unit Enthalpy Differnce W/m³	Average Temperature Difference × Hours	Heat Loss Efficiency	Energy Consumption kWh/m² per year	
Winter	*2.8*	*0.5*	J × L	*0.2*	*0.84*	U
Summer	*2.8*	*1.0*	K × M	*0.2*	*6.0*	V

(Accumulative Energy)

Indoor Heat Energy Consumption

Model	Load		UseTime	Energy Con. kWh	
Occupants	*400* × *100* W per capita	F_1	L+M	*62,000*	w
Lighting	*2* W/m² × A	F_2	*1,260*	*10,614*	
Appliances	Computers: *300* × *80* W	F_3	L+M	*37,200*	
	Water Heater: *1.2* kW etc.	F_4	*1,260*	*1,512*	
Occupant Coselection Rate *80* %					a

Winter: W × a ÷ A × *0.13* = *2.7* kWh/m² per year — Y
Summer: W × a ÷ A × *0.87* = *18.4* kWh/m² per year — Z

(Accumulative Energy)

Total Load

Heating Load
Q × G + U ÷ (L × J) × G × A - (F_1 + F_2 + F_3 + F_4) = *-12.9* kW — b

Cooling Load
Q × H + R + V ÷ (M × K) × H × A + (F_1 + F_2 + F_3 + F_4) = *120* kW — d

Cooling/Heating Source Energy Consumption

Model	Number	Functions	Adjusted Energy Efficiency	
BCT70	*2*	*Heating* *Cooling*	*0.88* *1.1*	e f
Energy Consumption	Winter (S+U-Y) ÷ e = *0* kWh/m²·a Summer (T+V+Z) ÷ f = *26.3* kWh/m²·a			g h

Transmission and Distribution System Energy Consumption

Model	Number	Motor Power kW	Operation Frequency Coefficient	Operation Time	Converted Primary Energy Consump. kWh/m²·a	
A/C Water Pump	*2*	*1.1*	*0.6*	L+M	*2.1*	m
Cooling Water Pump	*2*	*0.75*	*0.6*	M	*1.2*	
Cooling Tower	*2*	*1.5*	*0.6*	M	*2.5*	

(Accumulative Energy)

Ventilation and A/C Terminal Energy Consumption

Model	Number	Motor Power kW	Electricity Consumption kWh	Converted Primary Energy Consump. kWh/m²·a	
Heat Recovery Fresh Air Unit	*11*	*11.7*	*11.7* × C × P/A = 7.3	*7.3* × 4 = *29*	n

(Accumulative Energy)

Annual Energy Consumption Per Square Meter (Primary Energy) g+h+m+n

61.2 kWh/m²·a

Annual Total Power *36,716* kWh
Annual Total Gas *11,098* m³

Yearly CO_2 Emissions: *60.7* tons (14 kg/m²·a)

Design Approval(check✓)

☑ Qualified
☐ Excessive Energy Consumption, Change Design
☐ Calculation Error. Revise

Approval Body:
Approval Signature: **Date:**

Approval Number: *CS—BE000001*

APARTMENT NO. 1

Building usage: Staff dorm
Designed occupants: 380
Usage area: 4,700 m^2
Built in 1994 Retrofitted in 2009
Energy consumption before retrofitting: 339 kWh/m^2·a
Energy consumption after retrofitting: 64 kWh/m^2·a
Retrofit expense: 20,000 USD
Energy saving rate: 81%
Payback: 2 years

Before Retrofitting

Wall Insulation

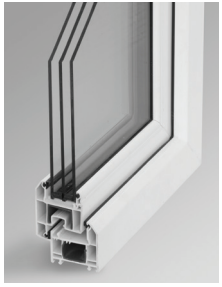
Thickness of polystyrene foam board: 150 mm, reducing heat transfer by 8 times.
Exterior thermal insulation technology is very easy to learn and can be executed by ordinary workers. Polystyrene foam board is fixed by anchor bolts which are inserted into 40 mm foam, eradicatiing heat transfer

Original Wall: Without insulation and exterior ceramic veneer

Triple-paned Plastic Framed Window

Reduces heat transfer by 8 times

Original Window: Single-paned aluminum window

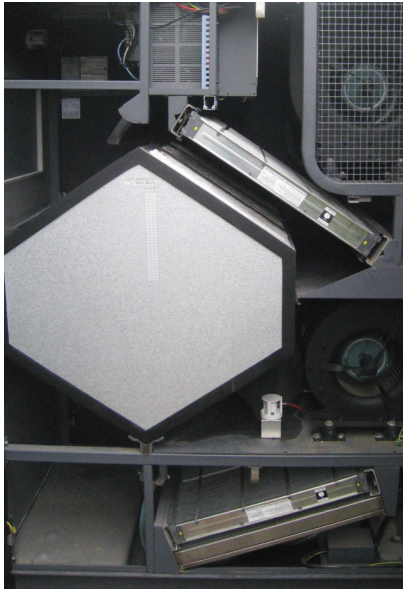


Balcony

Install steel balconies to dry clothes without the clothes dryer

Heat Recovery Fresh Air Unit

Approx. 70% in summer, 90% in winter
Air purification efficiency: 99%



APARTMENT NO. 2

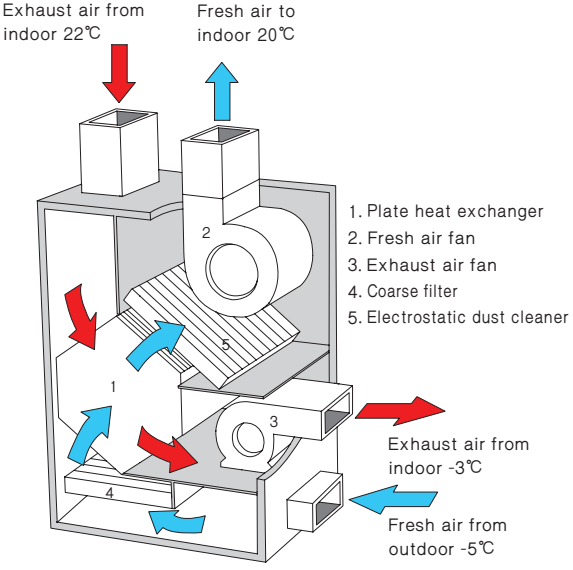
Building usage: Staff dorm
Designed occupants: 400
Usage area: 3,578 m^2
Built in 1995 Retrofitted in 2009
Energy consumption before retrofitting: 345 kWh/m^2·a
Energy consumption after retrofitting: 63 kWh/m^2·a
Retrofit expense: 203,000 USD
Energy saving rate: 82%
Payback: 2.6 years

Before Retrofitting

APARTMENT NO. 3

Building usage: Staff dorm
Designed occupants: 500
Usage area: 5,011 m^2
Built in 1996 Retrofitted in 2009
Energy consumption before retrofitting: 552 kWh/m^2·a
Energy consumption after retrofitting: 126 kWh/m^2·a
Retrofit expense: 272,000 USD
Energy saving rate: 77%
Payback: 1.7 years

Before Retrofitting



MEDITERRANEAN CLUB

Building usage: Chinese restaurant, western restaurant, gym, swiming pool, guest suites
Designed occupants: 250
Usage area: 3,150 m^2
Built in 1999 Retrofitted in 2010
Energy consumption before retrofitting: 412 kWh/m^2·a
Energy consumption after retrofitting: 82.5 kWh/m^2·a
Retrofit expense: 230,000 USD
Energy saving rate: 80%
Payback: 2.7 years

Before Retrofitting

Wall Insulation

Thickness of polystyrene foam board: 200 mm, reducing heat transfer by 11 times
Red sandstone decoration wall was restored after thermal insulation

Original Wall:
Clay brick wall
Dry-hung red sandstone

Column Insulation

Thickness of polystyrene foam: 50 mm, reducing heat transfer by 2.5 times

Original Column

Sun-roof Insulation

Thickness of polystrene foam board: 150 mm, reducing heat transfer by 12 times
Fix blinds for solar shading

Block Big Windows

Thickness of polystyrene foam board: 150 mm.
The rest windows were changed into triple-paned plastic framed windows, reducing heat transfer by 12 times

NANSHAN VILLA NO. 1

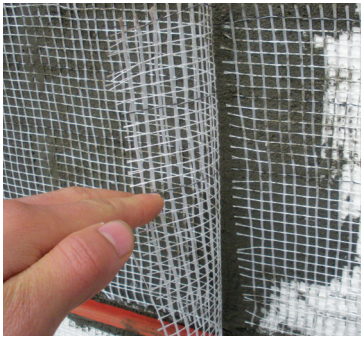
Building usage: Residence
Designed occupants: 16
Usage area: 850 m^2
Built in 1999 Retrofitted in 2010
Energy consumption before retrofitting: 340 kWh/m^2·a
Energy consumption after retrofitting: 65.4 kWh/m^2·a
Retrofit expense: 50,000 USD
Energy saving rate: 81%
Payback: 3.7 years

Before Retrofitting

Wall Insulation

Thickness of polystyrene foam board: 150 mm, reducing heat transfer by 8 times
The imitated granite decoration wall was grooved after thermal insulation

Original Wall: Clay brick with granite



Roof Thermal Insulation

Thickness of extruded board:150 mm, reducing heat transfer by 10 times
The original tiled roof was restored after thermal insulation

Original Roof: No thermal insulation, villa concrete-tile roof

Exterior Motor Blinds Solar Shading

Reduces heat transfer by 0.3 kW

Original interior solar shading

Heat Recovery Fresh Air Unit

Installed under the eaves

NANSHAN VILLA NO. 2

Building usage: Residence
Designed occupants: 16
Usage area: 850 m^2
Built in 2000 Retrofitted in 2009
Energy consumption before retrofitting: 353 $kWh/m^2 \cdot a$
Energy consumption after retrofitting: 59 $kWh/m^2 \cdot a$
Retrofit expense: 74,200 USD
Energy saving rate: 83%
Payback: 3.8 years

Before Retrofitting

Wall Insulation

Thickness of polystyrene foam board: 200 mm, reducing heat transfer by 11 times
The original wall was imitated by grooving after thermal insulation

Original Wall: Clay brick with sandstone

Extra Triple-paned Plastic Framed Window

Triple-paned windows were added on the original double-paned windows, reducing heat transfer by 5 times

Original: Double-paned aluminum window

Door Insulation

Original double-paned aluminum door remains unchanged, extra double-paned plastic framed door added

Exterior Motorized Blinds Solar Shading

Reduces heat transfer by 0.3 kW

Original: Interior sun blind

Heat Recovery Fresh Air Unit

Installed in the lobby

AMERICAN VILLA

Building usage: Residence
Designed occupants: 8
Usage area: 264 m^2
Built in 2000 Retrofitted in 2009
Energy consumption before retrofitting: 436 kWh/m^2·a
Energy consumption after retrofitting: 63.3 kWh/m^2·a
Retrofit expense: 20,300 USD
Energy saving rate: 86%
Payback: 2.7 years

Before Retrofitting
(outlook completely restored)

SPANISH VILLA

Building usage: Residence
Designed occupants: 10
Usage area: 330 m^2
Built in 2000 Retrofitted in 2010
Energy consumption before retrofitting: 352 kWh/m^2·a
Energy consumption after retrofitting: 54.5 kWh/m^2·a
Retrofit expense: 33,400 USD
Energy saving rate: 84%
Payback: 4.3 years

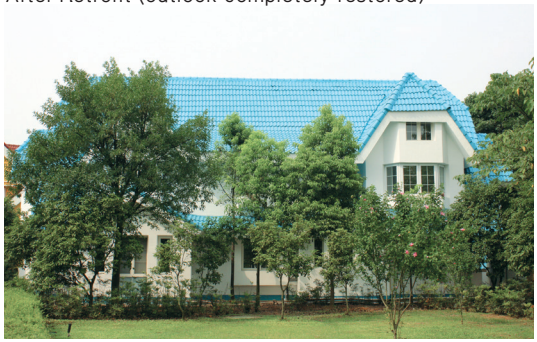
Before Retrofitting

GERMAN VILLA

Building usage: Residence
Designed occupants: 8
Usage area: 307 m^2
Built in 1999 Retrofitted in 2011
Energy consumption before retrofitting: 402 $kWh/m^2 \cdot a$
Energy consumption after retrofitting: 41.8 $kWh/m^2 \cdot a$
Retrofit expense: 44,300 USD
Energy saving rate: 90%
Payback: 3.7 years

Before Retrofitting

After Retrofit (outlook completely restored)



JAPANESE VILLA

Building Usage: Residence
Designed Occupants: 12
Usage area: 320 m^2
Built in 1999 Retrofitted in 2011
Energy consumption before retrofitting: 380 kWh/m^2·a
Energy consumption after retrofitting: 66.6 kWh/m^2·a
Retrofit expense: 30,800 USD
Energy saving rate: 82%
Payback: 4 years

Before Retrofitting

ARK HOTEL

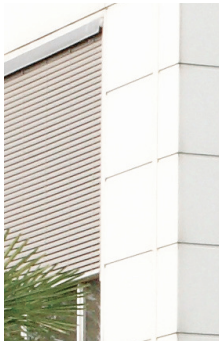
Building usage: Residence
Designed occupants: 70
Usage area: 1,420 m^2
Built in 1997 Retrofitted in 2008
Energy consumption before retrofitting: 556 kWh/m^2·a
Energy consumption after retrofitting: 86.5 kWh/m^2·a
Retrofit expense: 92,300 USD
Energy saving rate: 80%
Payback: 2.2 years

Before Retrofitting

MARKETING BUILDING

Building Usage: Office
Designed Occupants: 150
Usage area: 949 m^2
Built in 1999 Retrofitted in 2009
Energy consumption before retrofitting: 413 kWh/m^2·a
Energy consumption after retrofitting: 59.8 kWh/m^2·a
Retrofit expense: 66,200 USD
Energy saving rate: 86%
Payback: 2.6 years

Before Retrofitting



ENVIRONMENTAL PHILOSOPHY INSTITUTE

Building usage: Meeting, training
Designed occupants: 440
Usage area: 4,500 m^2
Built in 1999 Retrofitted in 2012
Energy consumption before retrofitting: 320 kWh/m^2·a
Energy consumption after retrofitting: 84.1 kWh/m^2·a
Retrofit expense: 692,300 USD
Energy saving rate: 74%
Payback: 8 years

Before Retrofitting

Roof Insulation

Polyurethane spray coating: 200 mm, reducing heat transfer by 20 times
Double layer waterproof membranes be paved after thermal insulation

Original Roof: Cast-in-site, roof with perlite insulation

Wall Insulation

Thickness of polystyrene foam board: 80-200 mm
EPS decorative components were restored after retrofit

Original Wall: Concrete brick with decorative cement components

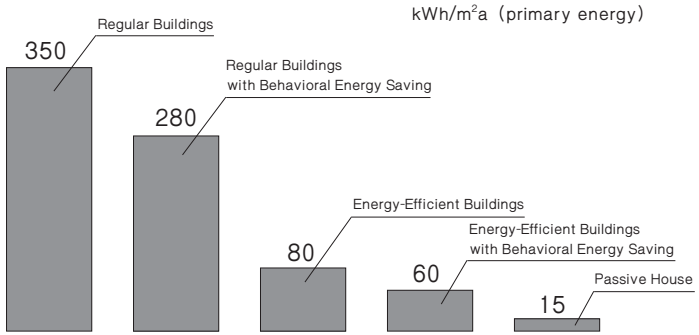
Decoration for Exterior Thermal Insulation

Polystyrene foam board decoration

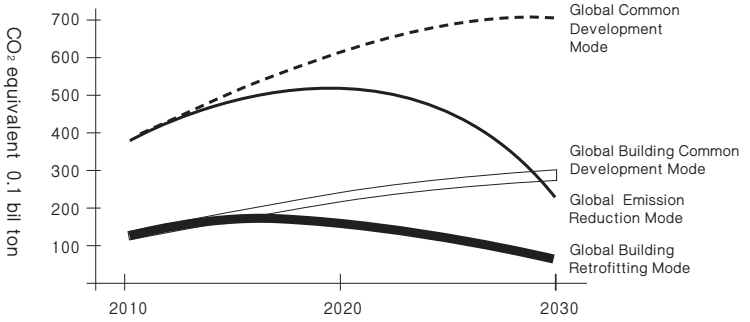
Original Decoration: Decorative cement opponents

Carved board

TYPICAL BUILDING ENERGY CONSUMPTION



GLOBAL CO_2 EMISSION TREND



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