Business and Technical Concepts of Deep Energy Retrofit of Public Buildings - IEA EBC Annex 61

EBC
Energy in Buildings and Communities Programme

Deep Energy Retrofit Guide

Subtask A

Objectives

- Provide guidance on **core technologies** for DER focusing on building envelope ECMs
- **Technology Characteristics** (e.g., U-values, building and duct air tightness, illumination levels and LPD, etc.)
- **Critical design, construction requirements and recommendations** (how-to and how-not-to)
- **Important architectural details** for
  - Wall cross-sections
  - BE elements connections
  - Continuous air barrier
  - Continuous vapor barrier
  - Thermal bridge remediation

Subtask A: DER Guide - Outline

- **Introduction**
- **What is Deep Energy Retrofit**
- **Energy efficiency technologies and strategies**
- **Core technologies for DER**
- **Building Envelope**
  - Wall and roof cross-sections
  - Insulation types and levels for different climate conditions
  - Thermal Bridges
  - Window types and characteristics for different climate conditions
  - Air barrier requirements
  - Water and Vapor control for different climate conditions
- **Lighting systems**
- **HVAC systems : core requirements to energy efficiency of equipment, HR, ducts and pipes**

DER Guide – Outline (Cont)

- **Attachments**
  - Insulation Materials
  - Catalogue of thermal bridges
  - Air barrier examples of good and bad practices
  - Windows –good practices and installation recommendations
  - Water and Vapor control: examples of good and bad practices
  - Lighting Design Guide
  - HVAC : examples of energy efficient technologies
- **Quality Assurance**
- **Conclusions**
- **References**

Core Technologies Bundle

Category	Name	Specification
Building Envelope	Roof insulation	Level to be defined through modeling
	Wall insulation	Level to be defined through modeling
	Slab Insulation	Level to be defined through modeling
	Windows	Parameters to be defined through modeling
	Doors	Parameters to be defined through modeling
	Thermal bridges remediation	See the BE Guide
	Air tightness	0.15 cfm/ft2 (for USA)
	Vapor Barrier	See the BE Guide
	BE QA	See the BE Guide
Lighting and Electrical Systems	Lighting design , technologies and controls	See the USACE Lighting Guide
	Advanced plug loads, smart power strips and process equipment	TopTen (Europe, USA), Top Tier EnergyStar, FEMP Designated, etc
HVAC	High performance motors, fans, furnaces, chillers, boilers, etc	ASHRAE Std 90.1 2013 and EPBD (Table will be provided in the Guide)
	DOAS	See the Guide
	HR (dry and wet)	>80% efficient, see the Guide
	Duct insulation	Based on EPBD requirements
	Duct airtightness	Based on EPBD requirements
	Pipe insulation	Based on EPBD requirements

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Other Energy Efficiency Technologies (> 400 from the Annex 46)

2 Energy Efficiency Technologies and Process Related Measures for Building Retrofits

This chapter provides categorized listings of energy efficiency technologies and process improvement measures (will be referred to as "Energy Efficiency Measures," or "EEMs") that can be applied to enable buildings energy use and cost reduction. It identifies some commonly applied elements that can improve building performance, but does not include all of available options. Some EEMs have low or no investment cost (e.g., control strategies, lighting systems improvements, occupant behavior change, etc.). Other, require higher investment costs (e.g., building envelope related measures), but have significantly greater impact on energy use reduction. When selecting specific EEM, it is important that each EEM has a payback during its life before its replacement. When selecting EEMs consider synergistic effect of energy efficient bundles of load reduction technologies (e.g., related to building envelope) and energy generating or converting technologies (e.g., HVAC systems and energy plants), which may significantly reduce overall investment costs. Some measures such as demand response/control may also save energy as an incidental side benefit. Other measures may result in extension of the capacity of given infrastructure systems and/or the ability for energy efficiency to defer or eliminate the need for plant expansions. Such results can be factored into the resulting return on investment (ROI) or life cycle cost (LCC) analysis.

The list has been compiled through extensive literature review, including results of previously completed IEA ECBCS Annexes, materials presented during annual and national workshops and conferences organized throughout duration of the Annex 46, as well as during the ASHRAE Technical Committee 7.6 working group meetings.

2.1 Building Envelope

2.1.1 Walls

- Insulate walls. Retrofit insulation can be external and internal.
- External post insulation makes large savings possible, as this type of insulation contributes not only to a reduction of the heat loss through large wall surfaces, but also eliminates the traditional thermal bridges where floor and internal wall are anchored in the exterior wall.
- Internal insulation is typically done when external insulation is not allowed (e.g., for historical buildings).
- Insulate cavity walls using spray-in insulation.
- Consider converting internal courtyard into an atrium to reduce external wall surface.

2.1.2 Roofs

- Use "cool roof" (high-reflectance roofing material) with reroofing projects.
- Determine roof insulation values and recommend roof insulation as appropriate.
- Insulate ceilings and roofs using spray-on insulation.
- Where appropriate, exhaust hot air from attics.

2.6.1 Daylighting

- In areas illuminated by daylight, evaluate opportunities for daylight harvesting. Measure light levels on a day with a clear sky both with the electric lighting turn on and turned off. If daylighting provides sufficient light level then install daylight switching or daylight dimming controls (and appropriate ballasts if the lighting system is fluorescent or High Intensity Discharge [HID]) to reduce the use of electric lighting.
- Install interior and/or exterior shading as appropriate to reduce solar heat gain and cut down on heat loss and control the amount of light entering the space from the exterior.
- Install a skylight, tubular daylighting device, or sunlight delivery system to reduce the use of electric lighting and provide natural daylight to the internal spaces of the building.

2.6.2 Luminaire upgrades

- Upgrade incandescent lamps in existing luminaires with more efficacious sources such as halogen, integrally ballasted compact fluorescent, solid state (LED), or metal halide retrofit lamps. Alternatively, replace incandescent luminaires with luminaires using these sources.
- Upgrade T12 fluorescent luminaires with more efficacious sources such as high-performance T8 or T5 systems by: (1) replacing lamps and ballasts, (2) using luminaire up-grade kits, or (3) installing new luminaires.
- If the lighting system is already a high-performance fluorescent system, consider replacing the lamps with reduced wattage lamps (where appropriate).
- For fluorescent lighting, install high-performance electronic ballasts that are multi-level or continuously dimmable with the appropriate controls.
- Replace mercury vapor or probe-start metal halide HID luminaires with pulse start metal halide or high-performance T8 or T5 fluorescent luminaires.
- Upgrade task and display lighting, including lighting in refrigeration and freezer cases, to more efficacious sources such as LED.

2.6.3 Signage

- Evaluate upgrading standard fluorescent or neon signage with more efficacious sources such as high-performance T8 or T5 fluorescent systems or solid state (LED) systems.
- Upgrade all exit signs to solid state (LED) exit signs. Supplemental lighting may need to be added if the existing exit sign also provided general lighting.

2.6.4 Lighting controls

- Reduced lighting usage through management and controlled systems – in general, consider bringing the lighting control protocols for the building up to 90.1-2010 (Section 9.4.1) standards; this includes the following.
- Reduce operating hours for lighting systems through the use of controls and building management systems. This includes the use of shut off controls such as time switches.

Guidance for Insulation Values and window

- Based on modeling results ranges for insulation levels and windows will be developed fro different climate zones
- Example for the DOE climate zone 5

Item	Component	Recommendation	
		Assembly Max (2)	Min R-Value (2)
Roof	Insulation Entirely Above Deck	U-0.020	R-50ci
	Metal Building		R-13 + R-13 + R-34ci
	Vented Attic and Other		R-60
Walls	Mass	U-0.033	R-30ci
	Metal Building		R-19 + R-17ci
	Steel Framed		R-19 + R-20ci
	Wood Framed and Other		R-19 + R-14ci
	Below Grade/Basement	U-0.067	R-15ci
Floors Over Unconditioned Space	Mass	U-0.033	R-16 Spray Foam + R-11ci.
	Steel Joist		R-16 Spray Foam + R-13ci.
	Wood Framed and Other		R-19 + R-10ci.
Slab-on-Grade	Unheated	F-0.54	R-10 for 24 in.
	Heated	F-0.44	R-15 for 36 in. + R-5ci below
Doors	Swinging	U-0.60	Insulated
	Non-Swinging	U-0.40	Insulated
Vertical Glazing	Window to Wall Ratio (WWR)	< 20%	
	Thermal Transmittance (U-value)	≤ 0.27	
	Solar Heat Gain Coefficient (SHGC)	≤ 0.40	

Building Envelope Section of the Guide

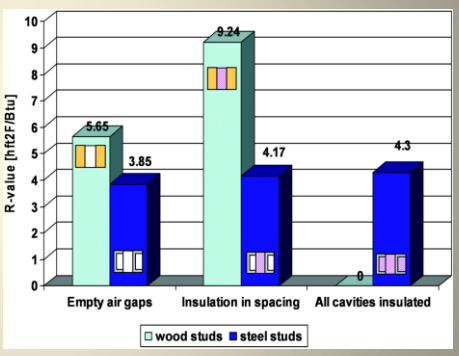
The BE Guide will address the following wall structures:

- CMU or concrete wall with interior insulation
- CMU or concrete wall with exterior insulation
- Steel stud infill wall in steel or concrete
- Steel tube blast-resistant curtain wall perimeter
- Precast sandwich panel

- Historical Buildings w/interior insulation
- The Guide will address the following roof structures
  - Flat roofs (concrete slabs and steel deck)
  - Sloped roofs (metal and wood frame)

Framed Wall Systems: Imperfection in Installing Cavity Insulation

- Examples of heat flow complication in framed walls which can not be captured by 1D R-value:
- Imperfection in installing cavity insulation affects thermal bridging (Kosny et al, 2002)



Calculated clear wall R-values for wood and steel framed walls

Fraunhofer USA

Required R-value Implementation

- Minimum thickness of insulation can be determined from table depending on the placement and type of insulation. Below example is the steel framed wall to reach target R-20.

Description	Existing R-value	Cladding R-value Type	Minimum Required Insulation to reach R-20			
			Interior Insulation	Exterior Insulation	Cavity &Interior Insulation	Cavity & Exterior Insulation
2x4 Steel Framed wall	R-2.8	< R-2	**Wood Strips** XPS– 3in nominal + 1in bridging EPS– 4in nominal + 1in bridging PIC– 3in nominal PU– 2.5in nominal + 0.5in bridging Fiber glass batt – 5 in nominal Mineral wool batt– 4in nominal + 1in bridging **Wood Framing** … **Nailing** …..	**Adhesive** EIFS with 2in EPS **Wood Strips** XPS– 3in nominal + 1in bridging …. **Z-Furring Channel** … **Wood Framing** … **Nailing** …..	**Wood Strips** Fiberglass Batt in Cavity XPS interior– 1 in nominal + 1in bridging EPS– 2in nominal + 1in bridging PIC– 1in nominal ….	**Z-Furring Channel** Fiberglass Batt in Cavity PU exterior– 1 in nominal + 1in bridging ….. **Possible combination options of insulation types and attachment system types** **All possible insulation options for this attachment system**
		R-2 to R-4	…	…	….	

The same as mass wall example

Insulation attachment system

Needs to be populated with the same methodology

Roof Insulation Details

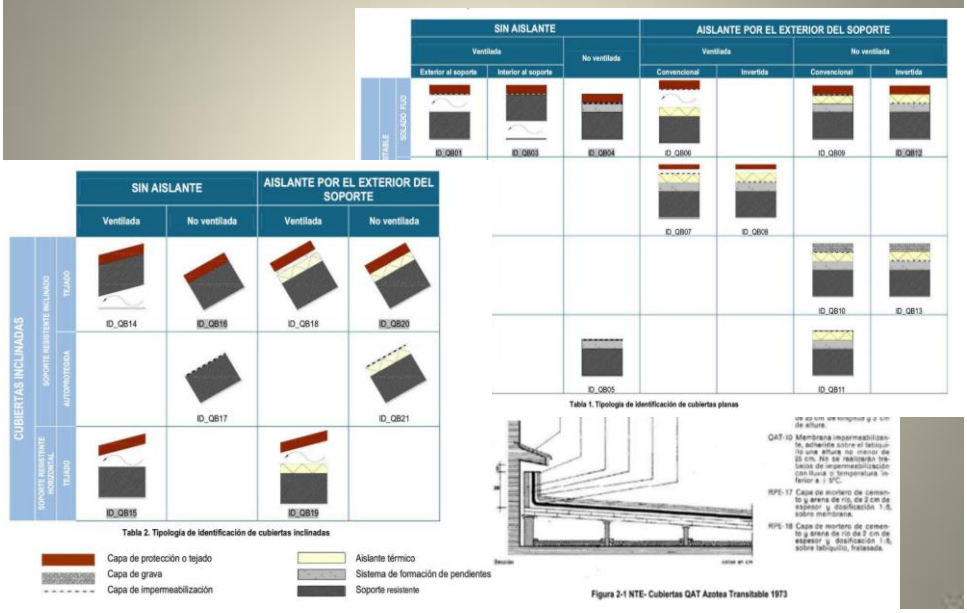


Tabla 1. Tipología de identificación de cubiertas planas

Tabla 2. Tipología de identificación de cubiertas inclinadas

Figura 2-1 NTE- Cubiertas QAT Azotea Transitable 1973

Wall Insulation

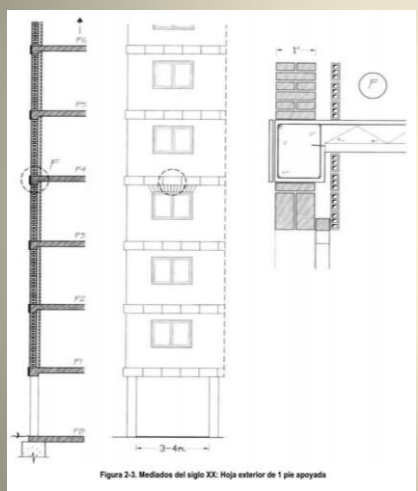
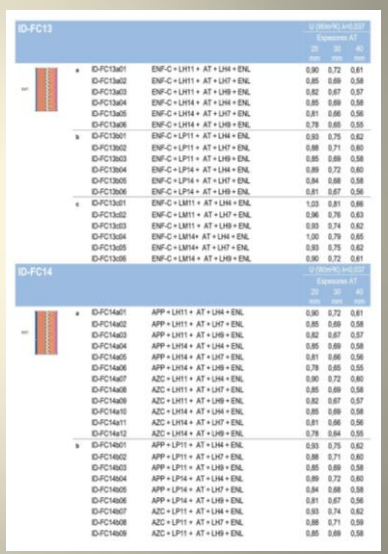
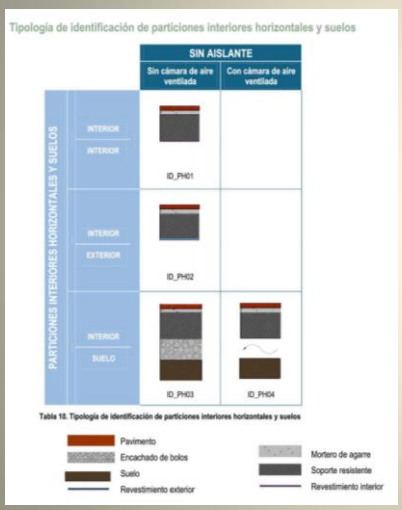
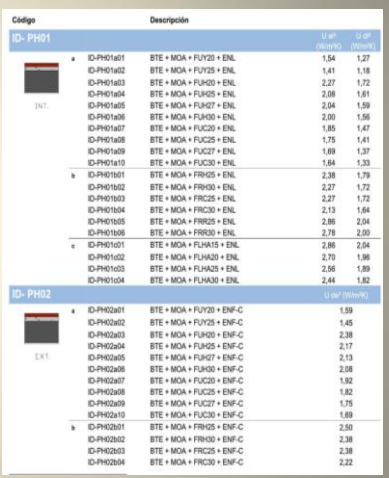


Figura 2-3. Mediados del siglo XX: Hoja exterior de 1 pie apoyada



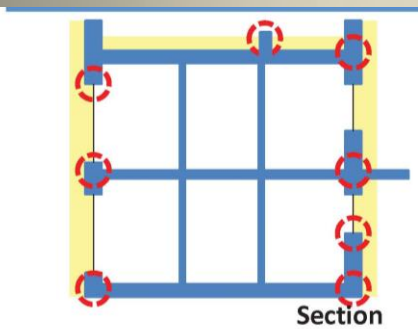
Slab Insulation

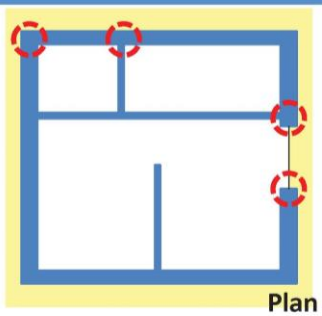




Código		Descripción	U ph² (W/m²K)	U dh² (W/m²K)
ID- PH01				
	a	ID-PH01a01	BTE + MOA + FUY20 + ENL	1,54	1,27
		ID-PH01a02	BTE + MOA + FUY25 + ENL	1,41	1,18
		ID-PH01a03	BTE + MOA + FUH20 + ENL	2,27	1,72
		ID-PH01a04	BTE + MOA + FUH25 + ENL	2,08	1,61
		ID-PH01a05	BTE + MOA + FUH27 + ENL	2,04	1,59
		ID-PH01a06	BTE + MOA + FUH30 + ENL	2,00	1,56
		ID-PH01a07	BTE + MOA + FUC20 + ENL	1,85	1,47
		ID-PH01a08	BTE + MOA + FUC25 + ENL	1,75	1,41
		ID-PH01a09	BTE + MOA + FUC27 + ENL	1,69	1,37
		ID-PH01a10	BTE + MOA + FUC30 + ENL	1,64	1,33
	b	ID-PH01b01	BTE + MOA + FRH25 + ENL	2,38	1,79
		ID-PH01b02	BTE + MOA + FRH30 + ENL	2,27	1,72
		ID-PH01b03	BTE + MOA + FRC25 + ENL	2,27	1,72
		ID-PH01b04	BTE + MOA + FRC30 + ENL	2,13	1,64
		ID-PH01b05	BTE + MOA + FRR25 + ENL	2,86	2,04
		ID-PH01b06	BTE + MOA + FRR30 + ENL	2,78	2,00
	c	ID-PH01c01	BTE + MOA + FLHA15 + ENL	2,86	2,04
		ID-PH01c02	BTE + MOA + FLHA20 + ENL	2,70	1,96
		ID-PH01c03	BTE + MOA + FLHA25 + ENL	2,56	1,89
		ID-PH01c04	BTE + MOA + FLHA30 + ENL	2,44	1,82
ID- PH02				U dh² (W/m²K)	
	a	ID-PH02a01	BTE + MOA + FUY20 + ENF-C	1,59	
		ID-PH02a02	BTE + MOA + FUY25 + ENF-C	1,45	
		ID-PH02a03	BTE + MOA + FUH20 + ENF-C	2,38	
		ID-PH02a04	BTE + MOA + FUH25 + ENF-C	2,17	
		ID-PH02a05	BTE + MOA + FUH27 + ENF-C	2,13	
		ID-PH02a06	BTE + MOA + FUH30 + ENF-C	2,08	
		ID-PH02a07	BTE + MOA + FUC20 + ENF-C	1,92	
		ID-PH02a08	BTE + MOA + FUC25 + ENF-C	1,82	
		ID-PH02a09	BTE + MOA + FUC27 + ENF-C	1,75	
		ID-PH02a10	BTE + MOA + FUC30 + ENF-C	1,69	
	b	ID-PH02b01	BTE + MOA + FRH25 + ENF-C	2,50	
		ID-PH02b02	BTE + MOA + FRH30 + ENF-C	2,38	
		ID-PH02b03	BTE + MOA + FRC25 + ENF-C	2,38	
		ID-PH02b04	BTE + MOA + FRC30 + ENF-C	2,22	

Thermal Bridges

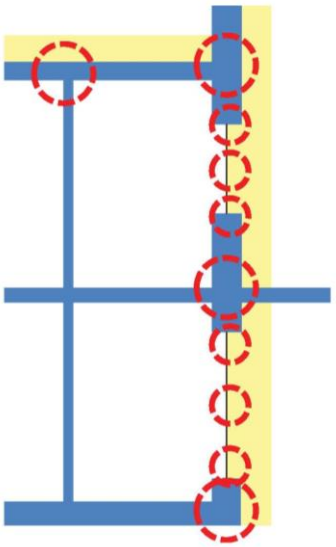




Details of Major Magnitude
1. At Eaves/Ridge
2. Window and Door Fitting – Head, Sill and Jamb
3. At Projections, Shades Or Intermediate Floors
4. Internal Walls to External Walls
5. Intermediate Floors
6. At Grade

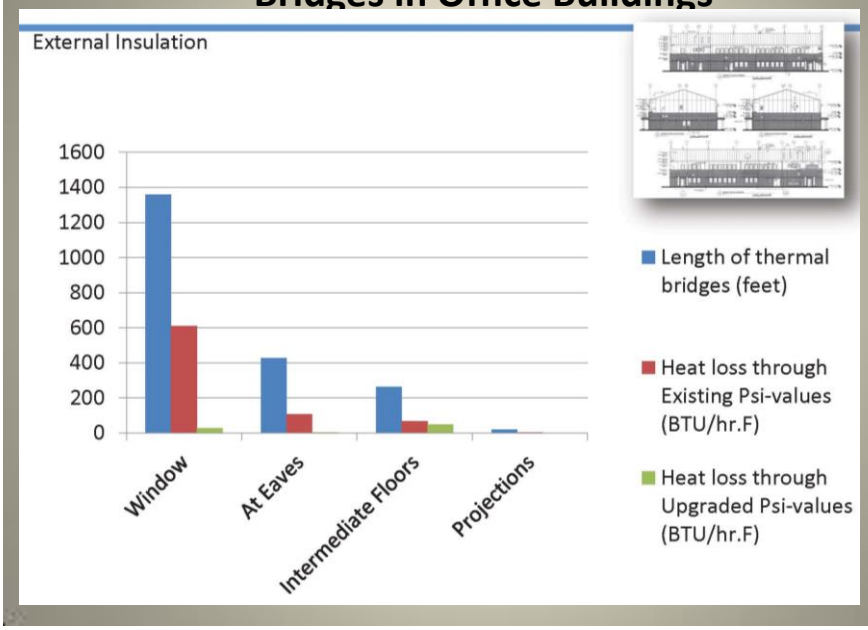
Details of Minor Magnitude
1. Wall Corner – Never Usually an Issue
2. Threshold or Door
3. Duct and Service Connections
4. Penetrations at Installations in Roof; PV or Water Tanks

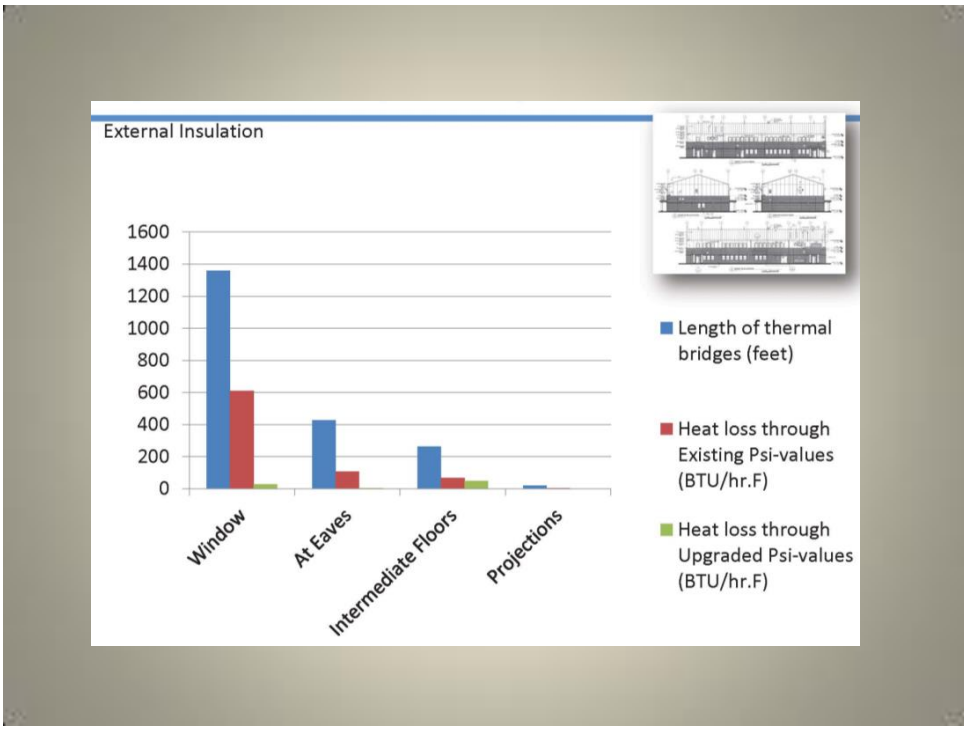
Main Offenders



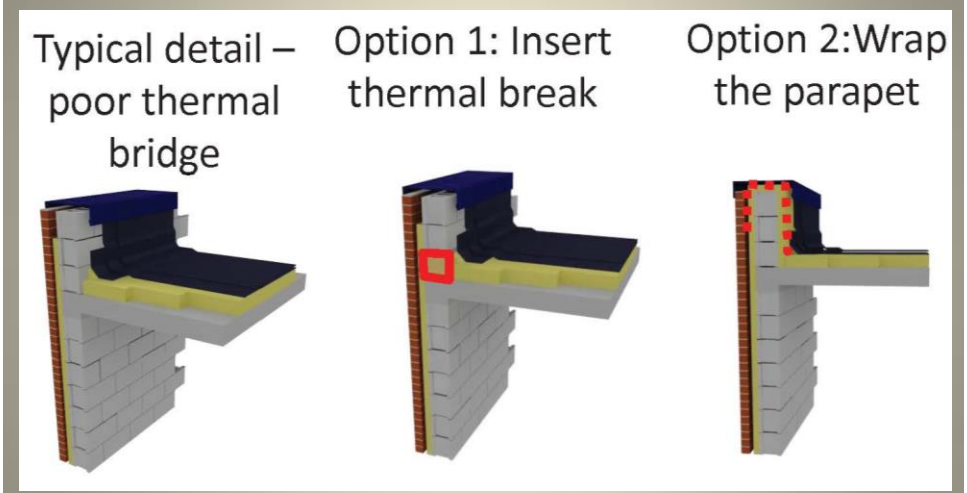
1. At Eaves/Ridge
2. Window and Door Fitting – Head, Sill and Jamb
3. At Projections, Shades Or Intermediate Floors
4. Internal Walls to External Walls
5. Intermediate Floors
6. At Grade

Magnitude of Heat Losses through Thermal Bridges in Office Buildings

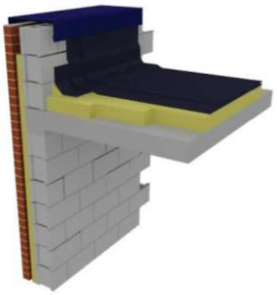




Example of Thermal Bridge Remediation

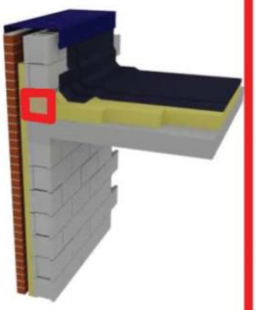


Old Junction



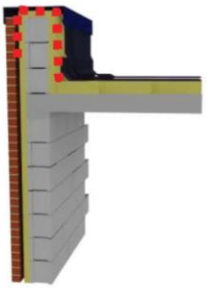
0.247 BTU/hr.ft.F

Option 1: Insert thermal break



0.010 BTU/hr.ft.F

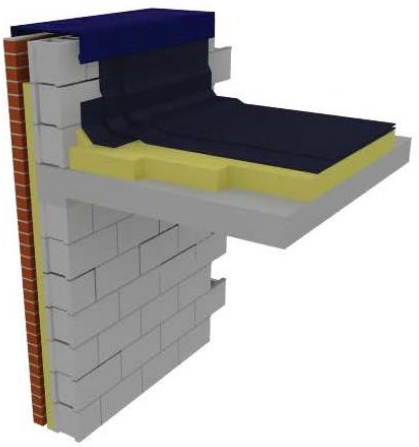
Option 2:Wrap the parapet



0.039 BTU/hr.ft.F

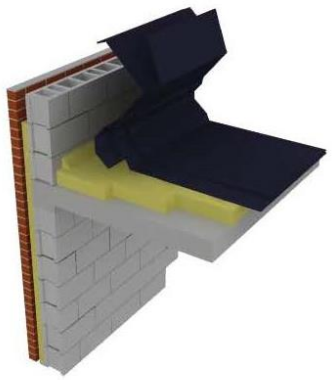
Option 2: Wrapping

Remove capping, flashings and roof coverings to expose CMU wall and roof insulation

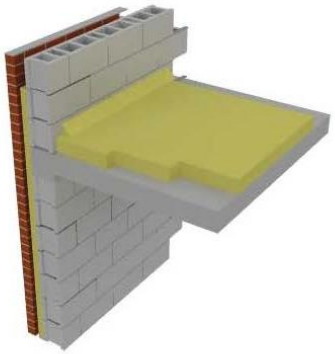


Remove capping, flashings and roof coverings to expose CMU wall and roof insulation

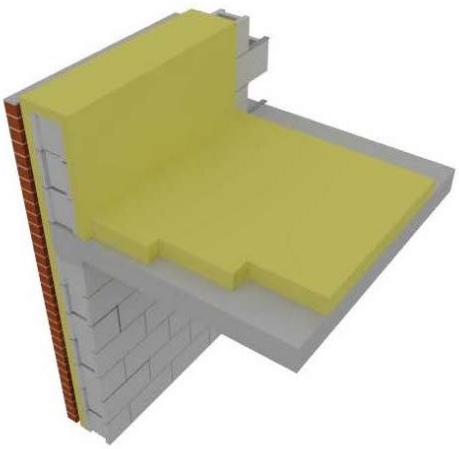
Remove capping, flashings and roof coverings to expose CMU wall and roof insulation



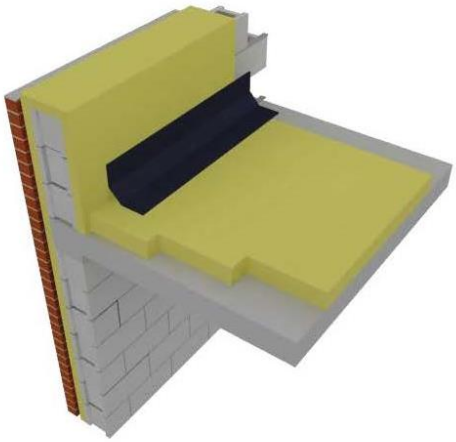
Remove capping, flashings and roof coverings to expose CMU wall and roof insulation



Now add rigid insulation to the rear and top of the parapet as well as the cavity if possible



Lastly, all waterproofing, flashings and coping needs to be reinstated



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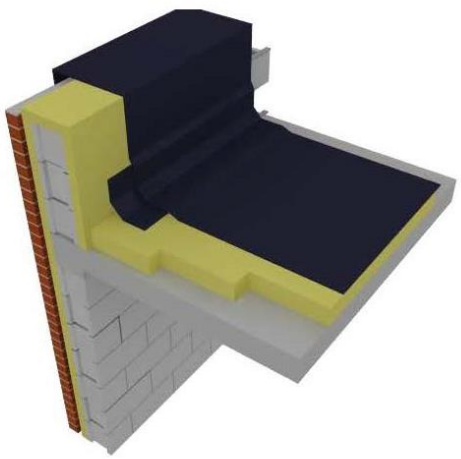

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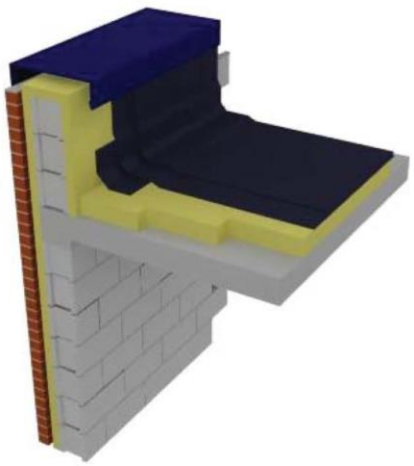
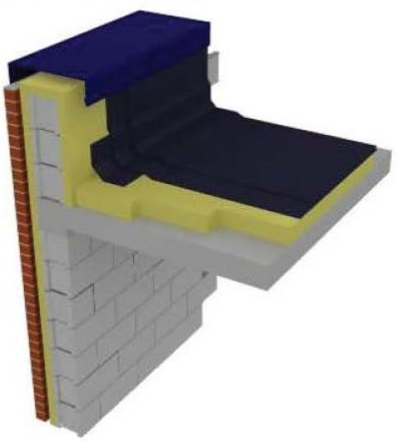


Old Junction:

0.247 BTU/hr.ft.F

New Junction:



0.039 BTU/hr.ft.F

Some Architectural Details for Thermal Bridge Remediation (ERDC contribution)

Wall

1. CMU or concrete wall with interior insulation

a.At grade (stem wall)
b.At suspended slab (w/steel stud or exposed block)
c.At parapet with concrete roof, concrete parapet
d.Steel roof joists at parapet
e.Window jamb
f.Window head
g.Window sill
h.Blast resistant window jamb
i.Door jambs to CMU
j.Thru slab projection eg. shade or balcony

2.CMU or concrete wall with exterior insulation (CMU+2"+brick)

a.Roof parapet with concrete roof
b.Roof parapet with OWSJ + deck
c.At grade transition (stem wall)
d.Window jamb
e.Window head
f.Window sill
g.Blast resistant window jamb
h.Blast resistant window head
i.Suspended slab at shelf angle

3.Steel stud infill wall in steel or concrete frame (SS+2"+brick)

a.Roof parapet with steel frame
b.Window jamb
c.Window head
d.Window sill
e.Steel tube blast-resistant curtainwall perimeter
f.Steel beam penetration

4.Steel building with Insulated Metal Panel

a.Eave Detail

5.Precast sandwich panel

a.Roof of steel joists bearing on inner wythe of sandwich

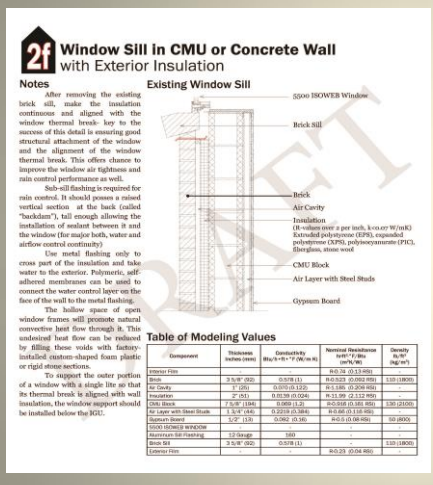
6.Important Clearwall Details

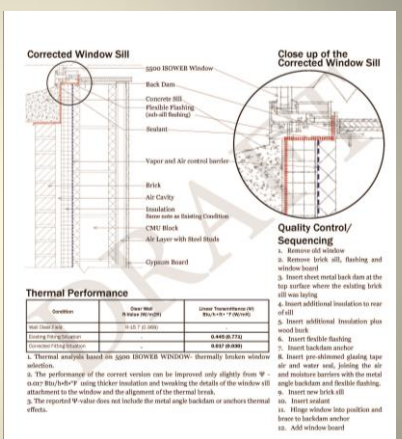
a.6" steel studs @16" w/brick ties
b.Horizontal Z-girts on sheathing & steel studs
c.Batten and counter-batten Z-girts on 16" sheathing & steel studs

7.Historical Details w/interior insulation

a.Stone veneer over CMU @ grade or parapet
b.Window sill in solid brick masonry

Examples





Lighting Design Guide for Low Energy Buildings – New and Retrofits

OFFICE (OPEN)

Lighting Technologies	
LAMP L01 Fluor 32WT8 LED **BALLAST/DRIVER** B01 Multi-Level B02 Dimming B04 Program Start	**LUMINAIRE** F03 Non-Planar Lensed Troffer F04 Suspended Direct/Indirect F05 Furniture Integrated F09 or F51 Task F12 Wallwash F40 or F50 Adjustable Accent **CONTROLS** C03 Dual Tech Occ/Vac Sensor C07 Dimming Photosensor C08 Switching Photosensor

Target Illuminance	Target LPD
30-50fc	0.70 W/ft²

SPACE DESCRIPTION

Open offices are designed to accommodate multiple individual work areas, typically separated by movable partitions and circulation areas. Individual work areas typically contain a computer, telephone, personal storage, and desk space for reading and writing. Furniture locations are not permanent and may change with needs and staffing. Open offices typically have one or more perimeter window walls which can provide views to the outdoors and usable daylight.

CONSIDERATIONS

Users' age, job function, and occupancy varies in each open office area. Work plane illuminance, as suggested by the IESNA, ranges from 30 fc to 50 fc for most office reading tasks. The visual needs of an older occupant in one work area may be different than that of a younger occupant. In most cases, the circulation space between work areas requires little if any lighting in addition to that provided for work areas. It is typical to find some work areas occupied and some vacant throughout the work day. Direct and reflected glare should be considered. Direct sunlight on work surfaces can contribute to glare and make it difficult to perform work. Lighting in the daylight zone (approximately twice the window head height) can often be turned off or reduced to a low power setting during the day.

Lighting Guide

RECOMMENDED LIGHTING POWER DENSITY AND ILLUMINANCE VALUES

Space Type	Target Illuminance	Target LPD
Common Spaces		
- Conference Room	40 fc	0.80 W/ft²
- Corridor	10 fc	0.50 W/ft2
- Dining	20 fc	0.60 W/ft2
- Dishwashing/ Tray Return	50 fc	0.65 W/ft2
- Kitchen/ Food Prep/ Drive Thru	50 fc	0.65 W/ft2
- Living Quarters	5-30 fc	0.60 W/ft2
- Mechanical/ Electrical	30 fc	0.70 W/ft2
- Office (Open)	30-50 fc	0.70 W/ft2
- Office (Enclosed)	30-50 fc	0.80 W/ft2
- Reception/Waiting	15-30 fc	0.50 W/ft2
- Restroom/ Shower	20 fc	0.80 W/ft2
- Server Room	30 fc	0.85 W/ft2
- Serving Area	50 fc	0.70 W/ft2
- Stair	10 fc	0.50 W/ft2
- Storage (general)	10 fc	0.50 W/ft2
- Storage (dry food)	10 fc	0.70 W/ft2
- Telecom / Sipnet	50 fc	1.20 W/ft2
- Vault	40 fc	0.70 W/ft2
Training		
- Readiness Bay	40 fc	0.75 W/ft2
- Training Room (Small)	15-30 fc	0.70 W/ft2
Vehicle Maintenance		
- Consolidated Bench Repair	50 fc	0.60 W/ft2
- Repair Bay/ Vehicle Corridor	50 fc	0.85 W/ft2