EBC
Energy in Buildings and Communities Programme

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

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Technical Day
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Introduction

- Governments worldwide are setting more stringent targets for energy use reductions in their building stocks
- To achieve these goals, there must be a significant increase in both the annual rates of building stock refurbishment and energy use reduction, for each project (EU: refurbishment rate of 3% p.a., USA: 3% p.a. site energy reduction compared to CBECS 2003 through 2015 and 2.5% between 2015 and 2025)

EU Energy Performance of Buildings Directive (EPBD 2010)

- Member States shall develop policies and take measures such as setting targets to stimulate the transformation of buildings to be <u>refurbished to a nearly zero-energy condition.</u>
- A Member State <u>shall not be required to set minimum energy performance requirements that are not cost-effective</u> over a building’s estimated economic lifecycle.
- A nearly zero-energy building is defined as “*a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.*”
- The term “high performance building” (as used in Austria, Germany, the Czech Republic, and Denmark) was developed by the Passivhaus Institute (PHI) for the German building market, and has the same definition as “nearly zero-energy.”

Major Drivers for Energy Use Reduction in US Federal Facilities

- Building Site Energy Use Reduction:
  - The Energy Policy Act of 2005. Federal facilities shall be built to achieve at least a 30% energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1, as appropriate; energy efficient designs must be life cycle cost effective;
  - Department of Energy 10 CFR Part 433. Energy Efficiency Design Standards for New Federal Commercial and Multi-Family High-Rise Residential Buildings of July 9, 2013. Buildings must be designed to exceed the energy efficiency level of the ASHRAE Standard 90.1 2010 by 30 percent if life-cycle cost-effective;
  - EISA 2007, Sec. 431. Sets refurbishment rates for Federal Agency Building Portfolio and Site Energy Reduction Goals against 2003 Baseline at: 3% p.a., 30% by 2015
- Fossil Fuel Reduction. The Energy Independence and Security Act of 2007 does not require site energy reduction.
- Army Policy. Achieve eight net-zero energy (NZE) installations by 2020; all NZE Installations by 2031.

Issues and How to Overcome Them

- Hurdles in the public sector to increase the number and pace of energy retrofits:
- Lack of knowledge about separated and bundled (integrative) energy saving measures and the resulting synergies
- Absence of public funding
- In recent years, Energy Saving Performance Contracting (ESPC) has been proven to be a very energy and cost efficient application tool in many countries to overcome these hurdles

Current National Standards for Major Renovation Projects.

Country	Building Energy	Building Envelope	HVAC	Lighting
Austria	OIB Directive Nr.6	OIB RL 6, 2011	EN 1507, EN 12237 ÖNORM H 5057, OIB RL 6, 2011	EN 12464-1 and -2 EN 15193
Denmark	Danish Building Regulation 2010, DS Std 418	Danish Building Regulation 2010	Standard 447 Standard 452	DS/EN ISO 12464-1
Estonia	Ordinance No. 63. RT I, 18.10.2012, 1, 2012; Ordinance No. 68. RT I, 05.09.2012, 4, 2012	EVS-EN ISO 10077, EVS-EN 1026 EVS-EN 12207 EVS-EN 12208	EVS-EN 13779, EN 12237 Ordinance No. 70. RT I, 09.11.2012, 12	Ordinance No. 70. RT I, 09.11.2012, 12
Germany	DIN 18599- 1; EnEV 2014	EnEV 2014, DIN 18361 DIN 18355 , DIN V 18599/2 DIN 4102, DIN 4108 DIN EN 13162, DIN EN 13163 DIN EN 13164, DIN EN 13165 DIN EN 13167, DIN EN 13171	EnEV 2014, DIN V 18599- 2 and 7 DIN 1946- 6, DIN EN 13779 DIN 24192 II/III/IV DIN 4108- 6, DIN 4701- 10, EnEV 2009/2014	DIN 18599- 4, DIN 5035 T 1- 14
Latvia	Law On the Energy Performance of Buildings; Cabinet Regulation s No. 348; No. 383; and No. 382.	Latvian Construction Standard LBN 002-01	Latvian Construction Standard LBN 231-03 Latvian Construction Standard LBN 003-01	-
UK	BS EN 15603:2008	Building Regulations- Conservation of Fuel and Power in New Buildings Other Than Dwelling: Part L2A.	BS EN 15727:2010 BS 5422:2009 Non-Domestic Building Services Compliance Guide:2013	BS EN 12464-1:2011
USA	ASHRAE Std 90.1 2010 ASHRAE Std 100 2015	ASHRAE Std 90.1 2010	ASHRAE Std 90.1 2010	ASHRAE Std 90.1 +IESNA recommended practices, 2010

Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) – Annex 46

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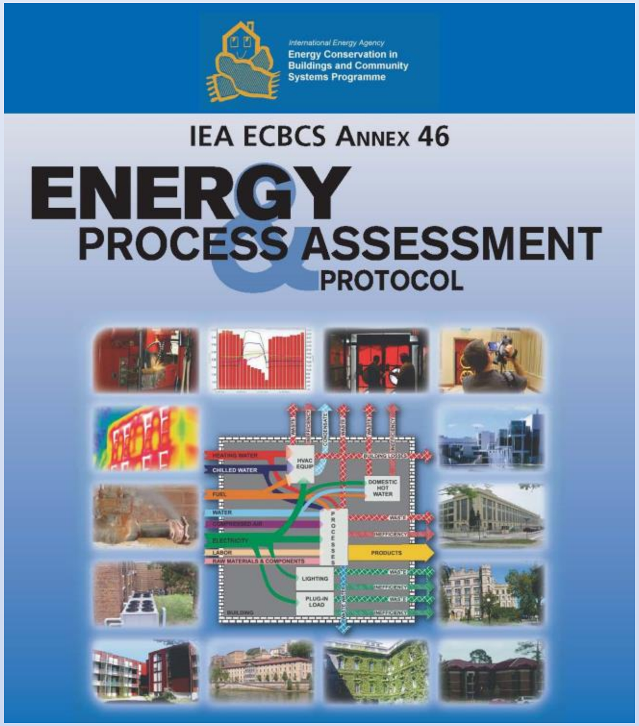
Energy Conservation in Buildings and Community Systems Programme

Operating Agent: Alexander Zhivov
US Army Corps of Engineers, R&D Center

2006-2010

Protocol Content

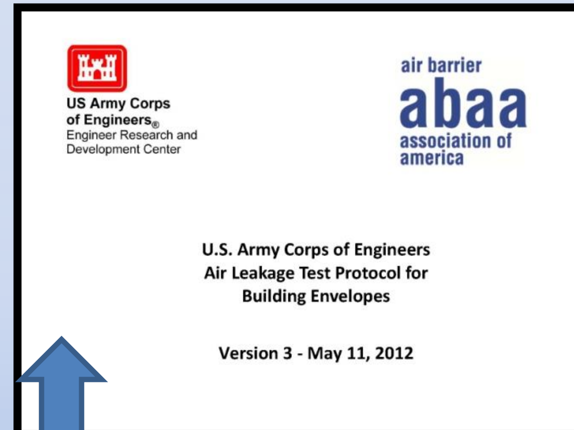


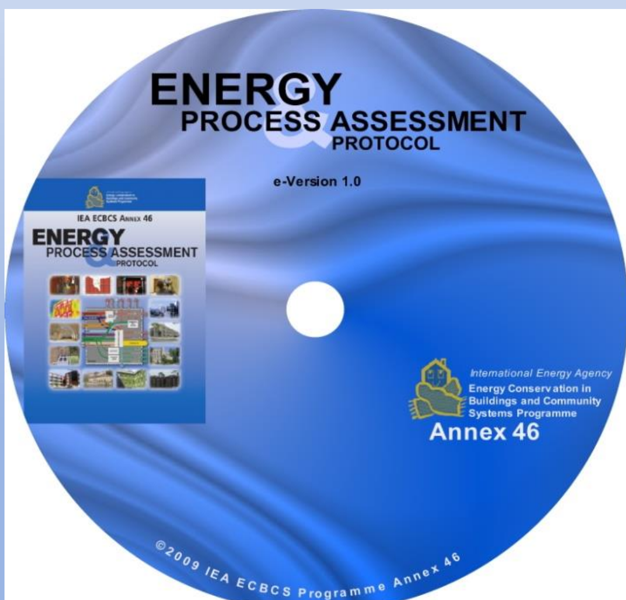
Preface
Introduction

Part I:
Energy Assessment Procedure
Energy assessment as part of energy management
Organizing energy assessment
Energy assessment as a means of continuous improvement
Key players in an energy assessment
Assessment procedure
After the energy assessment
Continuous commissioning

Part II: Energy-saving opportunities
Special features of industrial sites
Special features of non-industrial sites
Typical areas to look for improvement
Glossary
References

APPENDIXES A-O
Total: 380 pp





Published by the ASHRAE,
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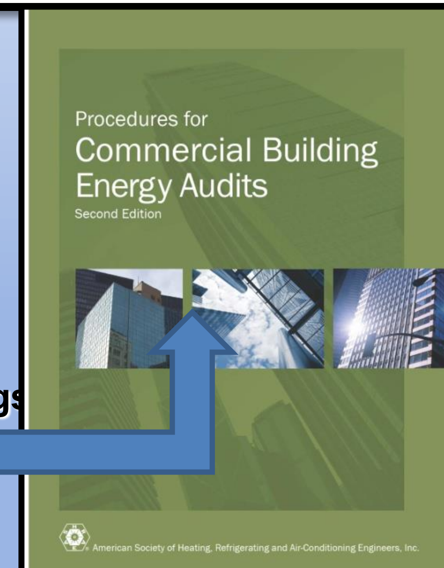
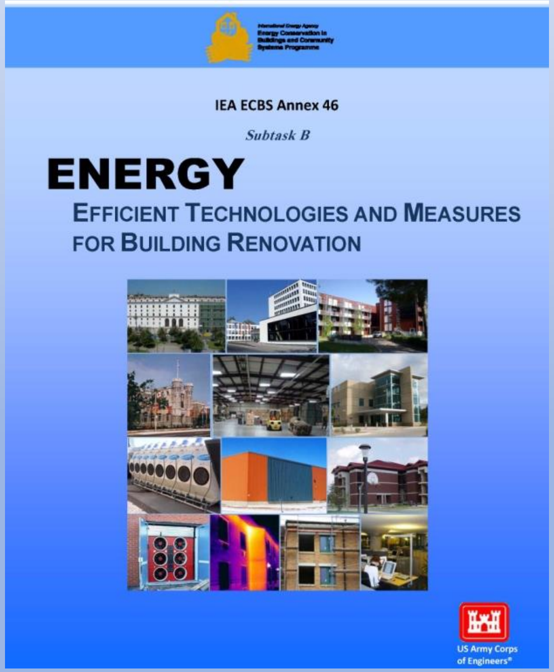
Referenced in the ASHRAE Std. 100
”Energy Conservation in Existing Buildings
Referred to in the ASHRAE Guide.

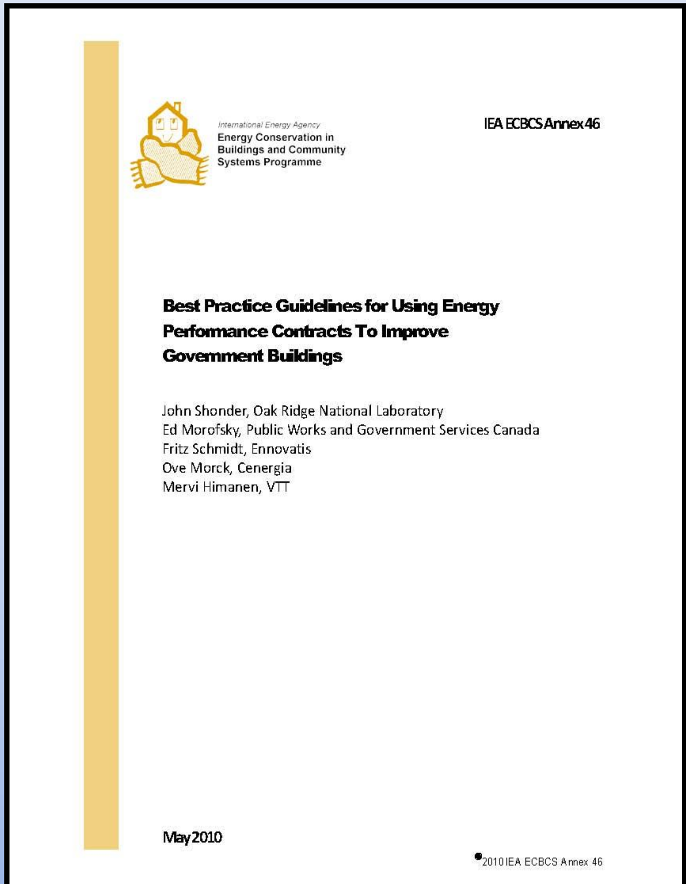


Subtask B: Database of "Energy Saving Technologies for Building Retrofits" with examples of best practices

- Document best practices of buildings retrofits with energy efficient technologies
- Develop a database with case studies of promising energy saving technologies
- Identify tools/computer programs and develop a procedure to screen selected candidate technologies/measures, and screen for representative conditions
- Summarize results of the screening analyses and the case studies by categories and present in a user-friendly format.



Best Practices Guide for Energy Performance Contracts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Best Practice Guidelines for Using Energy Performance Contracts To Improve Government Buildings

John Shonder, Oak Ridge National Laboratory
Ed Morofsky, Public Works and Government Services Canada
Fritz Schmidt, Ennovatis
Ove Morck, Cenergia
Mervi Himanen, VTT

May 2010

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- Definition of Energy Performance Contract
- Motivations For Using EPCs for Government Facilities
- Most Common Energy Conservation Measures (ECMs)
- Implementation Process
- EPC Best Practices
  - Policy and Legal Framework
  - Pre-negotiated/Model Contracts
  - Training and Assistance
  - Competition
  - Measurement and Verification
  - Quality Assurance During Project Performance Period
- Continuous Program Improvement
- Conclusions

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

Annex 61

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Deep Energy Retrofit (IT-Tool)

Objectives

- To provide a framework and selected tools and guidelines to significantly reduce energy use (by more than 50%) in government and *public buildings and building communities undergoing renovation*
- To gather, research, develop, and demonstrate *innovative and highly effective bundled packages of ECMs* for selected building types and climatic conditions
- To develop and demonstrate *innovative, highly resource-efficient business models for retrofitting/refurbishing buildings and community systems* using appropriate combinations of public and private funding such as ESPC and other concepts to be developed together with the building owners
- To support decision makers in *evaluating the efficiency, risks, financial attractiveness, and contractual and tendering options* conforming to existing national legal frameworks
- To *engage end users, mainly building owners and other market partners*, in the proceedings and work of the Annex Subtasks.

Receptors

- Executive decision-makers and energy managers of public and governmental administrations
- ESCOs
- Financing industries
- Energy utility companies
- Designer-, architect- and engineer-companies
- Manufacturers of insulation, roofing materials, lighting, controls, appliances, and HVAC and energy generation equipment, including those using renewable sources.

Subtasks

- **Subtask A:** Bundles of Technology:
  - Prepare and evaluate case studies on existing deep energy retrofit concepts resulted in a Book with examples of good practices and lessons learned
  - Develop a DER Guide with core technologies resulting in financially attractive deep energy retrofits of buildings and building communities.

- **Subtask B -** Business models for market implementation:
  - Develop business models for deep energy retrofit of buildings and building groups using combined government/public and private funding to overcome existing hurdles in technical funding, to reduce risks associated with deep retrofits.

Subtasks (Continued)

- **Subtask C:** Demonstrate selected deep energy retrofit concepts using combined government/public and private funding, and prepare case studies describing completed and/or partially completed projects.

- **Subtask D:** Develop an IT-tool for decision-makers and ESCOs that emphasizes low-risk approaches for early stages of design and decision-making.

Definition of Deep Energy Retrofit

Deep Energy Retrofit (DER) is a <u>major building renovation project</u> in which <u>site energy use intensity</u> has been <u>reduced by at least 50%</u> from the pre-renovation baseline.

Some Examples of Deep Energy Retrofit Projects

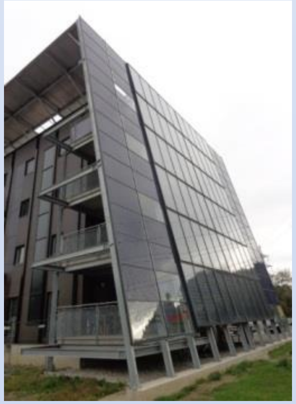
Residential buildings renovation: 75% energy use reduction
Karlsruhe (Germany)

Residential building renovation:
78% energy use reduction
Freiburg (Germany)

Barracks renovation: 45% energy use reduction, Ft Polk (USA)

More Examples of Deep Energy Retrofit Projects

Renovation of the medieval Franciscan monastery in Graz, Austria to Zero Energy building



Renovation of a residential building in Kapfenberg (Austria) – renovated to 85% site energy use reduction

Renovation of a kindergarten in Denmark
Primary energy used reduced from
224 kWh/m²/year to 103 kWh/m²/year

Renovation of a school campus in Aachen. Primary energy use reduced from 240 kWh/m²year to 78 kWh /m² year

U.S. Buildings with Energy Use Reduced by More than 50% from Pre-Renovation Baseline (NBI, GSA)



Name	Location	Building Type	Size (m^2)	% Over Baseline	Baseline	Measured or Estimated	Project Completion
Home on the Range	Billings, MT	Office	747	79%	ASHRAE 90.1-1999	Measured	2006
Pringle Creek Painter's Hall	Salem, OR	Office, Assembly	324	68%	Other	Measured	2009
Jefferson Place	Boise, ID	Office, Retail	6750	60%	Pre-data	Estimated	Still in design
King Street Station	Seattle, WA	Transportation	5400	56%	ASHRAE 90.1-2007	Estimated	2010
St. Als RMC South Tower	Boise, ID	Health Care	37080	56%	CBECS	Estimated	Still in design
Johnson Braund Design Group	Seattle, WA	Office	720	51%	Other	Measured	Ongoing
Wayne N. Aspinall Federal Building	Grand Junction, CO	Office, Court House	436	65%	Pre-renovation	Measured	Complited

DER Case Studies

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CASE STUDIES

Country	Site	Building Type	Pictures
1.Austria	Kapfenberg	Social housing	
2.Germany	Ludwigshafen-Mundenheim	Multi-stories apartment	
3.Germany			
4.Germany	Ostfildern	Gymnasium	
5.Germany	Baden-Württemberg	School	
6.Germany	Osnabrueck	School	
7.Germany			
8.Germany	Darmstadt	Office building	
9.Denmark	Egedal, Copenhagen	School	
10.USA	Grand Junction, Colorado	Office Building / Courthouse	

14 - current number of case studies; 6 in work

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 Technology” Bundle for DER

Category	Name
Building Envelope	Roof insulation
	Wall insulation
	Slab Insulation
	Advanced Windows
	Insulated Doors, Vestibules
	Thermal bridges remediation
	Air tightness
	Water/Vapor Barriers
	BE Quality Assurance
Lighting and Electrical Systems	Lighting design and efficient technologies and controls, efficient motors, VFD drives
HVAC	Smaller sized High performance fans, furnaces, chillers, boilers, etc.
	DOAS
	HR (dry and wet)
	Duct insulation
	Duct air tightness
	Pipe insulation

Wall Insulation Levels by Country

Country	U-value (SI/IP) W/m²K (BTU/h °F ft²)	R-value (IP) (h °F ft²)/BTU
Austria (c.z. 5A)	0.12 (0.021)	47.3
China c.z. 7 c.z. 4A c.z. 3A c.z. 2A c.z. 3C	0.124 (0.022) 0.268(0.047) 0.327(0.057) 0.370 (0.065) 0.446(0.079)	46 21.3 17.5 15.4 12.6
Denmark (c.z. 5A)	0.15 (0.026)	37.9
Estonia (c.z. 6A)	0.17 (0.03)	33
Germany (c.z. 5A)	0.2 (0.035)	29
UK (c.z. 4A)	0.22(0.039)	26
USA c.z. 1 c.z. 2 c.z. 3 c.z. 4 c.z. 5 c.z. 6 c.z. 7 c.z. 8	0.76 (0.133) 0.38 (0.067) 0.28 (0.050) 0.23 (0.040) 0.19 (0.033) 0.14 (0.025) 0.11 (0.020) 0.11 (0.020)	7.5 15 20 25 30 40 50 50

Wall Insulation by DOE Climate Zone

Climate zone	U-value (SI/IP) W/m^2K (BTU/h °F ft^2)	R-value (IP) (h °F ft^2)/BTU
1	0.76 (0.133)	7.5
2	0.37 (0.065)	15
3	0.28-0.33 (0.050 – 0.057)	18-20
4	0.22-0.27 (0.039-0.047)	21-26
5	0.12-0.20 (0.021-0.035)	28-47
6	0.14-0.17 (0.025-0.03)	33-40
7	0.11-0.12 (0.02-0.022)	46-50
8	0.11 (0.02)	50

Guidance for Insulation Values

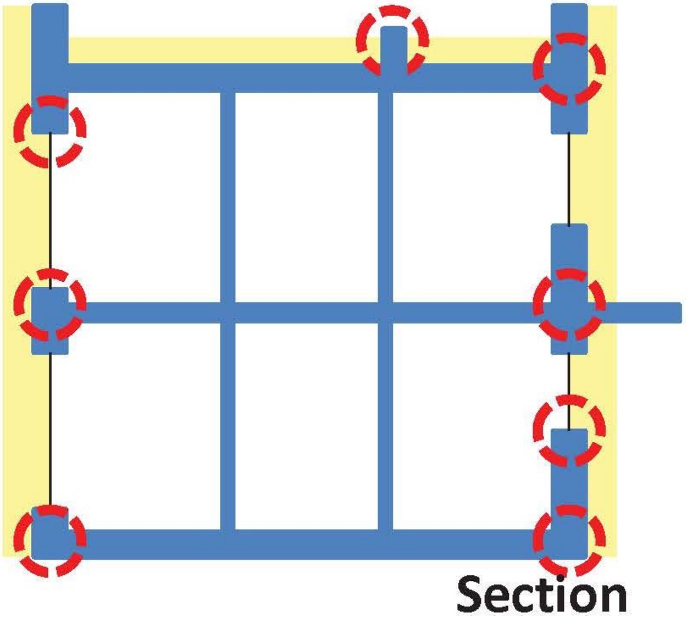
Based on modeling results, ranges for insulation levels and windows was developed for various climate zones

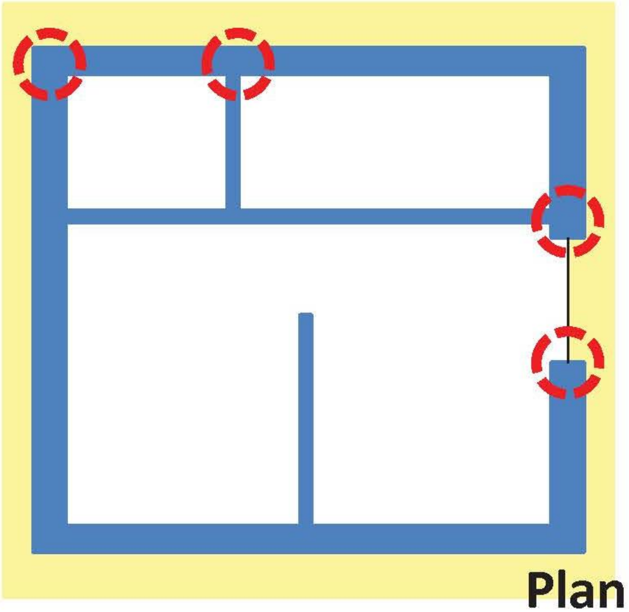
	Item	Component	Recommendation	
			Assembly Max (2)	**Min R-Value (2)**
DOE Climate Zone 5	**Roof**	Insulation Entirely Above Deck	U-0.020	R-50ci
		Metal Building		R-13 + R-13 + R-34ci
		Vented Attic and Other		R-60
	Walls	Mass	U-0.033	R-30ci
		Metal Building		R-19 + R-17ci
		Steel Framed		R-19 + R-20ci
		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

Window assembly U-value ranges resulted from Modeling Studies.

Climate zone	U-value (SI) W/m^2K (BTU/h ^oF ft^2)	R (IP) (h ^oF ft^2)/BTU	SHGC
1	< 1.98	➢ 2.9	< 0.25
2	< 1.98	2.9 – 4.3	<0.25
3	1.2-1.7	3.3 - 3.8	0.25
4	0.95-1.7	3.3 - 5.9	0.35-0.4
5	0.85-1.5	3.7 - 6.7	0.4-0.63
6	1.1-1.4	4.1 – 5.3	0.6
7	1.1-1.25	4.5 – 5.6	NR
8	< 1.02	➢ 5.6	NR

Thermal Bridges

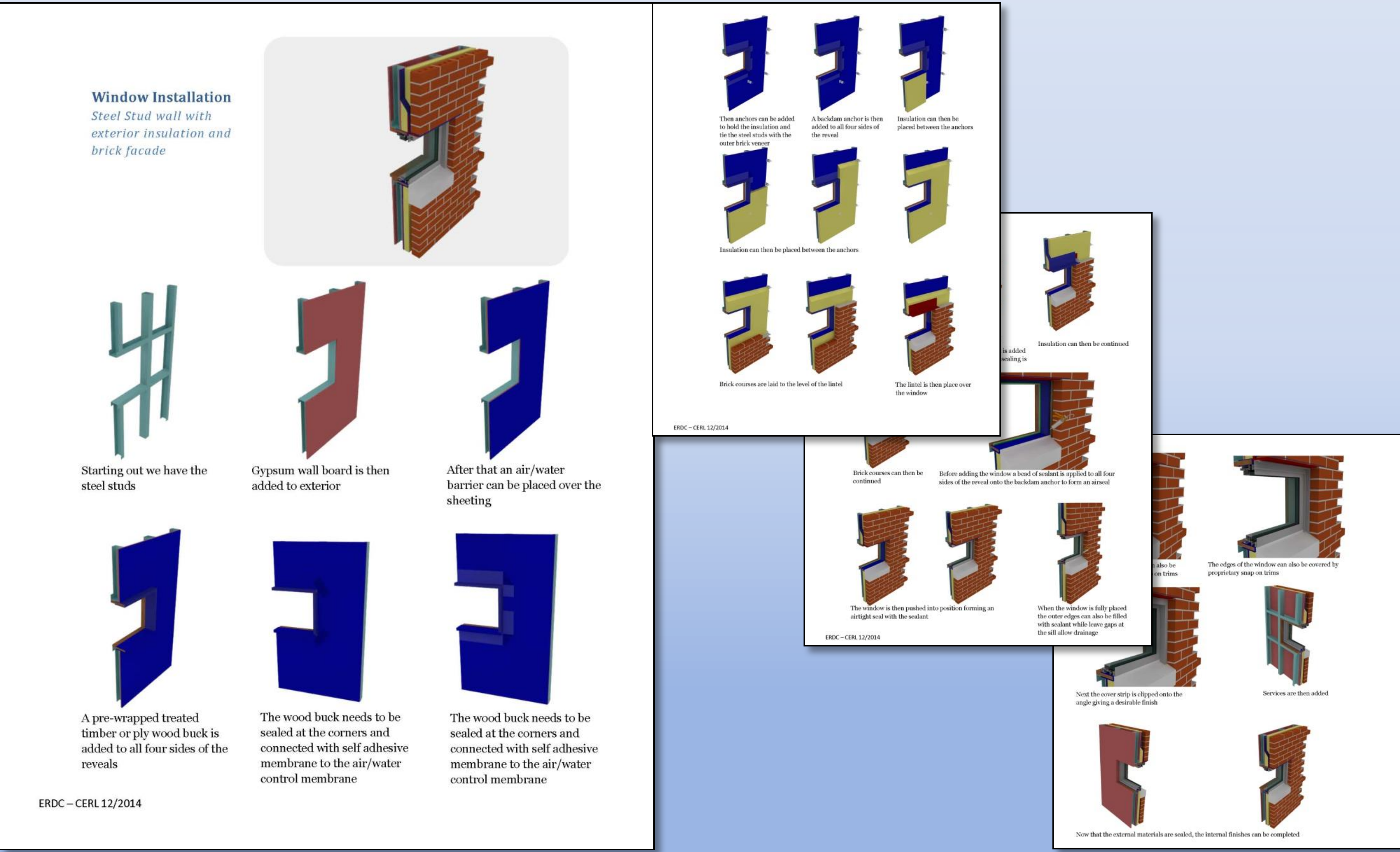




Details of Major Magnitude
1. At Eaves/Ridge
2. Window and Door Fitting – Head, Sill and Jamb
3. At Projections, Shades Or Intermediate Floors
4. Internal Walls to External Walls
5. Intermediate Floors
6. At Grade

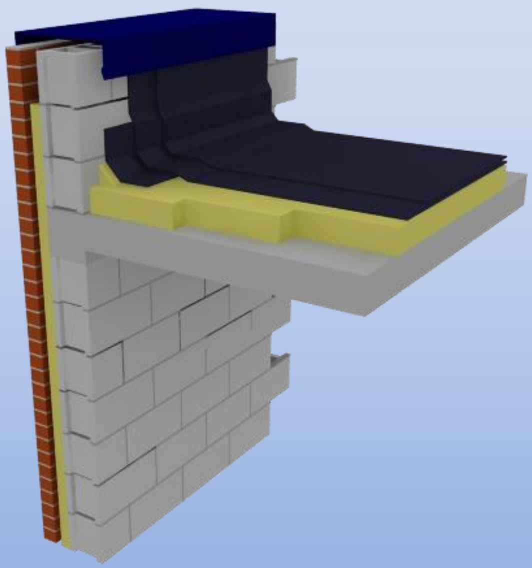
Details of Minor Magnitude
1. Wall Corner – Never Usually an Issue
2. Threshold or Door
3. Duct and Service Connections
4. Penetrations at Installations in Roof; PV or Water Tanks

Example of Window Replacement Sequencing (with improved insulation, air and thermal barriers)

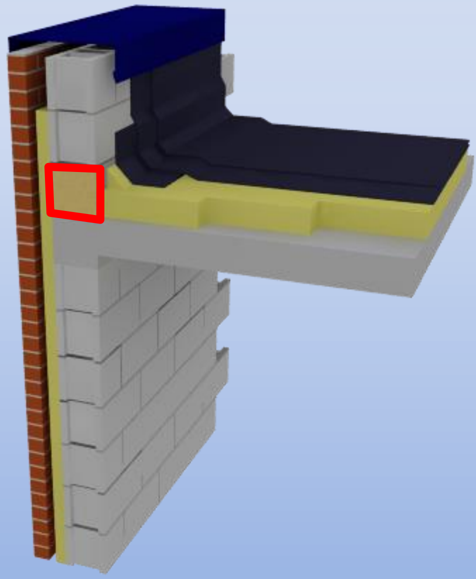


Thermal Bridge Remediation

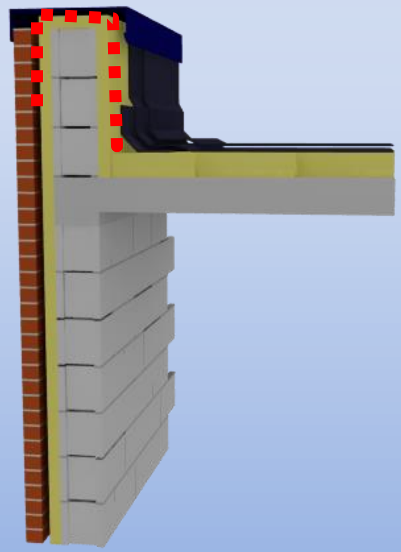
Typical detail poor thermal bridge



Insert thermal break



Wrap the parapet



Example

2f Window Sill in CMU or Concrete Wall with Exterior Insulation

Notes

After removing the existing brick sill, make the insulation continuous and aligned with the window thermal break- key to the success of this detail is ensuring good structural attachment of the window and the alignment of the window thermal break. This offers chance to improve the window air tightness and rain control performance as well.

Sub-sill flashing is required for rain control. It should posses a raised vertical section at the back (called "backdam"), tall enough allowing the installation of sealant between it and the window (for major both, water and airflow control continuity)

Use metal flashing only to cross part of the insulation and take water to the exterior. Polymeric, self-adhered membranes can be used to connect the water control layer on the face of the wall to the metal flashing.

The hollow space of open window frames will promote natural convective heat flow through it. This undesired heat flow can be reduced by filling these voids with factory-installed custom-shaped foam plastic or rigid stone sections.

To support the outer portion of a window with a single lite so that its thermal break is aligned with wall insulation, the window support should be installed below the IGU.

Existing Window Sill

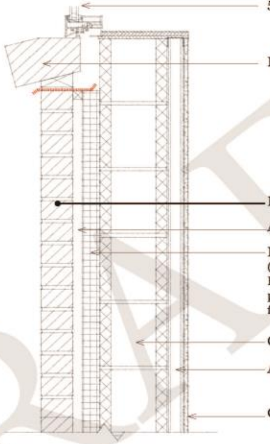
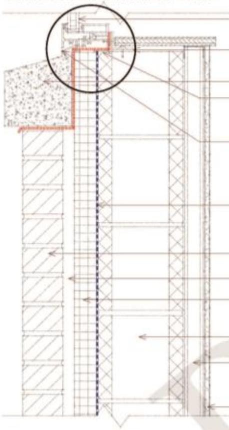


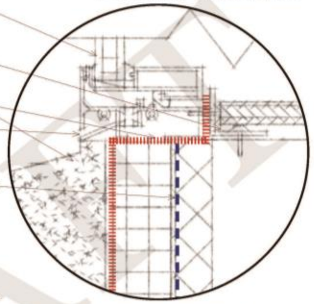
Table of Modeling Values

Component	Thickness Inches (mm)	Conductivity Btu/h•ft•°F (W/m K)	Nominal Resisitance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)
Interior Film	-	-	R-0.74 (0.13 RSI)	-
Brick	3 5/8" (92)	0.578 (1)	R-0.523 (0.092 RSI)	110 (1800)
Air Cavity	1" (25)	0.070 (0.122)	R-1.185 (0.209 RSI)	-
Insulation	2" (51)	0.0139 (0.024)	R-11.99 (2.112 RSI)	-
CMU Block	7 5/8" (194)	0.069 (1.2)	R-0.916 (0.161 RSI)	130 (2100)
Air Layer with Steel Studs	1 3/4" (44)	0.2219 (0.384)	R-0.66 (0.116 RSI)	-
Gypsum Board	1/2" (13)	0.092 (0.16)	R-0.5 (0.08 RSI)	50 (800)
5500 ISOWEB WINDOW	-	-	-	-
Aluminum Sill Flashing	12 Gauge	160	-	-
Brick Sill	3 5/8" (92)	0.578 (1)	-	110 (1800)
Exterior Film	-	-	R-0.23 (0.04 RSI)	-

Corrected Window Sill



Close up of the Corrected Window Sill



Quality Control/ Sequencing

1. Remove old window
2. Remove brick sill, flashing and window board
3. Insert sheet metal back dam at the top surface where the existing brick sill was laying
4. Insert additional insulation to rear of sill
5. Insert additional Insulation plus wood buck
6. Insert flexible flashing
7. Insert backdam anchor
8. Insert pre-shimmed glazing tape air and water seal, joining the air and moisture barriers with the metal angle backdam and flexible flashing.
9. Insert new brick sill
10. Insert sealant
11. Hinge window into position and brace to backdam anchor
12. Add window board

Thermal Performance

Condition	Clear Wall R-Value (W/m2K)	Linear Transmittance (Ψ) Btu/h•ft•°F (W/mK)
Wall Clear Field	R-15.7 (0.369)	-
Existing Fitting Situation	-	**0.445 (0.771)**
Corrected Fitting Situation	-	**0.017 (0.030)**

1. Thermal analysis based on 5500 ISOWEB WINDOW- thermally broken window selection.
2. The performance of the correct version can be improved only slightly from Ψ - 0.017 Btu/h•ft•°F using thicker insulation and tweaking the details of the window sill attachment to the window and the alignment of the thermal break.
3. The reported Ψ-value does not include the metal angle backdam or anchors thermal effects.

Building Air Tightness

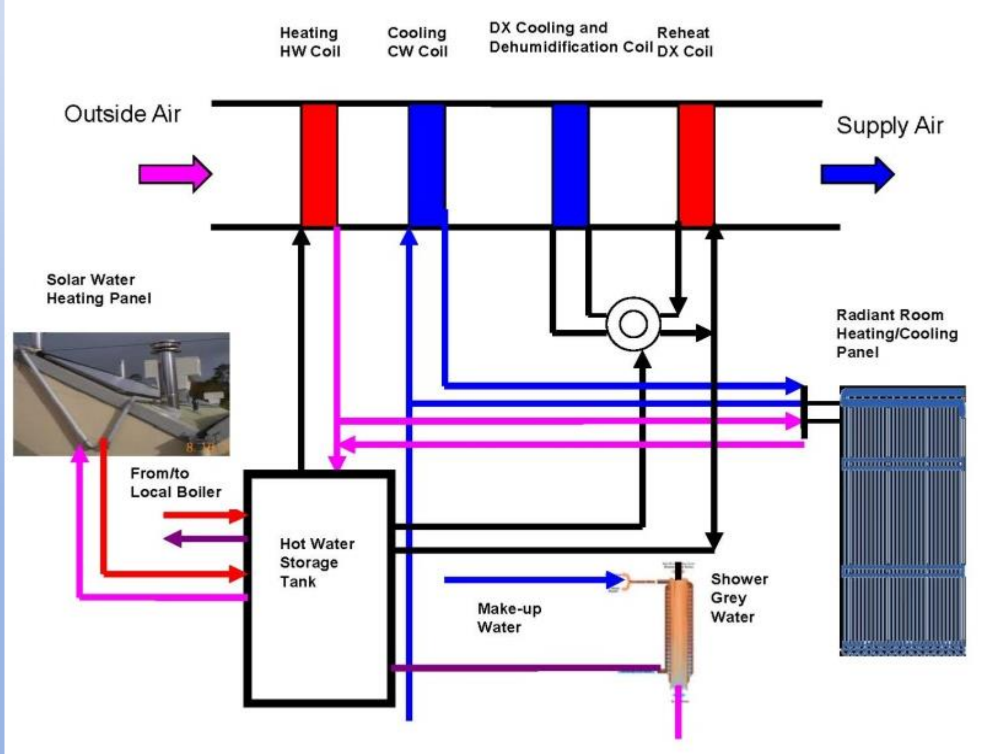
Country	**Source**	**Requirement***	**cfm/ ft^2 at 75Pa**
Austria	OIB RL 6, 2011 for buildings with mechanical ventilation	1.5 1/h at 50 Pa	**0.28**
Germany	DIN 4108-2	1.5 1/h at 50 Pa	**0.28**
USA	ASHRAE Standard 90.1 – 2013, USACE ECB for all buildings [21]		**0.25**
USA	USACE HP Buildings and DER proposed requirement		**0.15**
UK	TS-1Commercial Tight	2 $m^3/h/m^2$ at 50 Pa	**0.14**
Germany	Passive House Std	0.6 1/h at 50 Pa	**0.11**

Based on four-story building, 120 x 110 ft, n=0.65.

Advanced HVAC Systems

- Dedicated outdoor air system (DOAS)
- Heating and Cooling equipment per current national standard (e.g., ASHRAE 90.1-2013)
- Heat recovery (sensible and latent) > 80% efficiency
- Duct air tightness – class C
- Hot and chilled water pipes insulation per current national standard

- Low exergy heating and cooling systems: indirect evaporative cooling (e.g., Coolerado), radiant heating and cooling, energy flow cascading, etc.



Lighting – Improved Design and Technology

Lighting Design Guide for Low Energy Buildings – New and Retrofits

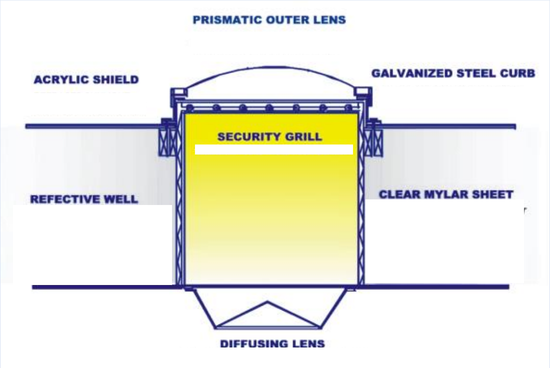
RECOMMENDED LIGHTING POWER DENSITY AND ILLUMINANCE VALUES

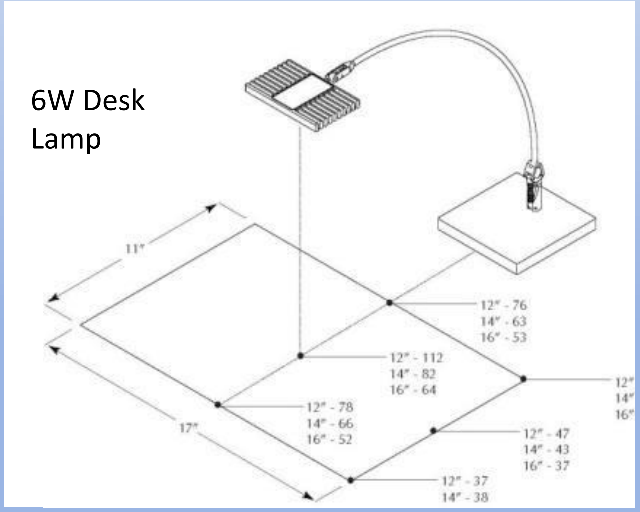
Space Type	Target Illuminance	Target LPD
Common Spaces		
- Conference Room	40 fc	0.80 W/ft^2
- Corridor	10 fc	0.50 W/ft2
- Dining	20 fc	0.60 W/ft2
- Dishwashing/ Tray Return	50 fc	0.65 W/ft2
- Kitchen/ Food Prep/ Drive Thru	50 fc	0.65 W/ft2
- Living Quarters	5-30 fc	0.60 W/ft2
- Mechanical/ Electrical	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 / Siprnet	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

Improved Design
Reduced illuminance
Reduced electrical power

Lighting Controls

- Use daylight responsive controls in frequently occupied spaces with daylight access
- Use vacancy sensors in spaces with daylight access
- Use occupancy sensors in spaces without daylight access
- Control lighting with time-clocks for building-wide energy conservation





Allowable (Cost Effective) Budget Increase for DER

ΔC = NPV *ΔFirst Cost ($) + NPV *ΔMaintenance ($) +
+ NPV *Replacement ($) + NPV *Δ Energy ($).

$$NPV = \frac{(1+i)^N - 1}{i \cdot (1+i)^N}$$

NPV = Net Present Value function
N = study life in years
i = interest or discount rate

$$\Delta \text{First Cost}_{\text{budget}} = \text{SR}_{\text{energy}} \cdot (\Delta \text{Energy Cost}_{\text{annual}}) + \text{SR}_{\text{maint}} \cdot (\Delta \text{Maintenance})$$

Examples of SR or selected economic project life, interest, discount and escalation rates.

	Economic Life (yrs)			5	10	15	20	25	30	35	40	45	50
	Interest	Discount	Escalation										
1	0%	0%	0%	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
2	6%	0%	0%	4.2	7.4	9.7	11.5	12.8	13.8	14.5	15.0	15.5	15.8
3	6%	0%	3%	4.6	8.7	12.4	15.9	19.2	22.5	25.8	29.2	32.8	36.6
4	6%	0%	6%	5.0	10.3	16.0	22.4	29.7	38.5	48.9	61.7	77.5	97.0
5	6%	2%	0%	4.2	7.4	9.7	11.5	12.8	13.8	14.5	15.0	15.5	15.8
6	6%	2%	3%	4.6	8.6	12.3	15.6	18.6	21.5	24.3	27.0	29.8	32.5
7	6%	2%	6%	5.0	10.2	15.6	21.5	28.0	35.4	43.7	53.3	64.5	77.7
8	6%	4%	0%	4.2	7.4	9.7	11.5	12.8	13.8	14.5	15.0	15.5	15.8
9	6%	4%	3%	4.6	8.6	12.1	15.3	18.1	20.6	23.0	25.1	27.1	29.0
10	6%	4%	6%	5.0	10.1	15.3	20.7	26.5	32.5	39.0	46.0	53.6	61.9
11	6%	6%	0%	4.2	7.4	9.7	11.5	12.8	13.8	14.5	15.0	15.5	15.8
12	6%	6%	3%	4.6	8.6	12.0	15.0	17.6	19.8	21.8	23.4	24.9	26.2
13	6%	6%	6%	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
14	6%	8%	0%	4.2	7.4	9.7	11.5	12.8	13.8	14.5	15.0	15.5	15.8
15	6%	8%	3%	4.6	8.5	11.9	14.7	17.1	19.1	20.7	22.1	23.2	24.1
16	6%	8%	6%	5.0	9.9	14.7	19.3	23.7	27.8	31.7	35.2	38.5	41.5

ΔC for Barracks Renovation with 25 years project life

- 9000 m2 barracks, 41% site energy savings

	Energy Reduction (%)	Electric (kBtu)	Gas (kBtu)	Total (Kbtu)	Total Utility Cost ($)	Delta First Cost ($)	Total SPB Budget 25 yrs ($)	SR= 10	SR= 15	SR= 18	SR= 20
Base case (minimum standard)		*4,883,022*	*8,639,604*	*13,522,626*	*208,427*						
DER	*41%*	*2,996,573*	*4,969,746*	*7,966,319*	*124,845*	*1,639,474*	*2,089,550*	*835,820*	*1,253,730*	*1,504,476*	*1,671,640*

Questions, Comments, Want to be a part of the TEAM?

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