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

<table>
<thead>
<tr>
<th>Category</th>
<th>Name</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Building Envelope</td>
<td>Roof insulation</td>
<td>Level to be defined through modeling</td>
</tr>
<tr>
<td></td>
<td>Wall insulation</td>
<td>Level to be defined through modeling</td>
</tr>
<tr>
<td></td>
<td>Slab insulation</td>
<td>Level to be defined through modeling</td>
</tr>
<tr>
<td></td>
<td>Windows</td>
<td>Parameters to be defined through modeling</td>
</tr>
<tr>
<td></td>
<td>Doors</td>
<td>Parameters to be defined through modeling</td>
</tr>
<tr>
<td></td>
<td>Thermal bridges remediation</td>
<td>See the BE Guide</td>
</tr>
<tr>
<td></td>
<td>Air tightness</td>
<td>0.15 cfm/ft² (for USA)</td>
</tr>
<tr>
<td></td>
<td>Vapor Barrier</td>
<td>See the BE Guide</td>
</tr>
<tr>
<td></td>
<td>BE QA</td>
<td>See the BE Guide</td>
</tr>
<tr>
<td>Lighting and Electrical Systems</td>
<td>Lighting design, technologies and controls</td>
<td>See the USACE Lighting Guide</td>
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<tr>
<td></td>
<td>Advanced plug loads, smart power strips and process equipment</td>
<td>TopTen (Europe, USA), Top Tier EnergyStar, FEMP Designated, etc</td>
</tr>
<tr>
<td>HVAC</td>
<td>High performance motors, furnaces, chillers, boilers, etc</td>
<td>ASHRAE Std 90.1 2013 and EPBD (Table will be provided in the Guide)</td>
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<tr>
<td></td>
<td>DOAS</td>
<td>See the Guide</td>
</tr>
<tr>
<td></td>
<td>HR (dry and wet)</td>
<td>&gt;80% efficient, see the Guide</td>
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<tr>
<td></td>
<td>Duct insulation</td>
<td>Based on EPBD requirements</td>
</tr>
<tr>
<td></td>
<td>Duct airtightness</td>
<td>Based on EPBD requirements</td>
</tr>
<tr>
<td></td>
<td>Pipe insulation</td>
<td>Based on EPBD requirements</td>
</tr>
<tr>
<td></td>
<td>Other Energy Efficiency Technologies</td>
<td>(&gt; 400 from the Annex 46)</td>
</tr>
</tbody>
</table>

### 2 Energy Efficiency Technologies and Process Related Measures for Building Retrolfits

This chapter provides a prioritized listing of energy efficiency technologies and process improvement measures that will be referred to as energy efficiency measures, or “EEMs.” The EEMs are categorized according to the energy management strategies, lighting systems improvements, occupancy behavior changes, etc., and can result in significant energy and cost savings. For example, the following measures can be applied to different building systems:

- **Roof insulation**
- **Wall insulation**
- **Slab insulation**
- **Windows**
- **Doors**
- **Thermal bridges remediation**
- **Air tightness**
- **Vapor Barrier**
- **BE QA**

### 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, 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

### Other Energy Efficiency Technologies

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

### 2.6 Daylighting

- **Daylighting**: In areas illuminated by daylight, evaluate opportunities for daylight harvesting. Measure light levels on a daily basis using both the electric lighting system on and turned off. If daylight provides sufficient light level to maintain daylight switching, or daylight dimming controls and appropriate ballasts in the lighting system is fluoresecn or high intensity discharge (HID) to reduce the use of electric lighting. Install daylighting controls to monitor and control the amount of daylight entering the space from the exterior. Replace mercury vapor or pulse start metal halide HID lumeinaries with pulse start metal halide HID lumeinaries as high performance systems, by (1) replacing lamps and ballasts, (2) using lumeinaries which maintain lumeinaries or (3) integrating new luminaires.

### 2.6 Lighting upgrades

- **Upgrades**: Evaluate upgrading standards fluorescent or neon signage with more efficacious sources such as halogen, integrated ballast compact fluorescent, solid state (LED), or metal halide retrofults. Alternatively, replace incandescent luminaries with fluorescent using these sources.

- **Upgrades**:
  - **Luminaire upgrades**: Upgrade luminaire to available lumeinaries with more efficacious sources such as high performance T8 and T5 systems by (1) replacing lamps and ballasts, (2) using lumeinaries which maintain lumeinaries or (3) integrating new luminaires.

### 2.6.4 Lighting controls

- **Lighting controls**: Reduce lighting use through management and controlled systems — in general, consider bringing the lighting control protocols for the building up to BE 1.2010 (Section 9.4.1 standards, this includes the following.

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**Note:** This text is a snapshot of the page and does not capture all details due to the limitations of text-only transcription. For a comprehensive understanding, the complete document should be reviewed.
Guidance for Insulation Values and window

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
<th>Assembly Max R (ci)</th>
<th>Min R-Value (ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>Insulation Entirely Above Deck</td>
<td>9.020</td>
<td>R-50ci</td>
</tr>
<tr>
<td></td>
<td>Metal Building</td>
<td></td>
<td>R-13 + R-13 + R-34ci</td>
</tr>
<tr>
<td></td>
<td>Attic Attic and Other</td>
<td></td>
<td>R-60</td>
</tr>
<tr>
<td>Walls</td>
<td>Mass</td>
<td>0.033</td>
<td>R-30ci</td>
</tr>
<tr>
<td></td>
<td>Metal Building</td>
<td></td>
<td>R-19 + R-17ci</td>
</tr>
<tr>
<td></td>
<td>Steel Framed</td>
<td></td>
<td>R-19 + R-20ci</td>
</tr>
<tr>
<td></td>
<td>Wood Framed and Other</td>
<td></td>
<td>R-19 + R-14ci</td>
</tr>
<tr>
<td></td>
<td>Below Grade/Basement</td>
<td>0.067</td>
<td>R-15ci</td>
</tr>
<tr>
<td>Floors Over Uncondensed Space</td>
<td>Mass</td>
<td>0.033</td>
<td>R-16 Spray Foam + R-11ci</td>
</tr>
<tr>
<td></td>
<td>Steel Joist</td>
<td></td>
<td>R-16 Spray Foam + R-13ci</td>
</tr>
<tr>
<td></td>
<td>Wood Framed and Other</td>
<td></td>
<td>R-19 + R-10ci</td>
</tr>
<tr>
<td></td>
<td>Unheated</td>
<td>0.54</td>
<td>R-10 for 24 in.</td>
</tr>
<tr>
<td>Slab-on-Grade</td>
<td>Heated</td>
<td>0.44</td>
<td>R-15 for 36 in. + R-5ci below</td>
</tr>
<tr>
<td>Doors</td>
<td>Swinging</td>
<td>0.40</td>
<td>Insulated</td>
</tr>
<tr>
<td></td>
<td>Non-Swinging</td>
<td></td>
<td>Insulated</td>
</tr>
<tr>
<td>Vertical Glazing</td>
<td>Window to Wall Ratio (WWR)</td>
<td>&lt; 20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thermal Transmittance (U-value)</td>
<td>≤ 0.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solar Heat Gain Coefficient (SHGC)</td>
<td>≤ 0.40</td>
<td></td>
</tr>
</tbody>
</table>

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

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.

<table>
<thead>
<tr>
<th>Description</th>
<th>Existing R-value</th>
<th>Required R-value Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framed wall</td>
<td>R-2.8</td>
<td>R-2.2</td>
</tr>
<tr>
<td>Insulation attachment system</td>
<td>R-2 to R-4</td>
<td>R-2.2 to R-4</td>
</tr>
</tbody>
</table>

The same as mass wall example

Needs to be populated with the same methodology

Possible combination of insulation types and attachment system types

All possible insulation options for this attachment system
Slab Insulation

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

[Graph showing data on length of thermal bridges and heat loss through external insulation]
Example of Thermal Bridge Remediation

Typical detail – poor thermal bridge

Option 1: Insert thermal break

Option 2: Wrap the parapet
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

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.
Lastly, all waterproofing, flashings and coping needs to be reinstated.
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 jams 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
   b. Precast sandwich panel
     a. Roof of steel joists bearing on inner wythe of sandwich
5. 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
6. Historical Details w/interior insulation
   a. Stone veneer over CMU @ grade or parapet
   b. Window sill in solid brick masonry

Examples

OFFICE (OPEN)

LIGHTING TECHNOLOGIES

- LAMP
  - LED Pin F14W 3000K 9W
  - LED Pin F35W 3000K 13W

- BALLAST DRIVES
  - 250 Mili Volt
  - 2000 W
  - 4000 W

- DIMMER
  - 0-10V

- CONTROL
  - 2035, 2040, 2045
  - 2075, 2080, 2085

RECOMMENDED LIGHTING POWER DENSITY AND ILLUMINANCE VALUES

<table>
<thead>
<tr>
<th>Space Type</th>
<th>Target Lumen/ft²</th>
<th>Target Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>0.70 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Office (Open)</td>
<td>0.70 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Office (Enclosed)</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Reception</td>
<td>1.00 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Restroom/Shower</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Server Room</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Serving Area</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Store</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Toilet/Toilet Paper</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Tattoo/Spa</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Salon</td>
<td>0.50 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Training</td>
<td>0.75 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Treatment Room</td>
<td>0.75 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Patient Rooms (Clean)</td>
<td>0.75 W/ft²</td>
<td>1200 lux</td>
</tr>
<tr>
<td>Vehicle Maintenance</td>
<td>0.75 W/ft²</td>
<td>1200 lux</td>
</tr>
</tbody>
</table>

CONSIDERATIONS

- User age, clothing, and activity level in each office area
- Workday luminance level suggested to the ANSI ranges from 90 to 100 for most office lighting tasks
- Visual needs of an office occupant in one work area may be different from that of a worker occupant in another work area
- Maintain a circulation rate between work areas to reduce artificial lighting glare
- Use a variety of lighting sources to reduce glare and provide a comfortable work environment
- Natural light sources during the work day
- Dimmable lighting is recommended
- Effective task lighting is necessary for visual comfort
- Adjustable light settings can often be turned off or reduced to a low power setting during the day.