Code of Practice – Methodology for the energy efficient retrofit of existing domestic dwellings

Thomas English
Architecture/Building Standards Section
Department of the Environment, Community & Local Government
Presentation

• **Brief background** on the development of the draft Code of Practice

• **Description** of the layout and structure of the document – how it can be utilised

• **Key points** regarding Planning a Retrofit and Building Science

• **Overview** of the Code of Practice sections that cover - Dwelling Fabric, Dwelling Ventilation and Dwelling Services

• **Guidance** regarding Project Management of a retrofit project

• **Benefits** that can gained from utilising the document
Retrofit Code of Practice - Draft

- **NSAI/DECLG/DCENR/SEAI - S.R.54: Code of Practice — Methodology for the energy efficient retrofit of existing domestic dwellings**

- Public Consultation completed. Comments being reviewed.

- Consultants - **Building Research Establishment (BRE)**

- Provides guidance for design and building professionals

- Contents include overall approach, fabric and services

- Schedule for completion **Q4 2013**
Introduction

Purpose and scope
- Provide technical guidance on energy efficient refurbishment of post 1940s low-rise dwellings

Audience
- Property managers, designers, specifiers and installers

Use
- Application of measures to fabric, ventilation and services
- Consult specific section for guidance but CoP considers refurbishment holistically

Level
- Detailed technical guidance - assumes users have appropriate qualification and experience of retrofit projects

Support
- Building Science section covers basic concepts
- Management Section for delivering retrofit projects
Elements Addressed

Roofs
- Pitched
- Timber flat
- Concrete flat

Lighting
- Lamps (tungsten, tungsten halogen, CFL, LED etc.)
- Luminaires
- Controls

Heating
- Gas
- Oil
- Solid fuel
- Electric
- Warm air
- Room
- Pipework, emitters and controls

Walls
- Hollow block
- Cavity
- Solid
- Timber frame
- Steel frame
- IWI/EWI/CWI

Floors
- Suspended pre-cast
- Suspended timber
- Ground bearing

Ventilation
- Room
- MV
- PSV
Retrofit Code of Practice
- Document Structure -

• Scope
• Building Science
• Planning a Retrofit
• Dwelling Fabric
  - Floors
  - Walls
  - Openings
  - Roofs
• Dwelling Ventilation
• Dwelling Services
  - Heating and Hot Water
  - Residential Lighting
• Project Management
• U-values – Driven Rain Index – Thermal Bridging - Bibliography
Retrofit Code of Practice
- Document Structure -

• **Same approach** - for each fabric element and service

• **Probable existing condition** – described for each, likely problems highlighted and current performance level

• **Options for a retrofit** – list of those considered acceptable

• **Design Considerations** for each retrofit option, e.g.
  • Materials to use
  • Adapting to existing conditions
  • Technical risks etc.

• **Installation considerations**, e.g.
  • Construction Sequence
  • Particular detailing to avoid thermal bridging etc.
Building Science - General

Purpose

- Provides users of the Code of Practice with basics of building physics
- Supports technical aspects and is a reference section

Dwelling treated as a system

- Movement of heat, moisture and air through envelope and within dwelling and its effects on occupants
- Driving forces for movement, i.e. gradients/differences in energy, concentration and pressure
Building Science - Structure

Heat
- Conduction
- Convection
- Radiation

Moisture
- Water vapour
- Liquid
- Solid

Air
- Wind pressure
- Stack pressure

Flow through envelope and within dwelling

Effect on occupants
Building Science – Flow through dwelling

<table>
<thead>
<tr>
<th>Insulation Material</th>
<th>Thermal conductivity range (W / mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Highest performance</strong></td>
<td></td>
</tr>
<tr>
<td>Vacuum insulation panels</td>
<td>0.008</td>
</tr>
<tr>
<td>Aerogel</td>
<td>0.019</td>
</tr>
<tr>
<td><strong>Polyurethane</strong></td>
<td></td>
</tr>
<tr>
<td>Polyurethane with pentane up to 32 kg/m³</td>
<td>0.027</td>
</tr>
<tr>
<td>Polyurethane soy based</td>
<td>0.026</td>
</tr>
<tr>
<td>Foil faced Polyurethane with pentane up to 32 kg/m³</td>
<td>0.030</td>
</tr>
<tr>
<td>Polyurethane with CO₂</td>
<td>0.038</td>
</tr>
<tr>
<td>In-situ applied Polyurethane (sprayed or injected)</td>
<td>0.036</td>
</tr>
<tr>
<td><strong>Polyisocyanurate (PIR)</strong></td>
<td></td>
</tr>
<tr>
<td>Polyisocyanurate up to 32 kg/m²</td>
<td>0.026</td>
</tr>
<tr>
<td>Foil faced Polyisocyanurate up to 32 kg/m²</td>
<td>0.029</td>
</tr>
<tr>
<td>In-situ applied Polyisocyanurate (sprayed)</td>
<td>0.028</td>
</tr>
<tr>
<td><strong>Phenolic foam</strong></td>
<td></td>
</tr>
<tr>
<td>Phenolic foam</td>
<td>0.022</td>
</tr>
<tr>
<td>Foil faced Phenolic foam</td>
<td>0.022</td>
</tr>
<tr>
<td><strong>Expanded polystyrene (EPS)</strong></td>
<td></td>
</tr>
<tr>
<td>Expanded polystyrene up to 30 kg/m³</td>
<td>0.030</td>
</tr>
<tr>
<td>Expanded polystyrene with graphite (grey)</td>
<td>0.031</td>
</tr>
<tr>
<td><strong>Extruded polystyrene (XPS)</strong></td>
<td></td>
</tr>
<tr>
<td>Extruded polystyrene with CO₂</td>
<td>0.026</td>
</tr>
<tr>
<td>Extruded polystyrene with HFC 35 kg/m³</td>
<td>0.029</td>
</tr>
<tr>
<td><strong>Wool and fibre</strong></td>
<td></td>
</tr>
<tr>
<td>Glass wool [up to 48 kg/m³]</td>
<td>0.030</td>
</tr>
<tr>
<td>Glass wool [50 kg/m³] or greater than 48 kg/m³</td>
<td>0.040</td>
</tr>
<tr>
<td>Stone wool [less than 160 kg/m³]</td>
<td>0.028</td>
</tr>
<tr>
<td>Stone wool [160 kg/m³]</td>
<td>0.037</td>
</tr>
<tr>
<td>Sheep's wool [22 kg/m³]</td>
<td>0.024</td>
</tr>
<tr>
<td>Cashmere fibre [dry brown 24 kg/m³]</td>
<td>0.038</td>
</tr>
<tr>
<td>Hemp fibre</td>
<td>0.030</td>
</tr>
<tr>
<td>Polyester fibre</td>
<td>0.035</td>
</tr>
<tr>
<td>Wood fibre (WF)</td>
<td>0.030</td>
</tr>
</tbody>
</table>

*Thermal conductivity ranges are a minimum and maximum obtained from the thermal conductivity values declared by manufacturers (or suppliers) and those given in the European Thermal Values publication.*
Building Science – Flow through dwelling

Convective heat flow bypassing insulating layer
Leaves of party wall
Insulated ceiling
Warmed air exfiltrating from party wall cavity
Cavity
Conductive heat flow from party wall cavity into loft space
Cold external air infiltrating into party wall cavity
Conductive heat flow from party wall cavity into loft space
Planning a Retrofit - General

**Purpose**
- Sets out retrofit planning and assessment – Energy Surveys & Improvement Plans
- Gives context in how to use the Code of Practice to achieve successful retrofit

**Scope**
- Impact of Planning and Building Regulations requirements
- Suitable use of materials
- Process to define scope of retrofit project
- Dwelling Survey to benchmark performance and identify relevant issues for retrofit
- Examples of retrofit projects using performance levels contained in the code
Planning a Retrofit - Project Stages and Scope

Defining Project Scope

- Size (single task, multiple tasks, whole house or multiple dwellings)
- Budget
- Performance required
- Time available
- Disruption

Survey
- Selection and specification of measures
- Works
- Commissioning and Handover

Described in detail in Code of Practice
Planning a Retrofit - Survey 1

Benchmark existing performance & Potential for improvement through energy survey

Energy Improvement Plan

- Meets needs of occupants
- Assess capital costs, savings, improved comfort
- Considers possible future works
- Assess likely disruption

Building Energy Rating (BER)

The Building Energy Rating (BER) is an indication of the energy performance of this dwelling. It covers energy use for space heating, water heating, ventilation and lighting, calculated on the basis of standard occupancy. It is expressed as primary energy use per unit floor area per year (kWh/m² yr).

A rated properties are the most energy efficient and will tend to have the lowest energy bills.

<table>
<thead>
<tr>
<th>Building Energy Rating kWh/m² yr</th>
<th>MOST EFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Warm Orange</td>
</tr>
</tbody>
</table>

Carbon Dioxide (CO²) Emissions Indicator kg CO²/m² yr

- Best (D) 0
- Worst (G) 150

The less CO² produced, the less the dwelling contributes to global warming.

Important: This BER is calculated on the basis of data supplied to and by the BER Assessor, and using the version of the assessment software at the time. A future BER assigned to the dwelling may be different as a result of changes to the dwelling or if the assessment software.

Space heating 60%
Water heating 24%
Cold appliances 3%
Consumer electronics 3%
Cooking 3%
Lighting 3%
Wet appliances 2%
Miscellaneous 2%
Planning a Retrofit - Survey 2

Depending on extent of proposed work then further survey to assess condition of existing fabric and services

<table>
<thead>
<tr>
<th>Area</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall, roof and floor</td>
<td>• Type (e.g. hollow block), presence of insulation (e.g. CWI)</td>
</tr>
<tr>
<td></td>
<td>• Condition and cause (e.g. condensation, damaged rain water goods, soil levels etc.)</td>
</tr>
<tr>
<td>Windows and doors</td>
<td>• Type – use laser gauges to identify thickness, air gap width etc.</td>
</tr>
<tr>
<td></td>
<td>• Condition, particularly with respect to proposed intervention</td>
</tr>
<tr>
<td>Heating</td>
<td>• Type and fuel used</td>
</tr>
<tr>
<td></td>
<td>• Condition</td>
</tr>
<tr>
<td></td>
<td>• Presence of thermostats and controls</td>
</tr>
<tr>
<td></td>
<td>• If off-gas scope for provision or potential to store fuel</td>
</tr>
<tr>
<td>Ventilation and airtightness</td>
<td>• Presence of openings, including under-floor and under eaves</td>
</tr>
<tr>
<td></td>
<td>• Assess airtightness by visual inspection or by test</td>
</tr>
<tr>
<td>Lighting</td>
<td>• Types of lamps and fitting</td>
</tr>
<tr>
<td></td>
<td>• Scope to enhance natural daylight</td>
</tr>
<tr>
<td>Layout and size</td>
<td>• Identify heating zones, in particular Zone 1</td>
</tr>
<tr>
<td></td>
<td>• Size and height of rooms</td>
</tr>
<tr>
<td></td>
<td>• Widths of stairs, doorways and passageways</td>
</tr>
</tbody>
</table>
Planning a Retrofit - Application

Examples based on Tabula

<table>
<thead>
<tr>
<th>Building elements</th>
<th>Insulation</th>
<th>U-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Concrete hollow block, drylined</td>
<td>15-25 mm</td>
</tr>
<tr>
<td>Roofs</td>
<td>Pitched, insulation between joists</td>
<td>100 mm</td>
</tr>
<tr>
<td>Floors</td>
<td>Solid</td>
<td>10-15 mm</td>
</tr>
<tr>
<td>Windows</td>
<td>Double glazed, metal frame, 6 mm gap</td>
<td>n/a</td>
</tr>
<tr>
<td>Doors</td>
<td>Double glazed, metal frame, 6 mm gap (front)</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Solid wood (kitchen door)</td>
<td>none</td>
</tr>
</tbody>
</table>

Heating systems characteristics:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Central heating boiler, pipework uninsulated</td>
</tr>
<tr>
<td>Secondary</td>
<td>Open fire in grate</td>
</tr>
<tr>
<td>Hot water</td>
<td>From primary heating system. Electric immersion heater is used in summer</td>
</tr>
<tr>
<td>Cylinder</td>
<td>Insulated with loose jacket, 35 mm thick, no thermostat</td>
</tr>
<tr>
<td>Controls</td>
<td>Programmer</td>
</tr>
</tbody>
</table>
# Planning a Retrofit - Application

## Table 6 — Specification for different performance levels for Semi-detached dwelling (hollow block)

<table>
<thead>
<tr>
<th>Element</th>
<th>Base Case</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Insulation 100 mm between joists</td>
<td>250 mm between and over joists</td>
<td>300 mm between and over joists</td>
<td>400 mm between and over joists</td>
</tr>
<tr>
<td>Roof — Pitched</td>
<td></td>
<td>Conductivity 0.04 W/mK</td>
<td>0.04 W/mK</td>
<td>0.04 W/mK</td>
<td>0.04 W/mK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U-value 0.4 W/m²K</td>
<td>0.16 W/m²K</td>
<td>0.14 W/m²K</td>
<td>0.10 W/m²K</td>
</tr>
<tr>
<td>Walls — Hollow block</td>
<td>Internal insulation (IWI) 15-25mm drylined</td>
<td>60mm IWI</td>
<td>90mm IWI</td>
<td>120mm IWI</td>
<td>160mm IWI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conductivity 0.025 W/mK</td>
<td>0.025 W/mK</td>
<td>0.025 W/mK</td>
<td>0.025 W/mK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U-value 1.1 W/m²K</td>
<td>0.35 W/m²K</td>
<td>0.27 W/m²K</td>
<td>0.21 W/m²K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>External Insulation (EWI)</td>
<td>90 mm EWI</td>
<td>120 mm EWI</td>
<td>160 mm EWI</td>
<td>220 mm EWI</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conductivity 0.035 W/mK</td>
<td>0.035 W/mK</td>
<td>0.035 W/mK</td>
<td>0.035 W/mK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U-value 0.35 W/m²K</td>
<td>0.27 W/m²K</td>
<td>0.21 W/m²K</td>
<td>0.15 W/m²K</td>
</tr>
<tr>
<td>Floor</td>
<td>Insulation Solid 10-15mm</td>
<td>Solid 20 mm</td>
<td>Solid 70 mm</td>
<td>Solid 100 mm</td>
<td>Solid 120 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conductivity 0.035 W/mK</td>
<td>0.035 W/mK</td>
<td>0.035 W/mK</td>
<td>0.025 W/mK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U-value 0.57 W/m²K</td>
<td>0.45 W/m²K</td>
<td>0.25 W/m²K</td>
<td>0.21 W/m²K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Windows</td>
<td>Type</td>
<td>Type</td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High performance double glazed, low-e, argon</td>
<td>High performance double glazed, thermally broken, low-e</td>
<td>High performance double glazed, thermally broken, low-e</td>
<td>High performance double glazed, thermally broken, low-e</td>
</tr>
<tr>
<td>U-value</td>
<td>3.7 W/m²K</td>
<td>1.6 W/m²K</td>
<td>1.4 W/m²K</td>
<td>1.3 W/m²K</td>
<td>1.3 W/m²K</td>
</tr>
<tr>
<td>Doors</td>
<td></td>
<td>High performance triple glazed, low-e, argon</td>
<td>High performance triple glazed, low-e</td>
<td>High performance triple glazed, low-e, argon</td>
<td>High performance triple glazed, low-e, argon</td>
</tr>
<tr>
<td>Type (Front)</td>
<td></td>
<td>High performance double glazed, low-e, argon</td>
<td>High performance triple glazed, low-e, argon</td>
<td>High performance triple glazed, low-e, argon</td>
<td>High performance triple glazed, low-e, argon</td>
</tr>
<tr>
<td>U-value (Front)</td>
<td></td>
<td>3.7 W/m²K</td>
<td>1.6 W/m²K</td>
<td>1.4 W/m²K</td>
<td>1.3 W/m²K</td>
</tr>
</tbody>
</table>
Planning a Retrofit - Application
Floors - General

Purpose
- Different types of floor construction
- Insulation methods
- Materials available
- To achieve the targeted energy savings.

Scope
- Three typical types of floor -
  - suspended precast concrete floors,
  - suspended timber floor, and,
  - ground supported concrete floor.
## Floors - Suspended Precast Concrete

<table>
<thead>
<tr>
<th>U-value(^b) W/m(^2)K</th>
<th>Un-insulated floor</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,58</td>
<td>0,45</td>
<td>0,25</td>
<td>0,21</td>
<td>0,15</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insulation conductivity ((\lambda)) W/mK</th>
<th>Insulation thickness needed (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,040</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>0,035</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>100</td>
<td>170</td>
</tr>
<tr>
<td>0,030</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>90</td>
<td>150</td>
</tr>
<tr>
<td>0,025</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>0,020</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>0,015</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>45</td>
<td>75</td>
</tr>
</tbody>
</table>

\(^a\) The U-value given for Level 4 is the value required when installing underfloor heating.

\(^b\) House type used for calculations is a semi-detached house with a ground floor area of 63 m\(^2\) with an exposed perimeter of 23 m\(^2\).
## Floors – Design Considerations

| **Occupant disruption** | • Overfloor solutions will require skirting boards, low level sockets and possibly door heads to be raised.  
• Underfloor solutions will most likely require decanting the occupant during the retrofit. |
| **Floor conditions** | • Timber floor joists may require replacing  
• Underfloor ventilation to be maintained or increased  
• Areas of dampness in retained concrete floors to be addressed, leaking services can allow for localised repair. |
| **Underfloor heating** | • Where underfloor insulation solutions being provided, consider provision of underfloor heating, either for the installation of a heat pump now or in the future. |
**Floors – Installation Considerations**

### Airtightness
- Ensure that all service penetrations and floor perimeters are sealed correctly.
- Provision of full central heating may lead to shrinkage of existing floor boards, so consider replacing flooring or overdecking.

### Suspended timber floors
- Mesh not to be so taught as to compress insulation
- Seal joints between sections of rigid insulation
- Ensure that gap between last joist and wall is insulated.

### Ground supported concrete floors
- Provide a radon barrier and radon sump for replacement floors.
Floors – Ground Supported Concrete

- External Wall
- External render
- Insulation edge detail
- Concrete floor
- Vapour control layer
- Rigid board insulation
- DPM linked into existing wall DPC
- Hardcore and blinding
Walls – General

Purpose

• This section covers the different types of wall construction, insulation methods and materials available to achieve the targeted energy savings.

Scope

• There are four typical constructions:
  • Hollow block walls,
  • Cavity walls,
  • Solid walls, and
  • Timber/steel frame walls
Walls – General

Survey & Preparatory Works
- Construction Type & Structure
- Airtightness & Ventilation
- Condensation
- Dampness
- Exposure

Retrofit Options
- EWI – External Wall Insulation
- IWI – Internal Wall Insulation
- CWI – Cavity Wall Insulation
- Selection Table
## Walls – Selection Criteria for Insulation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>EWI</th>
<th>IWI</th>
<th>CWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Internal disruption to occupants</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2. Reduces thermal bridging</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3. Retains thermal mass of building</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Reduces dwelling floor space</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5. Installation affected by external weather conditions</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>6. Scaffolding required</td>
<td>Yes</td>
<td>No</td>
<td>Noa</td>
</tr>
<tr>
<td>7. External services (e.g. downpipes, gullies, cables, gas meter box, electricity meter box, flues, etc.) may require relocation</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>8. May require planning approval for works which materially alter exterior appearance of the dwelling</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9. System requires approved installers for works</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>10. Internal pipes, radiators, electrics etc. require relocation</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>11. Internal skirting, architrave, fitted kitchens, wardrobes etc. require relocation</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>12. Internal vapour control layer required</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>13. Practical to achieve advanced U-value without combining with another system</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>14. Specification subject to wind driven rain exposure</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>15. May impact on access provision to side of dwelling</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>16. May impact external accessibility requirements to dwelling</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>17. May impact on corridor/stair widths internally</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>18. May require modification of eaves/gable roof line</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>19. Improves external weatherproofing and appearance of building</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>20. Local Authority consulted where encroaching on public footpath</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

a Subject to installer's safety assessment
Walls – Applicable Retrofit Methods – Internal Wall Insulation

Diagram showing the layers of a wall including:
- Exterior
  - External render
- Blocks
- Existing plaster
- Timber stud
- Insulation
- Laminated insulation board
- Vapour control layer (VCL)
- Plasterboard
- Screw fixings
- Interior
## Walls – Cavity Walls

### Cavity Wall Types
- Clear cavity
- Partial filled cavity
- Cavity that cannot be filled

### Cavities suitable for filling
- Clear cavities in moderate driven rain locations

### Cavities not suitable for filling
- Partial filled cavities
- Clear cavities in severe driven rain locations
- Cavity width too narrow
Walls – Cavity Walls – **Suitable for** Cavity Fill Insulation, 2 Stage Process

**Stage 1**
- Fill cavity to achieve at least minimum performance.

**Stage 2**
- Provide either internal or external insulation to achieve improved performance.
Walls – Cavity Walls – Suitable for Cavity Fill, with Internal or External Insulation

<table>
<thead>
<tr>
<th>Baseline U-Value (W/m²K)</th>
<th>50 mm</th>
<th>75 mm</th>
<th>110 mm</th>
<th>Target U-Value (W/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.040</td>
<td>0.67</td>
<td>0.64</td>
<td>0.62</td>
<td>0.50</td>
</tr>
<tr>
<td>0.035</td>
<td></td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td>0.030</td>
<td></td>
<td></td>
<td></td>
<td>0.55</td>
</tr>
<tr>
<td>0.025</td>
<td></td>
<td></td>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td>0.020</td>
<td></td>
<td></td>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td>0.015</td>
<td></td>
<td></td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
</tbody>
</table>

NOTE 1 Where internal insulation thickness exceeds 75 mm (shaded in blue), the insulation may be installed in two or more layers; i.e. the first between battens, and the last layer as a laminate or separate layer.

NOTE 2 Where the overall thickness of the external insulation becomes significant (e.g., exceeds 100 mm) then the approach shall be to insulate the cavity to a higher performance level by using a cavity wall insulant of lower thermal conductivity.
Walls – Cavity Walls – Not Suitable for Cavity Fill Insulation

Option 1

• Provide internal wall insulation (IWI) to achieve required performance.

Option 2

• Fill cavity and provide external wall insulation (EWI) to achieve required performance.
## Walls – Solid Walls

### Cavity Wall Types
- Cavity that cannot be filled
- Clear cavity
- Partial filled cavity

### Prevalence
- Solid walls mainly consist of no fines concrete or mass concrete.
- Solid block walls and precast concrete panels also used, but less widespread

### Existing performance
- Partial filled cavities
- Clear cavities in severe driven rain locations
- Cavity width too narrow
Walls – No Fines Concrete Walls

305 mm No-fines, two coat plaster Inner face, rendered outside U-value 1.53 W/m²K

254 mm No-fines, drylined on studs or dabs Inner face, rendered outside, U-value 1.23 W/m²K

203 mm No-fines, cellular cored drylining on studs or dabs Inner face, rendered outside U-value 1.10 W/m²K
Walls – Framed Walls

Timber frame

- Cavity wall construction with inner leaf of structural timber.
- More than 25 years old, little or no insulation.
- Less than 25 years old, insulation partially or fully filled

Steel frame

- Relatively recent form of construction
- Warm steel frame, insulation on the outside of frame.
- Hybrid steel frame, insulation on outside and between frame.
Walls – Timber Framed Walls – Partially Filled, Topped up and Overboarded with Thermal Laminate
Walls – Hybrid Steel Frame
Walls – Design Considerations

**Occupant disruption**
- External and cavity fill insulation solutions only minor disruption.
- Internal insulation solutions will most likely require decanting the occupant during the retrofit.

**Wall type**
- Ensure that correct wall type is identified by suitable survey.
- Driven rain exposure conditions may require external insulation, again ensure suitable survey.

**Wall condition**
- Rectify pre-existing defects, structural failure, dampness etc.
# Walls – Design Considerations

| **Interstitial condensation** | • Ensure consideration of preventing interstitial condensation done for whatever insulation solution proposed.  
|                             | • Internal insulation solutions to solid walls, WUFI modelling inconclusive due to lack of data and external rain penetration. |
| **Ventilation**             | • Ensure that purpose provided ventilation for combustion appliances maintained  
|                             | • Background ventilation and subfloor ventilation to be maintained. |
| **Thermal bypass or looping** | • External insulation solutions to cavity walls, fill cavity also.  
|                             | • Hollow block walls, seal at roof insulation level. |
Walls – Installations Considerations

### Airtightness
- Ensure that all service penetrations and wall perimeters are sealed correctly.

### External wall insulation
- Use certified system and installer
- Provide perimeter insulation down to ground level to reduce internal surface condensation
- Reposition services.
- Ensure level surface prior to installing insulation

### Internal wall insulation
- Plasterboard on dabs may not be able to support internal wall insulation.
- Plasterboard provides fire resistance and may provide racking resistance to timber framed walls
Openings – General

Purpose
• This section covers the different types of openings and how to achieve the targeted energy savings.

Scope
• There are three typical openings:
  • windows,
  • rooflights,
  • doors.
## Openings – Windows and Rooflights – Applicable Retrofit Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Draughtproofing</strong></td>
<td>• Either to frame, window or both.</td>
</tr>
<tr>
<td><strong>Secondary glazing</strong></td>
<td>• Windows only</td>
</tr>
<tr>
<td><strong>Replacement glazing</strong></td>
<td>• Existing double glazing unit replaced with high performance system</td>
</tr>
<tr>
<td><strong>Replacement window unit</strong></td>
<td>• Replacing single glazed window with double or triple glazed system</td>
</tr>
</tbody>
</table>
## Openings – Overall Thermal Performance

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U-value</strong></td>
<td>• of glazing and whole unit.</td>
</tr>
<tr>
<td><strong>Airtightness</strong></td>
<td>• of whole frame.</td>
</tr>
<tr>
<td><strong>Solar factor</strong></td>
<td>• g-value, measure of potential solar heat gain.</td>
</tr>
<tr>
<td><strong>Solar energy transmittance</strong></td>
<td>• daylight gain, can have an effect on internal lighting requirement.</td>
</tr>
</tbody>
</table>
Openings – Design Considerations

**Changes and disruption**
- Overhaul & Serviced, Upgraded or Replaced
- Replacement units may lead to rooms needing redecoration.
- Airtightness and ventilation

**Means of escape**
- Replacement units to allow for escape or rescue.

**Safety glazing**
- Replacement glazing or whole units in critical locations
## Openings – Installation Considerations

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airtightness</strong></td>
<td>• Correct installation of draughtproofing to existing and new windows and doors</td>
</tr>
</tbody>
</table>
| **Ventilation** | • Maintain background ventilation  
                     • Ensure permanent ventilation for combustion appliances maintained |
| **DPCs** | • Replacement windows and doors may allow the installation of vertical and horizontal DPCs around openings |
Roofs – General

• Guidance covers both warm and cold roofs (depending on which side of insulation the main structural timbers are)

Pitched roof
• Structural timbers or pre-fabricated roof trusses form roof void
• Structure covered by sarking and waterproof layer of slate or tile
• Typically, insulation 25-100mm at joist/ceiling level

Flat roof - Timber
• Joists span opposing walls with firing to allow for drainage
• Covered by weatherproof sheeting and coverings

Flat roof - Concrete
• Concrete slab surrounded by parapet walls
• Insulation present above or below weatherproof layer
Roofs – Applicable Retrofit Methods

Pitched roof
- Lay (additional) insulation at ceiling level to achieve required performance
- Alternative is to insulate below and between rafters if loft conversion proposed
- Could insulate above if replacing roof coverings
- Existing room-in-the roof could have insulated laminated plasterboard to inside face of room

Flat roof - Timber
- **Cold deck roof** (Apply underside of ceiling and between roof joists where ceiling is replaced)
- **Warm deck sandwich roof** (On top of existing roof deck and covered with weatherproof membrane)
- **Warm deck inverted roof** (Laid directly on top roof surface)

Flat roof - Concrete
- Can only be applied above concrete surface
- New weatherproof membrane applied above or below insulation
- Upstand of parapet wall to be insulated

U-value tables in Annex C

Table C.1 — Insulation placed at ceiling level

<table>
<thead>
<tr>
<th>Insulation thermal conductivity (W/mK)</th>
<th>Total insulation thickness needed (mm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.044</td>
<td>270</td>
</tr>
<tr>
<td>0.040</td>
<td>200</td>
</tr>
<tr>
<td>0.037</td>
<td>230</td>
</tr>
<tr>
<td>0.032</td>
<td>220</td>
</tr>
<tr>
<td>0.0221*</td>
<td>180*</td>
</tr>
<tr>
<td></td>
<td>180*</td>
</tr>
<tr>
<td></td>
<td>260*</td>
</tr>
</tbody>
</table>

* NB The first layer is placed between the ceiling joints, with the remainder placed above

Table C.3 — Insulation placed above existing timber flat roof

<table>
<thead>
<tr>
<th>Insulation thermal conductivity (W/m²K)</th>
<th>Total insulation thickness needed (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.037</td>
<td>130</td>
</tr>
<tr>
<td>0.034</td>
<td>120</td>
</tr>
<tr>
<td>0.030</td>
<td>110</td>
</tr>
<tr>
<td>0.022</td>
<td>80</td>
</tr>
<tr>
<td>0.0141*</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>65</td>
</tr>
</tbody>
</table>

* High performance insulation can be used throughout or to facilitate inclusion of an access walkway or storage platform.
Roofs – Design Considerations 1

**Roof condition**
- Work on roofs (e.g. replace waterproof layers, rotted timbers etc.) provides opportunity for insulation
- Survey and strengthen roof to future-proof or accommodate solar technologies

**Services**
- Freezing risk to water tanks/cylinders and pipework
- Overheating risk to cables and light fittings
- Airtightness around penetrations
- Access to services

**Condensation**
- Key concern with warm, moist air from dwelling below
- Installation of VCL
- Provision of purpose-built ventilation
Roofs – Design Considerations 2

Thermal bridging
- Junction between walls and eaves is key so insulation needs to be continuous
- Assessment in Annex G and H

Light shafts
- Insulate walls of light shafts in loft area

Flat roof access
- Access may be required for repair, means of escape etc.
- Assess imposed loads to ensure thermal insulation has appropriate compressive strength

Cabling
- Insulation around cables can lead to overheating so best to route above
- If not possible, increase cable size to carry load
- Protect cables from polystyrene insulation
Roofs – Cold Pitched Roof, Ceiling Insulation

- Use flexible insulation, e.g. mineral wool, spray foam/cellulose or blown fibre
- Build-up layers between joists then lay across
- Use blown fibre where space restricted

Design considerations – Roof void ventilation

- **Eaves** – Vents should not block passage of air and use facia strips to help ensure 10mm gap
- **Ventilation tiles** – Located 450mm up slope (300mm above insulation) to provide 10mm gap
- **Breather membrane** – Can replace existing sarking if replacing roof coverings
Roofs – Cold Pitched Roof, Ceiling

Insulation

Design considerations – Moisture prevention

- **Cold water tanks** – insulate around and above tanks and seal tank
- **Wet rooms** – provide adequate ventilation
- **Recessed light fittings** – avoid if possible, but provide sealed enclosure that dissipates heat
Roofs – Cold Pitched Roof, Ceiling Insulation

Installation considerations

- **Loft hatches** – Seal and insulate, using high performance insulation
- **Platforms** – Use high performance insulation beneath and on joists
- Laying pattern – 300-350mm mineral wool: lay between joists, then lay over and overlap platform
- **Recessed light fittings** – Seal and provide high performance insulation above
Roofs – Cold Pitched Roof, Rafter Insulation

- Common where room-in-the-roof exists or proposed
- Insulation placed between or below rafters (or both) with vented void between rafters above insulation
- Use flexible and semi-rigid insulation but need significant thickness to achieve more demanding U-values so require high performance insulation
Roofs – Cold Pitched Roof, **Rafter Insulation**

- **Preventing moisture** – As before
- **Eaves + ridge ventilation** – Provide 25mm gap within soffit or fascia, 5mm gap at ridge and 50mm gap between top of insulation and roof covering
- **Ventilation tiles** – Use where not possible to vent at eaves and ridge, equivalent to 25mm gap for every rafter void
- **Breather membrane** – Use if replacing existing sarking instead of providing 50mm gap
**Installation considerations**

- Overlap mineral wool, for dwarf stud walls place insulation between stud timbers and across wall faces
- Install VCL to insulation layer then internal insulation as separate layer
- Tape joints of foil backed insulation to achieve requirement of VCL
- Seal service penetrations, and cut rigid insulation to fit snugly between rafters
Roofs – Warm Pitched Roof

- Insulation placed over and sometimes between rafters
- Ventilation required between top of insulation and roof covering using counter battens
- Suitable when replacing roof covering and preparing for room-in-the-roof
- Slates/tiles fixed by battens through breathable membrane/insulation, needs to be rigid and max 100mm thickness, more can be placed between rafters
Roofs – Warm Pitched Roof

Design and installation considerations

- **Ridge line** – May require planning
- **VCL** – As internal surfaces are on warm side of insulation then reduced risk of condensation but VCL helps to improve airtightness
- **Eaves details** – Avoid thermal bridging and maintain ventilation
- **Insulation** – Cut accurately to give snug fit
- **Moisture prevention** – As before
Roofs – Flat Roof, Cold Deck

- Most common form of flat roof
- Insulation between joists, and void above is ventilated at eaves level at opposite sides
- Insulate between and below joists if roof replaced, or use insulated thermal laminate board if ceiling retained
- Might need high performance insulate to achieve more demanding U-values
• **Internal wall insulation** – Use additional thermal laminate beneath ceiling to achieve required U-value; fit IWI before ceiling

• **Parapet with EWI** – Use abutment vent, insulate internal face of parapet wall and replace upper courses beneath coping with lightweight block
Roofs – Warm Deck, Sandwich Roof

- Insulation on top of flat roof with roof covering above
- When proposed to renew roof coverings it is less disruptive to form warm flat roof rather than providing a cold vented roof
Roofs – Warm Deck **Sandwich Roof**, Improvement Options

- Can be improved with insulation below plus IWI, provided roof covering in good condition
- Also improved where existing insulation and covering are replaced plus EWI
- Equivalent to converting cold deck to warm deck which was previously uninsulated (or existing insulation removed)
- Top-up insulation and provide new roof covering plus EWI
Roofs – Warm Deck Sandwich Roof

- Use dense semi rigid insulation
- Protective layer should bond to insulation without fixing unless is approved
- Raises roof height so might need new stepped dpc or cavity trays, and parapet walls raised
- Careful detailing at junctions with IWI and EWI
Roofs – Warm Deck Sandwich Roof

**Installation considerations**

- High performance VCL to be installed on top of decking with all joints taped
- Use solar reflective treatment to counteract higher temperatures and thermal movements they could induce
- Maintain existing drains internal to parapet walls
Ventilation – General

**Traditional forms of ventilation**
- Windows and doors
- Adventitious
- Background

**Improvement methods**
- Natural ventilation with intermittent extract fans
- Passive Stack Ventilation (PSV)
- Mechanical Extract Ventilation (MEV)

**Airtightness – links to other CoP sections**
- Loft hatches and light fittings (Roofs)
- Service entry points (Walls & Floors)
- Gaps around windows and doors (Openings)
- Use of wet plastering (Walls)

**Forms part of the overall refurbishment strategy**
Ventilation – Improvement Methods

• Integral part of the refurbishment strategy: “Build tight, ventilate right”
• Fabric improvements included in relevant sections of the CoP

Table 26 — Suitable ventilation strategies for dwelling refurbishment

<table>
<thead>
<tr>
<th>Ventilation strategy</th>
<th>Single room or partial house refurbishment</th>
<th>Full house refurbishment</th>
<th>Refurbishment to advanced air permeability level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural with extract fans</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Natural with PSV</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>SRHRV</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>MEV</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>MVHR</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Increasing complexity

SFP <0.3 W/(l/s)
<2 m³/m²/hr

Airtightness testing recommended (<5 m³/m²/hr)
Heating

• Traditional heating systems - for space heating and hotwater.
• Consider improvements or replacements - using same or different fuel type

Identification

• Fuel Type
• Heat Generator
• Hotwater Storage
• Distribution and Circulation
• Controls

User Demand

• Space Heating – whole house sizing method or room by room heat loss sizing method
• Water Heating – CIBSE Domestic Heating Design Guide or BS 6700

Potential for Improvements

• Retain & improve or replace. Question whether -
• Repair
• Modify or
• Upgrade
Heating

• Replacement of heating and hot water systems can also involve replacement of the fuel type currently used

Energy Appliances and Fuel

• Solid Fuel
• Gas (Mains, LPG)
• Oil
• Electricity
• Dual Fuel Link Up

Replacement Options

• Level A – upgrade using same fuel as existing
• Level B – improved upgrade but different fuel
• Level C – Advanced upgrade
## Heating

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Heating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid fuel (SF)</td>
<td><strong>M1</strong> A room heating appliance which consists of a firebox and flue outlet enclosed behind a door of heat proof glass. This category excludes any appliance for which the combustion air supply cannot be controlled. HETAS Appliance Categories E1, E2 and E3 from table 16 of Compliance Guide.</td>
<td><strong>B1</strong> <strong>Closed room heater</strong> fuelled by wood only. HETAS category E4 from table 16 of Compliance Guide.</td>
<td></td>
</tr>
<tr>
<td>Central heating / hot water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid fuel</td>
<td><strong>M4</strong> Boiler. HETAS appliance categories F, G1, G2, J1, J2, J3 and J4 from Compliance Guide. Should have thermostatic control of burning rate. Indirect hot water cylinder with thermostat. Full set of basic controls (time switch or programmer, room thermostat, single heating zone control, boiler interlock where firing is electrically controlled.</td>
<td><strong>B4</strong> <strong>Wood Pellet boiler.</strong> HETAS category J5 from Compliance Guide. High performance indirect hot water cylinder with thermostat. Full set of controls: (programmer, room thermostat(s), two heating zones, two pipe system, TRVs on all radiators except in rooms with a room thermostat, boiler interlock).</td>
<td><strong>A4</strong> As B4 with solar collector for water heating and twin coil cylinder.</td>
</tr>
</tbody>
</table>
Heating

- Replacement of an existing system with oil, gas or solid fuel alternatives

**System Options**
- Efficiency
- Appliance Type
- Fuel
- Flue Open/Balanced

**Design Considerations**
- Existing System Design
- Dwelling User Demand
- Sizing to maximum load - whole house sizing method or room by room heat loss sizing method

**Installation Considerations**
- Location, clearances
- Flues, ventilation, air supply
- Condensate Drain, Terminal Guard
- Storage of Fuel

- Replacement of electric systems – advanced appliances, electricity tariff options, controls, alternative system considerations etc
Lighting

Existing Types
- General Indoor Lighting
- Directional Indoor Lighting
- Outdoor Lighting

Lighting Technology
- Lamp Types
- Luminaires
- Controls — Manual, Dimmer, Presence/Absence, daylight sensors, timers, multi sensors

Replacement Performance Standards
- Level 1 Minimum Performance
- Level 2 Best Practice
- Level 3 Advanced Best Practice
Replacement Considerations

- Lamp and Luminaire suitability
- Lamp and Controls suitability
- Colour Temperature 2700 – 3000 k
- Colour Rendering 100 is ideal

**Table 39 — Lamp replacement options**

<table>
<thead>
<tr>
<th>Existing solution</th>
<th>Replacement option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten lamps</td>
<td>Plug-in CFLs of similar light output, warm colour appearance with colour temperatures (2700 to 3000) K, and compatible type and shape</td>
</tr>
<tr>
<td>T12 (38mm diameter) fluorescent lamps</td>
<td>Triphosphor T8 (25 mm diameter) tubes of similar length and wattage</td>
</tr>
<tr>
<td>Halophosphate T8 fluorescent lamps, normally have a 3</td>
<td>Triphosphor T8 tubes of similar length and wattage, (normally have a 3 digit code beginning 8 or 9 e.g. 830, 940)</td>
</tr>
<tr>
<td>lower number e.g. 630, 740</td>
<td></td>
</tr>
<tr>
<td>Tungsten halogen reflector lamps used for general</td>
<td>Highly efficient LED replacement lamps having warm colour appearance with colour temperatures (2700 to 3000) K</td>
</tr>
<tr>
<td>lighting in open luminaires</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1 — Summary of key characteristics for different lamp types

<table>
<thead>
<tr>
<th>Lamp type</th>
<th>Sample image</th>
<th>Luminous efficacy (lm/W)</th>
<th>Colour appearance (K)</th>
<th>Colour rendering (Ra)</th>
<th>Lamp life (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten lamp</td>
<td><img src="image" alt="Tungsten lamp" /></td>
<td>8 to 15</td>
<td>2 700</td>
<td>100</td>
<td>1 000</td>
</tr>
<tr>
<td>Tungsten halogen lamp</td>
<td><img src="image" alt="Tungsten halogen lamp" /></td>
<td>10 to 25</td>
<td>2 700 to 3 000</td>
<td>100</td>
<td>1 500 to 2 000</td>
</tr>
<tr>
<td>T8 linear fluorescent lamp</td>
<td><img src="image" alt="T8 linear fluorescent lamp" /></td>
<td>50 to 96</td>
<td>2 700 to 6 500</td>
<td>50 to 98</td>
<td>8 000 to 24 000</td>
</tr>
<tr>
<td>T5 linear fluorescent lamp</td>
<td><img src="image" alt="T5 linear fluorescent lamp" /></td>
<td>80 to 104</td>
<td>2 700 to 6 500</td>
<td>82 to 95</td>
<td>8 000 to 24 000</td>
</tr>
<tr>
<td>T2 linear fluorescent lamp</td>
<td><img src="image" alt="T2 linear fluorescent lamp" /></td>
<td>55 to 70</td>
<td>2 700 to 6 500</td>
<td>80 to 85</td>
<td>8 000 to 12 000</td>
</tr>
<tr>
<td>Plug-in compact fluorescent lamp</td>
<td><img src="image" alt="Plug-in compact fluorescent lamp" /></td>
<td>20 to 74</td>
<td>2 700 to 6 500</td>
<td>80 to 90</td>
<td>6 000 to 12 000</td>
</tr>
<tr>
<td>Pin-base compact fluorescent lamp</td>
<td><img src="image" alt="Pin-base compact fluorescent lamp" /></td>
<td>30 to 88</td>
<td>2 700 to 6 500</td>
<td>85 to 90</td>
<td>8 000 to 15 000</td>
</tr>
<tr>
<td>LED lamp</td>
<td><img src="image" alt="LED lamp" /></td>
<td>40 to 70</td>
<td>2 700 to 6 500</td>
<td>60 to 90</td>
<td>10 000 to 50 000</td>
</tr>
</tbody>
</table>

*A Colour appearance can also be referred to as the colour temperature.*
### Table 1 — Use of CFLs in common luminaire and their light distribution

<table>
<thead>
<tr>
<th>Luminaire</th>
<th>CFL type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translucent shade</td>
<td>![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Opaque shade</td>
<td>![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Translucent cylinder</td>
<td>![Icon] ![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Translucent drum</td>
<td>![Icon] ![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Translucent sphere</td>
<td>![Icon] ![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Wall uplighter</td>
<td>![Icon] ![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Pendant/Free standing uplighter</td>
<td>![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
<tr>
<td>Lamp holder</td>
<td>![Icon] ![Icon] ![Icon] ![Icon] ![Icon]</td>
</tr>
</tbody>
</table>

**NOTE 1** The relative size of the arrows indicates the proportion of light in that direction.

**NOTE 2** The Y indicates the most suitable CFL type for each style of luminaire.
Project Management

- Quotation and Estimate
- Level of Management and Oversight
- Specification
- Programme of Work
- Sequencing of Work Programme
- Method Statements
- Risk Assessments
- Contract Types
Thank you