Energy Efficiency in Industrial Buildings

Applicable to the Graphic Industry

Energy Efficiency

Lighting

Energy Management Services

Heating Ventilation

Insulation

INTERGRAF
International confederation for printing and allied industries a.i.s.b.l.
ENERGY EFFICIENCY
IN INDUSTRIAL BUILDINGS
Applicable to the GRAPHIC INDUSTRY

INTERGRAF GUIDEBOOK

TABLE OF CONTENTS

INTRODUCTION 3

I. INSULATION OF BUILDINGS 5

1.1 General concepts about thermal insulation of walls, ceilings and floors 5
1.2 Installation of insulation 6
1.3 Insulation Materials 7
1.3.2 Closed-cell over open-cell foams 8
1.3.3 Mineral Wool 9
1.3.4 Foamed plastics 9
1.4 Radiant Barriers 11
1.5 Reflective Insulation: Foils, roof shingles and paint 12
1.6 Vapour Barriers – Vapour Retarders 14
1.7 Transparent Insulation Protection 14
1.8 Roof Insulation 15
1.9 Window Insulation 16
1.9.1 Window insulation film (plastic film 16
1.9.2 Double Glazed Units (Europe terminology) or Insulated Glazing Units in the US 16
1.9.3 Low-emissivity glass 16
1.9.4 Sealing Windows 17
1.9.5 Window Shutters 17
1.9.6 Window Blinds 18
1.10 External wall insulation 18

II. ENERGY EFFICIENCY OF LIGHTING INSTALLATIONS 19

1) INDOOR EQUIPMENT 19
1.1) Quality criteria for lighting: traditional and new criteria 19
1.2) General Considerations 19
1.3) Arguments for refurbishing lighting systems  
1.4) Recommended options  
1.5) Light control equipment  
1.6) Essential Requirements for LIGHT CONTROL Systems  
1.7) Performance “killers”  
2) OUTDOOR EQUIPMENT.  

III. HEATING, AIR CONDITIONING and VENTILATION  

1) Efficiency Rating of Furnaces and Boilers  
2) Hot air /radiation warming systems  
3) Heat pumps (Air Source Heat Pump / Ground Source Heat Pump)  
4) HVAC (Heating, ventilation, air conditioning combined system)  
5) Water Heating  
6) HEAT RECOVERY / HEAT EXCHANGERS  
7) COMMERCIAL/INDUSTRIAL BUILDINGS: COMBINED HEAT AND POWER (CHP)  
8) BUILDING COMMISSIONING.  

IV. Energy efficiency awareness and management  

1) ESCOS – Energy service company  
2) Building Energy management systems (BEMS)  
3) SMART GRIDS  
4) Audit and payback periods  

ANNEXES  

SOME FIRST-AID Recommendations  
Example of average distribution of energy consumption in an industry building  
Example of average distribution of electricity consumption in an industry building  
Sources of information.  
Compressed Air by Control Techniques.  

INTERGRAF, November 2011  
Cristiano Francese, Stagiaire specialized in energy disciplines  
AnneMarie De Noose, Policy Officer.
INTRODUCTION

Reducing energy consumption in printing companies has been identified as an area for substantial reductions in production costs in a competitiveness investigation about the printing sector, sponsored by the European Commission.

INTERGRAF took the initiative of compiling this report with the objective of providing European printing companies with a quick insight in major aspects of energy use in building infrastructure and equipment.

The European Union’s policy towards better energy performance in buildings is covered by two Directives on the Energy Performance of Buildings Directive (EPBD), respectively issued in 2002 and 2009. They provide a framework of measures, ranging from minimum requirements to benchmarking tools for residential, public and commercial buildings. The 2009 Directive had as a key new element the extension of the scope to all existing buildings undergoing major renovations, and developed a methodology to calculate “benchmarks”, the “cost-optimal” level of standards, against which Member States would have to compare their own requirements.

At an EU summit in December 2008, EU leaders re-stated the need for continued action. The energy and climate change ‘package’ aiming both at slashing greenhouse-gas emissions and boosting renewable energies by 20% by 2020.

Energy efficiency is one of the most cost effective ways to enhance security of energy supply, and to reduce emissions of greenhouse gases and other pollutants. In many ways, energy efficiency can be seen as Europe’s biggest energy resource.

Recent Commission estimates suggest that the EU is on course to achieve only half of the 20% objective. The EU needs to act now to get on track to achieve its target. Responding to calls from the European Council to take ‘determined action to tap the considerable potential for higher energy savings of buildings, transport and products and processes’, the Commission presented its comprehensive new Energy Efficiency Plan in March 2011.

Energy efficiency in buildings is recognized as being responsible for 40% of energy consumption and 36% of EU CO₂ emissions, and is at the same time a very complex subject, which requires the involvement of many actors in the construction sector. Intergraf believes therefore that it is essential to stimulate brainstorming thinking within printing companies on their current performance against possible improvements based on existing materials, technology and services.

In a nutshell, the Commission proposes simple but ambitious measures, likely to affect the industry:

- Legal obligation to establish energy saving schemes in all Member States! These schemes should enable energy distributors to fulfil their obligation to save every year 1,5 % of their energy sales. This should be achieved through the implementation of energy efficiency measures by their customers, private or industry. Alternatively, Member States have also the possibility to propose other energy savings mechanisms, for example, be funding programmes or voluntary agreements that lead to the same results but are not based on obligation on energy companies.

- The chapter dealing specifically with industry issues, provides for incentives for SMEs to undergo energy audits and disseminate best practices while the large companies will have to make an audit of their energy consumption to help them identify the potential for reduced energy consumption.

- In addition the European Commission is currently working on proposals to apply environmental taxes on transport and heating fuels in relation to their greenhouse gas emissions and energy content. More details are expected in the course of 2011.
Efficient energy is using less energy to provide the same level of energy service. For example, insulating a building allows using less heating and cooling energy to achieve and maintain a comfortable temperature. Efficient energy use is achieved by means of a more efficient technology or processes, and also by changes in individual behavior.

The Intergraf “Guidebook” therefore appears timely. It provides insight in concept, recommended measures, as well as commonly used measurement units, and some cost/benefit of pay back data when available.

Energy efficiency in compressed air applications used in the printing industry is another area of major interest; the report therefore includes recommendations from a Guide to Energy Saving with Compressed Air, published by Control Techniques, a world-wide group active in control techniques.

The report is based on publicly available information, via internet. A list of websites used as sources for information can be found at the end of the report. A major source of information was Wikipedia.
I. INSULATION OF BUILDINGS

A building’s location and surroundings play a key role in regulating its temperature and illumination. For example, trees, landscaping, and hills can provide shade and block wind. In cooler climates, designing buildings with a south facing windows increases the amount of sun (ultimately heat energy) entering the building, minimizing energy use, by maximizing passive solar heating. Tight building design, including energy-efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, and foundations can reduce heat loss by 25 to 50 percent. Dark roofs may become up to 39 C° hotter than the most reflective white surfaces, and they transmit some of this additional heat inside the building, white roof systems save more energy in sunnier climates.

1.1 GENERAL CONCEPTS ABOUT THERMAL INSULATION OF WALLS, CEILINGS AND FLOORS

Thermal insulation in buildings is an important factor to achieving thermal comfort and unwanted heat loss or gain, and can decrease the energy demands of heating and cooling systems. In a narrow sense insulation can just refer to the insulation materials, employed to slow heat loss, such as: cellulose, glass wool, rock wool, polystyrene, urethane foam, vermiculite. But it can also involve a range of designs and techniques to address the main modes of heat transfer - conduction, radiation and convection materials.

The effectiveness of insulation is commonly evaluated by its R-value, ie watts/Kelvins/m². The R-value is a measure of thermal resistance used in the building and construction industry. The overall coefficient of heat transmission is expressed as U-value, and indicates the heat flow through materials - the higher the figure, the higher the heat loss.

Heat transfer through an insulating layer is analogous to electrical resistance. The heat flow can be worked out by introducing resistance in series with a fixed potential. The resistance of each material to heat transfer depends on the specific thermal resistance [R-value]/[unit thickness], which is a property of the material and the thickness of the layer. A thermal barrier that is composed of several layers will have several thermal resistors in the analogous circuit, each in series.

However, an R-value does not take into account the quality of construction or local environmental factors for each building. Construction quality issues include inadequate vapor barriers, and problems with draft-proofing. In addition, the properties and density of the insulation material itself is critical. R-values of products may deteriorate over time. For instance the compaction of loose cellulose fill reduces the volume of air spaces and its insulation value. Some types of foam insulation, (such as polyurethane and polyisocyanurate) are blown with heavy gases. However, over time a small amount of these gases diffuse out of the foam and are replaced by air, thus reducing the effective R-value of the product. Other foams which do not change significantly with aging because they are blown with water or are open-cell. On certain brands, twenty-year tests have shown no shrinkage or reduction in insulating value. (Detailed information on individual R-values of insulation material is provided in the annex part of the document).

- COLD CLIMATES

In cold conditions, the main aim is to reduce heat flow out of the building. The components of the building envelope - windows, doors, roofs, walls, and air infiltration barriers are all important sources of heat loss. In a well insulated home, windows will then become an important source of heat transfer. The resistance to conducted heat loss for standard glazing corresponds to an R-value of about 0.17W/m²/K (compared to 2-4W/m²/K for glasswool batts). Losses can be reduced by good ‘weatherproofing’, bulk insulation, and minimizing the amount of non-insulative (particularly non-solar facing) glazing. Indoor thermal radiation can also be retarded with spectrally selective (low-e, low-emissivity) glazing. Some insulated glazing systems can double to triple R values.

- HOT CLIMATES
In hot conditions, the greatest source of heat energy is solar radiation. This can enter buildings directly through windows or it can heat the building shell to a higher temperature than the ambient, increasing the heat transfer through the building envelope. The Solar Heat Gain Co-efficient (SHGC - a measure of solar heat transmittance) of standard single glazing can be around 78-85%. Solar gain can be reduced by adequate shading from the sun, light colored roofing, spectrally selective (heat-reflective) paints and coatings and various types of insulation for the rest of the envelope. Specially coated glazing can reduce SHGC to around 10%. Radiant barriers are highly effective for attic spaces in hot climates. In this application, they are much more effective in hot climates than cold climates. For downward heat flow, convection is weak and radiation dominates heat transfer across an air space. Radiant barriers must face an adequate air-gap to be effective.

If refrigeration air-conditioning is used in a hot, humid climate, then it is particularly important to seal the building envelope, to reduce the need for dehumidification of humid air infiltration, which can waste significant energy. On the other hand, some building designs are based on effective cross-ventilation instead of refrigeration air-conditioning, in order to provide convective cooling from prevailing breezes.

- **THERMAL BRIDGE**
  Thermal bridges are points in the building envelope that allow heat conduction to occur. A thermal bridge is created when materials create a continuous path across a temperature difference, in which the heat flow is not interrupted by thermal insulation. Common building materials that are poor insulators include glass and metal. Thermal bridges can also be created by uncoordinated construction, for example by closing off parts of external walls before they are fully insulated. The heat conduction can be minimized by reducing the cross sectional area of the bridges, increasing the bridge length, or decreasing the number of thermal bridges.

- **CONDUCTIVE AND CONVECTIVE INSULATORS (‘BULK INSULATION’)**
  Bulk insulators prevent conductive heat transfer and convective flow, either into or out of a building. The denser a material is, the better it will conduct heat. Air has a low density and is a very poor conductor, and therefore makes a good insulator. Insulation aiming at resisting conductive heat transfer, uses air spaces between fibers, inside foam or plastic bubbles, and attribute a role to building cavities like the attic. This is beneficial in an actively cooled or heated building, but can be a liability in a passively cooled building; adequate measures for cooling by ventilation or radiation are needed.

- **TESTS FOR WALL INSULATION**
  Checking the wall insulation may be less straightforward and less immediate than auditing the attic insulation, which is largely based on direct observation.
  **Checking through a small hole in the wall**
  To check wall insulation, it is recommended to make a small hole in some hidden place, to inspect the wall cavity and see if it is filled with some sort of insulation, and its type and amount. In the case of solid walls remove a small section of the exterior siding. Such tests do not ensure that the insulation is applied in the entire wall, or that it is well settled and without defects
  **Infrared video checking**
  To prevent limitations a more sophisticated inspection by a professional audit, based on infrared video and cameras is recommended (these tools are part of what it is technically known as thermographic auditing).

### 1.2. INSTALLATION OF INSULATION

**WHERE TO INSULATE?**

Where to insulate depends on where the limits of ‘conditioned space’ end, and where unconditioned space begins. Unconditioned space should be treated as outdoors, omitting rain and snow constraints. This would also apply to crawlspace, attics etc, making sure it has adequate ventilation.

If only some sections of a defined space need to be heated, walls between the sections need to be insulated.
Insulation requires precautionary thinking. Chronic condensation problems are usually the result of excess humidity, which can result from badly conceived insulation. Condensation - When warmer air comes in contact with cold surfaces, it loses its ability to retain moisture and deposits it on the colder surface. When high humidity levels are present in your home, the moisture-saturated heated air will produce condensation. It is apparent first on glass windows and doors, due to their cooler surface, but less visible areas will be affected.

**GENERAL INSULATION NEEDS:**
- Attic, especially the attic door/hatch.
- Doors and windows (see weatherization/weatherproofing).
- Floors over unheated spaces.
- Ceilings with unconditioned spaces above.
- Knee walls (typically a short wall, usually lower than three feet in height) and rafters (parallel sloping beams that support a roof) of a finished or conditioned attic.
- All exterior walls.
- Walls between conditioned spaces and unconditioned spaces (such as unheated garage or storage area).
- Floors over unconditioned or outside spaces.
- Around the perimeter of a concrete floor.
- Walls of finished, conditioned basement.
- Foundation walls above ground area.
- Foundation walls in heated basements.
- At top of foundation, where foundation meets mudsill (lowest level of a structure).
- Around perimeter of house at band joist.
- Between rafters, but leave an air space for ventilation between the insulation and the roof deck.
- Floors above cold spaces, such as vented crawl spaces and unheated garages.
- Any floor section that is cantilevered beyond the exterior wall below.
- Around slab floors built directly on the ground.
- Foundation walls of crawl spaces (often crawl spaces are poorly insulated so that the insulation is ineffective).

In case there is a need to investigate in current insulation, following hints are applicable:
- Remove electrical cover plates and look through gap on side of electrical box,
- Remove siding elements.
- Drill hole in interior or exterior wall and extract sample.

**FACTORS AFFECTING THE TYPE AND SCOPE OF NEEDED**
- Climate
- Ease of installation
- Durability - resistance to degradation from compression, moisture, decomposition, etc.
- Ease of replacement at end of life
- Cost effectiveness
- Toxicity
- Flammability
- Environmental impact and sustainability.

Often a combination of materials are used to achieve an optimum solution and there are products which combine different types of insulation into a single form.

**1.3. INSULATION MATERIALS**

Insulation materials may be categorized by their composition (material), by form (structural or non-structural), or by their functional mode (conductive, radiative, convective).
Non-structural forms include batts, blankets, loose-fill, spray foam, and panels. Structural forms include insulating concrete forms, structured panels, and straw bales. Sometimes a thermally reflective surface, called a radiant barrier, is added to a material to reduce the transfer of heat through radiation as well as conduction. Following is a table of materials, most of which has been used for insulating buildings.

1.3.1. SPRAY POLYURETHANE FOAM (SPF) INSULATION

For large to mid scale applications, a two component mixture comes together at the tip of a gun, and forms an expanding foam that is sprayed onto concrete slabs, into wall cavities of an unfinished wall, against the interior side of sheathing, or through holes drilled in sheathing or drywall into the wall cavity of a finished wall.

ADVANTAGES
- Blocks airflow by expanding and sealing off leaks, gaps and penetrations.
- Can serve as a vapor barrier with a better permeability rating than plastic sheeting vapor barriers and consequently reduce the build up of moisture, which can cause mold growth.
- Can fill wall cavities in finished walls without tearing the walls apart (as required with batts).
- Works well in tight spaces (like loose-fill, but superior).
- Provides acoustical insulation (like loose-fill, but superior).
- Expands while curing, filling bypasses, and providing excellent resistance to air infiltration (unlike fabric batts and blankets, which can leave bypasses and air pockets, and superior to some types of loose-fill. Wet-spray cellulose is comparable.).
- Increases structural stability (unlike loose-fill, similar to wet-spray cellulose).
- Can be used in places where loose-fill cannot, such as between joists and rafters. When used between rafters, the spray foam can cover up the nails protruding from the underside of the sheathing, protecting your head.
- Can be applied in small quantities.
- Generally fireproof, eg cementitious foams.

DISADVANTAGES
- The cost can be high compared to traditional insulation.
- Most of all, with the exception of cementitious foams, release toxic fumes when they burn.
- According to the U.S. Environmental Protection Agency, there is insufficient data to accurately assess the potential for exposures to the toxic and environmentally harmful isocyanates which constitute 50% of the foam material.
- Depending on usage and building codes, most foams require protection with a thermal barrier such as drywall on the interior of a house. For example a 15-minute fire rating may be required.
- Can shrink slightly while curing if not applied on a substrate heated to manufacturer’s recommended temperature.
- Although CFCs are no longer used, many use HCFCs or HFCs as blowing agents. Both are potent greenhouse gases, and HCFCs have some ozone depletion potential.
- Most, such as Polyurethane and Isocyanate insulation, contain hazardous chemicals such as benzene and toluene. These are a potential hazard and environmental concern during raw material production, transport, manufacture, and installation.
- Many foam insulations are made from petrochemicals and may be a concern for those seeking to reduce the use of fossil fuels and oil. However, some foams are becoming available that are made from renewable or recycled sources.
- R-value will diminish slightly with age.
- Most foams require protection from sunlight and solvents.
- It is difficult to retrofit some foams to an existing building structure because of the chemicals and processes involved. If one does not wear a protective mask or goggles, it is possible to temporarily impair one’s vision. (2–5 days).

1.3.2. CLOSED-CELL OVER OPEN-CELL FOAMS
• Open-cell foam is porous, allowing water vapor and liquid water to penetrate the insulation. Closed-cell foam is non-porous, and not moisture-penetrable. (N.b., vapor barriers may be required by the Building Codes)
• Closed-cell foams are superior insulators. While open-cell foams typically have R-values of 3 to 4 per inch (RSI-0.53 to RSI-0.70 per inch), closed-cell foams can attain R-values of 5 to 8 per inch (RSI-0.88 to RSI-1.41 per inch). This is important if space is limited, because it allows a thinner layer of insulation to be used. For example, a 1-inch layer of closed-cell foam provides about the same insulation factor as 2 inches of open-cell foam.
• Closed-cell foam is very strong, and structurally reinforces the insulated surface. By contrast, open-cell foam is soft when cured, with little structural strength.
• Open-cell foam requires trimming after installation, and disposal of the waste material. Unlike open-cell foam, closed-cell foam rarely requires any trimming, with little or no waste.

1.3.3. MINERAL WOOL

There are two basic types of mineral wool insulation:

1.3.3.1. Glass Mineral Wool

Glass mineral wool is made from sand and recycled glass, limestone and soda ash. These are the same ingredients that are used to make familiar glass objects such as window panes or glass bottles. The glass is spun to form millions of fine fibres. A resin is used to bind the fibres together to form a mat of material. The density of the product determines whether the insulation is a lightweight quilt supplied in rolls, a flexible slab or a rigid slab, and it’s thermal insulation value.

CHARACTERISTICS
• Long fibre, giving good tear strength
• Suitable for temperatures up to 230°C
• Non-combustible
• Lightweight
• Available in rolls and slabs

MAIN USES
• Loft Insulation
• Cavity wall insulation
• Sound insulation (absorption) within partitions and floors.

1.3.3.2 Rock Mineral Wool

Rock mineral wool is made mainly from volcanic rock, typically basalt and/or dolomite. An increasing proportion is now recycled material from slag, a waste product from blast furnaces. The materials are melted and then spun into fine fibres. A resin is used to bind the fibres together to form a mat of insulation.

CHARACTERISTICS
• Short fibre - compressive strength
• Suitable for temperatures up to 850°C
• Non-combustible
• Denser than glass mineral wool
• Available in the form of slabs, rolls and mattresses
• High compressive strength.

MAIN USES
• Thermal insulation of flat roofs, rainscreen façades and external wall insulation
• Fire protection, including smoke and fire barriers
• High temperature applications
• Sound insulation for floors and walls.
1.3.4 FOAMED PLASRICS

There are four main types of plastic insulation:
- Extruded polystyrene (XPS)
- Extruded polyethylene (XPE)
- Expanded polystyrene (EPS)
- Polyurethane/Polyisocyanurate (PUR or PIR).

1.3.4.1. Extruded Polystyrene (XPS)

Extruded polystyrene (XPS) is made by mixing polystyrene pellets with various ingredients to liquify them. A blowing agent is then injected into the mixture, to form gas bubbles. Next, the foaming liquid is forced through a shaping die. When cooled, it produces a closed-cell foam that is rigid and moisture resistant.

CHARACTERISTICS
- Lightweight
- Very rigid
- Excellent water resistance
- Suitable for temperatures up to 75°C
- Typically available in 2.4m x 1.2m or 2.4m x 0.6m sheets
- Can be cut to various component shapes and thicknesses.

MAIN USES
- Ground floor
- Flat roofs
- Heavy duty floor insulation
- Panels and other fabrication applications.

1.3.4.2. Extruded Polyethylene (XPE)

Extruded polyethylene (XPE) is made by mixing polyethylene pellets and other ingredients, a blowing agent is injected in liquid form causing a foaming reaction. A conical shaping die is used to shape and form the XPE, producing a material that quickly cools into a flexible, closed cell plastic foam.

CHARACTERISTICS
- Lightweight
- Excellent acoustic properties
- Excellent moisture resistance
- Good compression resistance
- Typically sold in roll form
- Available in cut component rolls

MAIN USES
- Resilient layer in acoustic floors
- Flexible edge strip in screeded floors.

1.3.4.3. Expanded Polystyrene (EPS)

Expanded polystyrene (EPS) is manufactured from small spherical beads of styrene which are pre-expanded with Pentane. The beads then expand to over 40 times their original size when heated by steam. The expanded beads stick
together under heat and pressure inside a mould and the finished product consists of approximately 98% fresh air. Expanded polystyrene is also known as 'bead board'.

CHARACTERISTICS
- White/grey colour
- Lightweight
- Suitable for temperatures up to 75°C
- Mainly available in 2.4m x 1.2m sheets.

MAIN USES
- General/domestic-floor thermal insulation
- Wall insulation

1.3.4.4. Polyurethane (PUR) and Polyisocyanurate (PIR)

Polyurethane (PUR) is produced by blowing a non CFC (chlorofluorocarbon) gas (usually Hydro Carbon Pentane) into urethane resin to produce a free foaming insulation material (the gas used helps to improve the thermal performance of the product, but gradually escapes into the atmosphere over time). For this reason (and to stabilise the foam into boards), polyurethane and polyisocyanurate (PUR) boards are usually faced with aluminium foil. Polyisocyanurate is similar to polyurethane but usually contains long strand glass fibres within the PIR foam core which is formulated to give off less dense smoke in a fire.

CHARACTERISTICS
- Usually faced with aluminium foil or glass tissue
- Lightweight
- Good insulation performance
- Mainly available in board form, but can also be spray applied on site Suitable for temperatures up to 75°C
- Combustible
- Potential loss of thermal performance if there is a reduction in the foil facing emissivity.

MAIN USES
- Flat roofs
- Pitched roofs
- Partial fill cavity wall insulation
- Domestic under-floor insulation
- Foamed composite panels.

COMPARISON OF INSULATION MATERIALS

The table below compares key properties of insulation materials. This is for illustrative purposes only for commonly used applications for each product.

<table>
<thead>
<tr>
<th>Customer requirement</th>
<th>Glass mineral wool</th>
<th>Rock mineral wool</th>
<th>Extruded polystyrene</th>
<th>Expanded polystyrene</th>
<th>PUR and PIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal performance</td>
<td>high</td>
<td>medium</td>
<td>high</td>
<td>high</td>
<td>extra high</td>
</tr>
<tr>
<td>Customer requirement</td>
<td>Glass mineral wool</td>
<td>Rock mineral wool</td>
<td>Extruded polystyrene</td>
<td>Expanded polystyrene</td>
<td>PUR and PIR</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Cost</td>
<td>lower</td>
<td>low</td>
<td>high</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Sound absorption</td>
<td>high</td>
<td>high</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Reaction to Fire</td>
<td>non-combustible</td>
<td>non-combustible</td>
<td>combustible</td>
<td>combustible</td>
<td>combustible</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>low (suitable for some floors)</td>
<td>medium (suitable for all floors)</td>
<td>high (suitable for some floors)</td>
<td>medium (suitable for some floors)</td>
<td>medium (suitable for some floors)</td>
</tr>
<tr>
<td>Water resistance</td>
<td>high</td>
<td>high</td>
<td>very high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Weight</td>
<td>very light - medium</td>
<td>light - heavy</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Warehousing space</td>
<td>very low (8:1 packaged compression)</td>
<td>medium (2.5:1 packaged compression)</td>
<td>medium to high</td>
<td>medium to high</td>
<td>medium to high</td>
</tr>
<tr>
<td>Transport efficiency</td>
<td>very good</td>
<td>good</td>
<td>low</td>
<td>low</td>
<td>medium</td>
</tr>
</tbody>
</table>

1.4. RADIANT BARRIERS

Radiant barriers work in conjunction with an air space to reduce radiant heat transfer across the air space. Radiant or reflective insulation reflects heat instead of either absorbing it or letting it pass through. Radiant barriers are often used in reducing downward heat flow, because upward heat flow tends to be dominated by convection, and are particularly effective in roof insulation. This means that for attics, ceilings, and roofs, they are most effective in hot climates. They also have a role in reducing heat losses in cool climates. However, much greater insulation can be achieved through the addition of bulk insulators.

Some radiant barriers are spectrally selective and will preferentially reduce the flow of infra-red radiation in comparison to other wavelengths. For instance low-emissivity (low-e) windows will transmit light and short-wave infra-red energy into a building but reflect back the long-wave infra-red radiation generated by interior furnishings. Similarly, special heat-reflective paints are able to reflect more heat than visible light, or vice-versa.

Thermal emissivity values reflect the effectiveness of radiant barriers. They can however be difficult to interpret since a film of dirt or moisture can alter the emissivity, and hence the performance of radiant barriers.
Reflective foil insulation mainly resists radiant heat flow due to their high reflectivity and low emissivity (ability to reflect and re-radiate heat). The thermal resistance of reflective insulation products varies with the direction of heat flow and the brightness of the foil facing. Multi foil insulation products work in the same manner as reflective foil products whilst also containing several layers of a metalized component which are usually separated by a combination of wadding and foam.

There are two types of reflective foils:
- Foil faced bubble wrap
- Multi-layered foils.

Reflective foils and multi-layered foils are completely different types of insulation products to mineral wool and rigid plastic foam boards. They work mainly by reducing radiant heat transfer, which is largely dependent on the emissivity of the aluminium foil facing. PUR and PIR rigid board insulation products can also claim additional thermal performance if they are foil faced and the foil is adjacent to an airspace. In order to deliver their maximum thermal performance value, one or both sides of the product should face an unventilated airspace, if this type of product is installed without the required airspace of at least 20mm width, then the thermal performance of the product can be significantly reduced.

1.5.1. Aluminum foil (attached to some sort of backing material or two layers of foil with foam or plastic bubbles in between creating an airspace to reduce convective heat transfer).

The aluminum foil component in reflective insulation will reduce radiant heat transfer by up to 97%. As reflective insulation incorporates an air space to reduce convective heat flow, it carries a measurable R-Value.

- Foil or foil laminates.
- Foil-faced polyurethane or foil-faced polyisocyanurate panels.
- Foil-faced polystyrene. This laminated, high density EPS is more flexible than rigid panels, works as a vapor barrier, and works as a thermal break. Uses include the underside of roof sheathing, ceilings, and on walls. For best results, this should not be used as a cavity fill type insulation.
- Foil-backed bubble pack. This is thin, more flexible than rigid panels, works as a vapor barrier, and resembles plastic bubble wrap with aluminum foil on both sides. Often used on cold pipes, cold ducts, and the underside of roof sheathing.
- Light-colored roof shingles and reflective paint. Often called cool roofs, these help to keep attics cooler in the summer and in hot climates. To maximize radiative cooling at night, they are often chosen to have high thermal emissivity, whereas their low emissivity for the solar spectrum reflects heat during the day.
- Metal roofs; e.g., aluminum or copper.

Materials with one shiny side (such as foil-faced polystyrene) must be positioned with the shiny side facing an air space to be effective. An aluminum foil radiant barrier can be placed either way - the shiny side is created by the rolling mill during the manufacturing process and does not affect the reflectivity of the foil material. As radiant barriers work by reflecting infra-red energy, the aluminum foil would work just the same if both sides were dull.

ADVANTAGES
- Very effective in warmer climates
- No change thermal performance over time due to compaction, disintegration or moisture absorption
- Thin sheets takes up less room than bulk insulation
- Can act as a vapor barrier
- Non-toxic/non-carcinogenic
• Will not mold or mildew

**DISADVANTAGES**
• Must be combined with other types of insulation in very cold climates
• May result in an electrical safety hazard where the foil comes into contact with faulty electrical wiring.

**1.5.2. Insulative paint** is a paint containing ceramic micro-spheres that have the same heat reflective properties. These ceramic micro-spheres, with the consistency of talcum powder, make the paint insulating. Ceramic microspheres were developed by NASA to combat the extremely high temperatures that the space shuttle experiences during reentry. The micro-spheres are hollow, from which all gas has been removed, which creates a vacuum. In effect, they act as miniature thermos bottles.

The **heat insulation** industry refers to a **roof coatings** reflectivity as a ‘TSR’. (Total Solar Reflectivity). The ceramic composition enables the micro-spheres to block heat radiation and dissipate heat rapidly, preventing heat transfer through the coating with 90% of solar infrared radiation and 85% of ultraviolet radiation being radiated back into the atmosphere.

**Comparative examples of traditional colours**, compared to a reflective coating in the same colour. (TSR = Total Solar Reflectivity)

<table>
<thead>
<tr>
<th>Colour</th>
<th>Standard Roof Coating</th>
<th>Heat Reflective Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>15 - 20 % TSR (Worn)</td>
<td>85% TSR</td>
</tr>
<tr>
<td>Chocolate</td>
<td>7 % TSR</td>
<td>27 % TSR</td>
</tr>
<tr>
<td>Dark Green</td>
<td>7% TSR</td>
<td>35% TSR</td>
</tr>
<tr>
<td>Deep Blue</td>
<td>8 % TSR</td>
<td>30% TSR</td>
</tr>
<tr>
<td>Grey</td>
<td>10% TSR</td>
<td>27% TSR</td>
</tr>
</tbody>
</table>

**1.6. VAPOR BARRIERS – VAPOR RETARDERS**

Insulation materials are exposed to rain and humidity. Due to a diffusion process the moisture content of the insulation can increase. High temperatures at high moisture contents lead to a strong increase of the thermal conductivity because of pore diffusion. A **vapor barrier** refers to any material, typically a plastic or foil sheet, that resists diffusion of moisture through wall, ceiling and floor assemblies of buildings. Many of these materials are only **vapor retarders** as they have varying degrees of permeability.

Water vapor moves into building cavities by two mechanisms: diffusion through building materials and by air transport (leakage), which is usually far more significant and problematic. Permeability, rated in perms, is a measure of the rate of transfer of water vapor through a material \((1.0 \text{ US perm} = 1.0 \text{ grain/square-foot-hour-inch of mercury} = 57 \text{ SI perm} = 57 \text{ ng/s-m\(^2\)-Pa})\). Vapor retarding materials are generally categorized as impermeable (≤1 US perm, or ≤57 SI perm), semi-permeable (1-10 US perm, or 57-570 SI perm), and permeable (>10 US perm, or >570 SI perm). Vapor retarders slow the rate of vapor diffusion into the thermal envelope of a structure. Other wetting mechanisms, such as wind-borne rain, capillary wicking of ground moisture, air transport (infiltration), are equally important.

A common vapor barrier material is polyethylene plastic film, typically installed in thicknesses from .002" to .008" (0.05 mm to 0.2 mm). This material is inexpensive, transparent, easy to handle, and is available in wide widths. It can be attached by stapling, mastic, and other means. Vapor barriers can be attached to permeable insulation, such as glass fibre batts or blankets. A vapour barrier on the warm side of the envelope must be combined with a venting path on the cold side of the insulation, because no vapour barrier is perfect.

**Materials used as vapor retarders:**
• Aluminum foil, 0.05 US perm (2.9 SI perm).
• Paper-backed aluminum.
• Advanced Polyethylene vapor retarders that pass the ASTM E 1745 standard tests ≤0.3 US perm (17 SI perm).
• Asphalt-coated kraft paper, often attached to one side of fiberglass batts, 0.40 US perm (22 SI perm).
• Vapor retarder paints (for the air-tight drywall system, for retrofits where finished walls and ceilings will not be replaced, or for dry basements: can break down over time due to being chemically based).
• Extruded polystyrene or foil-faced foam board insulation.
• Exterior grade plywood, 0.70 US perm (40 SI perm).
• Most sheet type monolithic roofing membranes.
• Glass and metal sheets (such as in doors and windows).

1.7. TRANSPARENT INSULATION PROTECTION

Transparent insulation materials (TIMs) are used to replace standard opaque insulation materials. TIM not only performs similar functions to opaque insulation, reducing heat losses and controlling indoor temperatures, but allows solar transmittance of more than 50%. With a thickness of less than 20 cm, it can provide a financial return to building occupants when applied to building facades.

**Transparent thermal insulation** enables the passive use of solar energy on exterior walls. The short wave solar radiation passes through the transparent insulation material and reaches the wall partition behind and heats it up. The long wave radiation emitted from the partition cannot pass through the insulation layer, because the transparent insulation layer is opaque for infrared radiation. The Figure below displays the energy pathways in opaque and transparent insulation constructions in a qualitative manner. Depending on the ambient temperatures, the heated up exterior surface of the wall leads to a reduced transmission loss, or even to a transmission gain through the wall. In both cases the heating energy demand is reduced by the use of the transparent insulation construction. The energy gain per year and square meter area of transparent insulation amounts to 30-120 kWh.

The use of TIM is adequate for retrofitting application, and should best be combined with other measures, as described in Annex 2 which describes the Paul Robenson School in Leipzig case. The reduction in heating energy demand was 67%.

Different materials such as plastics, glass and aerogels have been used to produce TIMs, eg small-celled capillary and honeycomb structures of PMMA, polyethylene (TPX), polytetrafluorethylene (HFL). Could attention needs to be given ventilation requirements.

1.8. ROOF INSULATION

Most roof insulations are made from fiberglass which is laid down between the rafters and allow to retain warmth during cold wintry season inside buildings and to keep them cool during hot summers. The thickness and density of the fibers usually vary according to the manufacturer.
Another advantage secured by a roof insulation is elimination of possible moisture condensation and burst pipes. The maintenance associated with an insulated roof is usually rather simple; vendors themselves provide periodic service in addition to offering warranty periods.

Ceiling (and roof) insulation is usually associated with attic insulation, even if it requires lifting the roof, it may be a deserving task and investment. The benefits can be huge.

- **Insulation roof-ceiling Types**
  In cold climates, the insulation is usually restricted to the ceiling (or attic). In hot and warm climates insulation may also require reflective insulation for the roof (besides ceiling-attic insulation).

- **Types of roofs & Insulation**
  In the case of a pitched roof and an open attic, the insulation should be applied in the attic. Roof or ceiling insulation needs at least a R-45 insulation, (a R-60 isn’t too much). If existing insulation has less, add enough insulation to perform the recommended amounts. The most common solution is to blow enough loose-fill insulation (e.g. fiberglass) into attics and roof cavities.

- **Flat roofs and vaulted ceilings**
  Flat roofs and vaulted ceilings have often a small attic cavity. The new insulation should fill some, or the whole cavity. The small attic cavity limits the amount of insulation may demand high-density insulation material and engender ventilation problems, hard to solve and potentially controversial.

- **Structural approaches in badly designed ceilings and roofs**
  Structural approaches may be necessary to solve poor designs through building a pitched roof over the top of the flat or nearly flat roof, creating a new attic and installing the insulation in it.

- **Recommended R-values**
  Vary with climate. Roughly ranges are as follows:
  - Hot climates: R-19 in ceilings below ventilated attics.
  - Moderate climates: R-30 in ceilings below ventilated attics.
  - Cold climates: R-39 to R-49 in ceilings below ventilated attics.

- **A few checks before the Insulation**
  There is a reasonable chance of existence of asbestos in old attics insulated with vermiculite and perlite materials. Only certified contractors can handle and remove asbestos. In all cases, a general check is recommended:
  - repair roof leaks: check the attic ceiling for water signs, and make repairs.
  - seal air leaks in the attic floor and around ducts and cover openings, or around the chimney and frameings.
  - resistant caulk can seal smaller gaps and holes, and expanding foam or rigid foam larger ones.

- **Roofing Membranes**
  Membrane roofing is a type of roofing system for flat or nearly flat roofs to prevent leaks and move water off the roof. Membrane roofs are most commonly made from synthetic rubber, thermoplastic (PVC or similar material). These types of materials have become the replacement for asphalt roof systems, an older, less effective type of flat roofing system. Membrane roofs are most commonly used in commercial application.

- **Attic Ventilation**
  Attics should remain adequately ventilated. Insulation shouldn’t block vents which ensure removal of moisture in winter and excessive heat in summer.

### 1.9. WINDOW INSULATION

#### 1.9.1 WINDOW INSULATION FILM (PLASTIC FILM)

#### 1.9.1.1 SOLAR CONTROL FILM
This works by reflecting the infra-red component of solar energy (can reach 700W/M²) and absorbing the UV component. Some films are also silvered or tinted to reduce visible light.
Typical absorption for a silvered film is 65% for visible and infra red with 99% for UV. This type of film sticks directly onto the glass.

**1.9.1.2 CONVECTION CONTROL FILM**

This film is attached to the window frame using double sided pressure sensitive tape. The effect is to create a double glazed system with a still air layer about 0.5 inches thick between the film and the glass. This restricts the convective air flow which efficiently transfers heat onto the inside glass surface. Solar control film is an effective way to control excessive sunshine during the summer months.

**1.9.2 DOUBLE GLAZED UNITS (EUROPE TERMINOLOGY) OR IGU (INSULATED GLAZING UNITS, US)**

Due to higher energy costs, three sheets or more, i.e. "triple glazing" is becoming more common. Triple glazing or IGUs (insulated glass units) are manufactured to varying degrees of performance.

Most sealed units achieve maximum insulating values using a gas space of between 5/8 to 3/4” (16–19 mm) when measured at the centre of the IGU. When combined with the thickness of the glass panes being used, this can result in an overall thickness of the IGU of between 7/8 and 1” for 3 mm glass (22–25 mm) up to 1½” (28–31 mm) for 1/4” plate glass.

**1.9.3 LOW-EMISSIVITY GLASS**

Low-emissivity (Low-E) glass has a thin coating, often of metal, on the glass within its airspace that reflects thermal radiation or inhibits its emission reducing heat transfer through the glass.

A basic low-e coating allows solar radiation to pass through into a room. Thus, the coating helps to reduce heat loss but allows the room to be warmed by direct sunshine.

Further solar radiation control can be added through the use of tinted glass and/or metallic coatings. Low-e glass reflects the radiation rather than absorbing it improving performance compared to the glass in a simple greenhouse.

**A special type of low-emissivity coating is spectrally selective.** Spectrally selective coatings filter out 40%–70% of the heat normally transmitted through insulated window glass or glazing, while allowing the full amount of light to be transmitted.

Spectrally selective coatings are optically designed to reflect particular wavelengths but remain transparent to others. Such coatings are commonly used to reflect the infrared (heat) portion of the solar spectrum while admitting a higher portion of visible light. They help create a window with a low U-factor and solar heat gain coefficient but a high visible transmittance.

**There are two types of Low-e glass**

**Hard Coat Low E**, or pyrolytic coating, is a coating applied at high temperatures and is sprayed onto the glass surface during the float glass process.

**ADVANTAGES**
- The advantage is that the coating is relatively durable.
- Can be tempered after coating application.
- Can be used in single glazing applications.
- Utilizes passive solar heat gain.

**DISADVANTAGES**
- Higher U-values compared to soft coat Low-E products
- Slightly higher haze levels
- Higher solar heat gain coefficient compared to soft coat Low-E products.
- Hard coat glass also has the possibility of a slight haze, which can be visible under certain angles.
Soft Coat Low E, or sputter coating, is applied in multiple layers of optically transparent silver sandwiched between layers of metal oxide in a vacuum chamber. This process provides the highest level of performance and a nearly invisible coating.

ADVANTAGES
- High visible light transmission
- Ultra-low emissivity giving optimum winter U-values
- Up to 70% less UV transmission compared with standard clear glazing
- Optical clarity - minimal colour haze

DISADVANTAGES
- Soft coat Low E must be used in a double glazed unit; the soft coating is sensitive to handling.
- Most soft coat Low-E products require tempering the glass prior to the coating application.
- Edge deletion of the coating is required to insure a proper seal in an insulated unit
- There can be slight colour variations of coating.
- Generally speaking, a more expensive alternative than Hard Coat Low e glass.

1.9.4 SEALING WINDOWS

Older premises that still have their original windows often suffer from a significant amount of cold air leaking through old windows during the winter. There are several ways of dealing with this problem that don't involve a lot of time or money.

One option involves using a caulk gun and "weather stripping caulk sealant" or "temporary" caulking to seal up the cracks between the window and window frame. Weather stripping sealant is caulk designed to stick in place nearly as well as regular caulk but can be peeled off when it is no longer needed. It is available inexpensively in regular caulk tubes, and is a clear color. It is nearly invisible when in place and removes easily without damaging either paint. One drawback to temporarily caulking windows is that once the caulk is in place, the window can't be opened without destroying the seal.

Several lightweight plastic, disposable, interior "storm window systems" are also on the market and are effective in keeping out cold drafts and increasing the insulation performance of a window assembly. These kits consist of double-stick tape that is applied to the trim casing around the window, and lightweight plastic sheeting that is pressed onto the tape. Once the plastic is in place, a hair dryer is blown across the surface of the sheeting, causing the plastic to shrink and remove the wrinkles. Like caulking windows shut, this system is best used once.

1.9.5 WINDOW SHUTTERS

Window shutters—both interior and exterior—can help reduce heat gain and loss. Properly designed exterior shutters may provide the best possible window insulation system. They offer several advantages:
- Weather protection
- Added security
- No use of interior space
- No thermal shock to windows if left closed.

Exterior shutters must be integrated into the architecture of the building. Their mounting, drainage, and hinging will require special consideration; it's easier to address these design issues in new construction.

Most exterior shutter systems include a mechanical crank, rod, or motor to allow operation from indoors. Shutters can be inserted between two panes of glass, such as a roll-down curtain or polystyrene beads. The inside side of glass will warm up slightly, thereby reducing window condensation. When the shutter is opened, the window panes will not be subject to thermal shock as both panes are at a temperature close to equilibrium conditions, cold on the outside and warm on the inside. The drawback is required space in wall or ceiling. An insulated shutter with a resistance 2 to 3 times that of a window, eg R5, will reduce substantially the energy loss of that window, particularly at night.
1.9.6 WINDOW BLINDS

Window blinds—vertical or horizontal slat-type—are more effective at reducing summer heat gain than winter heat loss. Highly reflective interior blinds can reduce heat gain by around 45%.

1.8. EXTERNAL WALL INSULATION

An external wall insulation system (or EWIS) is a thermally insulated, protective, decorative exterior cladding system which consists of foamed polystyrene, mineral wool polyurethane foam, and mineral or synthetic plaster.

The thickness of thermal insulation must be at least 10 to 15 centimetres (3.9 to 5.9 in), to create a partition with a heat transmission factor of $U$ value = 0.25-0.3 W/m2K.

Application of thermal insulation 5 centimetres (2.0 in) thick will not improve wall insulation to the valid level. This means that in layer walls with a constant air void 3 to 6 centimetres (1.2 to 2.4 in) thick, standard cavity insulation will be inadequate. In many houses, elements such concrete beams or lintels act as thermal bridges providing poor insulation. Old houses should not have less than 12 centimetres (4.7 in) thick thermal insulation.
II. ENERGY EFFICIENCY OF LIGHTING INSTALLATIONS

1. INDOOR EQUIPMENT

1.1) QUALITY CRITERIA FOR LIGHTING: TRADITIONAL AND NEW CRITERIA

<table>
<thead>
<tr>
<th>Traditional</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonious brightness distribution</td>
<td>Changing lighting situations</td>
</tr>
<tr>
<td>Glare Limitation</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Good modelling- Correct light colour</td>
<td>light as an interior design element</td>
</tr>
<tr>
<td>Sufficient illumination level</td>
<td>Avoidance of reflections</td>
</tr>
<tr>
<td>Avoidance of reflections</td>
<td>Daylight integration</td>
</tr>
<tr>
<td>Appropriate colour rendition</td>
<td></td>
</tr>
</tbody>
</table>

1.2 GENERAL CONSIDERATIONS

Luminous flux
The luminous flux describes the quantity of light emitted by a light source. The luminous efficiency is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a lamp’s economic efficiency.

Luminous intensity
The luminous intensity describes the quantity of light that is radiated in a particular direction. This is a useful measurement for directive lighting elements such as reflectors. It is represented by the luminous intensity distribution curve.

Illuminance describes the quantity of luminous flux falling on a surface. It decreases by the square of the distance (inverse square law). Relevant standards specify the required illuminance (e.g. EN 12464 “Lighting of indoor workplaces”). It can be referred to as the maintenance value of a luminous flux in a unit area, calculated as “Value below which the illumination level must not fall in the visual task area” (Em).

Luminance
The luminance is the only basic lighting parameter that is perceived by the eye. It specifies the brightness of a surface and is essentially dependent on its reflectance (finish and colour).

Measurement standards:
UGR Index: Under the new European standard for interior workplace lighting EN 12464, glare (a light within the field of vision that is brighter than the brightness to which the eyes are adapted) is assessed by the unified glare rating method (UGR). The UGR method takes account of all the luminaires in the system that contribute to the glare sensation as well as the brightness of walls and ceiling. UGR limits (UGRL), that must not be exceeded:
- < / = 16 Technical drawing
- < / = 19 Reading, writing, training, meetings, computer-based work
- < / = 22 Craft and light industries.

Colour rendition is a quantitative measure of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source., according to Index Ra.
Light colour: the light colour describes the colour appearance of the light, ranging from reddish warm, white and bluish colour.

<table>
<thead>
<tr>
<th>Recommended values for PRINTING premises</th>
<th>Em</th>
<th>UGRL</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cutting, gilding, embossing, block engraving, work on stones and platens, printing machines, matrix making</td>
<td>500</td>
<td>19</td>
<td>80</td>
</tr>
<tr>
<td>• Paper sorting and hand printing</td>
<td>500</td>
<td>19</td>
<td>80</td>
</tr>
<tr>
<td>• Type setting, retouching, lithography</td>
<td>1000</td>
<td>19</td>
<td>80</td>
</tr>
<tr>
<td>• Colour inspection in multi-coloured printing</td>
<td>1500</td>
<td>16</td>
<td>90</td>
</tr>
<tr>
<td>• Steel and copper engraving</td>
<td>2000</td>
<td>16</td>
<td>80</td>
</tr>
</tbody>
</table>

1.3. ARGUMENTS FOR REFURBISHING LIGHTING SYSTEMS

Reduced operating costs: Efficiency of the luminaires can be improved from about 35 % to more than 80 %.

<table>
<thead>
<tr>
<th>Energy audit for 58 W fluorescent lamps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp diameter</td>
</tr>
<tr>
<td>Ballast</td>
</tr>
<tr>
<td>Lamp power</td>
</tr>
<tr>
<td>Dissipated power</td>
</tr>
<tr>
<td>Total power</td>
</tr>
<tr>
<td>Extra power consumption</td>
</tr>
</tbody>
</table>

- Savings in lamp replacement costs: The lamp lifetime of fluorescent lamps is extended by more than 50 % when operated with an electronic ballast (to 16,000 – 20,000 h)
- Savings in maintenance costs  
  - No need to buy a starter when using electronic ballasts  
  - Modular design of luminaires and tool-free installation make it easier and cheaper to replace components: no spare-parts problems, so lower maintenance costs (motto: complete refurbishment better than constant repairs).

1.4. RECOMMENDED OPTIONS

High-efficiency lamps, such as **T-5** and **T-8 fluorescent lamps** with electronic ballasts, provide the same or improved illumination as do fixtures with T-12 lamps and magnetic ballasts. Combined with de-lamping and high-efficiency reflectors, retrofit savings can approach a factor of two. Depending on usage patterns, installation costs, and other factors, paybacks for many lighting retrofits are often three years or less. Additional benefits of energy-efficient lighting include lowered cooling costs since less waste heat must be removed by the air conditioning system.

A wide range of **compact fluorescent lighting (CFL)** fixtures are now available whose characteristics are far superior to earlier models. Modern versions typically have zero hum, long-life electronic ballasts, excellent colour rendering, are four times more efficient than the incandescent ones, a lifetime of up to 10,000 hours, and bulk prices of less than $3 apiece. Since a CFL outlasts a typical incandescent by a factor of 10 or more, their upfront costs are now about the same. Lifetime savings of a 25-watt CFL over a 100-watt incandescent is 750 kWh - and maintenance costs are reduced as well. The ENERGY STAR program lists over 1,400 CFL bulbs that are “qualified” as high-performance by their criteria (which include lifetime, efficiency, and surface temperature limits), as well as about 10 percent of that number that have been deemed “unqualified.” These are shown by manufacturer and model number at [www.energystar.gov/ia/products/prod_lists/cfl_prod_list.pdf](http://www.energystar.gov/ia/products/prod_lists/cfl_prod_list.pdf).

Light emitting diodes (LEDs) last a long time (ten years or more) and are quite energy efficient. Accordingly, they are ideal for use in exit signs. Since exit signs operate for 8,766 hours in an average year, efficiency improvements can result in substantial savings. Old-style exit signs used 40 watts of power and bulbs had to be replaced often.
ENERGY STAR qualified exit signs use less than five watts per face; over 500 that meet this criterion are listed at [www.energystar.gov/ia/products/prod_lists/exit_signs_prod_list.pdf](http://www.energystar.gov/ia/products/prod_lists/exit_signs_prod_list.pdf).

In general, lighting distribution is more efficient and visually comfortable in **light-coloured spaces**, especially those in which the ceilings are white. This applies across a wide range of buildings from chicken coops and schools to offices and industrial facilities. In each of these cases, lighting quality improvements by the addition of white paint are frequently accompanied by improved productivity.

### 1.5. LIGHT CONTROL EQUIPMENT

Whenever feasible, retrofit lighting design strategies should be combined with **daylighting controls** to maximize energy efficiency. Such controls may locate a sensor outside to measure the amount of light entering spaces through windows or skylights, or be placed above the work plane to dim electric lights in response to the amount of natural light falling on key surfaces. Furthermore, a task/ambient lighting design strategy that provides an appropriate level of general light and task-level light where it is needed reduces the overall electricity load required for lighting. Good designs also enhance working and learning environments.

The ability to **control the daylight entering a building** is critical to a daylighting design's success. Studies show that school classrooms with skylights designed with manually-operated internal louvers result in a dramatic increase in student performance. At the same time, it is important to minimize glare caused by uncontrolled daylighting. Daylight tends to penetrate from a window into an interior space about 1.5 times the head height of the window.

Older industrial facilities often incorporate rooftop windows, either vertical or at an angle to the vertical, in a saw-tooth fashion. Sometimes these windows can be opened to enhance ventilation, but their main function is to supply natural light. Oftentimes, they perform this function too well, allowing direct beam sunlight to fall on work spaces below where they cause unwanted glare and produce harsh shadows. One solution is to redirect sunlight up on a light-coloured ceiling as illustrated below.

**Occupancy** sensors are electronic devices that detect the presence of people. They turn on lights or associated equipment such as computer monitors or copiers when people are detected, and turn things off if no people are detected after a programmable period of time, typically 5 to 15 minutes. Their sensitivities and areas of coverage may be adjusted to a degree, dependent upon on the technology used by the sensor, its location, and control settings.

Ultrasound sensors are quite sensitive and react to small motions. They are sensitive over large areas, but are subject to false triggering. Passive infrared sensors are less susceptible to false triggering, but their sensitivity drops off with the square of the distance. Some dual technology systems are available that incorporate the virtues of both technologies, but they are somewhat more expensive. In general, ultrasound occupancy sensors are best used in large areas, infrared in smaller areas.

Mounting occupancy sensors toward the tops of walls is best for smaller spaces like offices, copy rooms, and bathrooms. Ceiling-mounted sensors are best for larger open spaces.

In recent years, the quality and performance of occupancy sensors has become higher while costs have come down. Accordingly, for many applications they can save substantial energy and are quite cost-effective. The trick is to match the right sensor to the right circumstance to maximize energy saving performance while minimizing people hassle and cost. This is a judgment call that is a strong function of the patterns of the people that are using a given space. This is why potential energy savings for various kinds of spaces has such a broad range, as illustrated in the following table.

<table>
<thead>
<tr>
<th>TYPE OF SPACE</th>
<th>RANGE OF ENERGY SAVINGS FROM OCCUPANCY SENSORS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private office</td>
<td>13 - 50</td>
</tr>
<tr>
<td>Open-plan office</td>
<td>20 - 28</td>
</tr>
</tbody>
</table>
**Task Lighting:** Common incandescent or halogen bulbs vary in energy use from 40 W to 200 W and will also contribute heat gain to the building. These bulbs should be replaced by compact fluorescent lamps (CFLs). CFLs provide a similar quality of light, use much less energy and operate cooler than incandescent and halogen lamps. CFLs last up to 10,000 hours compared to 1000 hours for normal incandescent bulbs. CFLs can save 47% in task lighting energy use with a simple payback of 2 to 3 years, not including the greater life of the CFLs. CFLs fit into most existing fixtures so replacement of the fixtures is not necessary.

### 1.6. ESSENTIAL REQUIREMENTS FOR LIGHT CONTROL SYSTEMS

- Generalization statements on savings potential in lighting management is quite hazardous.
- Selecting the right light source is a major requirement, influencing the W/m² ratio.
- **Presence detectors** for switch off:
  - Savings in small offices +/- 50%
  - In open space offices 10/20%
- **Daylight sensors** can dim down slowly and switch off lights
  - In single person offices, daylight control saves +/-50%
  - In open plan offices, sophisticated daylight control saves +/-60%, depending on factors such as window configuration, room depth etc, and will be most significant in summer.
- **Situational control** systems allow for an individual user to select a lighting level adapted to his own requirements, eg sitting in the middle part. In small offices, savings will be +/-30% mainly in winter time.
- **Some positive contribution** can be expected from motion sensors or look-down sensors inside the premises.

### 1.7 PERFORMANCE “KILLERS”

- Room geometry, orientation, window system, furniture, type of profession, working hours regulations, meeting and holiday replacement habits, overall quality of the lighting system, accessibility of the controllers as well as working climate are all influencing the saving results. These “soft factors” are difficult to determine properly.
- Insufficient automated glare control on blind systems and resulting risk of manually closed blinds can result in 50% increase of energy use.
- Poor design of light control systems, eg linear sum of presence-, daylight- and situational savings is not allowed.
- Performance assessment should be measured after a first full year of operation of control systems.

### 2. OUTDOOR EQUIPMENT

**SELECTION CRITERIA**

Light fixtures should comply with following criteria:

- Restrict upwards wasteful light shining and use a high quality PIR (passive infrared) to reduce power consumption
- Use CFL compact fluorescent power saving bulbs
- Reduce painful glare & dazzle
- Reduce light spilling into neighbouring properties
- Be durable.
The use of high efficiency low energy lighting controlled by a photo-electric cell (dusk to dawn switch) is recommended. Such low wattage lighting, on permanently during the hours of darkness, provides an adequate level of illumination, is not as harsh and is more environmentally friendly than tungsten halogen floodlights. In cost terms, the low wattage ensures that even though the light is on all night, the cost to run is minimal.
Information here below is an introduction on major parameters and modern options recommended for commercial or industrial premises, but is however not an exhaustive list of all existing heating systems. It does not cover the traditional warm water heating systems, which were the standard in past years.

A few starting hints, if you own the building...

- Start by buying the best “Energy Star-rated” (official efficiency rating standard) system for your building. Bigger isn’t necessarily better—be sure to choose the system that best fits your specific conditions.
- Consider buying systems that include outside air economizers, which bring in cooler outside air when the temperature inside is warmer. These systems are especially good for offices with non-operable windows and are an excellent way to “flush” clean, cool air through a building in the early morning hours, before the heat—and the office workers—arrive.
- HVAC systems (i.e., Heat/Ventilation/Air conditioning, details page ...) providing timer-based thermostats that can be programmed to turn down the system when no one is in the building.
- Be sure the building is well-insulated.
- Solar shading can be achieved by using roof coatings, window shades and awnings, and planting trees and vegetation that keep the heat out.

If you lease the building...

- Be sure to monitor the efficiency of your HVAC system and report any inadequate functioning promptly.
- Make sure office personnel understand the proper operation of the HVAC system and train everyone to turn the system off when not needed.
- Adjust the temperature settings. Changing the temperature by even one or two degrees can yield savings of up to 3% of your energy costs. Install dialogue with your staff on this subject.

<table>
<thead>
<tr>
<th>Old, low-efficiency heating systems:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Natural draft that creates a flow of combustion gases</td>
</tr>
<tr>
<td>• Continuous pilot light</td>
</tr>
<tr>
<td>• Heavy heat exchanger</td>
</tr>
<tr>
<td>• 68%–72% AFUE (defined page 25).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mid-efficiency heating systems:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Exhaust fan that controls better the flow of combustion air and combustion gases</td>
</tr>
<tr>
<td>• Electronic ignition (no pilot light)</td>
</tr>
<tr>
<td>• Compact size and lighter weight to reduce cycling losses</td>
</tr>
<tr>
<td>• Small-diameter flue pipe</td>
</tr>
<tr>
<td>• 80%–83% AFUE.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High-efficiency heating systems:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Condensing flue gases in a second heat exchanger for extra efficiency</td>
</tr>
<tr>
<td>• Sealed combustion</td>
</tr>
<tr>
<td>• 90%–97% AFUE.</td>
</tr>
</tbody>
</table>
Heating control probably accounts on the average for 40% of office premises total energy use. The opportunity for big savings can be found in "heating, ventilation and air conditioning" (HVAC) systems, even for businesses that do not own the buildings and are limited in the scope of changes within their control. (See relevant heading).

1) EFFICIENCY RATING OF FURNACES AND BOILERS

A central furnace or boiler's efficiency is measured by its "annual fuel utilization efficiency" (AFUE). Specifically, AFUE is the ratio of heat output of the furnace or boiler compared to the total energy consumed by a furnace or boiler. An AFUE of 90% means that 90% of the energy in the fuel becomes heat and the other 10% escapes up the chimney and elsewhere. AFUE doesn't include the heat losses of the piping system or, which can be as much as 35% of the energy for output of the furnace when inadequately handled.

An all-electric furnace or boiler has no flue loss through a chimney. The AFUE rating for an all-electric furnace or boiler is between 95% and 100%. However, despite their high efficiency, the higher cost of electricity makes all-electric furnaces or boilers an uneconomic choice. If electric heating is preferred, a heat pump system should be considered.

The minimum allowed AFUE rating for a non-condensing fossil-fired, warm-air furnace is 78%; the minimum rating for a fossil-fired boiler is 80%; and the minimum rating for a gas-fired steam boiler is 75%. A condensing furnace or boiler condenses the water vapour produced in the combustion process and uses the heat from this condensation.

The AFUE rating for a condensing unit can be much higher (by more than 10 percentage points) than a non-condensing furnace. Although condensing units cost more than non-condensing units, the condensing unit can save you money in fuel costs over the 15- to 20-year life of the unit, and is a particularly wise investment in cold climates.

New furnaces are between 78% AFUE and 96% AFUE. Traditional "power combustion" furnaces are 80-82% AFUE. Above 90% AFUE, a furnace is "condensing," which means it recaptures some of the heat wasted in traditional systems by condensing escaping water vapour. Consider the following when selecting a new furnace.

Condensing furnaces, when appropriate to industrial buildings, achieve the highest performance and are strongly recommended, except in a warm climate. Retrofitting existing system with a heat pump can be considered. There are however many feasibility/appropriateness factors to be considered, which can only be analysed on a case by case basis. Among barriers to greater penetration of condensing boilers, the technical suitability ranks high. Only a small fraction of buildings (across housing, commercial or offices buildings) is appropriate for conversion to condensing boilers. Many buildings in each of these sectors will have one-pipe steam systems that cannot be economically converted to 2-pipe hot water systems. As steam systems, they do not have an adequate heat sink to condense flue gases. Many of the 2-pipe systems would require extensive reworking, at high cost, to use condensing boilers. Unless the distribution system can return low-temperature (<120°F or 39°C) water to the boiler, there will not be enough condensing of flue gases to warrant using a condensing boiler.

Calculating the payback period is a two-step process:

1. Determine the potential annual cost savings for each furnace, using this formula: (A - B) X C = Annual Savings in your currency, where A = Seasonal efficiency (AFUE) of the proposed furnace, B = Seasonal efficiency (AFUE) of the existing furnace and C = Projected energy cost.
2. Divide the annual savings into the total cost of the furnace to obtain the payback period.

2) HOT AIR /RADIATION WARMING SYSTEMS

Industrial buildings heating systems with special focus on reducing energy consumption, should consider two options: warm air heating units and/or radiant heating systems.
2.1 **Warm Air central heating** systems, also referred to as **forced air heating systems**, will provide quick warm up times to comfort levels. Warm air is introduced into the room via discreet registers or diffusers. Modern warm air heaters with electronic controls provide stable room temperatures, excellent comfort conditions and greater fuel efficiency. This is combined with smooth, quiet operation. In hot air mechanism, the hot air more lightweight than the cold air, tends to go up, without heating people. The main benefits are better air conditioning effect and up to 15-20% energy saving.

2.2 **Radiation heating** has an opposite behavior: heats directly the static bodies and as it goes down, it heats first the objects and the people. This situation helps to save energy up to 40 – 50% in favorable cases. However differences are not significant for very low rooms but they can be significant for very high rooms.

Radiant heating works in a similar way as the sun heats the earth; it exudes heat across a room to warm the occupants and objects, rather than the air itself. As experts, we would recommend radiant heating for well ventilated areas of open space – specifically that of a large industrial building or facility.

The heat energy is emitted from a warm element, such as a floor, wall or overhead panel. It warms people and other objects in rooms rather than directly heating the air. It exudes heat across a room to warm the occupants and objects, rather than the air itself. Experts would recommend radiant heating for well ventilated areas of open space – specifically of a large industrial building or facility.

When heat is transferred by radiation, the heated waves of energy will travel from one object to another through the atmosphere. When the heated energy comes into contact with an object (human or material), it will heat it up, making the object itself act as a secondary heater to gradually raise the temperature of the room. Due to the method the radiant heating system uses, it is very useful for buildings which have large open spaces and a lot of natural ventilation. Typically, this type of heating unit is seen in factories, warehouses and industrial building environments, where the shop doors are opened on a regular basis.

The radiant heating systems can be divided into:
- Underfloor heating systems
- Wall heating systems
- Radiant ceiling panels

Underfloor and wall heating systems often are be called low-temperature systems. Since their heating surface is much larger than with other systems, a much lower temperature is required to achieve the same level of heat transfer. The maximum temperature of the heating surface can vary from 29–35 °C (84–95 °F) depending on the room type. Radiant overhead panels are mostly used in production and warehousing facilities or sports centers; they hang a few meters above the floor and their surface temperature is much higher.

Best appropriate solutions need to be identified on a case by case basis.

3) **HEAT PUMPS (AIR SOURCE HEAT PUMP / GROUND SOURCE HEAT PUMP)**

The two main types of heat pumps are compression heat pumps and absorption heat pumps. Compression heat pumps always operate on mechanical energy (through electricity), while absorption heat pumps may also run on heat as an energy source (through electricity or burnable fuels).

A number of sources can be used as heat source for heating private and communal buildings.

- air source heat pump (extracts heat from outside air)
  - air–air heat pump (transfers heat to inside air)
  - air–water heat pump (transfers heat to a tank of water)
- geothermal heat pump (extracts heat from the ground or similar sources)
  - geothermal–air heat pump (transfers heat to inside air)
    - ground–air heat pump (ground as a source of heat)
    - rock–air heat pump (rock as a source of heat)
    - water–air heat pump (body of water as a source of heat)
- geothermal–water heat pump (transfers heat to a tank of water)
  - ground–water heat pump (ground as a source of heat)
  - rock–water heat pump (rock as a source of heat)
  - water–water heat pump (body of water as a source of heat).

Most commonly, heat pumps draw heat from the air (outside or inside air) or from the ground (groundwater or soil). The heat drawn from the ground is in most cases stored solar heat, and it should not be confused with geothermal heat, though the latter will contribute in some small measure to all heat in the ground. Other heat sources include water; nearby streams and other natural water bodies have been used, and sometimes domestic waste water which is often warmer than the ambient temperature.

When comparing the performance of heat pumps, the term coefficient of performance (COP) is used to describe the ratio of useful heat movement to work input.

When used for heating a building on a mild day, a typical air-source heat pump has a COP of 3 to 4, whereas a typical electric resistance heater has a COP of 1.0. (That is, one joule of electrical energy will cause a resistance heater to produce one joule of useful heat, while under ideal conditions, one joule of electrical energy can cause a heat pump to move much more than one joule of heat from a cooler place to a warmer place.)

Air-source heat pumps are relatively easy (and inexpensive) to install and have therefore historically been the most widely used heat pump type. However, they suffer limitations due to their use of the outside air as a heat source or sink. The higher temperature differential during periods of extreme cold or heat leads to declining efficiency, as explained above. In mild weather, COP may be around 4.0, while at temperatures below around −8°C (17°F) an air-source heat pump can achieve a COP of 2.5 or better, which is considerably more than the COP that may be achieved by conventional heating systems. The average COP over seasonal variation is typically 2.5-2.8

Ground source heat pumps, (which are also confusingly referred to as Geothermal heat pumps), typically have higher efficiencies than air-source heat pumps. This is because they draw heat from the ground or groundwater which is at a relatively constant temperature all year round below a depth of about eight feet (2.5 m). This means that the temperature differential is lower, leading to higher efficiency. Ground-source heat pumps typically have COPs of 3.5-4.0 at the beginning of the heating season, with lower COPs as heat is drawn from the ground. The tradeoff for this improved performance is that a ground-source heat pump is more expensive to install due to the need for the digging of wells or trenches in which to place the pipes that carry the heat exchange fluid. When compared versus each other, groundwater heat pumps are generally more efficient than heat pumps using heat from the soil.

The operating costs of an earth-energy system are usually considerably lower than those of other heating systems, because of the savings in fuel. Qualified heat pump installers should be able to give you information on how much electricity a particular earth-energy system would use. However, the relative savings will depend on whether you are currently using electricity, oil or natural gas, and on the relative costs of different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, your operating costs may be higher. The payback on an investment in an earth-energy system may be anywhere up to a decade or more.

4) SOLAR THERMAL ENERGY – SOLAR AIR PANELS

Solar thermal energy (STE) is a technology transforming solar energy into thermal energy. Cells called "photovoltaic", "PV" or "photoelectric" cells) convert light into electricity. The electricity produced has to be converted from direct current to alternating current by means of an electronic inverter. The PV solar collectors' lifespan is estimated at around 30 years.
Solar thermal collectors are classified (according to US Energy Information Administration) as low-, medium-, or high-temperature collectors. Low temperature collectors are flat plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat plates but are used for heating water or air for residential and commercial use. High temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production. The two main types of solar air panels are glazed and unglazed. Solar cells are often electrically connected as a module, creating an additive voltage.

Glazed Solar Collectors are designed for space heating and they recirculate building air through a solar air panel where the air is heated and then directed back into the building. The sheet of glass on the front (sun up) side, allows light to pass while protecting the semiconductor wafers from abrasion and impact due to wind-driven debris, rain etc.

Unglazed Solar Collectors are primarily used to preheat make-up ventilation air in commercial, industrial and institutional buildings with a high ventilation load. Also called, "transpired solar panels", employ a painted perforated metal solar heat absorber. Heat conducts from the absorber surface to the thermal boundary layer of air 1 mm thick on the outside of the absorber and to air that passes behind the absorber. The heated air is then drawn from behind the absorber plate into the building's ventilation system.

UTC are perforated sun-facing walls used for preheating ventilation air; they can raise the incoming air temperature up to 22 °C and deliver outlet temperatures of 45-60 °C. The short payback period of transpired collectors (3 to 12 years) make them a more cost-effective alternative to glazed collection systems.

The efficiency of a solar cell may be broken down into reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of each of these individual efficiencies. Due to the difficulty in measuring these parameters, efficiency is often measured as “quantum efficiency” or “integrated quantum efficiency” which also takes losses into consideration.

Different materials display different efficiencies and have different costs. Materials for efficient solar cells must have characteristics matched to the spectrum of available light. Some cells are designed to efficiently convert wavelengths of solar light that reach the earth surface. However, some solar cells are optimized for light absorption beyond earth’s atmosphere as well. Light absorbing materials can often be used in multiple physical configurations to take advantage of different light absorption and charge separation mechanisms. Materials presently used for photovoltaic solar cells include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide.

By far, the most prevalent bulk material for solar cells is crystalline silicon (abbreviated as a group as c-Si). Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon, or wafer.

1. **Monocrystalline silicon** (c-Si): Single-crystal wafer cells tend to be expensive, and because they are cut from cylindrical ingots, do not completely cover a square solar cell module without a substantial waste of refined silicon. Hence most c-Si panels have uncovered gaps at the four corners of the cells.
2. **Poly- or multicrystalline silicon** (poly-Si or mc-Si): made from cast square ingots — large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient.
3. **Ribbon silicon** is a type of multicrystalline silicon: it is formed by drawing flat thin films from molten silicon and results in a multicrystalline structure. These cells have lower efficiencies than poly-Si, but save on production costs due to a great reduction in silicon waste.
But what do solar panels cost? How much power do they generate? What's the "payback time"? Under the following link (http://www.talksolarpanels.co.uk/) it is possible to access a calculation system.

5) HVAC (HEATING, VENTILATION, AIR CONDITIONING) COMBINED SYSTEM

HVAC system is a major sub-discipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. It is thereby a comprehensive approach to indoor comfort. A HVAC control system is a computerized control system for climate control in buildings. Stand alone control devices may be pneumatic or electronic. Some may have microprocessors, a "control system" has computerized and networking functions. Often, these integrate fire, security, and lighting controls into one system.

For very small buildings, suppliers normally "size" and select adequate HVAC systems and equipment. For larger buildings, building services designers and engineers, such as mechanical, architectural, or building services engineers analyze, design, and specify adequate HVAC systems. Building permits and compliance inspections of the installations are normally required for all sizes of buildings.

These systems typically use one or more central controllers to command and monitor the remote terminal unit controllers, and they communicate with one or more personal computers that are used as the operator interface. These control systems are typically used on large commercial and industrial buildings to allow central control of many HVAC units around the building(s).

Energy efficiency can be improved even more in central heating systems by introducing zoned heating. This allows a more modular approach to heat. Zones are controlled by multiple thermostats. In water heating systems the thermostats control zone valves, and in forced air systems they control zone dampers inside the vents which selectively block the flow of air. In this case, the control system is very critical to maintain a proper temperature.

Basic principles for potential improvements:
- Indirect/direct evaporative cooling uses the physics of water evaporation to cool with reduced levels of compressor cooling, which is an energy intensive process. Evaporative coolers can save 60-80% of the cooling energy for spaces such as classrooms. In addition to saving energy, direct evaporative coolers also add needed moisture to the conditioned air.

Ventilation Energy recovery:
- Energy recovery systems sometimes utilize heat recovery ventilation or energy recovery ventilation systems that employ heat exchangers or enthalpy wheels to recover sensible or latent heat from exhausted air. This is done by transfer of energy to the incoming outside fresh air.
- Air conditioning energy:
  The performance of vapor compression refrigeration cycles is limited by thermodynamics principles. Traditional air conditioning and heat pump devices move heat rather than convert it from one form to another.

Example of Check List for a maximum efficiency of HVAC systems:
- Downsize to a new high-efficiency chiller.
- Choose high-efficiency packaged A/C units as listed in Energy Efficiency guidelines.
- Switch over to direct digital controls.
- Install variable air volume air handling systems with variable speed drives.
- Install premium-efficiency motors.
- Install demand-controlled ventilation.
- Ventilate garages in response to environmental conditions.
- Upgrade the energy management system; optimize settings to reflect usage, respond to changing weather patterns, and control peak electric loads.
- Verify economizer function and control.
- Consider using cool air from the cooling tower with water-cooled chillers.
- Consider indirect-direct evaporative cooling.

6) WATER HEATING

Heating water accounts for about 9% of an office energy load. Like the HVAC system, much of the adjustments here will need to be made by the building’s owner.

- Buy a water heater that is appropriately sized for the facility—large, home-sized tanks are usually unnecessary. Tankless systems are optimal but they can be pricey. Re-set the temperature to 120 degrees maximum.
- Use low-flow fixtures and install aerators on all faucets. Consider installing a solar pre-heating collector which will cut energy costs by as much as one-half. And though toilets do not require heated water, installing low-water units can save a bundle since flushing accounts for one-third of all water use in U.S. buildings.
- Outside, be sure to employ watering controls for landscaping, and use native plants as much as possible to reduce watering needs.
- Fix all leaks promptly.

Low flow shower heads and faucet aerators can save very substantial amounts of both water and energy. In order to ensure acceptance by users and long life, high-quality devices should be selected. Shower heads including user selectable spray patterns usually satisfy most users and can save substantial spray of water per minute of shower. Under moderate to heavy use, paybacks for installing low-flow devices are frequently only a month or two. In high water-using facilities, installing gray (or waste) water heat recovery equipment can save 60 percent or more of the water-heating energy. Systems serving fixtures on upper floors need no pumps and little or no maintenance. For below-grade applications, systems with demand-operated pumps are available. Where there is less simultaneous hot water drain and supply flow (as in laundries), gray water heat-recovery systems with heat storage can be installed. Heat storage systems require more space, as well as regular inspection and cleaning, but they can be very cost-effective. Depending on the end use and the installation, heat recovery efficiencies of up to 82 percent can be achieved. Efficient solar thermal energy solutions for water heating exist as well.

7) HEAT RECOVERY – HEAT EXCHANGERS

There are areas in such buildings as hospitals, zoned as "once-through" systems, in which the air that heats, cools, and ventilates is used only once. However, much of this HVAC energy can be recovered before it exits the building by installing heat-recovery coils in the exhaust air handlers. This heat can then be used to precondition the outside air coming into the building. Energy can be recovered without risk of contamination.

When a solid, liquid or gas has to be heated up or cooled down a heat exchanger is used, where a hot fluid (e.g. hot water or steam) is used to heat a cooler fluid. The two fluids will be separated by some physical barrier such as a tube wall or a metal plate. The aim of a heat exchanger designer is to make sure that the area of the tube walls or metal plate is large enough for the required amount of heat to be transferred from the hot fluid to the cold fluid.

Waste heat recovery on boiler stacks can be used to preheat boiler makeup water, thereby improving overall energy efficiency quite substantially. Heat recovery from stacks in heat treating furnaces is frequently used to preheat combustion air, thereby achieving savings of well over 50%.

Air-to-air heat exchangers are widely used in processes which require heating materials to high temperatures over long periods of time. Instead of allowing the hot combustion air to be vented directly to exhaust stacks, heat exchangers...
recover as much as 80% or more of the heat from the exhaust stream and use it to pre-heat combustion air. This can save well over half of the primary energy used in such facilities.

Other examples of the use of heat exchangers include:
- Condensing steam from a boiler to produce hot water for service hot water or other processes;
- Isolating two systems operating at different pressures while extracting heat from the higher temperature system;
- Moving heat or cool in various refrigerator cycles that may include changing of state from liquids to gases in the heat exchanger;
- Moving heat into and out of thermal storage containers.

The subject is quite complex and individual solutions have to be adapted to specific requirements. They can include also air to water, water to water systems.

8) COMBINED HEAT AND POWER (CHP) - COMMERCIAL/INDUSTRIAL BUILDINGS

A cogeneration plant, also known as Combined Heat and Power (CHP) plant, is an energy production installation that simultaneously generates thermal energy and electrical and/or mechanical energy from a single input of fuel. CHP refers to generating electricity at/near the building where it is used, and then "recycling" the waste heat and using it for space heating, water heating, process steam for industrial steam loads, humidity control, air conditioning, water cooling, product drying, or for nearly any other thermal energy need. The end result is significantly more efficient than generating cooling, heating, and power separately.

The heat from most conventional large-scale power plants is wasted. This is because electricity can be sent over long distances but the heat cannot. And since power plants are typically located far from population centres and far from buildings that could beneficially use the heat, that thermal energy is instead just vented to the surrounding environment.

On the other hand, small-size power plants can be located close to or even within facilities which can make good use of the heat resulting from electricity generation, thereby raising the net efficiency of generating electricity by a factor of two or more and saving substantial energy and money. Hospitals, commercial buildings, and industrial facilities can often take advantage of combined heat and power (CHP) systems.

To make them most economical and practical, CHP systems need to have a relatively high and constant thermal load so it can match the heat output of the generation process. In addition to supplying heat for eg hot water, low pressure steam for heating, and some industrial needs, CHP systems can also supply cooling energy via absorption chilling equipment.

There are Small-scale CHP installations are based on packaged units, with a spark ignition gas reciprocating engine as prime mover. The engine is used to drive an electrical generator, usually synchronous, with heat being recovered from the exhaust and cooling systems. Packaged reciprocating engine CHP units are typically in the range of 50 kWe to 800 kWe output.

Note: A watt is a unit of energy. A watt-hour is a unit of power (total energy produced or consumed). KWH is a larger unit of power (1,000 watts - one hour). The unit kWe represents electrical power produced or consumed (or transmitted kWt). Therefore the power installation can be rated both in kWe or kWt for different purposes. Source(s):

The range of CHP available for buildings is:
- Micro CHP (up to 5 kWe)
- Small scale (below 2 MWe) (Spark Ignition engines, micro-turbines (30-100 kWe), small scale gas turbines (500kWe)
- Large scale (above 2 MWe): Large reciprocating engines, large gas turbines.

CHP - Key facts
- It is on-site electricity generation with heat recovery
• Most appropriate sites have a year round heat demand, CHP is economic if it runs for more than 5,000 hours/year
• An independent feasibility study is essential, based on reliable demand profiles
• CHP should always be the lead ‘boiler’
• Economics improves if used as standby generation
• Sizing somewhat above the base heat load usually provides the best economics, however oversizing CHP can lead to excessive heat dumping which destroys the economics.

9) BUILDING COMMISSIONING

Commissioning a building, either when new or after a major retrofit, is the process of testing all elements of a building's energy and mechanical systems to ensure that they are adjusted properly and functioning optimally. Suppliers of services and equipment should be tasked with providing commissioning services as a condition of the purchase agreements. One important element of the commissioning process is to ensure that the building's maintenance staff is fully trained to understand, test, and maintain the equipment, including the consequences of interaction between systems.

Continuous commissioning is a maintenance function through which all critical elements of a building's energy and mechanical systems are routinely monitored for proper adjustment and functioning. The idea is to enhance preventative maintenance chores and solve difficulties before they become real problems. Key elements of a successful continuous commissioning process are the output of the energy management system, regularly inspected energy bills, and a knowledgeable and dedicated maintenance staff. Following benefits can be mentioned:

- Improved building system control;
- Increased energy efficiency;
- Improved building equipment performance;
- Improved indoor air quality, occupant comfort, and productivity;
- Decreased potential for owner liability;
- Reduced operation and maintenance costs.
1. ESCOS – ENERGY SERVICE COMPANY

An energy service company (acronym: ESCO or ESCo) is a professional business providing a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management. The ESCO performs an in-depth analysis of the property, designs an energy efficient solution, installs the required elements, and maintains the system to ensure energy savings during the payback period. The savings in energy costs is often used to pay back the capital investment of the project over a five- to twenty-year period, or reinvested into the building to allow for capital upgrades that may otherwise be unfeasible. If the project does not provide returns on the investment, the ESCO is often responsible to pay the difference.

Developing an energy saving project

The energy savings project usually begins with the development of ideas that would generate energy savings, and in turn, cost savings. This task is usually the responsibility of the ESCO. Once the owner is aware of the possibility of an energy savings project, he or she may chose to place it out for bid, or just stick with the original ESCO.

During the initial period of research and investigation, an energy auditor from the ESCO tours the site and reviews the project’s systems to determine areas where cost savings are feasible, usually free of charge to the client. This is the energy audit, and the phase is referred to as the feasibility study. A hypothesis of the potential project is developed by the client and the auditor, and then passed onto the ESCO’s engineering development team to expand upon and compile solutions.

This next phase is referred to as the engineering and design phase, which further defines the project and can provide more firm cost estimates. The engineers are responsible for creating cost-effective measures to obtain the highest potential of energy savings. These measures can range from highly efficient lighting and heating/air conditioning upgrades, to more productive motors with variable speed drives and centralized energy management systems. There is a wide array of measures that can produce large energy savings.

Once the project has been developed and a performance contract signed, the construction or implementation phase begins. The monitoring, maintenance or measurement, and verification (M & V) phase begins. This phase is the verification of pre-construction calculations, and is used to determine the actual cost savings. The owner should consider three options during the performance contract review. These options range from least to most expensive ones:

- No warranty other than that provided on the equipment
- ESCO provided M & V to show the projected energy savings during the short term following completion
- ESCO provided M & V to show the projected energy savings during the entire payback period.

A typical contract can involve that the ESCO borrows cash to purchase equipment or to implement energy-savings for its clients. The client pays the ESCO its regular energy cost (or a large fraction of it), but the energy savings enable the ESCO to pay only a fraction of the amount to their energy supplier. The difference is affected to defined needs, which can be the payment of interests due on a loan, or to profit. Typically, ESCOs are able to implement and finance the efficiency improvements better than their client company could do by itself.
2. BUILDING ENERGY MANAGEMENT SYSTEMS (BEMS)

BEMS are generally applied to the control of systems such as heating, ventilation, and air-conditioning (HVAC). It uses software to control energy-consuming plant and equipment, and can monitor and report on the plant’s performance. The performance of the BEMS is directly related to the amount of energy consumed in the buildings and the comfort of the building’s occupants. BEMS generally comprise:

- controllers, sensors (temperature, humidity, luminance, presence…) and actuators (valves, switches…) for different types of parameters;
- HVAC central system with local controllers for each area or room, and central computer assisted control;
- central control management software for areas or rooms;
- monitoring through energy consumption measurement devices.

According to scientific experiences energy saving through a BEMS can reach at least 10 % of the whole energy consumption.

ISO 50001:2011 establishes a framework to manage energy for industrial and commercial plants, state owned buildings. Targeting broad applicability across national economic sectors, it is estimated that the standard could influence up to 60 % of the world’s energy use. ISO 50001:2011 specifies requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance.

3. SMART GRIDS

A Smart grid is a type of electrical grid which attempts to predict and intelligently respond to the behavior and actions from all electric power users connected to it - suppliers, consumers, in order to efficiently deliver reliable, economic, and sustainable electricity services.

A smart grid delivers electricity from suppliers to consumers using two-way digital technology to control the energy use of appliances, reduce cost and increase reliability and transparency. A smart grid is an umbrella term that covers modernization of both transmission and distribution grids. The goals include facilitating greater competition between providers, enabling greater use of variable energy sources.

Information provided should make it possible for energy suppliers to charge variable electric rates so that charges would reflect the large differences in cost of generating electricity during peak or off-peak periods. Such capabilities allow control switches to control large energy consuming devices, such as hot water heaters so that they consume electricity when it is cheaper to produce. To reduce demand during the high cost peak periods, communication and metering technologies inform smart devices installed in the premises, tracking how much electricity is used and when it is used.

On the basis of this information, customers should shift usage to off-peak hours, and perform what is called peak curtailment or peak levelling. Prices for electricity are then increased during high demand periods, and decreased during low demand periods. When consumers see a direct economic benefit of not having to pay double price for the same energy use, they will try to become more energy efficient; they will include energy cost requirements in their building construction/renovation decisions.

Thanks to smart grid planning, the amount of reserve that electric utilities have to keep on stand-by should be reduced via the use of automatically generated load curve data.

4. OVERVIEW OF SOME RESULTS OF PRELIMINARY AUDITS AND PAYBACK PERIODS

Industrial buildings have high thermal loads, high air-change rates, long operating hours and significant pollution control requirements. The information hereafter (link listed at the end of the document) presents the results of preliminary
audits carried out on a sample of 12 representative small business enterprises in Greece. Energy intensity varied from 50 to over 300 kWh/m², and with heavier industry buildings having values up to 1300 kWh/m².

The successful adoption of energy conservation measures in key energy waste areas was assessed, including: (1) building envelope, (2) artificial lighting, (3) heating, ventilating and air conditioning (HVAC) and refrigeration systems, (4) space and water heating, (5) electrical and mechanical equipment and (6) distribution and transportation. It was found that businesses had particular interest in energy conservation in the area of air conditioning followed by electromechanical equipment.

Retrofitting measures in relation with space heating, hot water production, cooling systems, lighting, and other equipment lead to the following conclusions: Regarding heating, energy consumption in isolated buildings is 20% lower than in non-isolated ones, and it was estimated that payback was about 6-8 years. Installing double glazing and reducing thermal bridges led to some 6.1% reduction (payback 4-7 years); improving the efficiency in heat production and distribution led to 10%. In warm climate conditions, proper shading can reduce cooling energy by 30%.

The UK Carbon Trust did similar investigations, and their conclusions appear on the enclosed table.

\[\text{CONFIDENTIAL DRAFT}\]

**Most measures pay back in <2 years, cost £3,000**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Median Initial Cost</th>
<th>Median Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon &amp; energy management</td>
<td>£500</td>
<td>2.0</td>
</tr>
<tr>
<td>Building construction &amp; fabric</td>
<td>£5,000</td>
<td>1.0</td>
</tr>
<tr>
<td>Controls &amp; operations</td>
<td>£2,200</td>
<td>1.2</td>
</tr>
<tr>
<td>Office equipment</td>
<td>£100</td>
<td>1.6</td>
</tr>
<tr>
<td>HVAC</td>
<td>£1,500</td>
<td>1.3</td>
</tr>
<tr>
<td>Lighting</td>
<td>£2,000</td>
<td>1.3</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>£22,000</td>
<td>4.4</td>
</tr>
<tr>
<td>CHP</td>
<td>£65,000</td>
<td></td>
</tr>
<tr>
<td>Motors</td>
<td>£3,470</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>£1,500</td>
<td>1.7</td>
</tr>
<tr>
<td>Waste</td>
<td>£500</td>
<td>0.7</td>
</tr>
<tr>
<td>Other*</td>
<td>£56,500</td>
<td></td>
</tr>
</tbody>
</table>

Source: Carbon Trust analysis

IRR: Internal rate of return
CHP: Combined heat and power.

Carbon Trust is a not-for-profit company providing specialist support to help business and the public sector boost business returns by cutting carbon emissions, saving energy and commercialising low carbon technologies.
1. SOME FIRST-AID RECOMMENDATIONS...

Low/moderate Cost Measures

- Replace incandescent light bulbs with compact fluorescent bulbs (CFLs).
- Install power strips to shuts off the power use of appliances that occurs even when they are switched off.
- Install ceiling fans and other fans to circulate air in the building.
- Insulate your water heater and hot water pipes.
- Replace furnace, air conditioner, and heat pump filters regularly.
- Install or replace weather stripping around windows and doors.
- Install storm windows.
- Install low-flow showerheads and release control valves (US faucet) to reduce use of hot water and repair leaky faucets.
- Install an ENERGY STAR equipment.
- Install dimmers and motion sensors on lights where possible to control electricity use.

Higher-Cost Measures

- Hire a qualified company to conduct an energy audit of the building.
- Weatherize and insulate the building.
- Replace old appliances with ENERGY STAR appliances.
- Replace individual air conditioner units with evaporative coolers, attic fans, or whole-house fans, if adequate for your activity.
- Replace old heating units and water heaters with high-efficiency systems.
- Install awnings, tinted window film, and roof cover options to reduce the heat gain of the building.

Equipment Measures

The label ENERGY STAR, available for energy-efficient office equipment, covers a wide range of products from simple scanners to complete desktop home computer systems. The requirements and specifications of a product to be labelled can be found at www.eu-energystar.org.

A product-comparison tool is available that allows the user to select the most energy-efficient equipment. For instance, it can be seen that depending on the choice of monitor, the power consumption varies from 12W to 50W. In this case the energy consumption in ‘on’ mode can be reduced by ~75%.
## 2. R-VALUES

per inch (1) given in SI (International System of measurement units) and Imperial units (British measurement units)

(See pages 7 to 12)

<table>
<thead>
<tr>
<th>Material</th>
<th>$m^2 \cdot K/(W \cdot \text{in})$</th>
<th>$ft^2 \cdot ^\circ \text{F} \cdot \text{h}/(\text{BTU} \cdot \text{in})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum insulated panel</td>
<td>5.28–8.8</td>
<td>R-30–R-50</td>
</tr>
<tr>
<td>Silica aerogel</td>
<td>1.76</td>
<td>R-10</td>
</tr>
<tr>
<td>Polyurethane rigid panel (CFC/HCFC expanded) initial</td>
<td>1.23–1.41</td>
<td>R-7–R-8</td>
</tr>
<tr>
<td>Polyurethane rigid panel (CFC/HCFC expanded) aged 5–10 years</td>
<td>1.10</td>
<td>R-6-R-8</td>
</tr>
<tr>
<td>Polyurethane rigid panel (pentane expanded) initial</td>
<td>1.20</td>
<td>R-6.8</td>
</tr>
<tr>
<td>Polyurethane rigid panel (pentane expanded) aged 5–10 years</td>
<td>0.97</td>
<td>R-5.5</td>
</tr>
<tr>
<td>Foil faced Polyurethane rigid panel (pentane expanded)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foil faced polyisocyanurate rigid panel (pentane expanded) initial</td>
<td>1.20</td>
<td>R-6.8</td>
</tr>
<tr>
<td>Foil-faced polyisocyanurate rigid panel (pentane expanded) aged 5–10 years</td>
<td>0.97</td>
<td>R-5.5</td>
</tr>
<tr>
<td>Polyisocyanurate spray foam</td>
<td>0.76–1.46</td>
<td>R-4.3–R-8.3</td>
</tr>
<tr>
<td>Closed-cell polyurethane spray foam</td>
<td>0.97–1.14</td>
<td>R-5.5–R-6.5</td>
</tr>
<tr>
<td>Phenolic spray foam</td>
<td>0.85–1.23</td>
<td>R-4.8–R-7</td>
</tr>
<tr>
<td>Thinsulate clothing insulation</td>
<td>1.01</td>
<td>R-5.75</td>
</tr>
<tr>
<td>Urea-formaldehyde panels</td>
<td>0.88–1.06</td>
<td>R-5–R-6</td>
</tr>
<tr>
<td>Urea foam</td>
<td>0.92</td>
<td>R-5.25</td>
</tr>
<tr>
<td>Extruded expanded polystyrene (XPS) high-density</td>
<td>0.88–0.95</td>
<td>R-5–R-5.4</td>
</tr>
<tr>
<td>Polystyrene board</td>
<td>0.88</td>
<td>R-5.00</td>
</tr>
<tr>
<td>Phenolic rigid panel</td>
<td>0.70–0.88</td>
<td>R-4–R-5</td>
</tr>
<tr>
<td>Urea-formaldehyde foam</td>
<td>0.70–0.81</td>
<td>R-4–R-4.6</td>
</tr>
<tr>
<td>High-density fiberglass batts</td>
<td>0.63–0.88</td>
<td>R-3.6–R-5</td>
</tr>
<tr>
<td>Extruded expanded polystyrene (XPS) low-density</td>
<td>0.63–0.82</td>
<td>R-3.6–R-4.7</td>
</tr>
<tr>
<td>Icynene loose-fill (pour fill)</td>
<td>0.70</td>
<td>R-4</td>
</tr>
<tr>
<td>Molded expanded polystyrene (EPS) high-density</td>
<td>0.70</td>
<td>R-4.2</td>
</tr>
<tr>
<td>Air-entrained concrete</td>
<td>0.69</td>
<td>R-3.90</td>
</tr>
<tr>
<td>Home Foam</td>
<td>0.69</td>
<td>R-3.9</td>
</tr>
<tr>
<td>Fiberglass batts</td>
<td>0.55–0.76</td>
<td>R-3.1–R-4.3</td>
</tr>
<tr>
<td>Cotton batts (Blue Jean insulation)</td>
<td>0.65</td>
<td>R-3.7</td>
</tr>
<tr>
<td>Molded expanded polystyrene (EPS) low-density</td>
<td>0.65</td>
<td>R-3.85</td>
</tr>
<tr>
<td>Material</td>
<td>R-value</td>
<td>Notes</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Icynene spray</td>
<td>0.63</td>
<td>R-3.6</td>
</tr>
<tr>
<td>Open-cell polyurethane spray foam</td>
<td>0.63</td>
<td>R-3.6</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0.52–0.7</td>
<td>R-3–R-4</td>
</tr>
<tr>
<td>Rock and slag wool batts</td>
<td>0.52–0.68</td>
<td>R-3–R-3.85</td>
</tr>
<tr>
<td>Cellulose loose-fill</td>
<td>0.52–0.67</td>
<td>R-3–R-3.8</td>
</tr>
<tr>
<td>Cellulose wet-spray</td>
<td>0.52–0.67</td>
<td>R-3–R-3.8</td>
</tr>
<tr>
<td>Rock and slag wool loose-fill</td>
<td>0.44–0.65</td>
<td>R-2.5–R-3.7</td>
</tr>
<tr>
<td>Fiberglass loose-fill</td>
<td>0.44–0.65</td>
<td>R-2.5–R-3.7</td>
</tr>
<tr>
<td>Polyethylene foam</td>
<td>0.52</td>
<td>R-3</td>
</tr>
<tr>
<td>Cementitious foam</td>
<td>0.35–0.69</td>
<td>R-2–R-3.9</td>
</tr>
<tr>
<td>Perlite loose-fill</td>
<td>0.48</td>
<td>R-2.7</td>
</tr>
<tr>
<td>Wood panels, such as sheathing</td>
<td>0.44</td>
<td>R-2.5</td>
</tr>
<tr>
<td>Fiberglass rigid panel</td>
<td>0.44</td>
<td>R-2.5</td>
</tr>
<tr>
<td>Vermiculite loose-fill</td>
<td>0.38–0.42</td>
<td>R-2.13–R-2.4</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>0.38</td>
<td>R-2.13</td>
</tr>
<tr>
<td>Straw bale</td>
<td>0.26</td>
<td>R-1.45</td>
</tr>
<tr>
<td>Softwood (most)</td>
<td>0.25</td>
<td>R-1.41</td>
</tr>
<tr>
<td>Wood chips and other loose-fill wood products</td>
<td>0.18</td>
<td>R-1</td>
</tr>
<tr>
<td>Snow</td>
<td>0.18</td>
<td>R-1</td>
</tr>
<tr>
<td>Hardwood (most)</td>
<td>0.12</td>
<td>R-0.71</td>
</tr>
<tr>
<td>Brick</td>
<td>0.030</td>
<td>R-0.2</td>
</tr>
<tr>
<td>Glass</td>
<td>0.025</td>
<td>R-0.14</td>
</tr>
<tr>
<td>Poured concrete</td>
<td>0.014</td>
<td>R-0.08</td>
</tr>
</tbody>
</table>

Inch = 2.54 centimeters (or 1 centimeter = 0.3937 international inches.)
1. OFFICE EQUIPMENT

Objectives can be up to reduce PC energy by 40%. PCs and monitors use almost three quarters the energy of all office equipment. In cases where the majority of PCs and monitors are left switch on overnight and at weekends, on a mandatory basis, a 40% reduction in energy consumption is achievable with PC and laptop power management software.

2. INDUSTRIAL EQUIPMENT

The technical options available for energy savings in the industrial sector are as diverse as the industries themselves. However, they principally revolve around the saving of energy in areas such as:

- Electric Motors
2.1 Energy Savings and Electric Motors

Electric motors usually account for almost half of total industry energy consumption, and represent a significant opportunity for financial savings from energy consumption. Four areas offer potential savings with regard to the selection and operation of electric motors:

- energy efficient motors
- variable speed drives
- correctly size motors
- regular maintenance.

Energy Efficient Motors

By definition, one motor will be more efficient than another motor if it uses less energy to produce the same rated output. Most energy efficient motors are usually constructed with higher quality materials and advanced manufacturing techniques and result in less waste energy being produced through reduced vibration, noise and heat. Some countries have adopted minimum energy performance standards for new electric motors, many others have developed standards, which motors must meet in order to be sold as energy efficient motors. These regulatory measures offer the potential for long-term savings, although are unlikely to result in wide scale energy reductions in the short term as they are rarely retroactive, relating only to future purchases, which may be made five to ten years in the future.

Variable Speed Drives

Electric motors, which are able to operate at different speeds according to the amount of power supplied to the drive unit, are known by a variety of terms including, Variable or Adjustable Speed Drives and Adjustable or Variable Frequency Drives, as well as inverters (although not all inverters are variable speed drives). Variable speed drives are ideal for situations where a motor, or the device the motor drives, does not operate at full capacity during its entire operation, for example fans and pumps in HVAC systems and distribution systems in processes. In these situations, the variable flow rate of the fluid (i.e. air, water, acid etc.), is often obtained by physically restricting the system to achieve the lower flow rate, or installing vanes and throttles. Variable speed drives allow the speed of the drive, and hence the flow rate of the fluid, to be reduced by decreasing the amount of power supplied through the use of power control units. The main advantage of these drives is when the speed of the fluid fluctuates between low and high flow rates. For example the flow rate of conditioned air in a temperature controlled building, a smaller amount of power can be used to drive the unit, as compared to single speed drives.

Correctly Sized Motors

In many applications, the speed of a device powered by an electric motor is relatively constant. In these situations, high efficiency single speed motors are ideal as they are usually more efficient near the rated load of a motor than variable speed drives. However, careful attention should be paid to ensuring that the motor is not significantly oversized given the usual load. As with applications where the load fluctuates, motors, which are operated at less than full load, are operating far less efficiently than those at or near the rated load.

Maintenance of Electric Motors

As with other pieces of capital, electric motors and the devices they drive should be regularly serviced and maintained, in order to:

- ensure components are clean and free from dust and oil,
- operating at peak performance as compared to the manufacturers specifications,
- identify areas of wear or damage degrading the performance of the motor,
- increase the operating life of the motor.
SOURCES OF INFORMATION

ON HEATING:
http://aboutenergysaving.com/reduce-the-energy-consumption-for-industrial-buildings-heating/
http://www.coloradoefficiencyguide.com/measures/motors.htm
More on HVAC: http://www.fsec.ucf.edu/En/consumer/buildings/commercial/hvac.htm
http://files.harc.edu/Sites/GulfCoastCHP/ProjectDevelopment/UKGoodPracticeGuide.pdf
http://www.darvill.clara.net/alternerg/solar.htm

ON LIGHTING:
http://www.coloradoefficiencyguide.com/measures/lighting.htm
http://www.zumtobel.co.uk/download/ilr_cp_TheLightingHandbook.pdf
http://www.lightinglab.fi/IEAAnnex45/meetings/0404helsinki/Werner.pdf
http://www.fsec.ucf.edu/En/consumer/buildings/commercial/index.htm

ON INSULATION:
http://en.wikipedia.org/wiki/Building_insulation_materials
Insulation materials chart: http://www.energysavingtrust.org.uk/Publication-Download/?p=1&pid=239
http://knaufinsulation.co.uk/selfbuildinsulationcom/types_of_insulation.aspx
http://www.energybooks.com/Toc.htm
http://www.house-power.com/blog/318/roof-insulation-different-options-to-choose/
http://en.wikipedia.org/wiki/Energy_service_company#The_beginning

ON ENERGY MANAGEMENT:
http://www.carbontrust.co.uk/Pages/Default.aspx
http://sustainablebusinessforum.com/rodtrent/51594/europe-s-energy-efficiency-economy
2.2 Printing Equipment related information: Compressed Air energy consumption issues