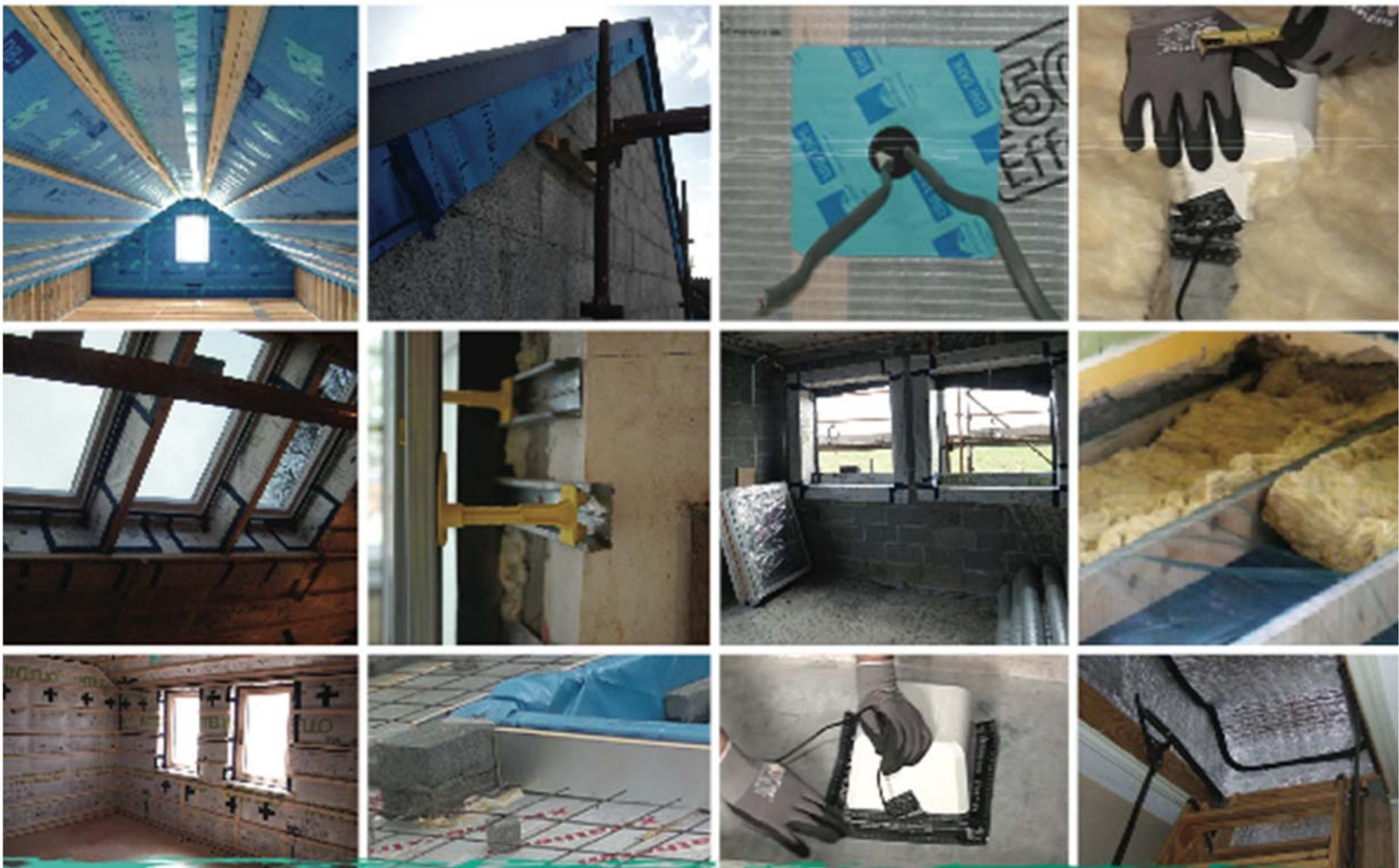
This course contains 6 Units

U1 U2 U3 U4 U5 U6

CERTIFICATE IN

Introduction to Low Energy Building Construction



Learners Handbook

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Co-funded by the Intelligent Energy Europe Programme of the European Union

Edition 2 - 14/07/16

Table of Contents

Introduction

Welcome to the Foundation Energy Skills programme (known as FES) for building construction workers or BCWs. This learner handbook is designed to give you all the information that you will need to complete the course successfully. It also provides links to further information that you may find useful when working on low energy buildings.

No matter how good we are at our job or how much information we have, we can always learn a little bit more. This course is aimed at all building trades –both craft workers and operatives in the construction sector. The principle reasons for doing the course are so that:

- Everyone has the same understanding of what is involved in creating a low energy quality building
- Everyone understands the contribution which they can make to such a building
- Everyone understands the impact of their work on everyone else who is trying to create a low energy building

In 2013, QualiBuild, an EU funded project under the Build UP Skills Ireland (BUSI II), was established. This project aims to help the construction sector respond to the new demands arising from EU's actions regarding energy use and, in particular, the energy efficiency of buildings. One of the key elements of the project is the development of a short training course for all construction sector workers to help them understand what makes a building energy efficient.

There are a lot of new Building Regulations and associated standards now in operation, which means that some changes are needed in how buildings are constructed. This is going to mean that you may have to make some changes in the ways in which you have worked in the past. An understanding of where these requests are coming from will make it easier for you to make the changes being asked of you.

Course Overview

This course will give you an idea of the background to the issues of energy efficiency and quality in buildings as well as good ways of achieving energy efficient, high-quality buildings. It will also help you to think about the ways in which you currently work and any changes which *you* might need to make yourself in the ways you carry out this work.

This course will introduce you to a variety of ideas which are important in the development of low-energy quality buildings. As a building construction worker, you have a very important role to play with respect to many of these.

This handbook will take you through the what, the how and the why of low energy buildings. To do this, the information follows a sequence with the following important ideas – note the sequence.

- Climate change, policies and regulations – The why
- Energy use in buildings – The what
- Nearly Zero Energy Buildings (NZEB) - The target
- Working together on site to make it happen – The how

It will examine some low energy building principles and help you to understand what you need to know and how you need to work on site to achieve a building built to a high energy efficient standard.

Have a look at the following phrases in the **Wheel of Key Words for Quality**. They all play their part in creating Low Energy Quality Buildings. You will be introduced to them all and will keep coming across them throughout the course. If you take the time to learn about these phrases before you start the classes/workshops, it will make the course much easier. You can read a little more about each concept later on in this handbook.

Figure 1: Wheel of Key Words for Quality

How the Course is Organised

The course is organised over 3 days including a demonstration day. An alternative approach will consist of 4 evening sessions and a demonstration day.

The course is divided into 6 units with 2 units being covered each day or one unit being covered per evening, depending on whether it is a daytime or evening delivery.

Each Unit of the course is equivalent to a session, which is approximately 3.5 hours long. Each unit covers topics which will progressively improve your understanding of low energy buildings Look at the Course Structure diagram Figure 2 which gives a breakdown of each unit and the topics to be covered during the course.

The following diagram (Figure 2) sets out the course structure -

Figure 2: Course structure and layout

You will notice that the course is divided into six units with a number of related topics covered in each unit.

Learning Outcomes for the FES Course

Learning Outcomes is an idea which you will come across throughout the course. Learning outcomes are the knowledge or skills which you should have developed by the end of the course and which are written down and agreed.

Learning outcomes are used by trainers and students so that everybody is clear on what the training is trying to achieve. You can use the learning outcomes to ask yourself whether the training is achieving for you what it is intended to achieve and to take action if it isn't.

These are the learning outcomes for this course.

On completion of this Course you will/should be able to:

1. List and describe the key policies and laws which are creating the requirement for low energy buildings.
2. Explain the key energy terms and measurement units associated with low energy buildings.
3. List and describe the key principles of the techniques for new build and renovation works which will produce low-energy buildings. These principles include insulation, air-tightness, ventilation and detailing to achieve healthy buildings.
4. Identify best practice in a number of common construction methods relevant to low-energy buildings and be able to recognise work practices which fall below this standard.
5. Understand why there is need to talk with other construction workers in order to produce low-energy buildings and be able have such discussions.
6. Describe some key challenges of implementing low energy high quality building projects and how to apply specific solutions to meet those challenges.

You should try to understand what these mean but, even if you are a little unsure, they will be introduced and explained during the course.

Tips for Using the FES Course Learners Handbook

We recommend the following:

- Work through the units in order, as you need to learn some things in one part before you start the next part.
- Complete the activities and self-tests as you go along.
- Take note of key points and summaries. These are designed to help you to remember important information.
- A list of abbreviations is provided at the start of the Handbook and a list of definitions at the end. You can use these to check on terms you are not familiar with.

If something is unclear make a note of it, so that you can discuss it with your tutor in the classroom and at workshops. The course is designed in this way to help you as much as possible.

List of Symbols

The following symbols are used to highlight sections of this handbook. The symbols will help you to know what you are looking at in the handbook

Learning outcomes

These are included at the beginning of each Unit

Key learning point

Highlighting main points in text

Activity

Where you are asked to complete an activity

Self-Test

These are provided throughout the handbook so you can see how you are getting on

Summary

At the end of each topic summing up the main points

Useful Links

You don't have to use these but they are there in case you are interested in finding out a bit more.

Finally a reminder of the reasons for the FES course

There are good logical reasons behind the development and delivery of this course. The reasons are all related to the reduction of the amount of energy we use in our buildings. The following diagram, Figure 3, sets out these reasons and the way they are related.

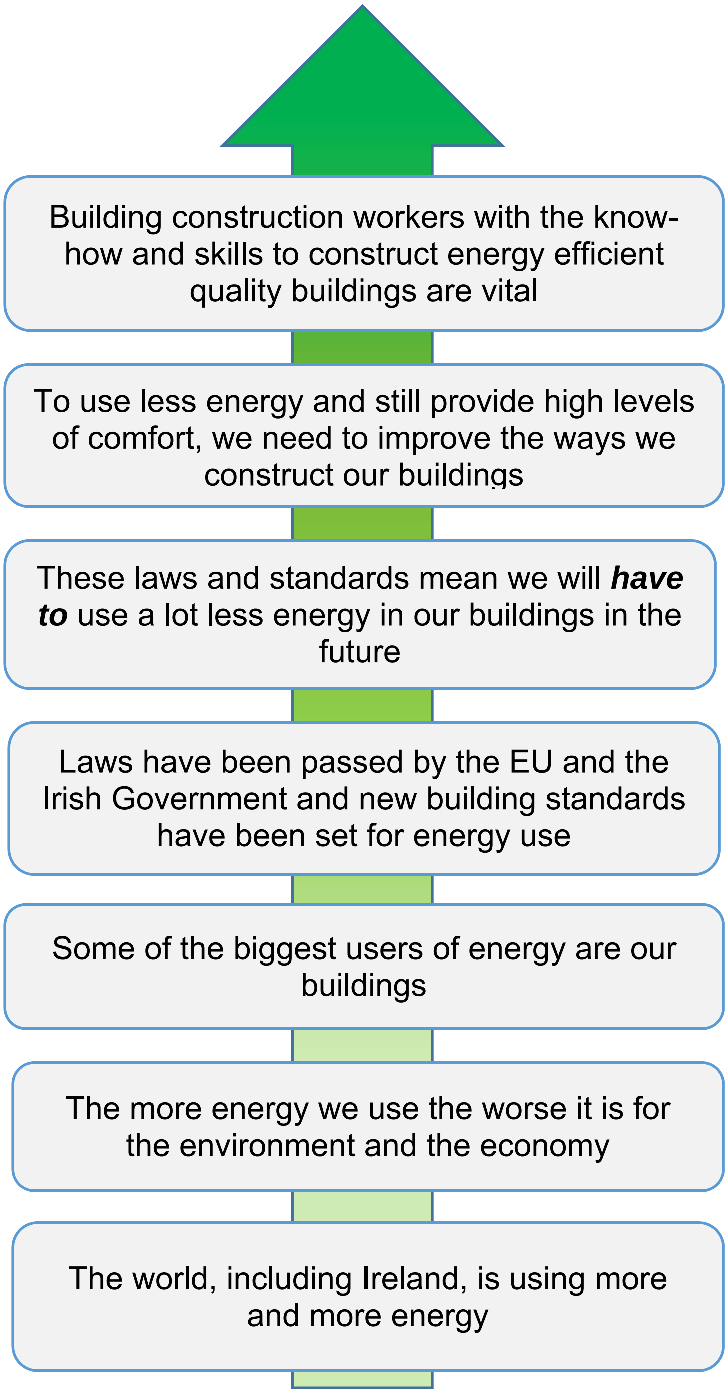


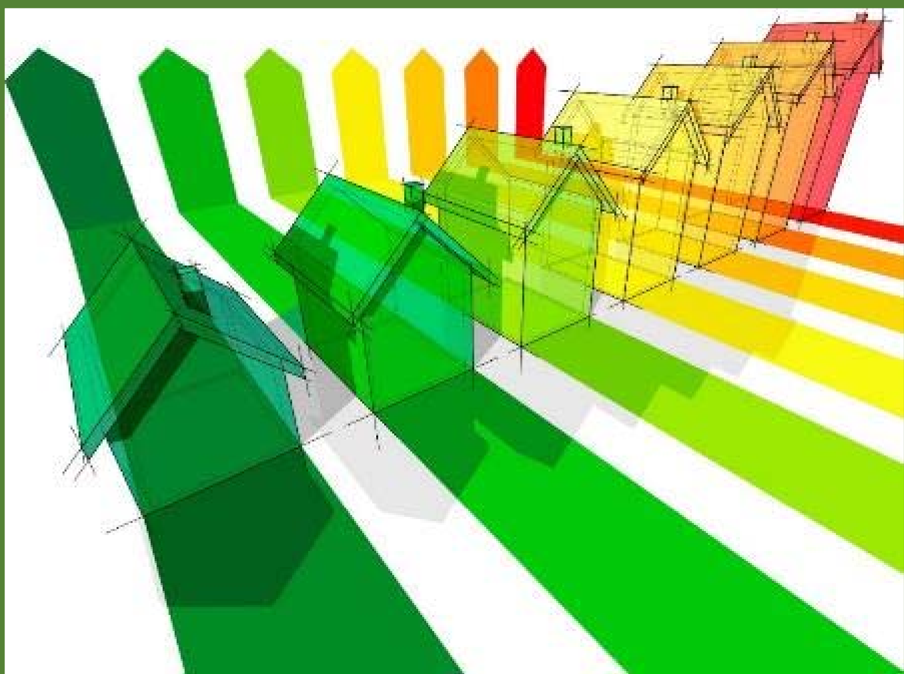
Figure 3: The reasons for the FES Course

List of Abbreviations

As you probably know already, abbreviations are part and parcel of the construction industry. They can drive you mad at times. This list is not something that you need to learn off by heart but it is useful to have available in case you come across abbreviations with which you are not familiar.

ACD	Acceptable Construction Details
BCW	Building Construction Workers
BER	Building Energy Rating
BUSI	Build Up Skills Ireland
CIBSE	Chartered Institution of Building Services Engineers
DCENR	Department of Communications, Energy and Natural Resources
DEAP	Dwelling Energy Assessment Procedure
DECLG	Department of the Environment, Community and Local Government
EC	European Commission
EU	European Union
EPBD	Energy Performance of Buildings Directive
ESD	Energy Services Directive
FEC	Final Energy Consumption
FES	Foundation Energy Skills
GHG	Green House Gases
KWh	Kilowatt Hour
NSAI	National Standards Authority of Ireland
NZEB	Nearly Zero Energy Buildings
PV	Photovoltaic
QQI	Quality and Qualifications Ireland
RES	Renewable Energy Sources
SEAI	Sustainable Energy Authority Ireland
SME	Small and Medium Enterprise
TGD	Technical Guidance Documents

Unit 1



Energy and Buildings

Unit 1: Energy and Buildings

Why is there such a focus now, on the energy performance of buildings?

Well, the short answer is that, buildings happen to use, and in many instances also waste, a lot of energy. Energy resources such as fossil fuels (oil, coal and gas for example) are becoming increasingly scarce and expensive. It is now also generally accepted that the gases from the burning of fossil fuels (particularly carbon dioxide or CO_2) contribute to global warming and changes in weather patterns, often resulting in extreme events such as hurricanes, floods and droughts.

In Europe, buildings account for almost 40% of energy use which releases large amounts of CO_2 to the atmosphere. Since 2002, the EU has introduced energy policies to make sure that countries become more energy efficient and increase the use of renewable energy sources such as wind, solar energy and bio-mass.

Unit Overview

Unit 1 provides the background to the move towards low energy buildings. This includes an overview of how energy is used in the different sectors and within buildings, the key terms used and the climate change and EU policies that are driving Irish building standards.

Energy Use in Buildings

This topic explores how energy is used in buildings and, most importantly, how the construction of buildings - new or retrofit - can assist in the significant reduction in energy consumption. It also examines what causes energy usage and loss within the building and how this affects the lives of people.

The Language of Low Energy

Outlines key terms within the energy and construction sector.

Climate Change, Regulations and Rules

Provides a brief summary of energy policy and legislation at EU and national level, in particular where they relate to energy and buildings.

Learning Outcomes

The successful completion of this unit will **help you to**:

- List and describe important terms and definitions associated with low energy buildings and the construction sector.
- Outline the factors affecting energy use in buildings and how these affect the comfort levels of the occupant and the building.
- Identify the main EU energy policies which have resulted in significant changes to Irish Building Regulations since 1997.

Energy use in different Sectors

Energy is needed for many reasons such as; to produce goods, feed ourselves, to keep warm and to travel in cars and public transport. In Ireland the energy used by Residential buildings alone is 23% and although a significant proportion of energy use within the Services and Industry sectors are not related to buildings, e.g. industrial processes, a significant percentage could be associated with energy use in buildings. Refer to Figure 1.1 below. The EU figure for energy use in residential and non-residential buildings in Europe is approximately 40% and the figures presented in Ireland are similar.

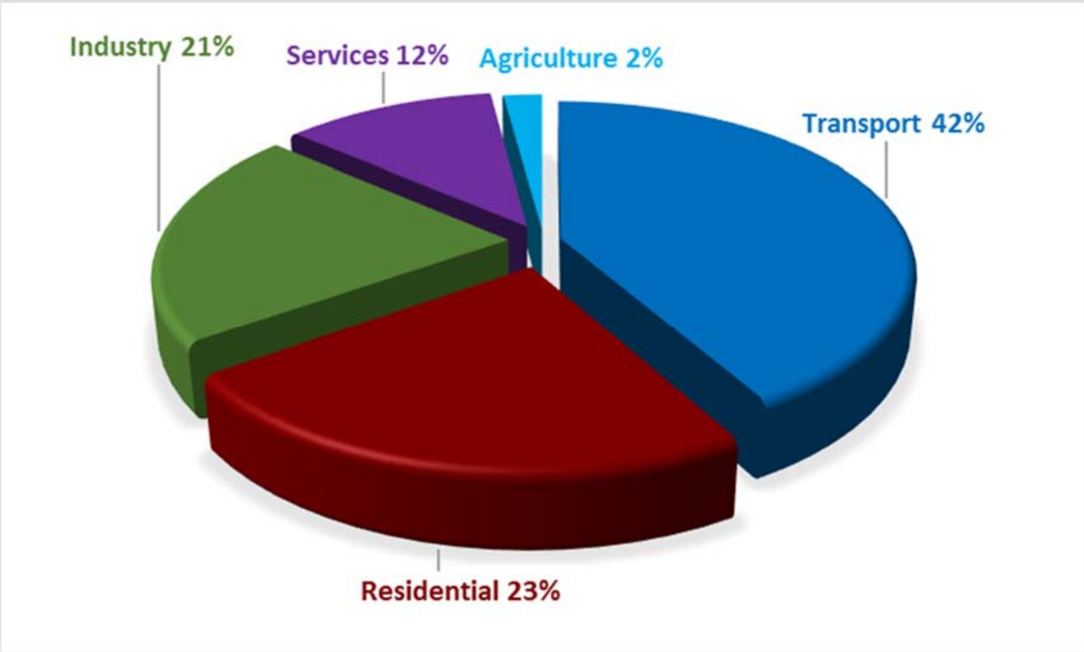


Figure 1.1: Total final energy consumption in Ireland by sector in % of total Mtoe.[1]

Therefore, Ireland has committed itself to:

- A 20% reduction in Final Energy Consumption (FEC), (as compared to average energy use in the period 2001-2005),
- A 20% reduction in Green-House Gas (GHG) (emissions from 2005 levels in the Non-Emissions Traded Sector),
- A 16% increase in the contribution of renewables to FEC by 2020.

Energy Use in Buildings

Continuing to waste energy is not sensible and simple ways to reduce this can be found. Buildings have a major contribution to make, by reducing energy

[1] Source: SEAI, Energy in Ireland 1990 – 2014 (2015 Report)

consumption. Low energy buildings are good news for the environment and will lead to lower energy bills and more comfortable buildings for us all.

A lot of heat is lost through the fabric of many homes in Ireland. The figure below (Figure 3) shows some of the most common parts of a dwelling through which heat is lost.

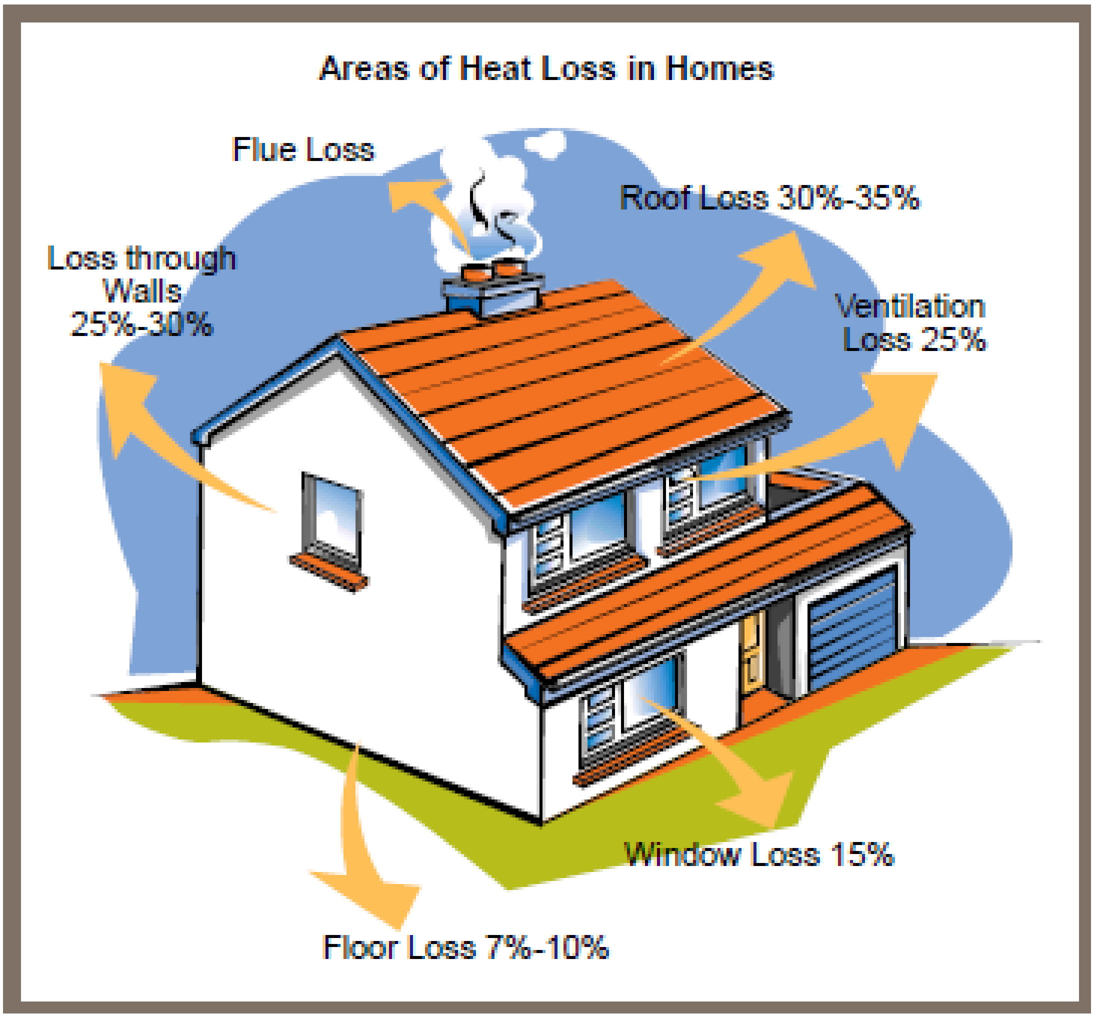


Figure 3: Typical proportions of heat loss from dwellings (source: Tipperary Energy Agency)

This amount of lost heat means that a lot of energy is wasted. The more heat we lose the more heat we need to produce to stay comfortable in our homes. And all of this extra heat uses more energy. When you add to that the fact that many heat producing and distribution systems are inefficient in themselves, we are using even more energy than necessary in staying warm. It's a double whammy – producing more heat than we need to be and using more energy than we should, to produce that heat.

Energy used in Buildings

Where is all this energy being used in buildings anyway?

Whether designing, building or just living in a house you should be aware of where energy is used. Information collected by SEAI has produced a % breakdown of the energy use in both the residential and non-residential sectors in Ireland and these are outlined below in Figure 1.2 and Figure 1.3.

Energy Use in the Residential Sector

Energy usage in the residential sector accounts for 23% of Ireland's total consumption. Reducing the amount of energy usage within the residential sector would make a huge impact on national energy savings. It is estimated that energy savings of approximately 27% are achievable in this sector by 2020 making it potentially the greatest contributor towards the targeted reductions for buildings. Figure 1.2 gives a breakdown of where energy is used in the home.

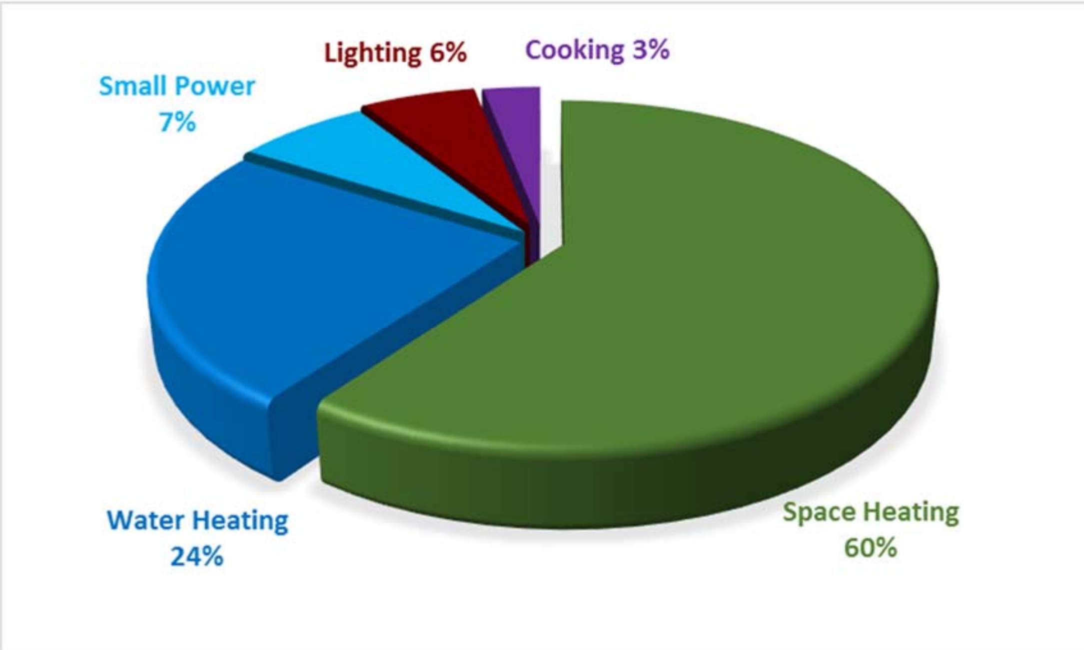


Figure 1.2: Energy Use in the Residential Sector in Ireland[2]

In this diagram Small Power refers to small electrical appliances including pumps and fans which are associated with heating and ventilation.

Space heating, water heating and lighting account for over 90% of energy usage, with space heating accounting for 60% of the that total. It is no surprise that these areas have been the main target of amendments to recent building regulations and should be targeted when carrying out retrofitting works.

How we build and renovate can play a major part in saving energy through:

[2] **Source: SEAI Publications Power of One - Sustainable Energy What It Means For You**

- Improvements to the building fabric performance.
- Installation of low energy light bulbs.
- Installation of high efficiency gas and oil boilers.
- Improved insulation of the hot water storage and distribution areas.
- Efficient heating controls.
- Use of renewable heating technologies.

Many EU policies have identified key areas of change in the residential sector and Ireland has carried out some of these changes to reduce greenhouse gas emissions and energy consumption. These include:

- Revisions to the building standards to improve energy performance by 40% over existing and grant schemes (through SEAI) to support the installation of renewable energy technologies.
- The introduction of mandatory building energy rating (BER) certification for all buildings for sale or lease.
- The phasing out of traditional incandescent light bulbs in favour of more energy efficient alternatives.

Energy Use in the Non-residential Sector

In non-residential buildings, energy is used differently with the space heating and cooling accounting for 34% and lighting and equipment accounting for 45% of the final energy consumption. Figure 1.3 shows that the highest proportion of energy demand in Ireland is for space heating and lighting/equipment.

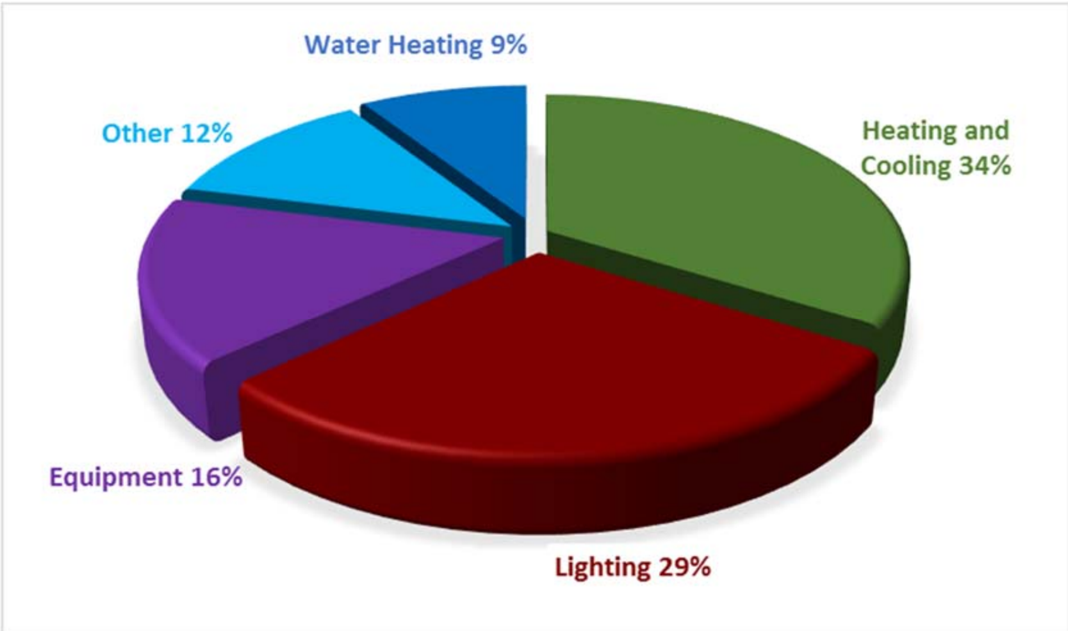


Figure 1.3: Energy Use in the Non-Residential Sector in Ireland[3]

[3] **Source data: Business – be your own energy manager, SEAI**

If Ireland is going to reach its energy saving targets, buildings are going to have to reduce energy usage.

What we need to consider now, is where exactly this energy is being consumed (or wasted) in our buildings and what are the factors which affect how much energy is being used?

Factors Affecting Energy Use in Buildings

It is well known that the insulation properties of the building envelope play an important role in reducing heat transfer. However, there is much less understanding of the major impact of air leakage and gaps in insulation on heat moving in and out of buildings. In order to get a better understanding of where all the losses and gains of the whole building occur, the energy use within the building needs to be looked at.

Common questions which are asked are:

- Why are the energy bills so high?
- And how can these be reduced?

The following sections highlight the different areas where energy is consumed in a building and factors which determine how much is used. The sections also identify where energy waste occurs, so that construction and retrofitting works can be carried out to the best solution.

For both residential and non-residential buildings, it has been noted that space heating, water heating and lighting account for the overwhelming proportion of energy consumption. We will overview how the building and its installations affect this energy use within the building and look at more detail in Unit 5.

The three main categories are:

- Space Heating
- Water Heating
- Lighting

It has been noted that space heating, water heating and lighting account for the overwhelming proportion of energy consumption in residential (90%) and non-residential (72%) buildings

Space Heating

Space heating is the heating provided so that the temperature within the living spaces of a building is comfortable to live in. The amount of energy used for space heating within a building are affected by all of the following (also illustrated in Figure 1.4):

- **Fabric losses:** heat lost through the external elements of the building, i.e. floors, walls, roofs, windows and doors.
- **Infiltration losses:** uncontrolled passage of air (leakage) through the building fabric at openings and junctions.
- **Solar gain**: heat energy gained into the building from the sun.
- **Internal gains**: heat generated by appliances, lighting and occupants of the building.
- **Control and response:** the level of heating controls adjusting heating to demand.
- **System efficiency**: the efficiency of the heat producing appliances and losses in distributing heat around a building.

Figure 1.4 Factors affecting energy use for space heating

Water Heating

Hot water is used in the day to day running of any home. The amount of energy required to provide a continuous hot water supply is influenced by the following factors (also illustrated in Figure 1.5):

- **Hot water required for daily usage**: the quantity of hot water required to meet daily demand

- **Distribution losses**: the loss of heat from pipes between the hot water store and the draw off points, e.g. taps, shower heads
- **Storage losses**: the heat lost from the hot water storage vessel
- **Primary circuit losses**: the loss of heat energy between the heat producing appliance and the hot water store
- **Solar input**: the effect of the sun on the temperature of the water to be heated
- **System efficiency**: the efficiency of the appliance heating the hot water

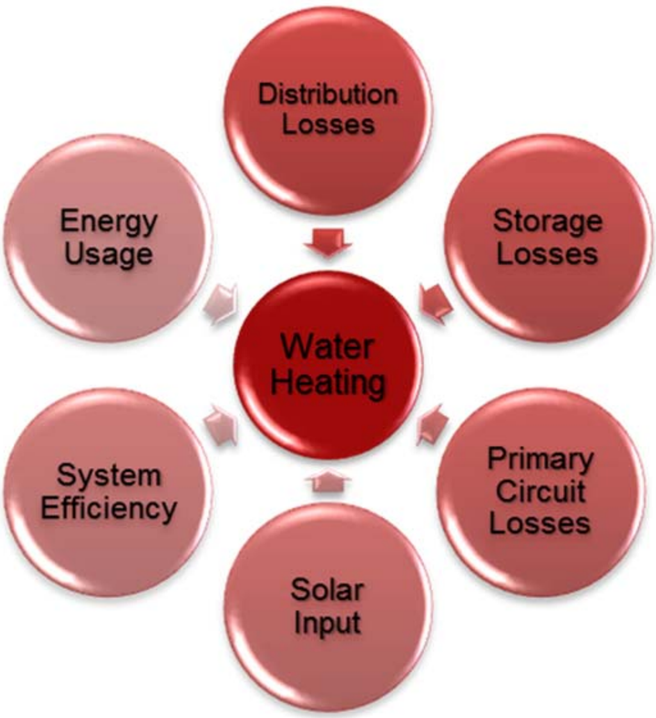


Figure 1.5 Factors affecting energy use for water heating

Lighting

Lighting accounts for a significant amount of energy use, particularly in non-residential buildings and the following factors are relevant (also illustrated in Figure 1.6):

- **Luminance level:** the level or intensity of light required for rooms within the building
- **Lamp efficiency:** the efficiency level of the light bulb or lamp, e.g. incandescent bulbs, LED lamps

- **Glazing ratio:** the proportion and size, number and position of windows or other transparent building elements affecting the amount of natural light available
- **Maintenance:** Regular maintenance and cleaning which improve efficiency.

Figure 1.6 Factors affecting energy use for Lighting

It may be the role of the designer to choose the type of lighting, but quite often it is left to the contractor or end user to decide where and how they will be installed. It can be useful to get some information about different types of lighting as these play a huge part on the energy use in the building especially by the end user.

Just replacing the existing light bulbs with energy efficient products can drastically affect the energy usage in the building. However, factors such as providing natural light and carrying out maintenance are also important factors to consider.

Thermal (Hot and Cold) Comfort

A person experiences thermal comfort when they are not feeling either too hot or too cold. Comfort levels for people can differ significantly depending on how they are dressed, how active they are and the temperature in the room. It can also be affected by a variety of environmental factors such as the following:

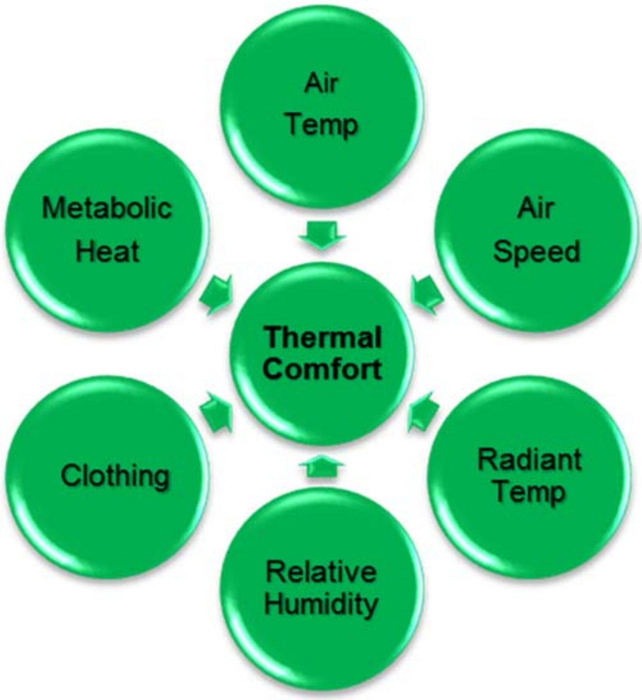


Figure 1.7 Diagram- Factors affecting Thermal Comfort

Air temperature.

Consider sitting next to a radiator where the air is heated to high temperatures and gradually becoming cooler the further you move away. The same applies when you sit next to a window which is heated by the sun (solar heating) compared to relaxing at the rear of the building further away from the sun.

Air speed

Draughts are basically air moving at a faster rate than the air in the rest of the room. This makes you feel colder.
Consider a shivering person near an open door (suffering from cold draughts) and a sweating person in the hot sunshine in front of the window (looking for a cooling breeze!!

Radiant temperature.

If you feel the inside face of the external wall of a building it can be colder than the air temperature in the room. This is the radiant temperature of the surface and can have an effect on the comfort level of a person.

Relative humidity (RH).

The ratio between the amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. The higher the RH then the heavier it feels, leading to sweating and shortness of breath. Humidity can have as big an impact on feelings of comfort as temperature.

Clothing.

Clothes insulate a person, keeping them warm. It also prevents the loss of heat through the evaporation of sweat.

Metabolic heat.

This is the heat you produce through physical activity i.e. a standing person will tend to feel cooler than a person that is exercising.

“You’re the fourth couple I’ve lagged this week.”

Self-Test One

1. List the 5 main energy use sectors in Ireland

   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________
   5) ______________________________

2. List the 3 main users of energy in residential buildings.

   1) ______________________________
   2) ______________________________
   3) ______________________________

3. List the 6 main factors affecting comfort levels in a building

   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________
   5) ______________________________
   6) ______________________________

4. List 3 ways of reducing energy usage for lighting

   1) ______________________________
   2) ______________________________
   3) ______________________________

The Language of Low Energy

A list of terms and definitions used in the energy and construction sector can be found at the beginning of this handbook.

Here we will look at just five key terms commonly used when discussing quality low energy building:

1. Nearly Zero Energy Building (NZEB)
2. Building Envelope
3. Air Tightness
4. Thermal Bridging
5. Interstitial Condensation

Nearly Zero Energy Building (NZEB)

The idea of a Nearly Zero Energy Building is one which has been used more and more in the context of energy efficiency in buildings. The following is a definition of the term as given by the EU –

"A building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (source - EPBD Recast, 2010/31/EC).

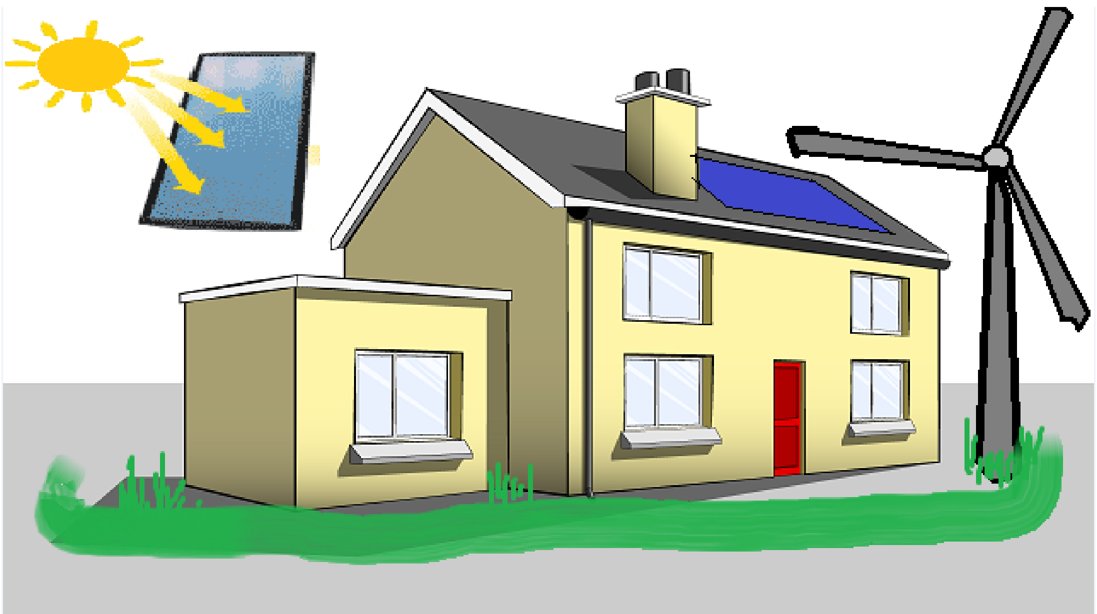


Figure 1.8 NZEB buildings with renewables

However each country in Europe is to provide its own definition.

Ireland is in the process of agreeing its own definition, but for dwellings it can be taken to include the following:

- A building which produces more or less the same amount of energy per year as it uses.
- This energy can be produced on or off-site.
- The building should produce a similar amount of *renewable* energy as the building aims to use.
- The building can generate this *renewable* energy on site or feed it back to the electricity grid.
- Alternatively, the renewable energy can be produced off site.

Read more about this in the document "Towards Nearly Zero Energy Buildings in Ireland" in the link: http://www.environ.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad%2C42487%2Cen.pdf

Building Envelope

The term building envelope is one which is used a lot in the context of energy use in buildings. The building envelope includes all the building components that separate the indoors from the outdoors. Building envelopes include the exterior walls, floors, roof, windows and doors.

The three basic elements of a building envelope are:

1. Weather/wind barrier.
2. Air barrier.
3. Thermal/insulation barrier.

In other words, the building envelope is the part of the building that provides protection against the elements, helps to control air movement in and out of a building and helps to control the way heat moves in and out of a building.

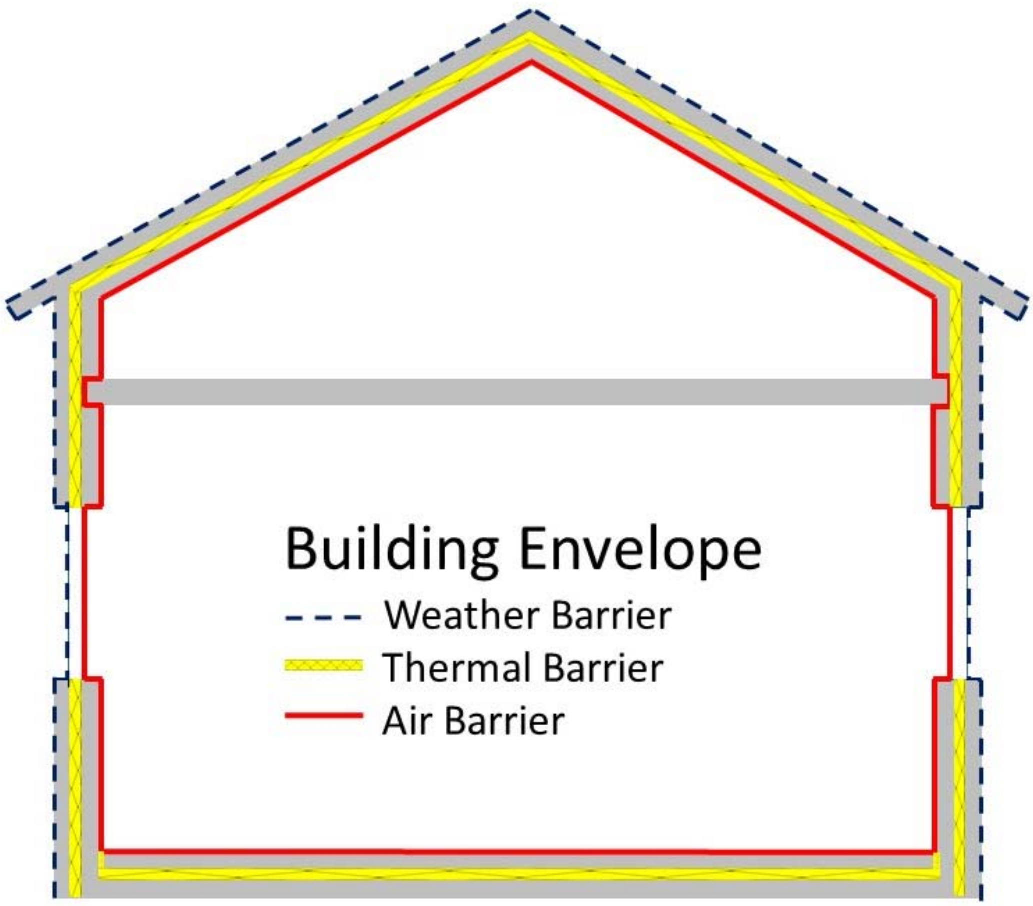


Figure 1.9 Building envelope showing position of weather, thermal and air barriers

As we will see later on in this handbook, all of these functions of the building envelope are important when it comes to energy efficiency. One of the important things from an energy efficiency point of view is to make sure that all three barrier functions of the building are working together to improve the building's energy efficiency.

This "fabric first" approach to building is based on the idea that we should look at designing and constructing the building itself in a way which will retain as much heat as required before looking at installing efficient heating and cooling systems.

Air Tightness

Air tightness is defined as the resistance of a building envelope to inward and outward air leakage. In other words, it is the extent that air movement from the inside and the outside is prevented.

Air leakage is "the uncontrolled flow of air through gaps and cracks in the external envelope of buildings" (sometimes referred to as air infiltration, exfiltration or draughts) and occurs where the air barrier is broken -

Figure 1.10 shows the parts of a house where air leakage is most likely to occur. These include around windows and doors, through the floor, into the attic or roof space and through other gaps and holes in the building envelope.

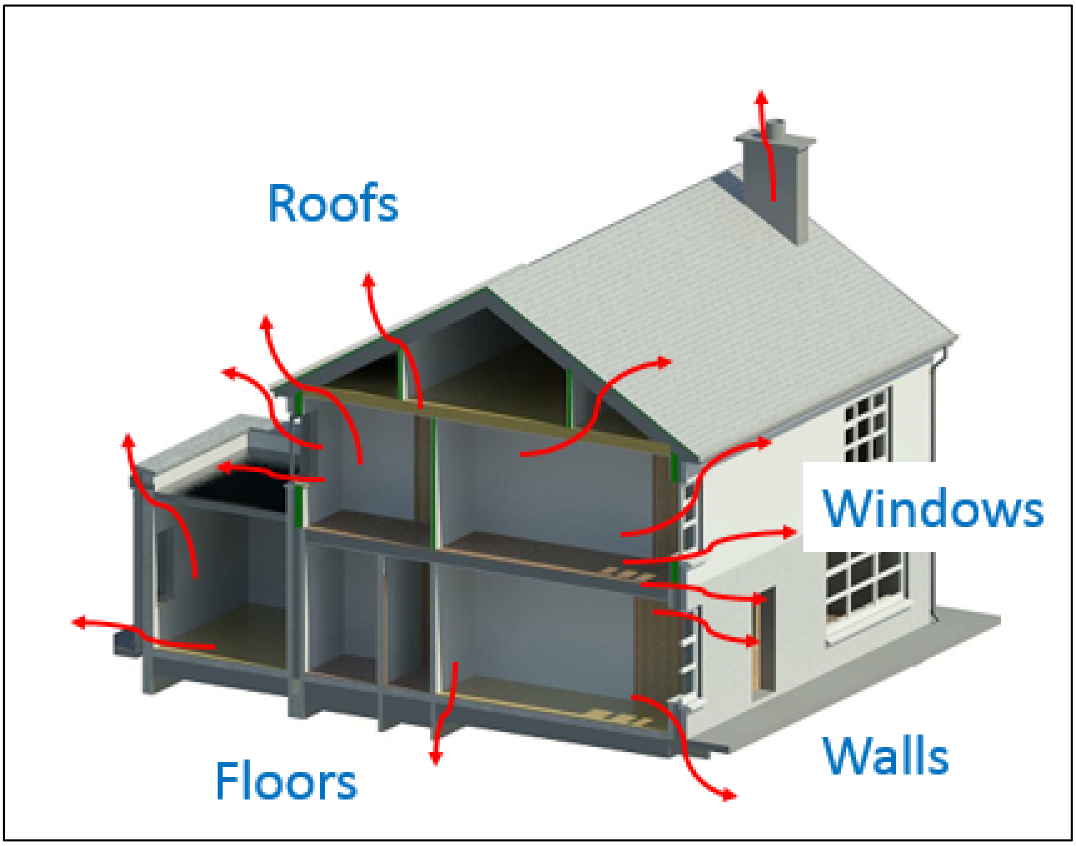


Figure 1.10 Common air leakages within the house

Imagine constantly filling a bucket with water, but the bucket has a hole in the bottom. The bucket will never fill up and water is being wasted as a result. The bucket needs to be fixed and the hole closed up properly. The same principle applies to a badly insulated and leaky house.

This does not mean that ventilation in a house is not required. As we will see later on in the course, air change in a house is needed for a variety of structural, comfort and health reasons. However, what is crucial in an energy-efficient house is that this ventilation is controlled. The difference between air leakage and efficient ventilation is the fact that efficient ventilation is deliberate and controlled.

Thermal Bridging

What is a thermal bridge?

A thermal bridge occurs with a change or break in the thermal barrier of the building envelope. It occurs at gaps between insulation materials or junctions between materials with different insulating properties. Heat loss occurs at different rates between the materials which can lead to issues such as condensation and mould.

Figure 1.11 shows some of the areas within a house where thermal bridging is most likely to occur. These include weak spot areas such as junctions and materials which allow easy heat transfer. Junctions include areas such as where the wall meets the floor, where the wall meets the roof, where doors and windows meet the walls and so on, indicated with the red circles. Other areas include weak spots where heat can travel easily due to the use of high conducting materials (marked with blue arrows).

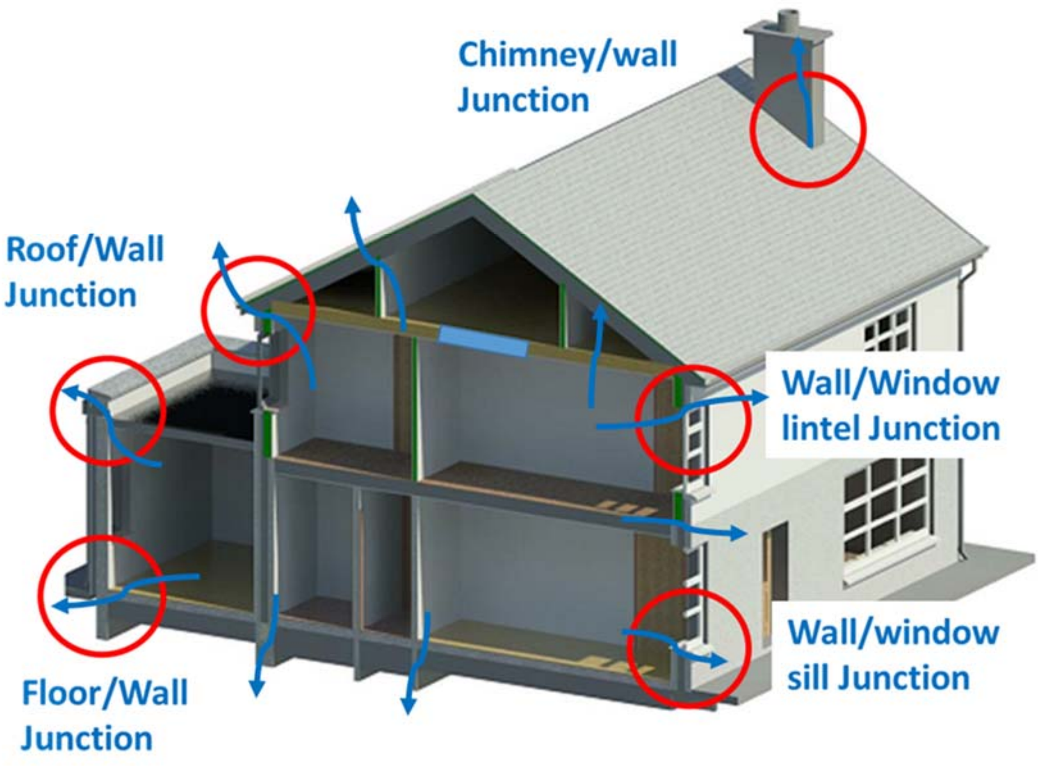


Figure 1.11 Common areas of thermal bridging within a house

Take an example of a steel lintel over a window. Heat transfers faster through steel than a concrete block. If the block wall is well insulated, then the rate of heat loss is even higher through the steel. This is because the materials have different thermal and conducting properties.

This is why the installation of continuous insulation is important at openings and junctions, both to reduce the level of heat transfer and to avoid cold temperatures in the fabric where condensation is likely to occur.

Looking at thermal bridging in more detail, Figure 1.12 is a typical example of how this heat transfer can occur. It shows how a concrete sill at a window provides a pathway for heat to escape from inside to outside the building, as shown by the coloured arrow which goes from red (hot) to blue (cold). This happens even though the wall below the window sill and the window above it are well insulated, preventing the heat escaping through those areas.

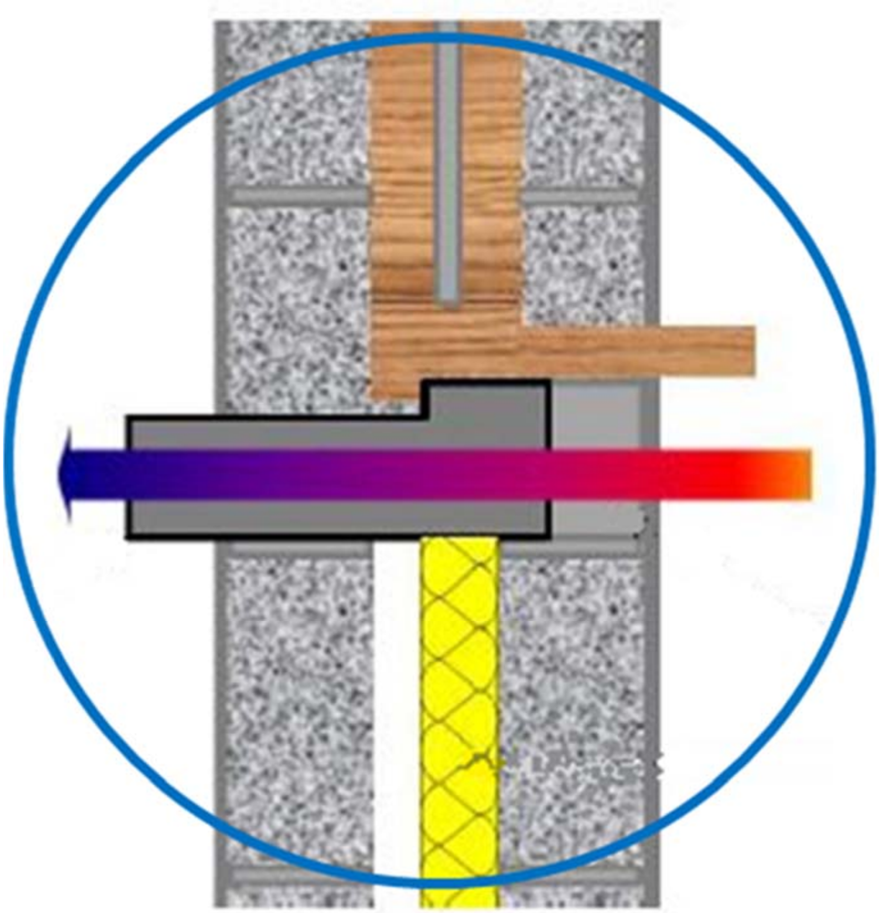


Figure 1.12 How thermal bridging can occur at a window sill.

Locations within a dwelling such as a concrete window sill needs to be detailed correctly and steps taken to deal with heat loss or thermal bridging.

This will be discussed in more detail in Unit 4 later in the handbook.

Interstitial Condensation

Interstitial condensation occurs when water vapour condenses within an element of the building, e.g., within a wall or roof.

This happens when warm damp air from inside the building, makes its way through gaps in the envelope, and turns to water when it meets cold temperatures within the material. This can lead to wet insulation that does not perform as well as it should, and can result in rot in the fabric.

The following diagram in Figure 1.13 shows a section through an external wall and how this sort of condensation can occur. The figure shows warm moist air (at 21°C) from inside the house moving through the fabric of a wall during cold weather (0°C outside) and meeting cold temperatures, resulting in water vapour turning into moisture.

You will certainly be familiar with the way in which warm air meeting a cool surface leads to condensation e.g. on a mirror in a bathroom. This is similar to what happens when the warm air meets the cold temperatures within the wall and moisture starts to form within the fabric.

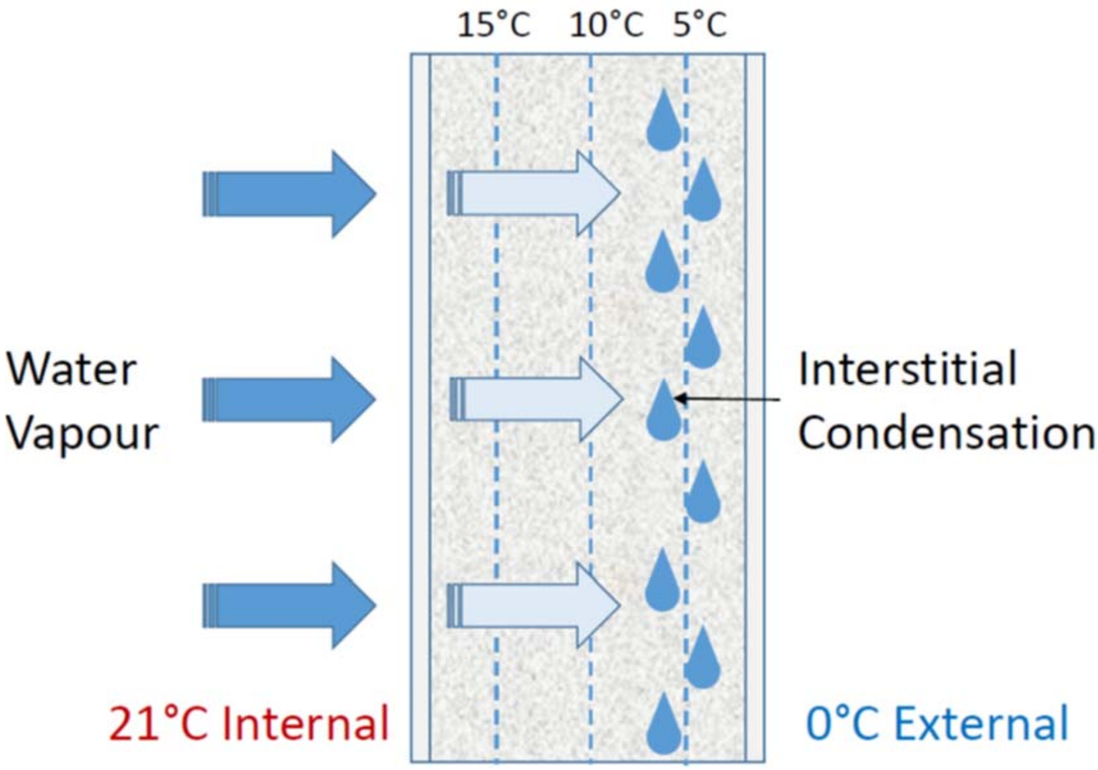


Figure 1.13 Interstitial Condensation in an external wall

Interstitial condensation can have significant effects on the structural strength of the building. It can lead to rot, corrosion of materials and mould growth.

Figure 1.14 shows mould growth on the inner surface of an external wall of a building near a window. In this case, the wall is so poorly insulated that the internal surface is cold enough for condensation to occur. There may also be poor ventilation, meaning that moisture is building up in the room.

The damp caused by this surface condensation provides an ideal environment for mould growth. Mould growth caused by surface condensation can be clearly seen and measures can be taken to improve insulation and/or ventilation to the area. However, when this mould growth is hidden within the fabric, the problem is much less obvious but still very damaging.

Figure 1.14 Photograph of mould on the wall

Self-Test Two

1. Name the 4 basic elements of a building envelope.

    1) ______________________________
    2) ______________________________
    3) ______________________________
    4) ______________________________

2. Nearly Zero Energy Buildings (NZEB) will be the standard for Irish buildings by 2020. How does the EU define NZEB?

3. What is the difference between interstitial and surface condensation?

4. Where do thermal bridges most commonly occur in the building envelope?

Regulations, Rules and Standards

As already stated, there are new and constantly changing standards in building that we have to comply with. These new rules and regulations are intended to ensure that our buildings perform well. It is not necessary for you to know all the detail of policies and regulations but it is important that construction workers understand the principle ideas behind them.

Why Have Energy Regulations?

The introduction of new energy policies at EU and national level has resulted in a fundamental change in the approach to new build and the renovation of existing buildings**. Ireland must comply with these rules or face big fines.**

In Europe, buildings account for approximately 40% of energy consumption, so improving the energy performance of buildings and introducing renewable energy sources are necessary to achieve energy saving targets for 2020 set by the EU.

It is important for building construction workers understand the driving forces behind this change, leading towards improved energy performance in the building sector.

The Building Regulations now require quality low energy building construction.

International Agreements and EU Legislation

So how did all this interest in energy and the management of energy efficiency start?

Well we will look at some of the most important steps along the way but first we need to consider the topic of climate change.

Climate Change

The issues of climate change and global warming are ones which you have probably read or heard about in the recent past. They are linked but have different concepts.

There has been a lot of disagreement about what is meant by climate change. Strictly speaking it refers to “a change in regional or global climatic conditions over a long period of time, irrespective of cause”

In recent years, the term is more generally used to describe changes in weather patterns (i.e. unusual temperatures, extreme weather, etc.). Hurricanes, freezing temperatures and unusual heat-waves have all been in the news in recent years.

It is still a topic of some disagreement but many scientists now agree that one of the major factors giving rise to recent climate change is the "greenhouse effect". This occurs when excess heat is prevented from leaving the earths' atmosphere by so-called greenhouse gases, such as CO_2, methane and other gases.

Some Facts about Global Warming

The surface of the earth needs to be within a certain temperature range for us to be able to enjoy the relatively stable environment to which we have become used. This means that we have a good idea of what the weather is going to do, the plants and animals with which we are familiar will survive, our sea levels will not vary too much and we will be able to grow enough food to feed the world's population. If, however, the surface temperature of the earth changes too much in either direction then a lot of bad things can happen.

Many believe that the climate change, or "global warming" as it is often referred to, is a direct result of the greenhouse effect. Normally heat energy from the sun is absorbed by the earth and re-radiated back into space. However, with the greenhouse effect this re-radiation is partially blocked due to greenhouse gases (GHG) in the atmosphere and is directed back towards the earth resulting in higher ground and sea temperatures (see Figure 1.15). **Energy related CO_2 emissions account for the majority of greenhouse gas in our atmosphere.**

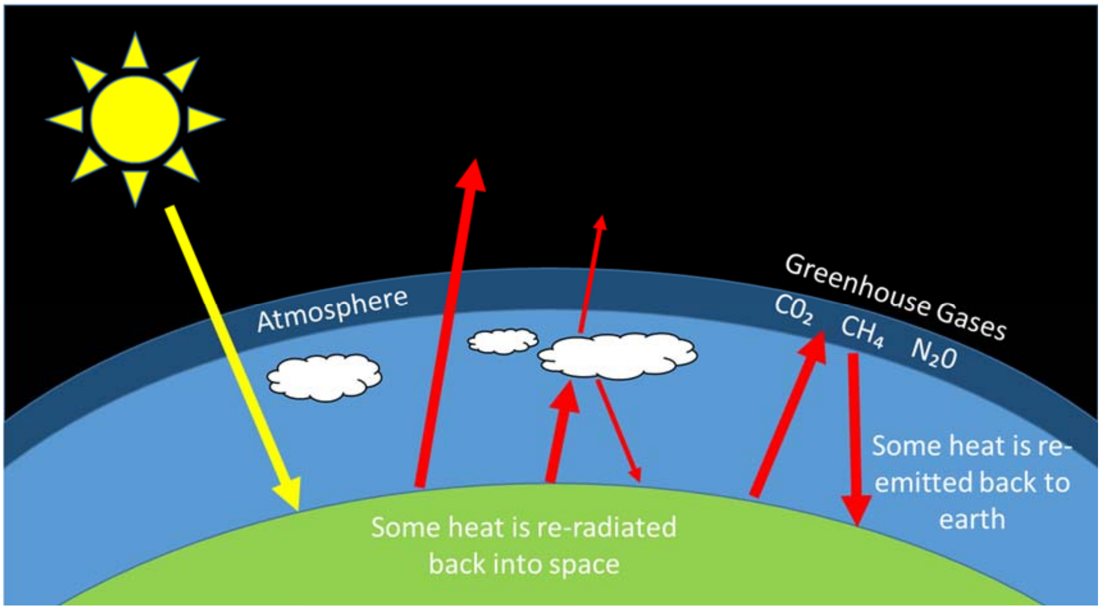


Figure 1.15 The Greenhouse Effect

The surface temperature of the earth is affected by a number of things. Firstly it is affected by the amount of sunlight which reaches it; then it is affected by how much of the heat of that sunlight is absorbed by the earth and how much of it is reflected back into space; and thirdly it is affected by anything in the earth's atmosphere which slows down the heat that is escaping. This is where the greenhouse gases, (GHGs) come in!! Because they are able to absorb the heat, they create a kind of blanket around the earth which makes it harder for the reflected heat to escape.

This means that, over time, the temperature of the earth will heat up and give rise to extreme weather. This extreme weather can lead to droughts, crop failure, melting ice-caps, rising sea levels and so on.

So why is this important for the construction sector?

Well, a lot of the GHGs which are produced by humans ~~comes~~ come from the energy we use, such as that used for heating our homes. In fact, energy related CO_2 emissions account for the majority of greenhouse gas in our atmosphere, because a lot of that energy comes from fossil fuels such as oil and coal which, when they are burned, release large amounts of CO_2. Other GHGs include chlorofluorocarbon (CFC), nitrous oxide (NO_2), methane (CH_4) and ozone (O_3).

Buildings make up over a third of all our energy usage in Ireland, so they make a major contribution to GHG emissions. So in order to reduce CO_2 emissions we must reduce our use of energy and change our energy sources and one of the most important things we must do in order to reduce our use of energy **is to reduce the amount of energy we use in our buildings**.

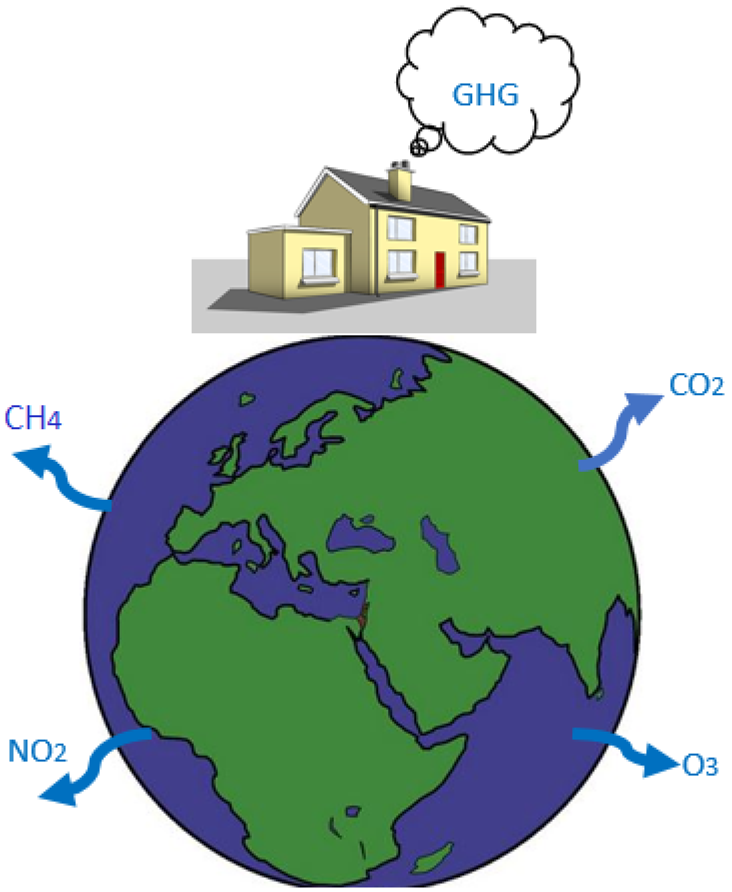
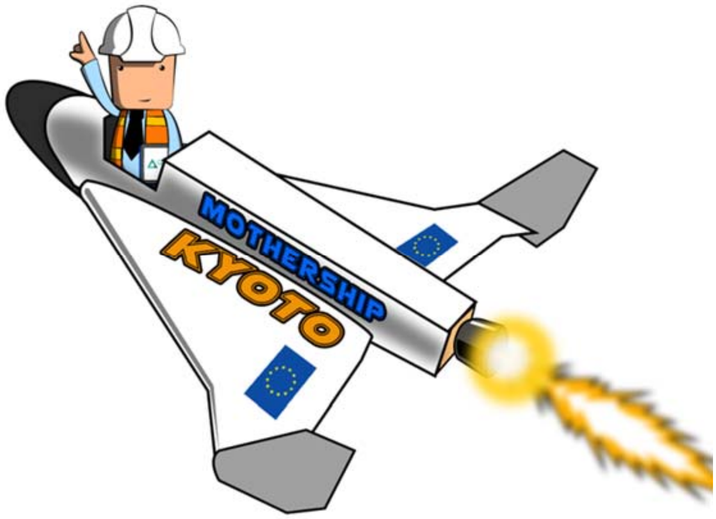


Figure 1.16 Global warming and GHGs.

Kyoto Protocol (1997) – The Mother Ship

It has been agreed internationally that there is a need to reduce the production of energy from fossil fuels. The Kyoto Protocol is very significant as it led to international efforts to reduce energy production from these sources. It could be considered to be 'the Mother Ship' of all the subsequent directives, policies and regulations which have driven changes to energy policies and building standards in Europe and Ireland.

The Kyoto Protocol was adopted in Kyoto, Japan in 1997. There are currently 192 signatories of the Protocol. The Protocol was agreed by the then 15 EU member states with the intention of setting out internationally accepted Greenhouse Gas emission reduction targets for the EU states. As a direct result of the Kyoto Protocol, the EU addressed the need to improve the energy efficiency of buildings, encourage renewable sources and reduce Green-House Gas (GHG) emissions.



The body responsible for providing scientific reports about climate change for the EU member states is the Intergovernmental Panel on Climate Change (IPCC). You might have heard their reports being discussed on the radio or TV.

In response to the Kyoto Protocol a number of other EU laws were introduced.

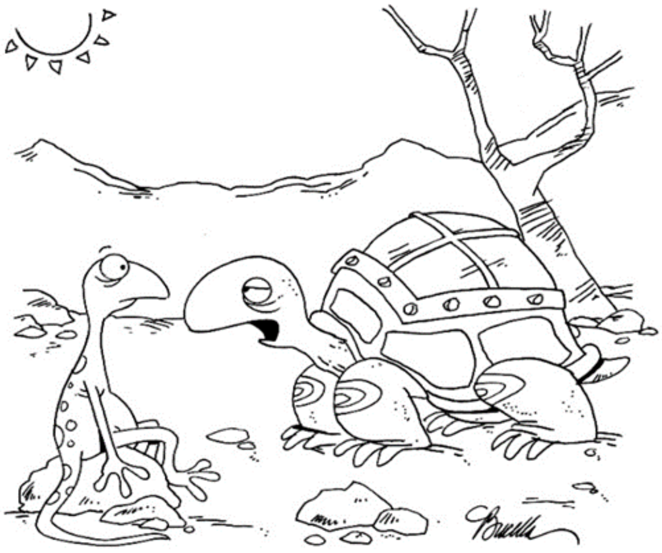
Energy Performance of Buildings Directive (EPBD)

The EU Energy Performance of Buildings Directive (EPBD) 2002, became law in Ireland from 2006 onwards. This Directive promotes improved energy performance in new and existing buildings and it was updated in 2010, known as the EPBD Recast (2010)

Amongst the things included in the EPBD Recast are the following:–

- The definition of a very low energy building was agreed.

- EU states are required to adopt policies and set targets in order to stimulate the construction sector to refurbish buildings into very low energy buildings.
- Public authorities that own or occupy a new building are expected to set an example by building, buying or renting such 'nearly zero energy building' as of 31 December 2018.
- All new buildings in the EU will have to consume 'nearly zero' energy and the energy will be 'to a very large extent' from renewable sources as of 31 December 2020.
- A more detailed procedure for issuing energy performance certificates is required in EU states.
- Control systems are to be put in place by EU states to check the quality and correctness of performance certification.
- States will be required to introduce penalties for non-compliance.



"I'm getting an energy credit for installing the solar panels."

The Energy Efficiency Directive (EED)

The Energy Efficiency Directive (EED) 2012 sets binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain from its production to its final consumption.

Under the Directive Member States of the EU are required to ensure that:

- Energy distributors or retail energy sales companies achieve 1.5% energy savings per year through the implementation of energy efficiency measures or through other means such as improving the efficiency of heating systems, installing double glazed windows or insulating roofs.

- The public sector in EU countries seek to purchase energy efficient buildings, products and services.
- Each year energy efficient renovations are carried out on buildings owned and occupied by Government and which account for 3% of the total floor area of such buildings.
- Energy consumers are encouraged to better manage consumption.
- National incentives are put in place for SMEs to carry out energy audit and that large companies carry out audits of their energy consumption to help them identify ways to reduce it.

The following diagram sets out a summary of the time-line of the main international and EU requirements.

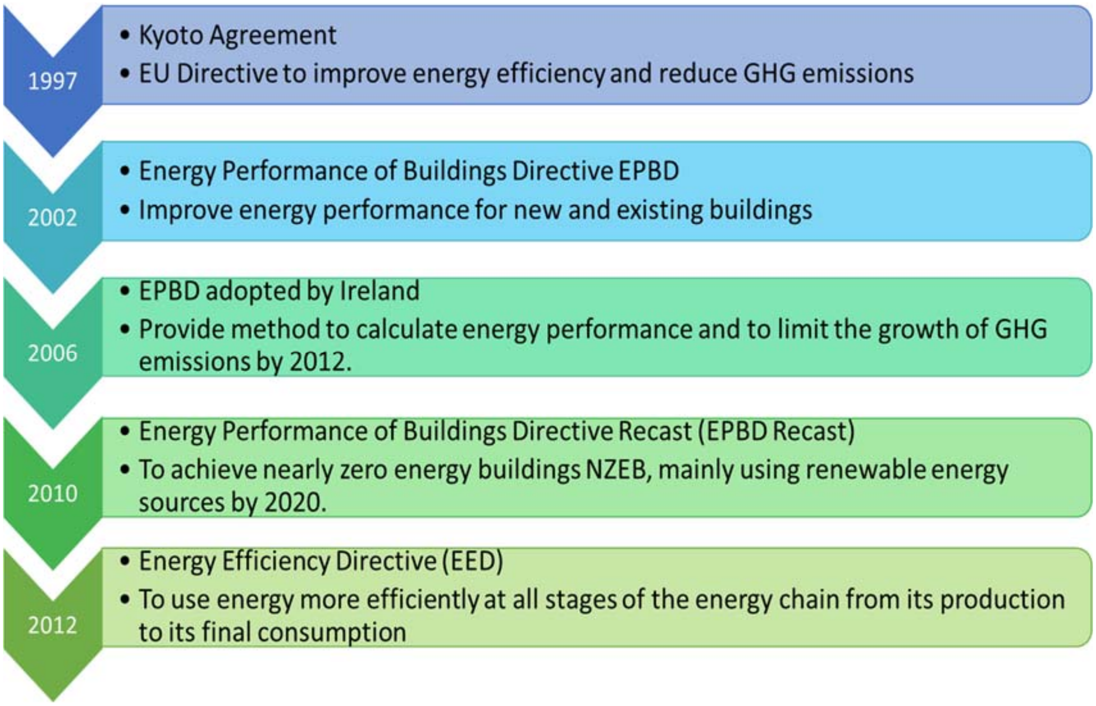


Figure 1.17 Diagram showing progression of EU laws

Now, let's look at how these EU laws affect Ireland.

National Policies

As a result of the Kyoto agreement, Ireland is legally bound to meet the energy and GHG emissions reduction target. Ireland's policies have changed over the years to help to improve the levels of energy efficiency and energy performance of buildings.

We will touch on what these changes are, by looking at a few of these important strategies:

- National Climate Change Strategy
- National Energy Efficiency Action Plan, NEEAP 3
- National Renewable Energy Action Plan, NREAP
- National Renovation Strategy for Ireland 2014
- Irish Building Control Act and the Building Regulations Technical Guidance Documents.

National Climate Change Strategy (2007)

The Department of the Environment, Community and Local Government published The National Climate Change Strategy 2007-2012. The document outlines Irelands approach to meeting the requirements of the Kyoto Protocol.

These targets were then developed and set three key objectives for 2020:

- 20% energy savings by 2020
- 16% of total primary energy to be provided from renewable sources by 2020
- 20% reduction in CO_2 emissions by 2020

The National Energy Efficiency Action Plan (2009)

The National Energy Efficiency Action Plan (NEEAP) for Ireland was published in 2009. Under this Plan:

- Ireland's commitment to a 20% reduction in energy demand by 2020 was outlined.
- An update was published in 2014 called NEEAP 3
- NEEAP 3 outlines the Nearly Zero Energy Building (NZEB) framework which is to be in place for new public buildings by 2018 and for all other buildings by 2020.
- A report on the most cost-effective levels of energy performance was published
- A new code of practice in retrofitting (S.R.54:2014) was also published.

The National Renewable Energy Action Plan (2010)

Irelands National Renewable Energy Action Plan (NREAP) was adopted in response to the Renewable Energy Sources Directive in 2009 and set out national targets for higher use of renewable resources in electricity, transport, heating and cooling up to the year 2020.

The NREAP set an overall target of 16% of energy to be produced from renewable resources by 2020 and to be achieved as follows:

- 40% supply of electricity from renewable sources
- 12% supply of heat from renewable sources
- 10% supply of transport fuels from renewable sources

National Renovation Strategy (2014).

The Department of Communication, Energy and Natural Resources, DCENR published *'Better Buildings – A National Renovation Strategy for Ireland'* in 2014. This document is the first of a new national renovation strategy outlining:

- The most cost effective renovation measures for each category of building in Ireland.
- The issues preventing a greater uptake of energy efficiency measures by homeowners and businesses.
- How to improve the level of knowledge and skills required to deliver low energy buildings and retrofit on a national scale.

Irish Building Control Act

The Building Control Act, 1990, covers 3 main functions:

1. Provides for the making of the Building Regulations - deals with issues such as building standards, workmanship, conservation of fuel and energy and access for people with disabilities.
2. Provides for making of Building Control Regulations - Commencement Notices, Fire Safety Certificates, Disability Certificates and Fees-Administration by Building Control Authorities.
3. Gives powers of enforcement and inspection.

There are two recognised assessment tools to determine the energy performance of buildings.

For residential buildings, assessment is carried out at the design and completion stages using the Dwelling Energy Assessment Procedure (DEAP).

For Non-residential buildings a similar, assessment is carried out using the Non-domestic Energy Assessment Procedure (NEAP).

Energy Performance Standards and Assessments

From 2005, Building Energy Rating (BER) was introduced as an energy performance rating for buildings in Ireland.

BER

Building Energy Rating (BER) certification is needed for all new dwellings and those for sale and letting. A BER is an energy label displaying the Irish energy performance standard for domestic buildings.

Figure 1.18 Energy Rating

The BER calculation is generally based on the insulation and air tightness qualities of the external building fabric and the efficiency of installed systems for space heating, water heating and lighting. It measures a buildings' energy performance in kilowatt hours (kWh), a unit of energy, per square meter of floor area (m²) for each year (yr), i.e. ***kWh/m²/yr.*** The result is graded on a scale of rating A to G, with A being the most energy efficient (see Figure 1.19).

The current building standards for dwellings achieve an **A3 rating** (energy use around 50 - 75 kWh/m²/yr) whilst a near zero energy building, NZEB would be in the category **A1-A2** (45kW/m²/yr).

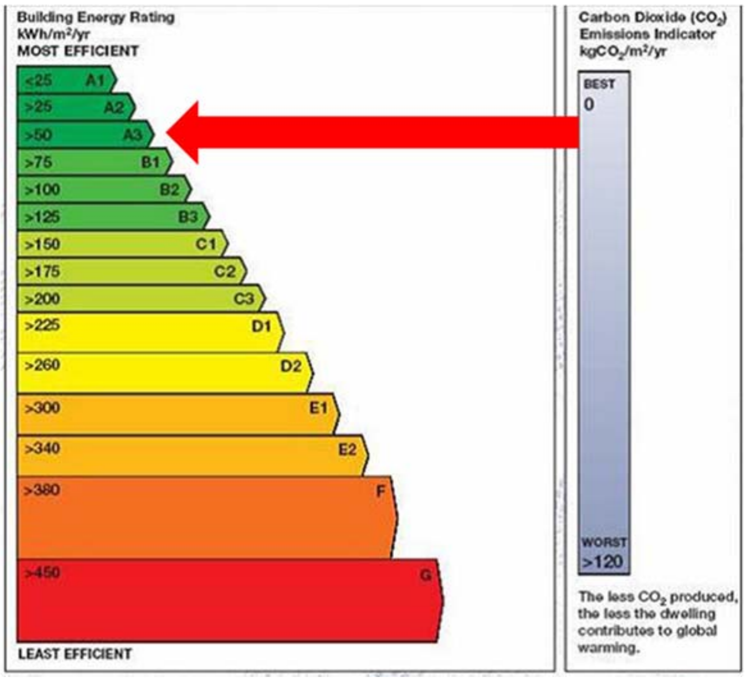


Figure 1.19 Building Energy Rating Categories (source – SEAI)

A good BER can enhance a building's value and this has increased public awareness of the benefits of energy efficient buildings.

Introduction to the Building Regulations

The Building Control Act 1990 led to the introduction of the 1997 Building Regulations. These Regulations apply to the construction of new buildings, extensions to existing buildings and material alterations and changes of use.

At a national policy level, Ireland has committed to reach energy reductions of 20% by the year 2020 and to meet these targets, building regulations and standards have been amended significantly to developing a new approach to construction and renovation.

The Building Control Act uses Technical Guidance Documents (TGDs) to assist designers and builders in meeting the requirements of the Building Regulations.

The Technical Documents, commonly known as TGD's give guidance on how to construct a building so that it complies with the regulations.

The Technical Guidance Documents (TGD's) are divided into 12 parts (listed A to M). They provide guidance for the construction of buildings towards compliance with regulations. Parts L, J and F will be looked at on this course as these relate to energy efficiency and performance.

- TGD Part L – Conservation of Fuel and Energy
- TGD Part F – Ventilation
- TGD Part J – Heating

Figure 1.20: TGD Part F, Part L and Part J Covers

Particular reference will be made to Part L – Conservation of Fuel and Energy, which is divided into two documents;

- Dwellings - including new buildings and extensions/renovations
- Buildings other than dwellings - such as commercial, industrial and apartment complexes.

In this handbook, particular attention will be paid to dwellings.

The Irish Building Regulations are available to download at http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents

or on the Qualibuild website: http://www.qualibuild.ie/useful-links/unit-3/

Figure 1.21 below, sets out the timeline of national standards since before the Building Regulations were introduced to the Nearly Zero Energy Building (NZEB) requirement which is due to be implemented in 2020. The diagram also shows the huge improvement in building energy efficiency from around 340 (kWh/m²/yr) in 1972 to 60 today, with this anticipated to drop to 25 in 2020 which is still higher than the requirement for Passiv House certification

This means that we are aiming for buildings (by 2020) to be over 458% more efficient than the 1970's builds.

Figure 1.21 also shows the improvements which occurred after the Building Regulations were introduced and then the additional improvements which came with each change to Part L of the Building Regulations, driven by EU requirements as set out in the EPBD and the EED.

Take some time to look at Figure 1.21 as it clearly shows the rate of change in standards for buildings and why everyone involved in building construction needs to keep their knowledge up to date.

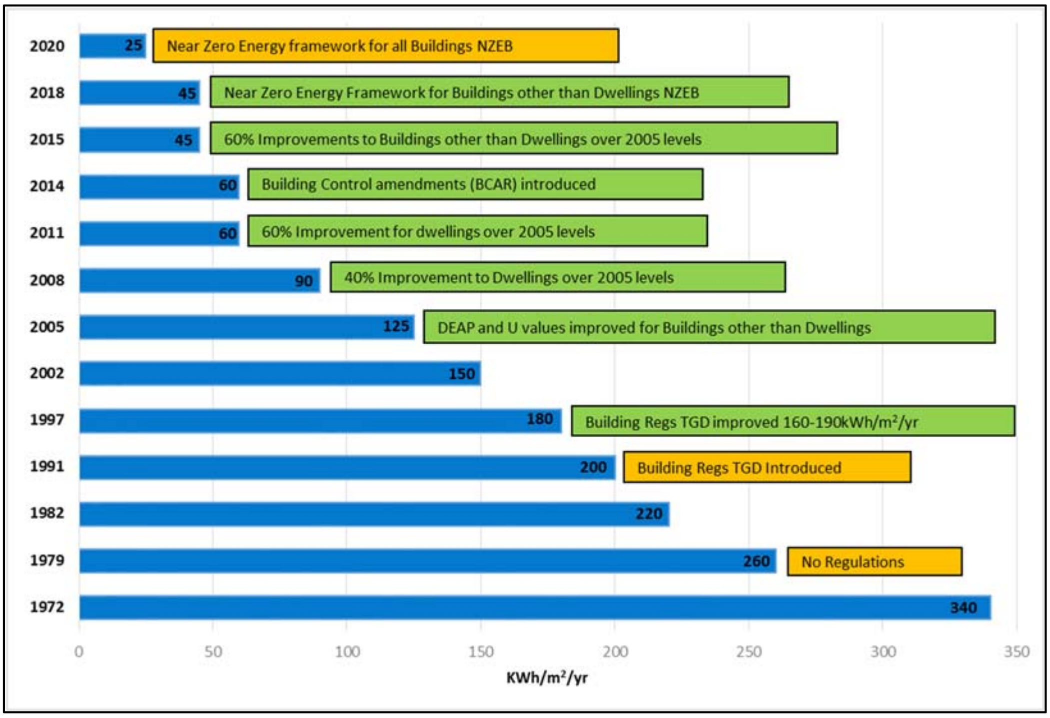


Figure 1.21 Evolution of Building Regulations for Part L, Conservation of Fuel and Energy

The latest changes to the Irish Building Regulations include improvements to the energy performance and ventilation requirements for buildings in particular updating Technical Guidance Documents (TGD) Part L for both documents - Dwellings and Buildings other than Dwellings and Part F - Ventilation. It should be noted that Part L for - Buildings other than Dwellings will be updated again in 2015/16.

In summary, the revisions to regulations since 2002 have focused on the following:

For the fabric of a building:

- Lower U-values
- Improving air tightness
- Reducing thermal bridging

For the installed systems for heating and lighting:

- High efficiency gas and oil boilers
- Improved insulation of pipes carrying hot water
- Improved insulation of hot water storage tanks
- Zoning and automatic control of heating
- Replacement of inefficient light bulbs with low energy alternatives
- The provision of some of the energy for heating and/or electricity from renewable energy sources (solar, wind, biomass and heat pumps)

Building Control - Regulations

Recent changes in March 2014, known as the Building Control (amendments) Regulations (BC(A)R) has stated that building construction workers have to demonstrate competency, co-ordination and compliance with building regulations. This is still under review and under great discussion throughout the building sector.

Opt Out of Statutory Certification – Single Dwellings and Extensions to Dwellings

Owners of new single dwellings, on a single development unit, and domestic extensions may opt out of the requirements for statutory certification. Compliance with Building Regulations must still be achieved and Building Control procedures will still apply.

Inspection and Enforcement

The Building Control Acts 1990 to 2014 vest the powers of inspection, enforcement and prosecution in the 31 Local Authorities. Authorised officers of each local Building Control Authority have delegated powers to:

- Scrutinise proposals and inspect works in progress.
- Serve enforcement notices on owners and builders for non-compliance.
- Institute proceedings for breaches of any requirements outlined in the Acts, or any regulations made thereunder.
- Seek High Court orders to mitigate danger to the public where serious non-compliance poses risks to public safety.

Failure by an owner or a builder, at the request of a Building Control Authority, to demonstrate compliance with Building Regulations or Building Control Regulations, or to rectify such non-compliance, may be an offence under the Building Control Acts.


Code of Practice

for

Inspecting and Certifying Buildings and Works

Building Control Regulations 2014

February, 2014

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

In 2014, the Building Control Act introduced the *Code of Practice for inspecting and certifying buildings and works*, to work alongside the existing Technical Guidance Documents providing direction on certifying and assessing quality of works.

The purpose of the Code of Practice is to provide guidance with respect to inspecting and certifying works or a building for compliance with the requirements of the Building Regulations.

Future Policies

Where is all of this going?

With all this legislation in Ireland it should lead to a greater demand for energy efficiency from clients (cost savings, comfort/living conditions in the building and environment issues), and from the government (EU legislation, penalties and environment issues i.e. flooding, cost of import, etc).

The provision of shelter by human beings is constantly changing. Human beings started living in cave dwellings with no thoughts as to how the energy they needed should be used. But, of course, there were very few humans and wood, the main fuel, was plentiful. Now there are over 7 billion of us and energy is much more scarce, harder to get and more expensive.

So now we are heading towards the building of houses which use almost no energy which is not renewable (that is which cannot be replaced). This means that building standards are rising all the time.

Figure 1.23 - From cave dwelling to NZEB

This will all have implications for the ways in which building construction workers approach their tasks.

Some important targets and objectives

Currently Ireland has adopted some key targets which are to be achieved by the year 2020. These targets are based on EU targets and are aimed at reducing Greenhouse Gases by actions which include the reduction of the amount of energy used in the country and by reducing fossil fuel generated energy.

- 20% energy savings
- 16% of total primary energy to be provided from renewable sources
- 20% reduction in CO_2 emissions

In addition to these general energy targets there are some specific EU targets with regard to buildings as follows:

- By the year 2018 - All new public buildings in the EU will have to consume 'nearly zero' energy.
- By the year 2020 - All new buildings need to achieve nearly zero energy status and be sourced 'to a very large extent' from renewable sources.

Some important ways for contributing to the achievement of these targets and objectives are:

- Minimising energy demand through the insulation of building envelopes to high performance levels
- Maximising the energy efficiency of installations for heating, cooling and lighting
- The integration of renewable energy systems

All of those involved in construction have a role to play in achieving these outcomes. The achievement of the ambitious targets set for energy savings from buildings will require a building construction workforce equipped with the necessary knowledge, understanding and skill

"The label says that it should be served at room temperature... Shall I put it in the freezer for half an hour?"

Self-Test Three

1. What Protocol can be regarded as the Mothership of energy efficiency in buildings and when was it adopted?

   ____

   ____

2. What does EPBD stand for?

   ____

3. Why was the EPBD adopted by Ireland?

   ____

   ____

4. What are the EU 20:20:20 targets?

   ____

   ____

   ____

5. What year were building regulations introduced into Ireland?

   ____

6. List the titles of the following TGDs and the year of the current version

   Part L

   ____

   ____

   Part F

   ____

   ____

7. What is a Building Energy Rating Certificate?

   ____

Summary

- Buildings account for a large proportion of Ireland's total energy consumption and CO_2 emissions, both of which contribute to climate change.
- The majority of energy used in residential buildings is used for space heating and water heating, whilst in the non-residential buildings space heating and lighting are the main users of energy.
- The first step in reducing energy consumption is to have building envelopes which reduce heat transfer as much as possible. Then, heating and lighting systems should be selected for their efficiency and installed to maximise the potential for energy saving.
- Significant energy savings in lighting can be made by using efficient lighting systems with sensor controls and maximising the use of daylight.
- Thermal comfort is the level of comfort that a person experiences. This experience can vary depending on the person and the conditions.
- These are the most important EU requirements for buildings:
  - 2002 - The European Energy Performance of Buildings Directive (EPBD).
  - 2010 - European Performance Building Directive (EPBD Recast).
  - 2012 - The Energy Efficiency Directive (EED).

- Ireland set out its own national action plans for energy efficiency and use of renewable energy sources leading to changes in the Irish Building Control Act and Building Regulations.
- Ireland's targets are:
  - 20% energy savings by 2020.
  - 16% of total primary energy provided from renewable sources by 2020.
  - 20% reduction in CO_2 emissions by 2020.

- Building Energy Ratings are required for all new buildings and for all buildings being sold. A good BER can enhance a building's value.
- The Building Regulations are regularly updated as Ireland strives to reach these nearly zero energy buildings (NZEB) requirements.
- The most relevant documents include:
  - Technical Guidance Documents (TGD) Part L 2008 and 2011
  - Technical Guidance Documents (TGD) Part F 2009

Useful Links

Energy Use in Buildings

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit1-part1

SEAI, (2013), *Energy in Ireland 1990 – 2012,* http://www.seai.ie/Publications/Statistics_Publications/Energy_in_Ireland/Energy_in_Ireland_1990_-_2012_Report.pdf

Climate Change, Regulations and Rules

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit1-part2

EC, (2002), European Performance of Buildings Directive, http://eurlex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:32002L0091&from=EN

EC, (2010), European Performance of Buildings Recast, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

EC, (2009), Renewable Energy Sources Directive, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

EC, (2012), Energy Efficiency Directive, Irish Government, *National Climate Change Strategy 2007-2012*, http://www.environ.ie/en/Publications/Environment/Atmosphere/FileDownLoad,1861,en.pdf

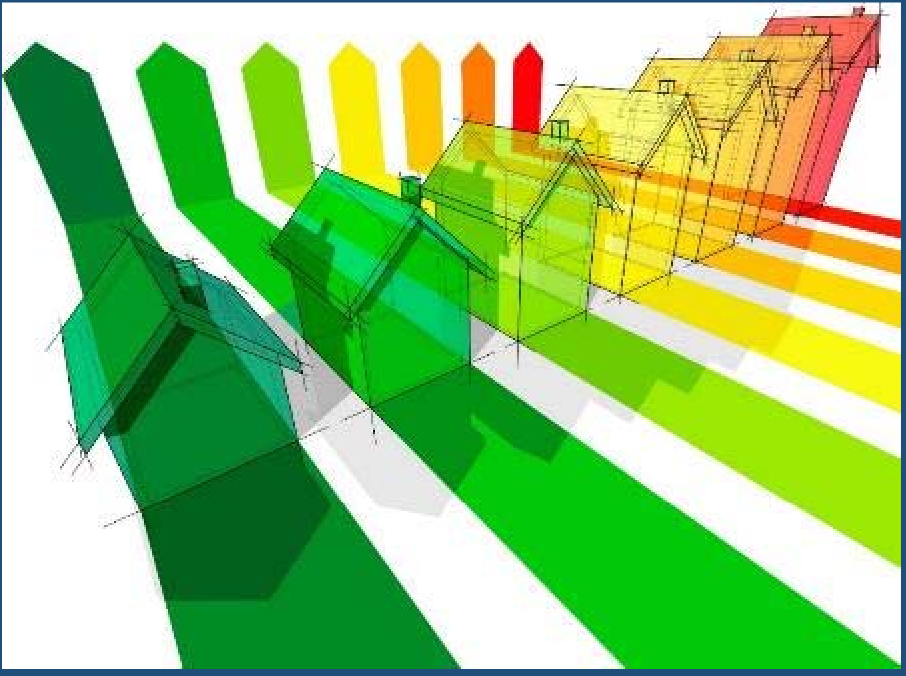
DCENR, (2013), Ireland's second National Energy Efficiency Action Plan to 2020, http://www.dcenr.gov.ie/NR/rdonlyres/B18E125F-66B1-4715-9B72-70F0284AEE42/0/2013_0206_NEEAP_PublishedversionforWeb.pdf

DCENR, (2014), National Energy Efficiency Action Plan 2014, http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCENRNEEAP2014publishedversion.pdf

DCENR, (2014), Better Buildings – A National Renovation Strategy for Ireland, http://www.dcenr.gov.ie/NR/rdonlyres/4337BCB7-E9B3-40E9-B41C-57B2A9B7FFE0/0/RenovationStrategyFirstVersion.pdf

NSAI, (2014), S. R. 54: 2014, *Code of practice for the energy efficient retrofit of dwellings*, http://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx

Unit 2



How Energy Works

Unit 2: How Energy Works

Now that we have looked at the background as to why we need to make buildings more energy efficient, we can now consider the basic principles of how low energy buildings work.

In order to understand how we can reduce heat loss we must first look at the ways in which heat moves in and out of a building. The rate of heat movement through different building materials is affected by a number of factors. As well as knowing what these factors are, we need to be able to measure their effects. In this section, the units used for measuring heat transfer through building materials will be explained.

Unit Overview

Unit 2 explains the ways in which heat moves in and out of buildings and the ways that this is measured.

Heat Transfer
How energy (as heat) moves in and out of a building.

Simple Explanation of Energy Units
How we measure this heat transfer and the insulating properties of building materials.

Learning Outcomes

The successful completion of this unit will help you to:

1. List and describe the modes of heat transfer
2. Identify the principles of how heat transfer occurs in buildings
3. Define the terms thermal conductivity, thermal resistance and U-value and identify the units of measurement used for them
4. List the minimum U-values required by current Irish Building Regulations

Heat Transfer in Buildings

This section provides an overview of the principles of energy in buildings by looking at factors which affect the rate of heat loss.

To understand this ***heat loss,*** it is necessary to explain the principles and the types of ***heat transfer***. There are different ways that heat transfer occurs through the building envelope. Because heat moves in various ways through different materials, an understanding of this is key to understanding how to reduce heat loss, which is essential for the construction of low energy quality buildings.

Compliance with building regulations in TGD, Part L has changed over the years with importance given to the energy performance of a building. It is now expected that a building is insulated to a high standard in order to minimise heat loss, providing comfort to the end-user and reducing energy bills.

Principles of Heat Transfer

Heat is the form of energy that we are most concerned about in low energy buildings. There are certain principles that affect how heat energy flows in and out of a building. The following four points are the most important to remember:

1. Energy only flows as heat if there is a temperature difference between two objects.
2. Heat energy always flows from a higher temperature to a lower temperature.
3. The greater the difference in temperature, the faster the energy flows.
4. Energy will continue to flow between objects until they are both at the same temperature.

These points are important because they explain why we need to prevent heat flowing from the warmth of a house to the coldness of the outside in winter and, perhaps, why we need to prevent heat flowing from the high temperature outside to the lower temperature inside a house in a hot summer. The heat wants to flow and we have to find ways of slowing it down!!

In order to know how to slow this heat movement down we need to know a bit more about how it happens.

Ways in which Heat Flows or Transfers

Let's look at how heat is transferred by looking at the three ways in which heat moves

- conduction
- convection
- radiation

Conduction

Different materials conduct heat at different rates. The rate of heat transfer through a material is called its ***thermal conductivity*** which is shown by the letter k, or the symbol λ (lambda).Thermal conductivity and insulation are closely related since the lower the thermal conductivity, the higher the insulating value of the material.

Heat transfer by conduction is a continuous loss of temperature in the direction of the heat flow (hot to cold) through a still solid material.

Conduction can be easily demonstrated by holding a steel rod over a flame (poker in the fire). As metals are generally good conductors, when the end of the steel rod is heated, the heat gradually travels up along the length of the rod until it becomes too hot to hold. Water, on the other hand, is a poor conductor of heat.

Example of Poor Heat Conduction - Figure 2.0 provides an example of poor heat conduction. As already mentioned, water is a poor conductor of heat. Therefore, in this example, even though the water at the top of the test tube will boil when heat is applied to the test-tube the ice at the bottom of the test tube will not melt.

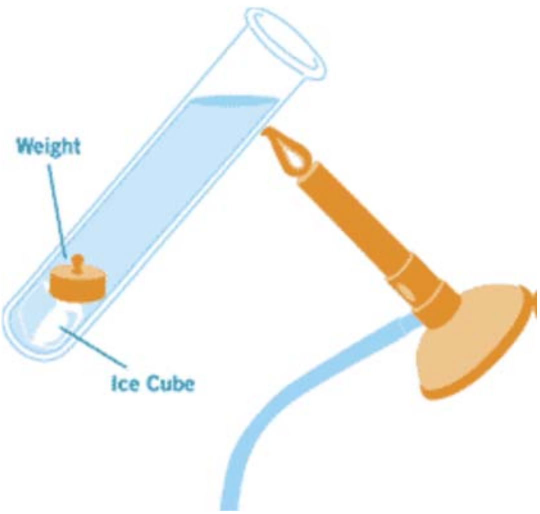


Figure 2.0 Example of Conduction[4]

Convection

Convection occurs when heat is transferred due to a flow of gas (including air) or liquid. When water or moisture moves through a material it will affect the overall temperature of the material. Similarly, a cool wind blowing through a building has a cooling effect on the surface temperature of the materials and therefore on the whole building.

[4] (www.seai.ie/schools/post_primary/subjects/physics/unit_6_heat_transfer/, n.d.)

Convection is the energy transfer from warmer locations to cooler locations by the movement of a heated liquid or gas (including air).

Example of Convection - As the liquid in the bottom of the saucepan is heated it rises to the top. As it reaches the top it gets cooler and sinks towards the bottom where it is heated further and rises again. This movement of the liquid is called convection and can apply to air as well as to a liquid, often referred to as convection currents.

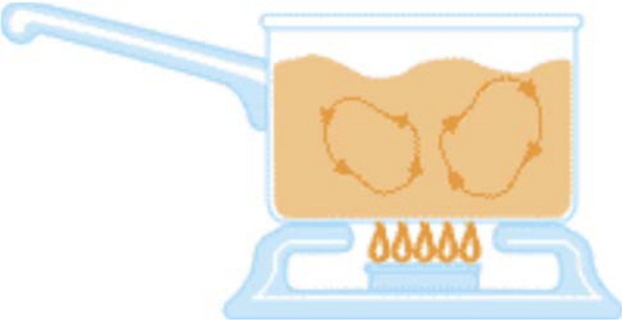


Figure 2.1 Example of convection [5]

Radiation

Have you ever wondered how the sun heats the earth? It can't be by conduction because it is not physically connected to the earth; it can't be by convection because there is no liquid or gas in space.

Radiation is the transfer of heat by means of electromagnetic waves

All objects radiate energy in the form of electromagnetic waves, the hotter the object, the more it radiates. Objects will radiate energy as infra-red waves which are not visible to the human eye but an infra-red camera is capable of detecting such radiation in the form of thermal photographs or videos (Figure 2.2).

[5] (www.seai.ie/schools/post_primary/subjects/physics/unit_6_heat_transfer/, n.d.)

Areas of heat loss can be seen through the external envelope of the building and where high levels of heat transfer can be detected. The hot areas, where heat loss is greatest, appear red in the images while cold areas are blue.

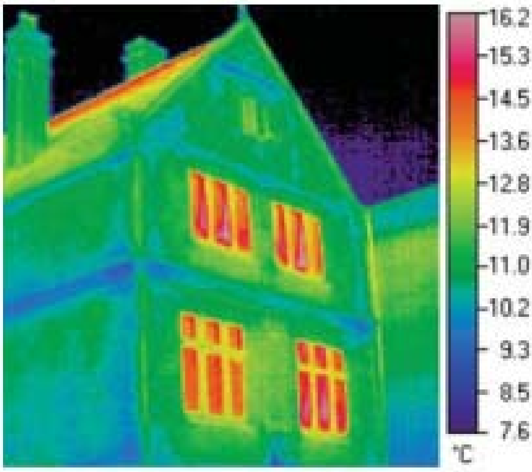


Figure 2.2: Thermographic image illustrating heat loss through a building envelope (source: SEAI, 2007[6])

Heat Transfer in Buildings

As we have seen, heat transfer happens in a variety of ways and producing an energy efficient building requires the management of these transfers in an effective way.

So let's look at where heat transfers - conduction, convection and radiation - can take place in a building.

Heat transfer through the building envelope

The following diagram in Figure 2.3 shows some of the ways in which heat transfers within a house and between the inside of the house and the external environment. You will see that all forms of heat transfer – conduction, convection and radiation are involved.

Heat moves through the envelope by **conduction** as the hot air inside the building is in contact with the materials of the wall, windows, floor, ceilings and roofs.. The hot air warms the inner surface of these materials while the colder outer air outside cools their outer surface. Since heat moves from the hotter to the colder area, it moves from the inner surface of the material to the outer surface.

Heat also moves around the house by **convection**. You can see how the air in a heated room moves up or down to a colder room through convection.

Finally, heat also moves around the house and in and out of the house through **radiation**. Human beings are themselves one source of radiant heat; that is one of

[6] *Passive Homes – Guidelines for the design and construction of passive house dwellings in Ireland*

the reasons a crowded hall heats up as the night goes on. As building materials heat up, they radiate heat from their surfaces to the outside (hot to cold)

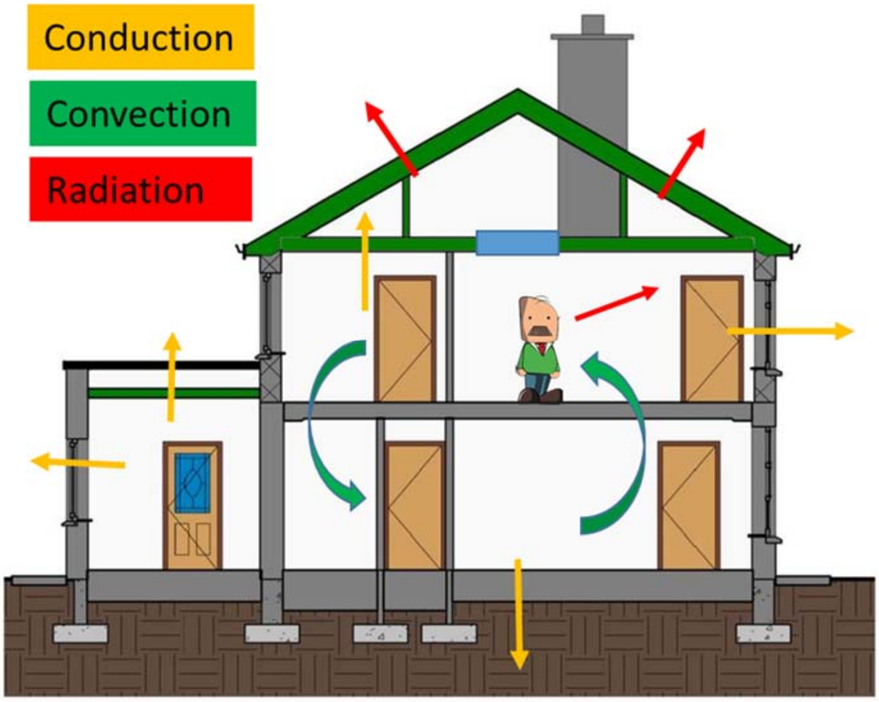


Figure 2.3 Typical heat loss pathways from a house during winter

Heat loss at a window

Heat transfer at windows has a significant effect on the comfort levels in a building and the greater the number of windows then the greater the transfer. As shown in Figure 2.4, heat radiates from inside out through the glass, conduction takes place through the solid material of the window i.e the frame, sash and glazing spacer; while warm air can pass between the sash and frame and around the frame which is an example of convection.

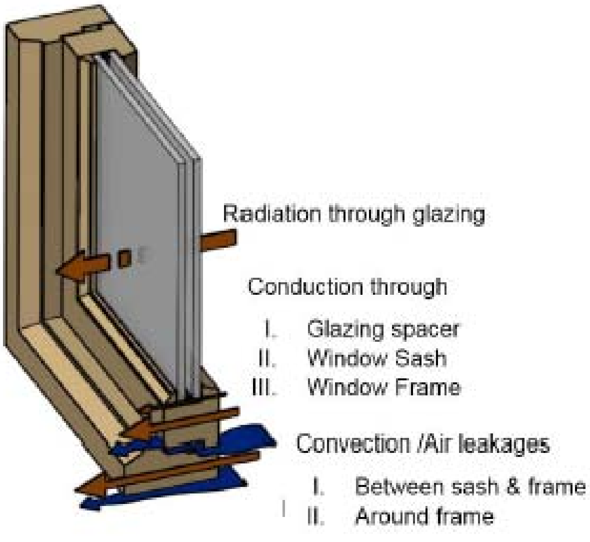


Figure 2.4 Heat loss through a window

Heat transfer in a heating system

Figure 2.5 shows the various ways in which a wet central heating system uses conduction, convection and radiation to transfer heat. Heat is transferred to the water in the system by conduction through the heat exchanger in the boiler, the water is then pumped around the system to the radiators (forced convection). The radiators then transfer heat to the air by radiation and the heated air moves around the house via convection.

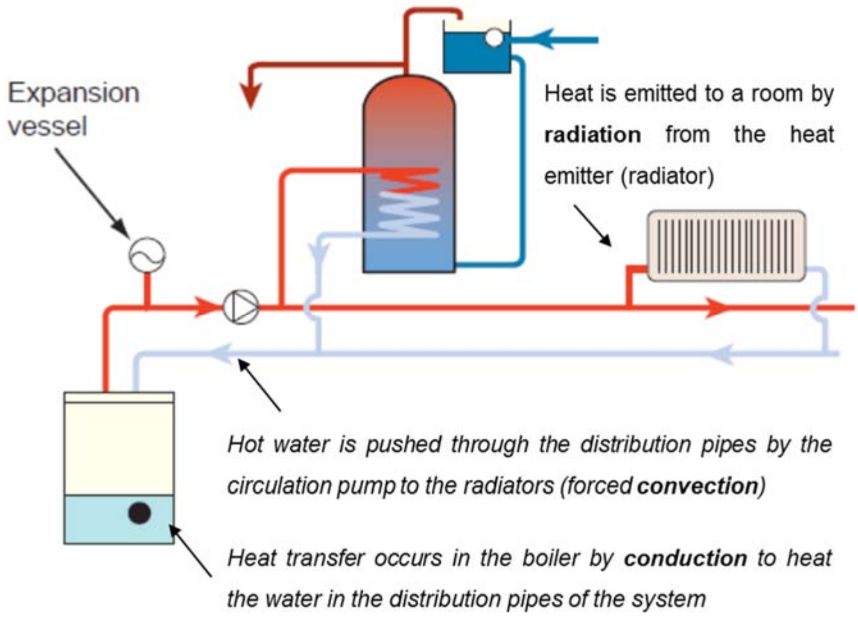


Figure 2.5 Sealed wet central heating system (Source: SEAI)

Factors Affecting Heat Transfer in Buildings

The amount of heat losses and gains in a building are largely dependent on the following factors:

- The weather – which includes the difference in temperature between inside and outside, the wind levels outside and the amount of heat gained from the sun (solar gain, see Figure 2.6)
- The amount of area of building elements exposed to the outside, e.g. a mid-terrace house only has two external walls, back and front, compared with a detached house with at least four walls.
- The thermal resistance of the building envelope.
- The level of airtightness of the building.

As building workers, we do not have control over the weather or the design of the building. But we can control the rate of this heat transfer through the use of appropriate insulation systems and maintaining an airtight building envelope

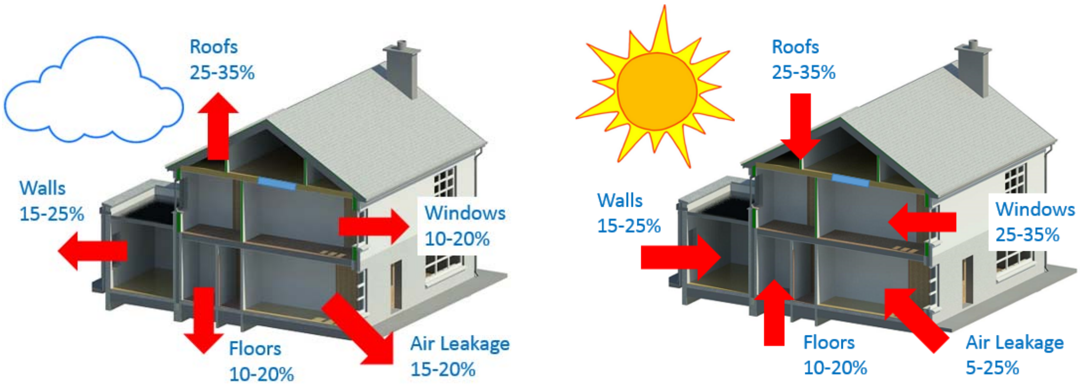


Figure 2.6 Percentage of heat losses in winter time and heat gains in summer time

Note the differences in the heat losses and gains, in particular through the windows at different times of year.

Solar Gain

The term 'Solar Gain' refers to the way in which the sun's rays increase the temperature inside a dwelling. Solar gain is highest through windows which provide the least resistance to radiant heat. A building with a lot of windows can, therefore, get a lot of temperature increase through solar gain.

There are, of course, many ways of controlling solar gain. We can use specific glass in the windows which is more resistant to radiant heat, and solar shading can be provided by overhangs on the structure and installing internal or external blinds.

Figure 2.7 shows how an overhang on the building prevents the high summer sun with greatest amount of radiant energy from penetrating the windows of the building. In the winter, when it is desirable to gain the extra heat, the sun is lower in the sky and the angle of radiation is also lower, so it can bypass the shading. As an alternative to the shading, special solar blocking glass, blinds or shutters can be used.

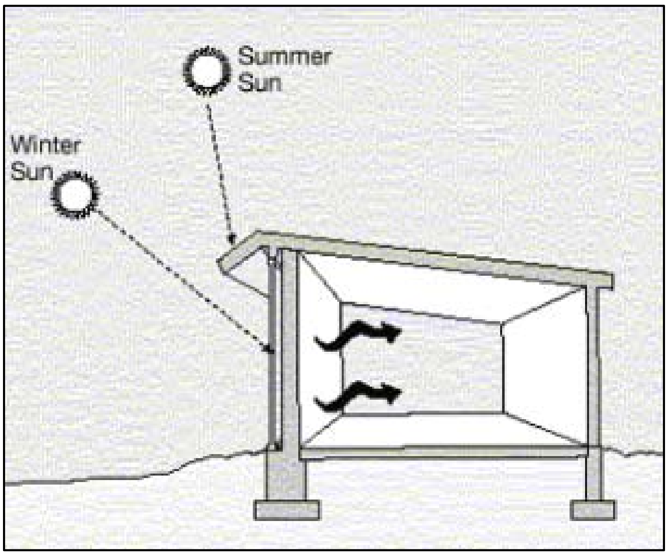


Figure 2.7 External shading to the window preventing overheating of a building.

Thermal Mass

Thermal mass refers to the ability of a material to store heat. This should not be confused with insulation which reduces the transfer of heat. You will have noticed how a hot day seems a lot hotter in a city than in the country. This is partly due to all the concrete which is present in the city buildings and roadways. Concrete absorbs and stores heat when it is warm, releasing it as temperatures drop (hot to cold)

If a building material is thermally massive, it can absorb the solar gains during the day and delay the release of this energy into the room for a number of hours (see Figure 2.8). If there is enough thermal mass it may delay the release until night time, meaning that the building remains warmer during cooler winter nights. During the summer, overhangs or shading can reduce the entry of solar energy and the stored heat is released to the ground. Ventilation can then be used at nigh time to keep internal air temperature down.

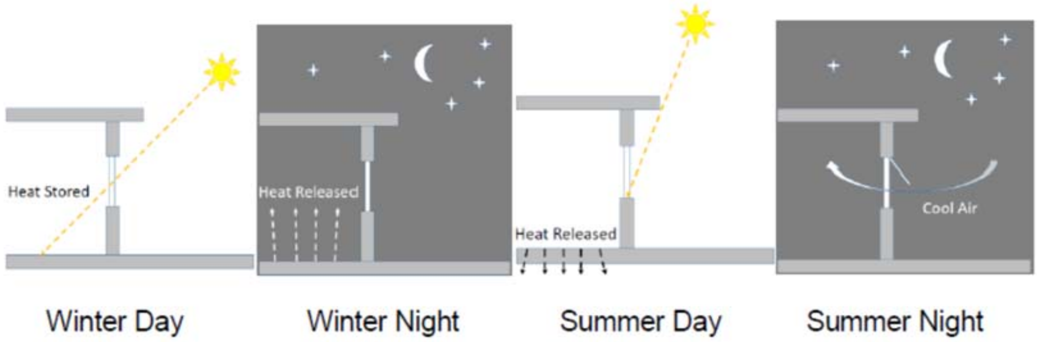


Figure 2.8 Illustration of effect of thermal mass

It is important to understand the principles of thermal mass and solar gain, and how these will affect heavy concrete or lightweight timber buildings and the importance of shading to the internal space to provide good thermal comfort.

Insulating Properties of Building Materials

As mentioned previously when describing conduction, different materials conduct heat at different rates. Every material has a particular thermal conductivity or capacity to transfer heat. This conductivity value affects the resistance levels of the material to the passage of heat. It is the total thermal resistance of the layers of materials in a floor, wall, window or roof that give their U-value. Lower U-values lead to less heat transfer.

Thermal Conductivity

The Thermal conductivity of a material is "the indication of its ability to transfer heat". If the thermal conductivity of a material is low then the rate of heat transfer will be low. The symbol for thermal conductivity is λ (pronounced lambda) or K and is measured in Watts per metre Kelvin (W/mK)

So let us explain briefly what these units Watts and Kelvin mean:

Watts

The Watt unit, denoted as the symbol W, is the unit of power (energy). The unit is defined as joule per second and can be used to express the rate of energy conversion or transfer with respect to time. ***For heat loss calculations, the Watt is a unit of heat energy.***

Kelvin

While the Celsius and Fahrenheit scales are the most widely used temperature scales. The scale used for heat loss calculation is the "Kelvin" temperature scale (Figure 2.9). This is a standard metric unit for the measurement of temperature.

For heat loss calculations, it is important to know that a degree Kelvin is equal to a degree Celsius.

So, in summary, thermal conductivity is measured as:

A unit of heat energy (W) per metre (m) per degree of temperature (K)

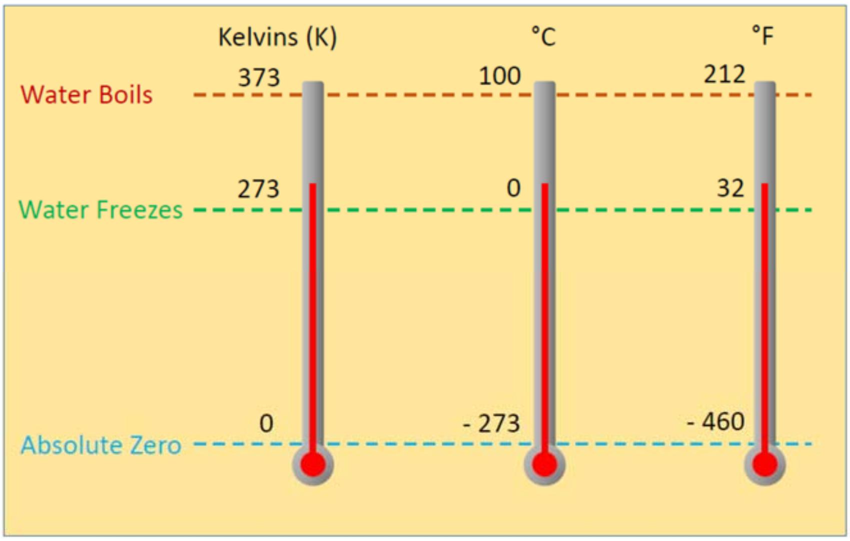


Figure 2.9: The Kelvin, Celsius and Fahrenheit Temperature Scales

How does thermal insulation work?

Air has a very low thermal conductivity so an insulating material which traps air in its make-up can slow down the rate of heat transfer. The air needs to be still to have effective insulation qualities, as we saw earlier that moving air transfers heat readily (convection). Certain gases have even lower thermal conductivity than air, such as Argon and Krypton which are used in double/triple glazing. Some materials such as sheep's wool naturally hold onto air, whereas other materials which we are familiar with as insulating material, like polystyrene, use a chemical reaction to capture air or gas in the form of bubbles.

Insulating materials work by having a low thermal conductivity. This means that they slow down the transfer of heat.

Figure 2.10 shows how insulation works for an external wall. The large red arrow shows the heat at one side of an insulated wall. The light spotted shape is a material with a low thermal conductivity (insulation), while the darker coloured shape has a higher conductivity (say a concrete block). The heat that transfers from one side of the wall to the other is reduced (as shown by the small red arrow) due to the low conductivity of the insulation.

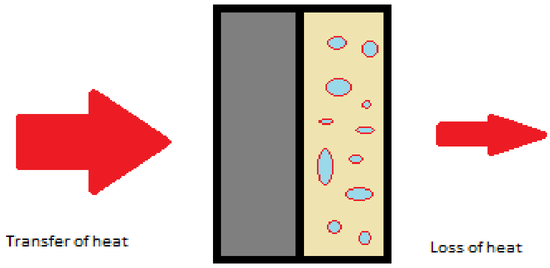


Figure 2.10 Insulation on an external wall reducing the rate of heat transfer

Thermal Resistance

Thermal conductivity is a measure of a material's capacity to transfer heat. Thermal resistance is the same thing the other way round!! It is a measure of a material's capacity to slow, reduce or resist the transfer of heat.

This is called the R-value and is measured in square metres Kelvin per watt, (m^2K/W).

The more a material is able to reduce heat transfer through it, the greater its thermal resistance, R value.

The higher the resistance, the better the insulation properties.

Therefore, it is important that we use materials with high thermal resistance in buildings so that we minimise heat transfer.

Importance of the thickness of the insulating material

The R-value of any piece of insulation is dependent on the thickness of the material as well as the thermal conductivity value.

This means that we can calculate the R-value of a material by dividing its depth/thickness (d) by its thermal conductivity (λ).

This is shown as: $\mathbf{R = d/\lambda}$

So, a thicker amount of the same material will have a higher thermal resistance and provide more insulation than a thinner amount.

This is why the thickness of insulation as well as the material used is so important.

Now let's have a look at the thermal properties of certain materials and compare them.

Figure 2.11 compares the thermal resistance properties of common materials and insulations used in construction with a thickness of 100mm. Note the difference between insulations and common materials such as glass and concrete block.

If the thickness of the materials increase, then the thermal resistance also increases therefore improving the thermal resistance of the element. Remember the thermal resistance is dependent not only on the thermal conductivity but also the thickness.

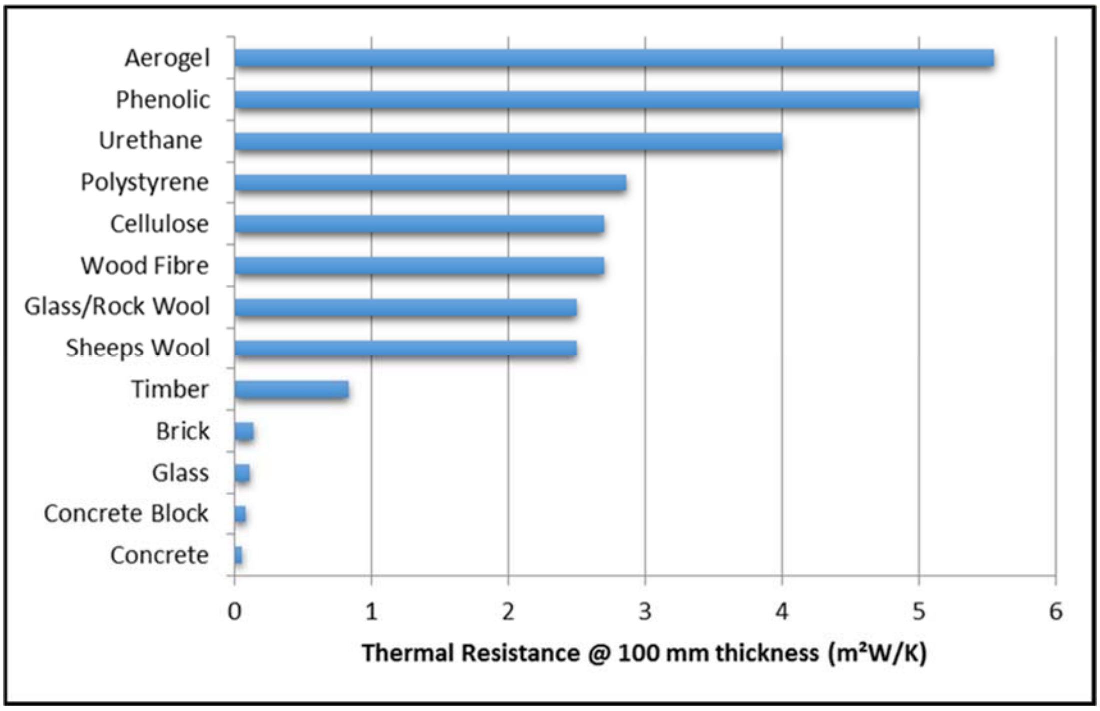


Figure 2.11 Chart comparing the thermal resistance for materials of 100mm thickness

Thermal Transmittance (U-Value)

The U-value is probably one of the terms which is most used when talking about the energy efficiency of buildings. The U-value is the measure of the rate of heat transfer through a building element, e.g. window, wall, roof, floor. It takes into account the resistances of all of the layers in the building element, including any air cavities

The U-value of a building element is the inverse of the total resistance of its layers (or 1 divided by the Total R). It is measured in Watts over meters squared Kelvin (W/m²K).

$$U - Value = \frac{1}{\text{Total R}}$$

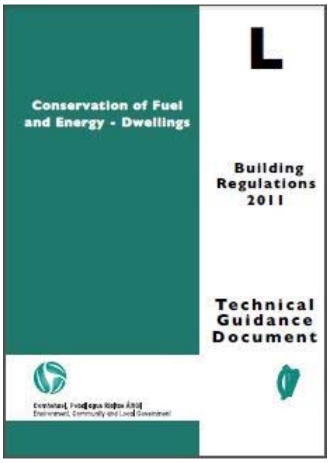
The lower the U-value, the lower the rate of heat transfer through that element.

Note that the materials with the best insulation properties have the highest thermal resistance and therefore the lowest U value. Therefore designers and builders should be striving for lower u-values to improve the energy performance of a building.

Irish Building Regulations

You have been introduced to the Technical Guidance Documents (TGD) in Unit 1. These cover all parts of construction for buildings including workmanship, fire safety, energy performance, heating systems, ventilation, structure and disability access etc. In this section we will be looking at Part L – Conservation of Fuel and Energy for Dwellings and Buildings other than dwellings, and the requirements that it sets out for U-Values of different building elements.

Residential



L3 For new dwellings, the requirements of L1 shall be met by: -
(a) Providing that the energy performance of the dwelling is such as to limit the calculated primary energy consumption and related carbon dioxide (CO_2) emissions insofar as is reasonably practicable, when both energy consumption and carbon dioxide (CO_2) emissions are calculated using the Dwelling Energy Assessment Procedure (DEAP) published by Sustainable Energy Authority of Ireland;
(c) Limiting heat loss and, where appropriate, availing of heat gain through the fabric of the building;

The following Figure 2.12 shows the current U-values for each element of a *residential* building (dwelling) to comply with the current building regulations.

These are the minimum, but we should aim higher if possible as standards continue to increase. Though further improvement is possible, however, it must be remembered that the standards required by the new regulations are a major improvement over those which applied in previous years. In fact, the standards under the current regulations are now similar to the NZEB standards and leading to the Passive House Standards of today.

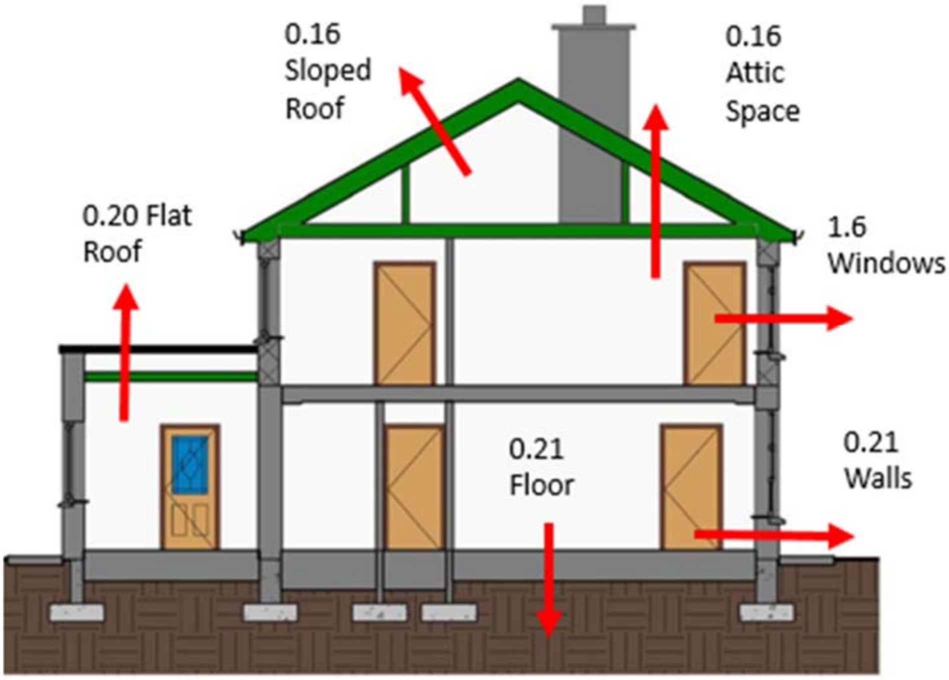
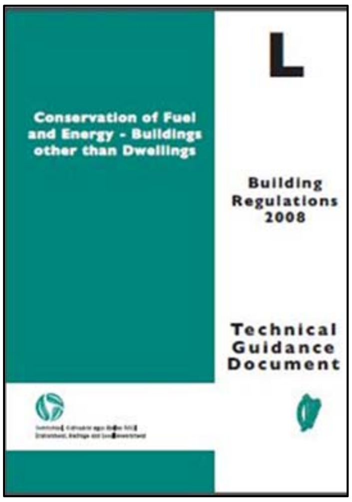


Figure 2.12 Permitted U-values for Dwellings taken from TGD Part L, 2011

Non-Residential



L4 For buildings other than dwellings, the requirements of L1 shall be met by:
(a) providing that the energy performance of the new building is such as to limit the calculated primary energy consumption and related CO_2 emissions insofar as is reasonably practicable, when both energy consumption and CO_2 emissions are calculated using the Non-domestic
Energy Assessment Procedure (NEAP) published by Sustainable Energy Ireland;
(b) limiting the heat loss and, where appropriate, maximising the heat gains through the fabric of the building;

In the next Figure 2.13 the diagram outlines the current U-values for each element of the building for new *non-residential* buildings. Again, bear in mind that these are the minimum values and are due to be amended and improved in the next year.

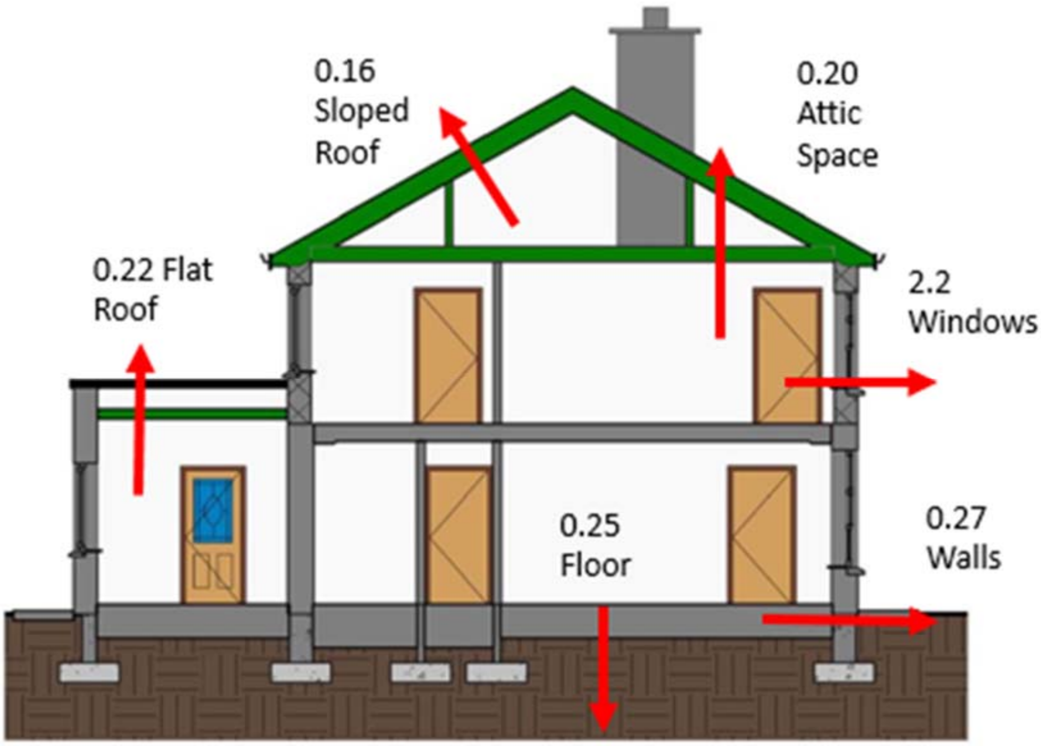


Figure 2.13 Permitted U-values for Buildings other than Dwellings taken from TGD Part L, 2008

If the U value is improved, there will be reduced heat loss through the building envelope of the building. This will contribute to lower heating costs and improved comfort levels.

To simplify:

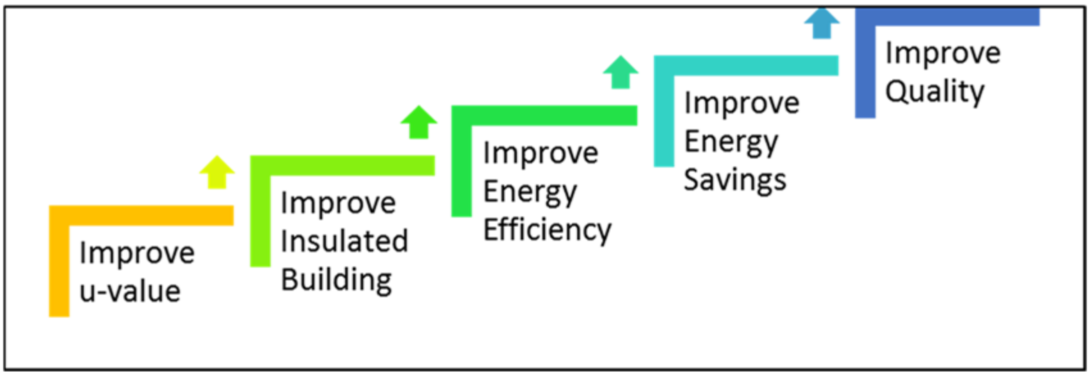
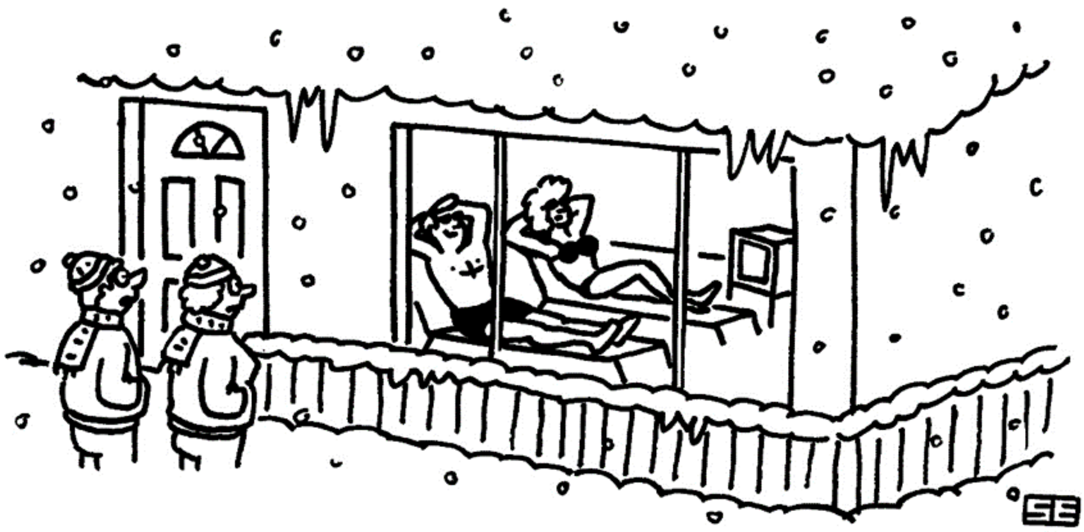


Figure 2.14 Demonstrating the steps to achieving Quality

Summary

- Heat loss in buildings is governed by the 3 main factors: Conduction, Radiation and Convection
- Energy only flows as heat, if there is a temperature difference.
- Heat energy flows from a higher temperature to a lower temperature.
- The greater the difference in temperature, the faster the energy flows.
- Heat loss in buildings occur through conduction, convection and radiation.
- Heat losses can be controlled by using materials with high levels of insulation in the construction of the external envelope and installing air and wind tightness barriers to prevent air leakages and uncontrolled ventilation within the building.
- Heat loss is the measure of a buildings thermal transmittance, known as the U-value.
- The Building Regulations specify maximum permitted U-values for all building elements - floors, walls, roofs windows, etc.
- All new builds whether for extensions or new buildings should comply with the most current building regulations. However, remember these U-values are minimum figures.



"They've got insulation to die for!"

Self-Test Four

1. What 3 principles apply to the transfer of heat?

1) ______________________________
2) ______________________________
3) ______________________________

2. Why are U-values important for quality building?

____
____
____
____

3. Give 2 examples of how heat loss within a building can be reduced.

1) ______________________________
2) ______________________________

4. What are the current U-Values for the following structural elements for dwellings?

Pitched Roof

____

External Walls

____

Ground Floors

____

Useful Links

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit2

TGD Part L, Conservation of Fuel and Energy - Dwellings, (2011), available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

See links below to videos illustrating heat loss principles and calculations:

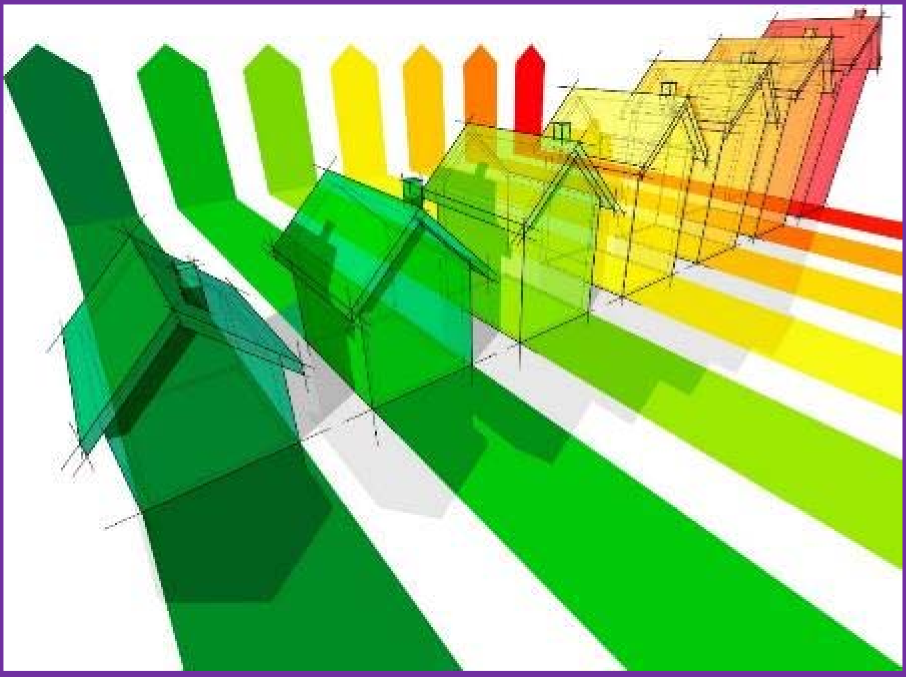
https://www.youtube.com/watch?v=DtTAWK9WBAM

https://www.youtube.com/channel/UCuVWfKPqDF9t1aSvcGkM0wQ

https://www.youtube.com/watch?v=jok1QbzAvJo

QualiBuild

Unit 3



Building Fabric – 1

Unit 3: Building Fabric - 1

We have now seen that a high proportion of energy usage in Ireland is due to the energy wasted in buildings. Therefore, in an attempt to reduce this energy waste, airtightness and continuous insulation needs to be included and maintained at all stages of design and construction.

Air tightness is a matter of concern for all those involved in the construction of a building. Even if you are not directly involved in the construction of the building fabric you need to understand the importance and principles of air and wind tightness, as you can affect them in your own work.

All trades should correctly close off any air leaks brought about by their own works, or to seek help from other trades, depending on the nature of the breach, i.e. hole in an external wall for pipes/cables.

In Unit 2, we looked at the principles of how heat is transferred; you will remember that convection or the movement of air is one of the ways in which heat/air moves. Therefore, controlling this air movement in and out of a building is a particularly important matter to consider.

Unit Overview

Unit 3 considers the impact of air tightness on energy efficiency and the methods used to reduce air leakage in buildings.

- What air tightness in buildings means
- The difference between air tightness and wind tightness
- How to achieve air tightness and why it is important to do so
- Examples of some key areas that need attention in buildings

Air Tightness

In this topic we will investigate the principles and then examine air tightness, how it can be achieved and how air leakage and heat-loss can be minimised before carrying out an air permeability test.

Wind Tightness

In this topic we will look at why it is important to provide for wind tightness to the external envelope of buildings.

Learning Outcomes

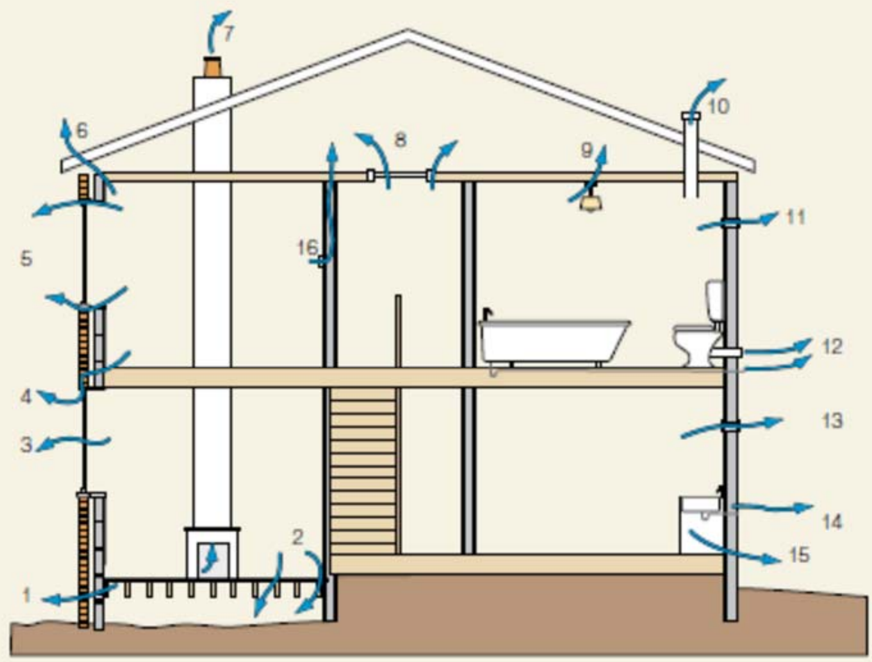
Successful completion of this Unit will help you to:

1. List and identify common areas of air leakage in buildings
2. Outline the principles of air tight and wind tight construction
3. Explain the importance of air-tightness and wind-tightness
4. Describe how an air permeability test is carried out.

Air Tightness in Buildings

As mentioned in Unit 1, air tightness refers to the reduction of *uncontrolled* movement of air in and out of a building. This movement is called 'air leakage'. It can refer to the movement of air from inside to outside (exfiltration) or from outside a building to inside (infiltration).

Figure 3.0 illustrates some of the most common air leakage points in dwellings. You will note that they result from work on both the fabric of the building and the installation of services. In other words, every trade onsite has some responsibility for ensuring that their work does not leave these types of leaks in the building envelope



Most common air leakage paths:

1 Underfloor ventilator grilles.
2 Gaps in and around suspended timber floors.
3 Leaky windows or doors.
4 Pathways through floor/ceiling voids into cavity walls and then to the outside.
5 Gaps around windows.
6 Gaps at the ceiling-to-wall joint at the eaves.
7 Open chimneys.
8 Gaps around loft hatches.
9 Service penetrations through ceilings.
10 Vents penetrating the ceiling/roof.
11 Bathroom wall vent or extract fan.
12 Gaps around bathroom waste pipes.
13 Kitchen wall vent or extractor fan.
14 Gaps around kitchen waste pipes.
15 Gaps around floor-to-wall joints (particularly with timber frame).
16 Gaps in and around electrical fittings in hollow walls.

Figure 3.0: Common air leakage pathways in a dwelling (source: Improving airtightness in dwellings, Energy Saving Trust, 2005)

Air exfiltration increases the amount of heat loss as the colder air from outside displaces the warm air coming from the inside of the building.

Commonly exfiltration occur through the walls, roof, floors, access hatches, windows, doors and service openings and at junctions where two different materials such as timber joists and block-work walls meet.

Air infiltration occurs at similar locations to air exfiltration and is shown in Figure 3.1. This shows the principal locations of air infiltration and the approximate percentage of infiltration which occurs through the different locations. Both types of air leakage are important in that they result in warm, heated air being replaced by cooler air.

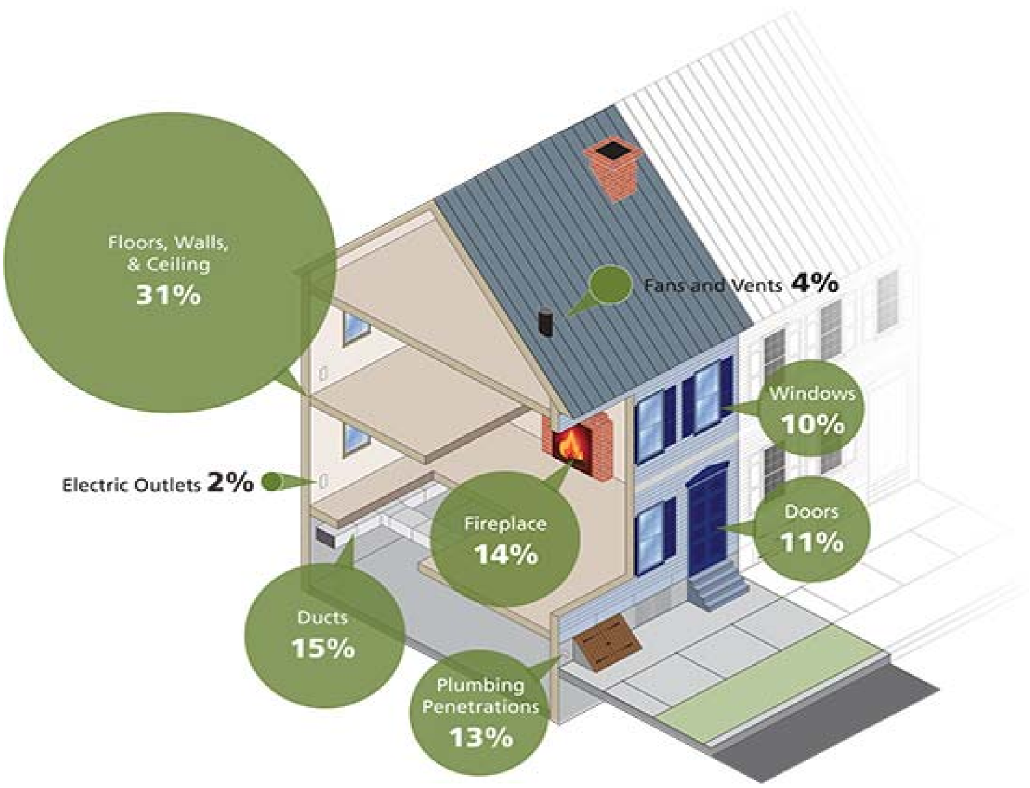


Figure 3.1 Percentage of air leakage through a typical building

As discussed in Unit 1, the energy use for space heating accounts for over 60% of the total use in buildings, and heat losses through the external envelope of the building can be reduced significantly if air leakage is controlled.

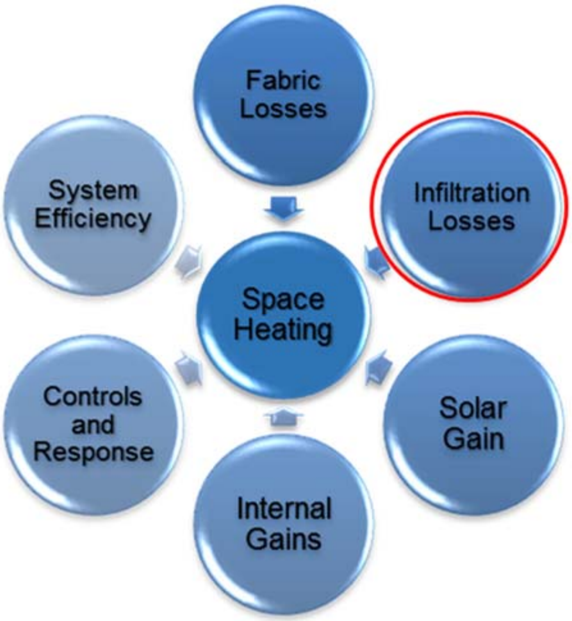


Figure 3.2 Diagram- Infiltration losses affecting energy use for space heating.

While air leakage is not desirable in an energy efficient building, controlled air movement is necessary. ***Controlled ventilation*** is necessary for a healthy building. Controlled ventilation will be discussed later in Unit 5, but for now all you need to remember is that air movement in a building is inevitable, but needs to take place in a controlled manner.

Why should a building be air-tight?

There are various reasons for providing an air tight building and these include providing a comfortable environment for the occupier such as the homeowner or worker in the office. There is nothing worse than having a draught on your back when you are trying to relax at home or work on a computer.

For an owner of the property or someone responsible for paying the bills it is important to reduce the heating costs. Providing air tightness can help with this.

These are the main reasons for making a building air-tight:

- Control movement of air.
- Reduce heat loss.
- Reduce energy costs by reducing energy waste.
- Improve BER rating and the value of the property.
- Improve the comfort of the occupant by removing draughts.

Air Tightness

As already mentioned in Unit 1, an air-tight building is one in which the *uncontrolled* leakage of air from inside to outside or from outside to inside is at a minimum and a completely air-tight building would be one in which such leakage was zero. Figure 3.3 shows the position of a continuous air tight barrier as it should be formed on the inside of a building envelope.

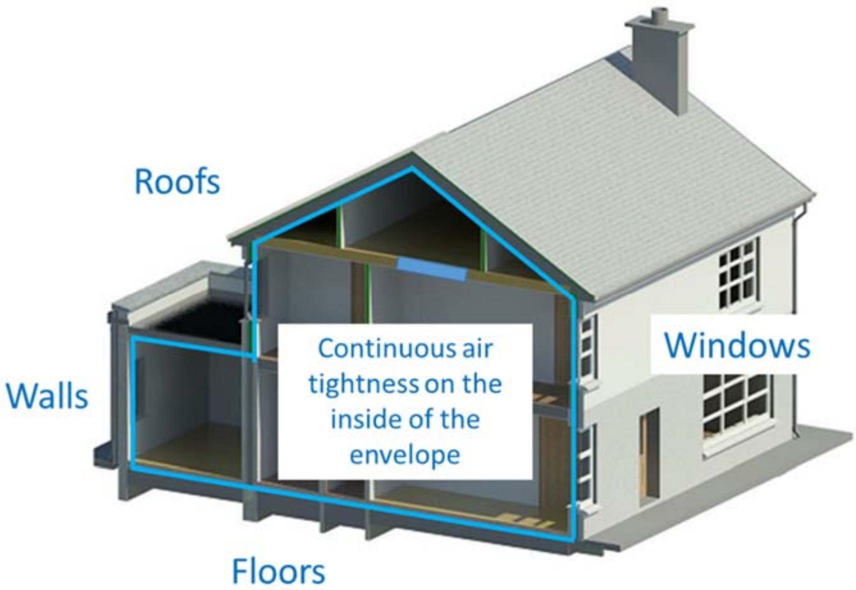


Figure 3.3 Air Tightness barrier in a building envelope

Air tightness is achieved by minimising the places where air can pass through the external fabric by minimising gaps and holes and by fitting air tight membranes, tapes and adhesives at certain locations where the fabric has to be penetrated.

Many parts of the fabric have good air-tightness qualities in themselves. Sand and cement plaster, for example, has good air tight properties, but this can be reduced by gaps caused by service holes and junctions with floors, ceilings or openings.

Wind-Tightness

Wind tightness is particularly important in the Irish climate given the high wind levels regularly experienced in many parts of the country. When wind penetrates the structure it reduces the thermal effect of any insulation which may have been installed. Figure 3.4 shows the position of a wind tight barrier in a building envelope.

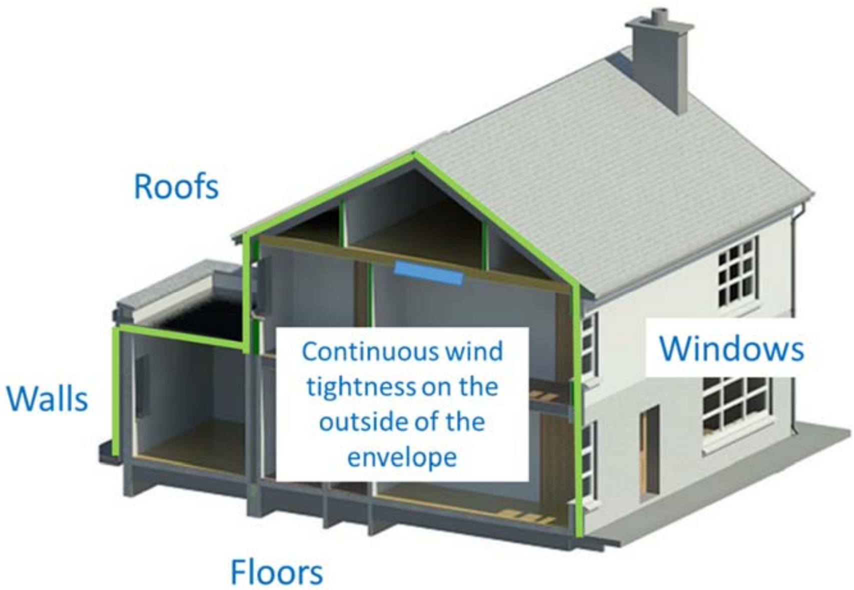


Figure 3.4 Diagram - Wind Tightness barrier around a building.

Historically in Ireland, roof structures in particular were designed in a manner that allowed wind to penetrate the roof area in order to address issues of ventilation and moisture associated with older building materials.

However, allowing wind to penetrate into the roof area can reduce the thermal performance of certain types of insulation, in particular fiberglass, rock or sheep's wool. This occurs because the wind cools the insulation thereby reducing their thermal performance.

Wind penetration can also occur around doors and windows. Once again driving wind penetrating these areas will lead to a reduced thermal performance.

Although wind tightness is currently not part of the Building Regulations, it is likely that it will be included over time.

Achieving Air and Wind-Tightness

There are 3 important steps to building air-tight/wind-tight:

1. Choose the correct wind/air tightness materials - fit for purpose.
2. Ensure the barriers are continuous – close off all gaps
3. Ensure minimal openings and gaps for services

Step 1: The following is a list of building materials which are suitable and unsuitable for air tightness:

Suitable:	Unsuitable:
Air tight membranes/tapes	Masonry (without render)
Manufactured boards	Silicone and acrylic sealants
Glass	Expanding foam
Compacted concrete / Wet plasters	Tongue and groove sheeting
Plastic/rubber	Rough timber
Metal sheets	
Mastic sealants (air tight grade)	

Step 2: It is important to ensure that all the elements of the building fit together in a way which minimises air gaps. This means that particular attention is needed at junctions between building elements and window/door openings.

Step 3: Minimise the numbers of holes and gaps, even small ones in the air-tight materials. This can sometimes be achieved by providing a service cavity on the inside of the air tight barrier pipes, cables and other services can be run. Where the creation of gaps and holes cannot be avoided (to allow for the installation of pipework for example), then steps need to be taken to seal up such gaps and holes to the maximum extent possible.

There are a variety of air tight membrane and tapes available for different types of construction and you should be aware of them, especially if you are involved in this line of work. Wind-tight membranes should also be fitted correctly, particularly in the roof area, to prevent excessive flow of air from Irish high winds, but remember to be careful of the possibility of a build-up of vapour and moisture within the structure.

Not all tapes and membranes will be suitable for use in all circumstances. It is important to be aware of the correct use and installation of each product and to use it in the right place and for the right purpose.

Key areas to watch out for to ensure air or wind tightness are:

- Correct use of wind tightness barriers and tapes below and/or above roof structures.
- Sealing of the attic hatch, especially if it is a cold attic.
- Sealing at the junctions of the timber floor joists and walls.
- Sealing of gaps around the skirting at floor levels
- Taping around windows and external door frames to stop draughts at the edges
- Sealing around pipes or wires pass through the external envelope.

Let's have a look at some of these key areas a bit more closely.

Underside of Roof

Providing air and wind tightness to the main roof structure is important as heat rises and the roof encounters the full force of our Irish weather. In Figure 3.5 the underside of the rafters and insulation are being lined with an air tight membrane. The top of the rafters should then be covered with a breathable membrane (that is, a material which allows water vapour to pass through it) that has all joints and penetrations taped (such as roof windows) for maximum protection from rain and wind (see Figure 3.6).

Figure 3.5 Air Barrier to underside of Rafter

Attic Hatch

The attic hatch is a common area for air leakage, encountering heat loss and down draughts. An insulated proprietary attic hatch may be fitted, complete with an air tight seal around its opening parts. Another option to achieve air tightness is to install an airtight tent as shown in Figure 3.6.

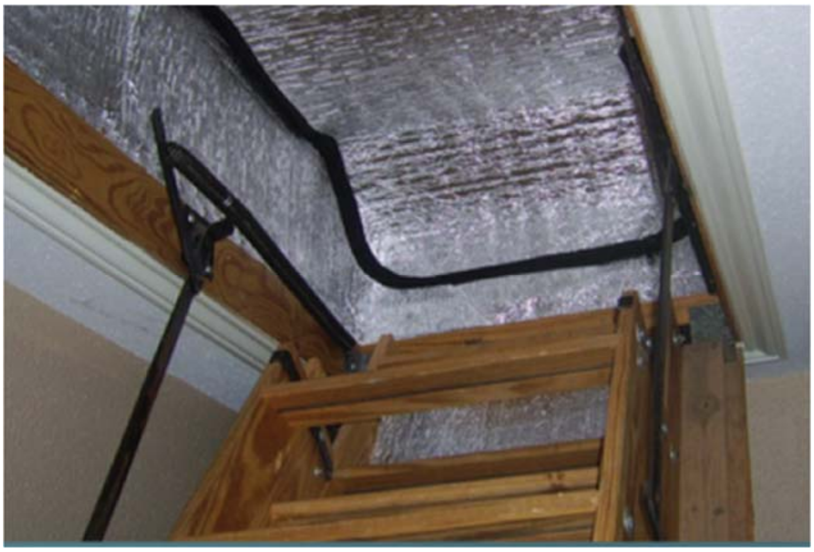


Figure 3.6 Airtightness tent to attic hatch

Floors and Walls

It is common to find that the wind/air tightness barrier is broken due to the penetration of the walls by the floor joists. Sealing the wall with a wind tight membrane helps to retain air tightness as seen in Figure 3.7. Other areas of weakness occur at skirting levels so the air tight barrier should be continued and sealed at ground level.

Figure 3.7 Wind tight membrane fitted at floor joist penetrations

Windows

Windows and doors are weak spots in the building envelope with draughts and cold spots often encountered by the occupants. Junctions between windows and walls can be made air-tight by making sure they are fitted snugly and sealed tight to the building fabric using appropriate plasters, sealants, membranes or tapes in the correct way to deal with any small gaps. Figure 3.8 shows membranes and tapes being employed to seal a window opening.

Figure 3.8 Air-tightness taping around windows

Services and Pipes

Some manufacturers of air tightness products supply special grommets to bring pipes or cables through air tightness membranes while maintaining a seal (Figures 3.9 & 3.10). Grommets are special designed sealer units which are easy to install and provide excellent sealing and flexibility. They also retain their position which is essential when installing wires and pipes through the building envelope. Alternatively, tapes may be used instead.

Figure 3.9 Air tightness grommet detailing for pipes

Figure 3.10 Air-tightness grommet for electrical services

Air Permeability Test

Air permeability is the measure of the air leakage levels that exist in a building. The amount of this air leakage is calculated by creating a pressure differential between inside and outside.

One of the main potential areas for heat loss in a building is the uncontrolled air exchange between the inside and outside of the building. The Building Regulations have been increasing their focus on this issue in recent years and are likely to increase this focus in the future. The Building Regulations use the concept of **air permeability.** Air permeability is defined as the amount of air leakage in cubic metres per hour per square metre of the building envelope assuming a pressure differential of 50 Pascals between inside and outside.

Current building regulations TGD Part L – for dwellings, sets a requirement for air pressure testing of new dwellings.

The permitted maximum air permeability level is **7 $m^3/hr/m^2$.**

An air permeability test to assess the air-tightness of a building is now a requirement of the Building Regulations.

It is also useful to carry out the test at practical completion stage (ie when the structure is complete and windows are installed, air tightness in place but before finishes) to check for any breaks in air tightness air leakage.

Figure 3.11 shows two photographs of the equipment used to carry out and measure an air-tightness test. The picture on the left is of the door and fan which is used to pressurise the building and the picture on the right is of the equipment used to measure the air-tightness.

Figure 3.11 Air permeability unit with fan and monitoring equipment

Air tightness and wind tightness are the mechanisms for ensuring that air-leakage is kept within the Building Regulation standards.

- The *Current Building Regulations* 2011 TGD-L (Dwellings) indicates that reasonable provision for airtightness is to achieve a pressure test result of no worse than $7m^3/(hr.m^2)$@50Pa.
- *Current Good Practice* for energy efficient dwellings includes achieving airtightness of less than $5m^3/(hr.m^2)$@50Pa
- *Best Practice* aims for $3m^3/(hr.m^2)$@50Pa.

Summary

- Air leakage is defined as the flow of air through the gaps and cracks in the building fabric. Uncontrolled air leakage (air infiltration, draughts, exfiltration or uncontrolled ventilation) increases the amount of heat loss as warm air is displaced through the envelope by the colder air from outside.
- Air and wind tightness can be achieved by using air and wind tight materials including membranes, tapes and sealants at strategic locations to:
- Minimise uncontrolled movement of air
- Reduce heat loss.
- Reduce energy costs by reducing energy waste.
- Improve BER rating and the value of the property.
- Improve the comfort of the occupant by removing draughts
- Current building regulations TGD Part L – for dwellings, set a requirement for air pressure testing of new dwellings of 7 $m^3/hr/m^2$ at 50 Pascal. (air permeability test).
- Future revisions of the regulations are likely to require better standards of air tightness to achieve compliance.
- Wind and air tightness should reduce energy waste provided that all persons involved in the design and construction process know what the requirements are, and therefore work together to achieve them.
- Attention to detailing at design and construction stage, as well as communication between all workers on-site is needed to achieve quality building.

Self-Test Five

1. Name two other terms commonly used to describe air leakage in a building?

   1) ______________________________
   2) ______________________________

2. List 4 areas where air leakage commonly occurs in buildings.

   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________

3. List 4 reasons why wind and air tightness helps the energy efficiency of a building.

   1) ______________________________
   ____
   2) ______________________________
   ____
   3) ______________________________
   ____
   4) ______________________________
   ____

4. What is the figure for the air permeability standards at 50 Pascals for dwellings as set out in the current building regulations and what figure is considered to be best practice?

____
____
____

Useful Links

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit3

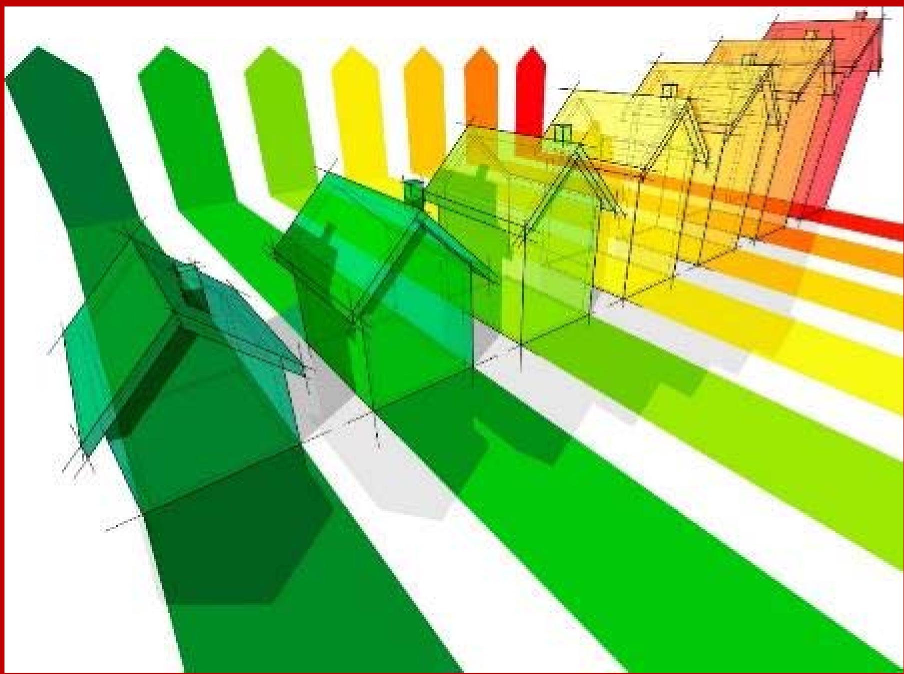
Department of Environment Community and Local Government, (2014), *Code of Practice for Inspecting and Certifying Buildings and Works*, Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,38154,en.pdf

Technical Guidance Documents (TGD) Available at: http://www.environ.ie/en/TGD/

Energy Savings Trust, (2005), *Improving airtightness in dwellings*. Available at: http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/Refurbishment/Improving-airtightness-in-dwellings-2005-edition

NSAI, (2014), S. R. 54: 2014, *Code of practice for the energy efficient retrofit of dwellings*, http://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx

Unit 4



Building Fabric - 2

Unit 4: Building Fabric - 2

The idea that "insulating the home first will keep the heat in, and the heating can be turned down" is vital to successfully achieving quality low energy buildings. Constantly turning the heat up and allowing most of it to escape is not a sensible idea and needs to be challenged. Remember heat can only be kept in a place if it is well insulated, as heat will escape through any gap or crevice from a heated area into a colder area i.e. inside to the outside.

The principles of how to control heat transfer due to air flow have already been highlighted in Unit 3, now we will look at how continuous insulation can contribute to energy savings and comfort levels within the building.

In this unit we will consider the concept of continuous insulation and how heat loss and other problems can occur due to thermal bridging at junctions. Examples of how to prevent these will be highlighted.

We will examine Best Practice methods of construction which lead to the Acceptable Construction Details (ACDs) that accompany the Building Regulations.

Unit Overview

Unit 4 looks at the importance of having a continuous insulation envelope to prevent needless and damaging heat loss.

Continuous Insulation

The importance of maintaining continuous insulation around the whole of the external envelope, ensuring that any gaps are kept to a minimum and how to choose materials which are fit for purpose.

Thermal Bridging

Looking at how thermal bridging occurs and how this can be controlled and reduced so that problems do not develop such as condensation and excessive heat loss.

Best Practice

Looking at ACDs and how to retain continuous insulation and air tightness within the structure of the building. Thermal imaging will also be discussed.

Learning Outcomes

The successful completion of this unit, will help you to:

- Outline the principles of continuous insulation and thermal bridging
- Identify insulation materials that are fit for purpose
- Explain the importance of avoiding thermal bridging in low energy buildings
- Investigate how to prevent thermal bridging at junctions using Best Practice details.

Continuous Insulation

Continuous Insulation is defined as "insulation that is continuous across all structural members other than fasteners and service openings". It is installed on the interior, exterior, or within the structure of the building envelope, e.g. external insulation, internal dry-lining systems and cavity insulation.

You will remember that we spoke previously of how heat can flow through solid material and that this is called **conduction.**

Remember from Unit 2, heat will always travel towards a cold spot

Now, think about what would happen if the building had a continuous layer of insulation all around it, as shown by the orange line in Figure 4.1. You will see that the continuous insulation, which, in this case is provided internally, but can equally be installed externally (as with external wall insulation, EWI).

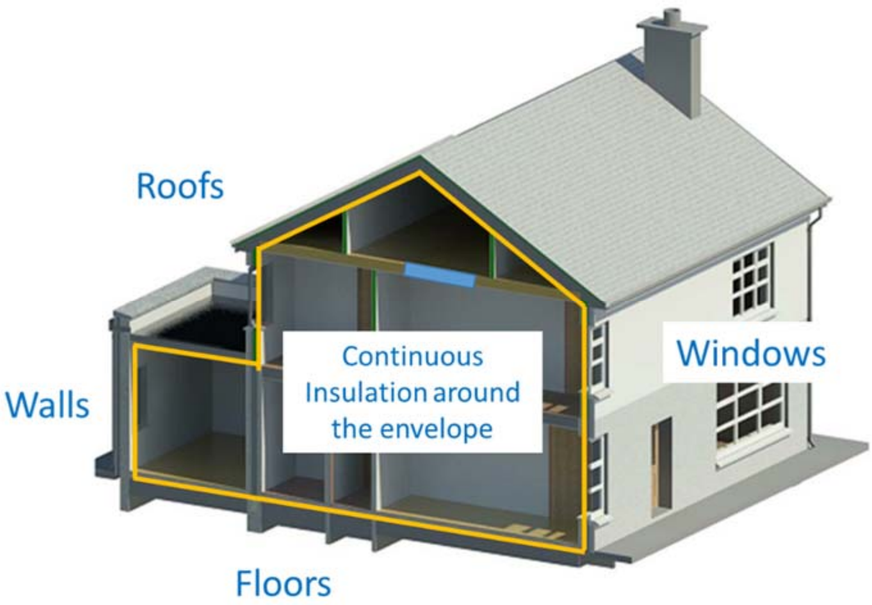


Figure 4.1 Continuous Insulation shown by orange line – eliminating heat flows through the envelope

This continuous thermal barrier can reduce the heat-loss from the building depending on the thermal resistance (R) of the insulation and also if it has minimal amount of gaps.

Remember, the lower the λ value, the higher the resistance. The higher the resistance of the material, the better the insulating properties

As long as the insulation is maintained around the building then heat loss and air leakage is minimised. These concepts have been discussed in Unit 1.

Remember how you wrap a jumper around you to keep warm and any hole in your jumper will provide a draught, discomfort and loss of heat. This also applies to a building.

How important is insulation?

Insulation is the main barrier to heat transfer in the building envelope. Fitting quality, high performance insulation has the following advantages:

- Reduce heat loss or control heat gain.
- Reduce energy costs (Space Heating or Cooling) by reducing energy usage.
- Improve thermal performance of the structure.
- Improve BER rating and the value of the property.
- Improve thermal comfort. (A steady temperature is maintained throughout the building) by reducing the transfer of heat.

So how do we achieve this continuous insulation?

There are 3 important points to remember when achieving continuous insulation

1. **Properties of Materials -** choose adequate and correct insulation on all parts of the external building envelope.
2. **Detailing** - Eliminate what is called **thermal bridging, (**as far as possible).
3. **Best Practice** - Eliminate any gaps and holes in the insulation (as far as possible).

Thermal Bridging

A thermal bridge is any break in the thermal barrier of the building envelope. This is why we should look to achieve continuous insulation, as the risk of thermal bridging is then greatly reduced.

Thermal bridging occurs when materials with a high thermal conductivity, such as steel, timber and concrete, create pathways for heat loss that bypass thermal insulation or break the continuous insulation barrier. This leads to added heat loss at these locations and cold spots on the walls which can lead to condensation, loss of comfort and mould growth.

As discussed in Unit 1, thermal bridging occurs at areas where:

- Two different materials with different thermal properties lie next to each other
- At junctions within the building envelope.

The following shows two common areas of thermal bridging.

Timber frame structure with insulation

Consider a layer of mineral wool insulation with low conductive properties fitted within a timber frame construction with medium conductive properties (Figure 4.2), heat will flow through the timber faster than the mineral wool and heat within the building will draw through the timber areas (weak spots) faster. This reduces the effectiveness of the insulation and increases the overall U-value of the wall. The arrows show heat loss paths (red) being drawn through the materials into a cold space (blue) i.e. from hot to cold, with greater heat loss through the timber stud.

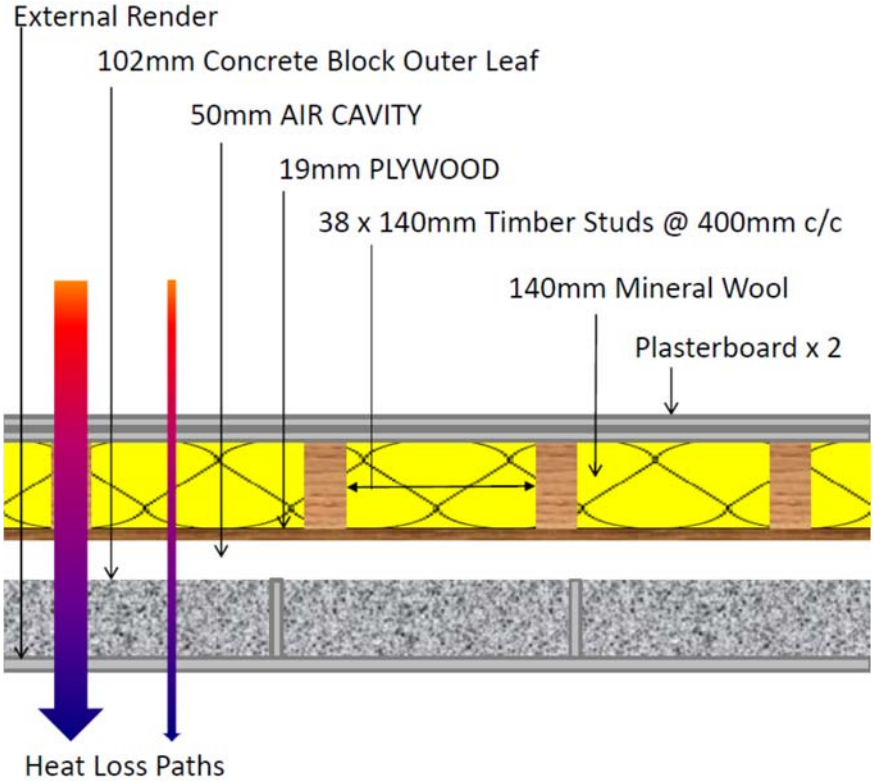


Figure 4.2 Typical timber frame external wall construction showing Thermal Bridging

To minimise the impact of the thermal bridge, additional insulation can be laid in front of the timber frame (Figure 4.3). This will provide a continuous layer of insulation and therefore reduce the impact of heat flow through the timber studs.

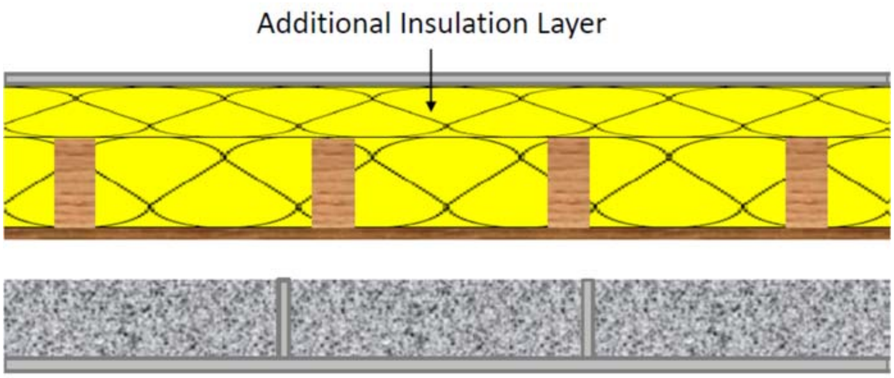


Figure 4.3 Addition of Insulation Layer to Counteract Thermal Bridging Affect

Thermal Bridging at Window Openings

Openings in external walls for windows and doors carry a high risk of thermal bridging. Detailing at window sills, reveals and heads needs particular attention to avoid breaks in the thermal barrier.

A typical case of thermal bridging occurring at the junction of a window sill in a cavity wall is shown in Figure 4.4. Quite often the window sill is either back filled with sand and cement or concrete. This breaks the continuity of the insulation layer, creating a clear path for rapid heat loss.

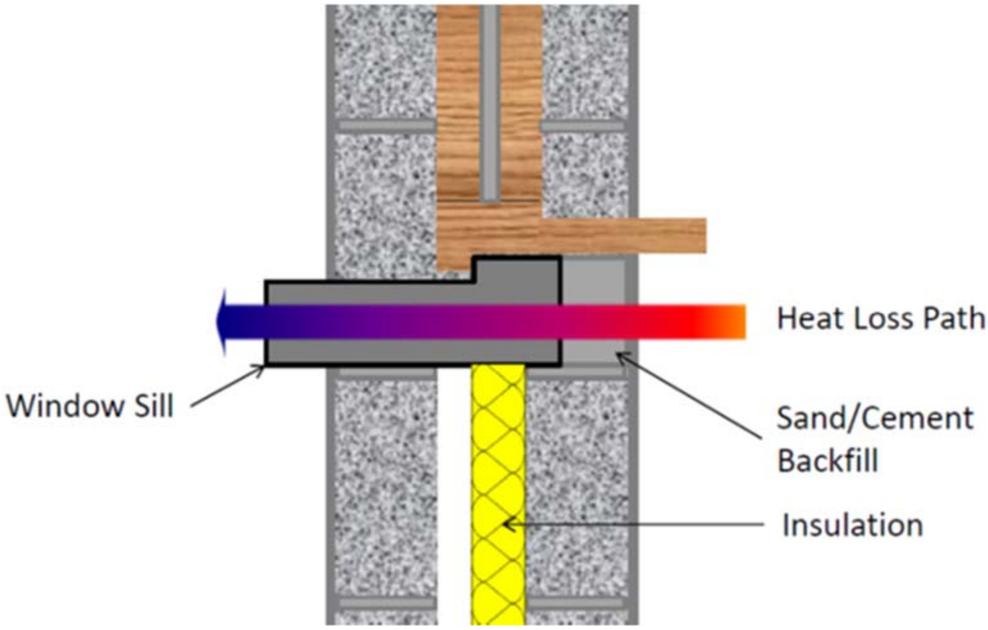


Figure 4.4 Cavity Wall Un-insulated Sill Detail showing Thermal Bridging

It is good practice that concrete sills are backed with insulation, as illustrated in Figure 4.5. Even using this detail, there is still a small gap left in the insulation layer. To improve this further, narrower sills can be used which allow the insulation to continue from the cavity up behind the sill until it meets the bottom of the window frame

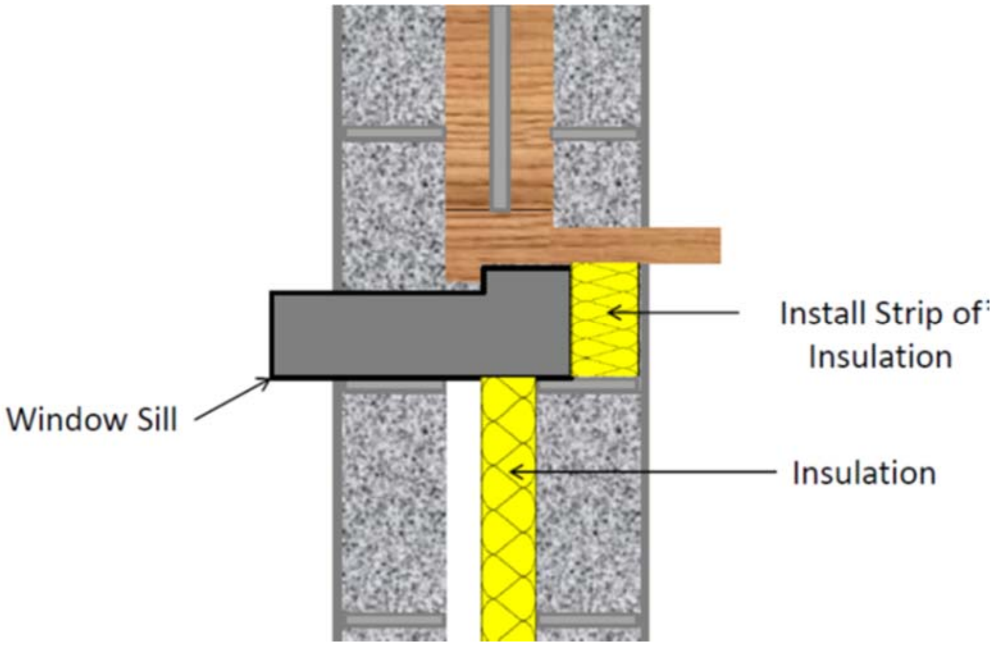


Figure 4.5 Cavity Wall with Insulation to Back of Sill with reduced Thermal Bridging

Another common example of thermal bridging is at window reveals. Traditionally, a cavity wall was closed at an opening by returning a block. This created a clear bridge of the insulation layer for the full width of the block (100mm).

To avoid this, a strip of insulation should be installed between the block and the external leaf. Otherwise, a proprietary insulated cavity closer can be applied at the junction (see Figures 4.6 and 4.7).

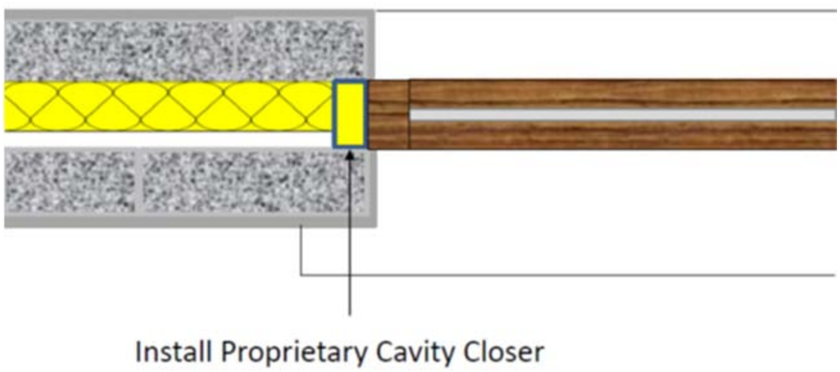


Figure 4.6 Proprietary Cavity Closer installed at Window Reveal

The cavity closer (insulated strip) is fitted within the wall so that the window can be tightly fitted to this to retain a continuous insulated layer. See Figure 4.7.

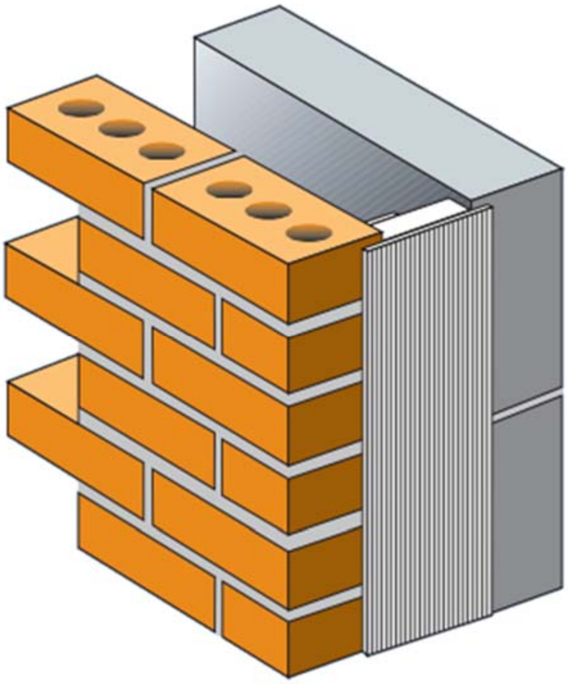


Figure 4.7 Example of an insulated cavity closer to the window opening.

Avoiding thermal bridging is very important, particularly when we are insulating to high standards. The more we insulate the faster the heat flow will move through areas where it is not insulated, especially at junctions and openings. This is known as accelerated heat loss, as the heat is following the path of least resistance (hot to cold). Added to this, the temperatures at these weak points are low in cold weather leading to much higher risk of surface and interstitial condensation.

So we need to ensure that these weak points are well insulated.

There is a general **Rule of Thumb of 1:2 that we should follow:**

Always ensure the weakest part of a structure has at least half the insulating properties of the strongest part, or there may be a risk of thermal bridging

Failure to provide continuous insulation will give rise to heat loss and thermal bridging

Properties of Materials

When deciding on the material to use we must be aware of the side effects caused by efforts to reduce thermal bridging such as:-

- Surface condensation and mould growth
- Deterioration of the building fabric caused by interstitial condensation
- Cold surface temperatures which affect occupant comfort levels

It is important to consider the properties and characteristics of the material when choosing insulation products and systems. In Unit 2, we looked at the different thermal properties of materials. However, other factors which should be considered are:

- Water or vapour resistance (breathability)
- Compatibility with other materials
- Wind or air resistance
- Life expectancy of the material

Breathability or Vapour Permeability

Moisture build-up is one of the dangers in highly insulated buildings. Breathability is a term often used to describe the capacity of a material to absorb and release moisture or to let it pass through.

Different insulating materials have varying breathability properties which is also called Vapour Resistance/Permeability ***(μ).***The breathability property of insulation needs to be considered when working with natural products such as stone, lime and timber etc. and particularly in old buildings which have a lot of these materials present. Care should be taken to ensure that insulations systems which prevent the drying out of the building fabric are avoided.

This ability to dry out is vital in certain types of construction and in particular solid stone walls. If vapour is not allowed to pass through the structure then condensation may occur which leads to structural damage (interstitial condensation) or health problems within the building from poor air quality. Internal insulation (or dry lining) should be added with caution to ensure that water vapour/ moisture is not trapped within the structure.

If you remember the issues of Interstitial Condensation was explained in Unit 1 of this handbook and how this can lead to mould growth and unhealthy buildings.

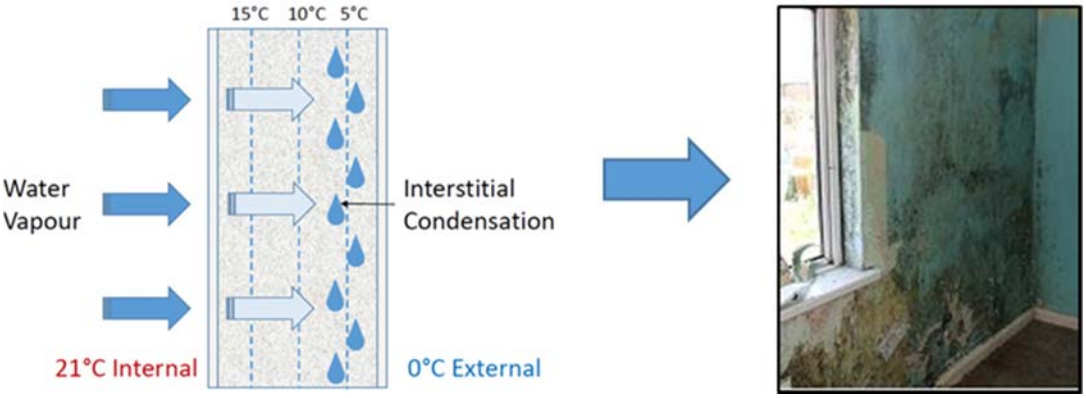


Figure 4.8 Interstitial Condensation leading to mould growth

The lower the breathability then the lesser the likelihood that natural air or vapour movement will flow through the material.

Materials with low breathability are suitable in specific locations within the building envelope and these include cavity full fill insulation, external insulation to masonry walls and below ground.

Compatibility with other materials

A variety of materials commonly used in the construction of buildings are listed in the following Tables 4.0 and 4.1. Take a look at these and see if any are familiar and where you have seen them fitted within the building envelope.

Building Materials

Table 4.0 Properties of Common Building Materials

Material Type	Category	Applications	Conductivity	Breathability
Metal	Aluminium, Steel	Windows, doors, cladding steel frame, lintels	230 45 45	Extremely low
Concrete	Precast concrete, In-situ concrete	Floors, walls, flat roof	1.13	very low
Concrete blocks	Heavy block, Medium blocks Hollow cavity block	Walls, rising walls	1.33 1.15 1.02	very low
Plasterboard	With foil back	Internal panelling (not for stone walls)	0.16-0.25	very low
Aerated	Cellular, lightweight material from quartzite sand, lime and water.	Wall blocks, walls panels, thermal bridging	0.33	fairly low

Pumiced	Lightweight material from pumice, cement and water	Walls, roof, floors, thermal bridging	0.18	fairly low
Clay blocks	Clay bricks, Aerated clay blocks	Walls, thermal bridging	0.77 0.30	fairly low
Plastic	uPVC,	Windows, rooflights, doors	0.14–0.28	low
Glass	windows	Curtain walls, windows, rooflights, doors	0.96	low
Cement	Cement based tiles, Cement fibre boards Render	Walls, external render, flat and pitched roof, internal render	0.5 0.35 0.18	low high
Timber	Timber, Laminated, Woodchip, Woodfibre, mdf,	Roofs, Walls, floors, external render, windows, doors	0.12-0.14	low - high
Plasterboard	Plasterboard, Mdf,	Internal panelling, to walls and roof.	0.16-0.25	high

Insulations

Table 4.1 Applications for Common Insulations

Insulation	Category	Applications
Aerogel	Quilt roll, thin strips,	Loft, walls, rafters, thermal bridging, glazing
Phenolic	Rigid slabs – sometimes composite with plasterboard	Concrete floor, rafters, flat roof, EWI, IWI
Polyisocyanurate	PIR board with foil coating	Concrete floor, rafters, flat roof,
(Poly)Urethane	PUR rigid board, PUR spray applied	Concrete floor, rafters, flat roof, EWI, IWI
Polystyrene	EPS boards, XPS boards, beads spray applied	Concrete floor, flat roof, EWI
Cellulose	Loose fibre – bags or spray applied	Loft, rafters, timber frame
Stone Wool Fibre	Quilt rolls, loose fibre, batt form, rigid slabs	Loft, rafters, timber floors, timber frame, EWI
Wood Fibre	Batt form slabs, rigid slabs	Loft, rafters, timber floors, timber frame, EWI, IWI
Mineral wool	Glass or stone mineral quilt rolls, batt form, loose fibre	Loft, rafters, timber floors, timber frame
Fibre Glass	Pyrogel XT	Loft, rafters, timber floors, timber frame
Sheepswool	Quilt rolls, batt form	Loft, rafters, timber floors, timber frame
Hemp	Quilt rolls, loose fibre, batt form, rigid slabs	Loft, rafters, timber floors, timber frame, EWI, IWI

In order to reduce the energy costs and improve the insulation levels of a building, the types of insulation and materials chosen and installed should be ***Fit for Purpose***.

This means for example, that the chosen insulating material should not result in problems within the structure such as interstitial condensation and mould growth and should be able to provide suitable U-values for that element of the building envelope.

As the Building Standards call for the energy performance of specific building elements to be improved, the choice of insulating materials and how these are fitted and detailed becomes increasingly important to achieve low energy quality building.

Acceptable Construction Details (ACDs)

The achievement of a high quality, energy efficient building needs to be considered from the design stage right through to the final stages of construction. As we have seen, two key elements in creating an energy efficient building are the provision of a layer of continuous insulation and an air-tightness layer in the building envelope.

The proportion of the overall heat loss due to thermal bridging in an average dwelling built in 2008 can be as much as 15%. This figure can be a lot higher with older dwellings due to poor detailing and choice of construction systems.

As this is so significant, the Building Regulations and TGDs now come with an accompanying set of Acceptable Construction Details (ACDs). ACDs have been developed to provide guidance on how continuous insulation and air-tightness can be maintained at specific locations (weak spots) in the dwelling to minimise heat loss and air leakage.

In short, ACDs provide sectional details that achieve continuity of the insulation and air barrier between each part of the construction and the next.

Compliance with the ACDs, therefore, is an important part of ensuring compliance with the Building Regulations.

Acceptable Construction Details (ACDs) are available from the QualiBuild website http://www.qualibuild.ie/useful-links/unit-1/

All materials used for airtightness in all buildings should also comply with **TGD Part D** of the Building Regulations “Materials and Workmanship”.

All installations and detailing should also adhere to compliance with the relevant and current **TGD Parts L and F,** as discussed in Unit 5.

Examples

The following are two examples of common ACDs in dwellings:

- Vented Attic – roof and wall junction
- Concrete Ground Floor – floor and wall junction

Both details indicate how to achieve continuous thermal performance and continuous air tightness and point out areas where attention should be directed. It should be noted that these details, although approved, can be improved upon further.

Vented Attic

Figure 4.9 shows requirement method for providing continuous insulation around the ceiling joists and over the wall plate of a cavity wall to insulated ceiling junction. Note that the ACDs use a colour coding to highlight the thermal barrier (in red) and the air barrier (in blue). The air tightness detailing requires sealing of all the joints with tapes and/or seal with wet plaster internally.

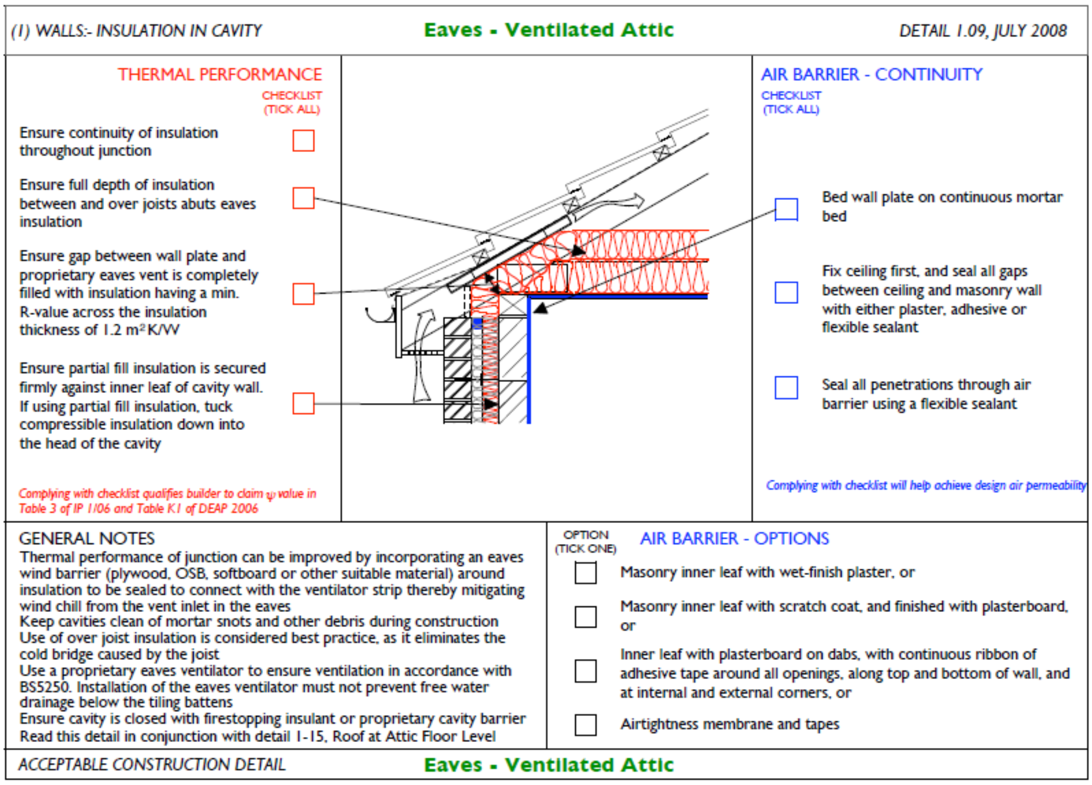


Figure 4.9 ACD at the junction of a cavity blockwork wall and a pitched roof

The photograph in Figure 4.10 shows the insulation applied between and above the ceiling joists to ensure continuity of insulation and obtain the correct U-value for the roof. When applying insulation in a ventilated roof space it is important to retain a ventilation gap at the eaves to the roof space to prevent condensation and the rotting of the timbers. This is highlighted in the ACD in Figure 4.9.

Figure 4.10 Checking that ventilation is maintained while insulating the ceiling of a pitched roof

Concrete Ground Floor

Another example is a junction between a cavity wall and a concrete ground floor slab. The ACD places importance on thermal bridging at the junction of the wall and concrete floor. It is important to provide perimeter insulation and use thermal blocks around the perimeter. A significant amount of heat can be lost if this weak spot is not correctly detailed.

To achieve air tightness, a flexible air tight sealant should be applied at the wall and floor junction behind the skirting board or, alternatively, carry an air tightness membrane from the wall over the floor and seal.

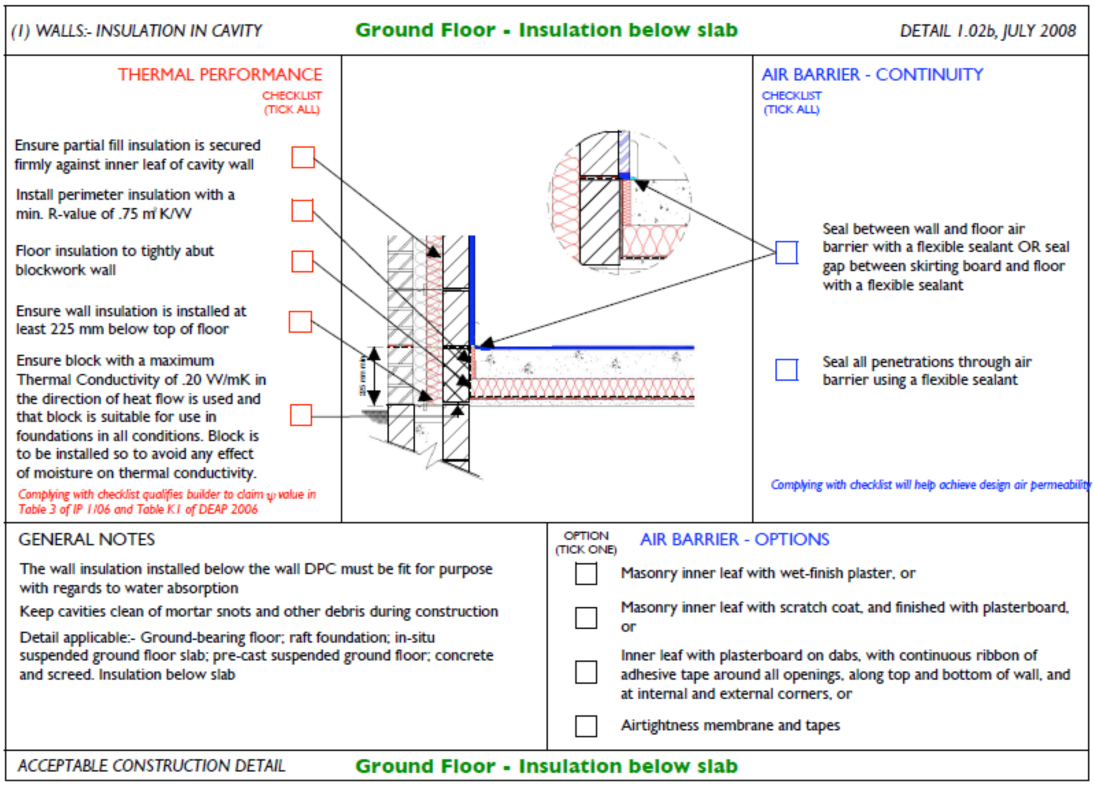


Figure 4.11 ACD at the junction of a concrete ground floor and cavity blockwork wall

If the floor insulation is installed under the concrete floor then thermal bridging can occur at the junction of the cavity wall and the concrete floor. Placing insulation to the perimeter of the external walls is now common place (Figure 4.12).

Figure 4.12 Applying perimeter insulation to the junction of a concrete ground floor and cavity blockwork wall

Thermal bridging can be further reduced by using structural thermal blocks to the first two rows of the internal blockwork wall with a thermal conductivity of 0.20W/mK.

Examples in Practice

The following section considers two examples of best practice approaches to building fabric detailing, including some common poor practice for comparison.

Pipework through the building envelope.

During the construction of a house, two waste pipes are run through a wall by providing a large hole in the blockwork and insulation (as shown in the photo on the right in Figure 4.13). This type of poor detailing will lead to significant loss of heat and air infiltration into the house. As discussed previously, air leakage needs to be controlled and the insulation around the building envelope should be continuous as far as possible with any unavoidable gaps kept to a minimum.

If the bricklayer and the plumber had early discussions on the details and locations of services then continuous insulation and air tightness could have been provided whilst the wall was being built.

Attention to detail should be considered when providing passage for services. – keep the gap to minimum.

The photo on the left in Figure 4.13 shows a best practice approach to running a waste pipe through the building envelope (roof in this case). Air tightness can be maintained internally by using a special rubber grommet over the pipe which can be taped to the air tight membrane. Pipes generally move after installation, due to the nature of pipework, and providing a flexible grommet or sleeve allows for this movement. Tape can also be used to seal the joint but may not have as much tolerance and could tear if not applied carefully.

Figure 4.13 Best practice and poor practice for pipes cutting through a building envelope.

Installation of a window.

Installing windows within the building envelope should be considered carefully. Ideally windows should be placed on the line of insulation to reduce thermal bridging. The example shown in the photo on the right in Figure 4.14 shows a window fixed in a partial filled cavity blockwork wall without the use of an insulated cavity closer and therefore creating a clear thermal bridge.

During retrofit, efforts should be made to reduce thermal bridging, such as insulating around the window reveal as shown on the left in Figure 4.14.

Figure 4.14 Best Practice and poor practice detailing around windows

Air tightness should also be provided and the example shown in Figure 4.15 shows the fixing of air tightness membrane around the window reveals and overlapping around the corners along the front wall. This ensures air tightness to the junctions before the plasterboard is applied.

Figure 4.15 The Best - Air tightness detailing around windows

Best Practice

Whilst, the ACDs are a good starting point, they are not necessarily the *very best* that we can do and we should always be considering how we can improve on the minimum requirements.

While there are obvious efforts made onsite to provide good insulation, detailing and air tightness, it is important that this is carried out to Best Practice methods.

This is not as difficult to achieve as you may think; it just requires:

- Good workmanship.
- Care and attention.
- Responsibility.
- Good communication between all trades.

Following best practice is important in order to achieve quality buildings. Every person on site, whether they are clients, assessors, Architects, project supervisors, contractors or construction workers have responsibility for achieving standards.

Remember:

There are 3 stages in achieving low energy buildings

- The first stage is to reduce the energy waste **by** the building i.e. provide air tightness and continuous insulation.
- The second stage is to improve the energy efficiency **in** the building i.e. upgrade the heating system and provide controlled ventilation.
- The final stage is to reduce energy usage by the end-user i.e. provide service and maintenance plans.

Thermal Imaging

Although not demonstrated as part of this course, it is useful to know about thermal imaging as it is becoming more and more used in the building sector.

Infra-red thermography (IRT) or thermal imaging, can detect heat using a special camera. Variations in temperature due to heat loss in the envelope of the building can be seen and recorded. The examples below generally show heat loss at certain junctions. If viewing the area from the inside, then heat loss is indicated with the colour blue (cold spot) and if viewing externally heat loss is shown with red, orange and yellow (heat escaping from the building).

Examples of thermal images at junctions

Take a look at the next three case studies/photographs and ask yourself the following questions:

- Do you see anything wrong with these pictures?
- If so what and how has the problem occurred?
- Why has this occurred?

Thermal Image - External

External Door

Heat loss occurs through the external envelope and is often significant around windows and doors, especially at the junctions with the wall. In this example heat loss occurs where the colour scale is shown as yellow to red as shown in Figure 4.16.

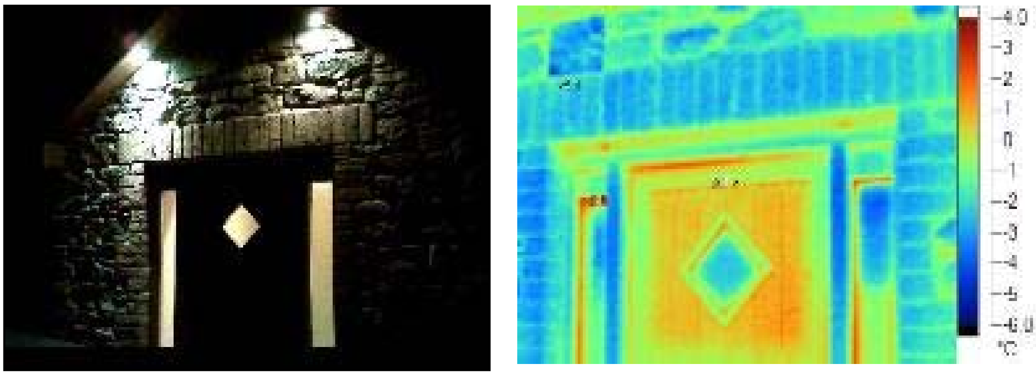


Figure 4.16 Thermal image around a door junction

The timber door has a low energy rating and heat loss is significant.

Warm air will flow to cold spots and escape often at junctions where two different materials meet.

Thermal Image – Internal

Hatch to the attic

Look at how much heat loss occurs through an unsealed and partly insulated attic hatch. Heat loss is shown as blue and note the heat loss at the junctions around the hatch in Figure 4.17. This could be alleviated by using seals and the hatch door could be further insulated to improve the energy performance.

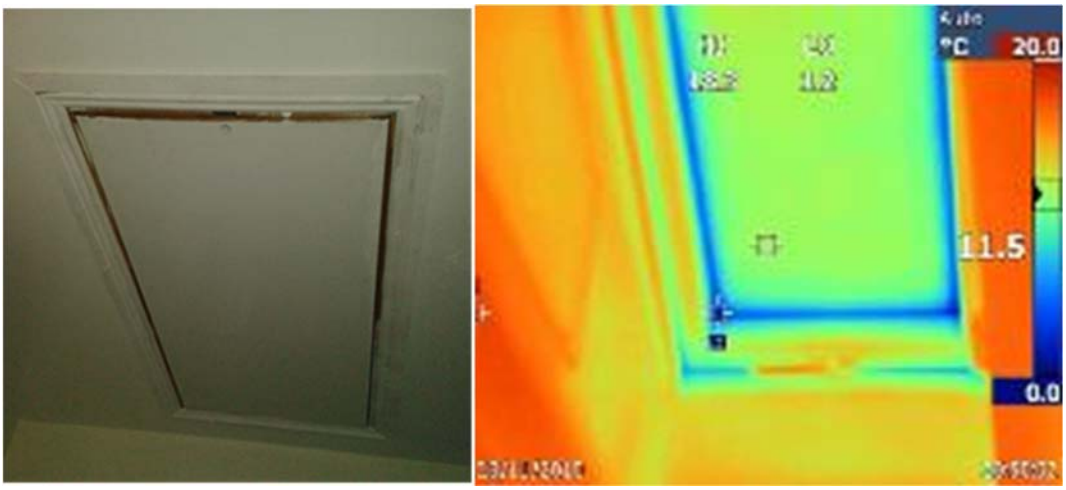


Figure 4.17 Thermal image of an access hatch

External Vents

Heat loss does not just occur at junctions but occurs at service areas. The example here shows heat loss as the blue coloration on the wall directly in the position of the vent. Significant heat loss is apparent and although services are required and some heat loss will occur at these points, effort should be taken by all construction workers to reduce the level of heat loss by minimising the number of service holes and reducing the size of these holes. Remember grommets to reduce air leakage and using suitable insulations around the pipework can also reduce heat/energy loss.

Think how this can be achieved, if alternative methods of construction were used to best practice?

Figure 4.18 Thermal image of a ventilation grille

Reduce heat loss by checking all junctions are correctly closed, minimise the size of service holes and reduce the number of these if possible.

Summary

- Insulation should be tightly fitted to the fabric with no gaps and should form a continuous layer around the building envelope. The heat flow of hot air will try to find any cold spots usually at junctions where two different materials meet.
- Reduce heat loss by checking all junctions are correctly sealed, minimise the size of service holes and reduce the number of these if possible.
- Common air leaks occur at junctions where elements meet such as between timber joists and blockwork walls.
- Always ensure the weakest part of a structure has at least half the insulating properties of the strongest part, or there may be a risk of thermal bridging.
- Failure to achieve continuous insulation will give rise to heat loss and thermal bridging, which in turn will create problems such as:
  - Surface condensation and mould growth
  - Deterioration of the building fabric caused by interstitial condensation
  - Occupant discomfort caused by cold surfaces
- ACDs provide sectional details that achieve continuity of the insulation and air barrier between one part of the construction and the next.
- To avoid excessive heat losses, reasonable care should be taken to maintain the continuity of insulation and limit local thermal bridging. At junctions this can be achieved by following the information in the ACDs.

Self-Test Six

1. Name 3 problems that will occur if continuous insulation or thermal breaks are not provided.
   1) ______________________________
   2) ______________________________
   3) ______________________________

2. What is thermal bridging?

   ____
   ____
   ____

3. When would you consider the use of insulation with high breathability properties?

   ____
   ____
   ____
   ____

4. Name five parts of a building where thermal bridging is likely to occur.
   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________
   5) ______________________________

5. What is the principal characteristic of a good insulating material?

   ____

Useful Links

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit4

Department of Environment Community and Local Government, (2008) *Acceptable Construction Details*, Section 1, Introduction and General Theory of Insulation Continuity and Air Tightness, Available at: http://www.environ.ie/en/TGD/

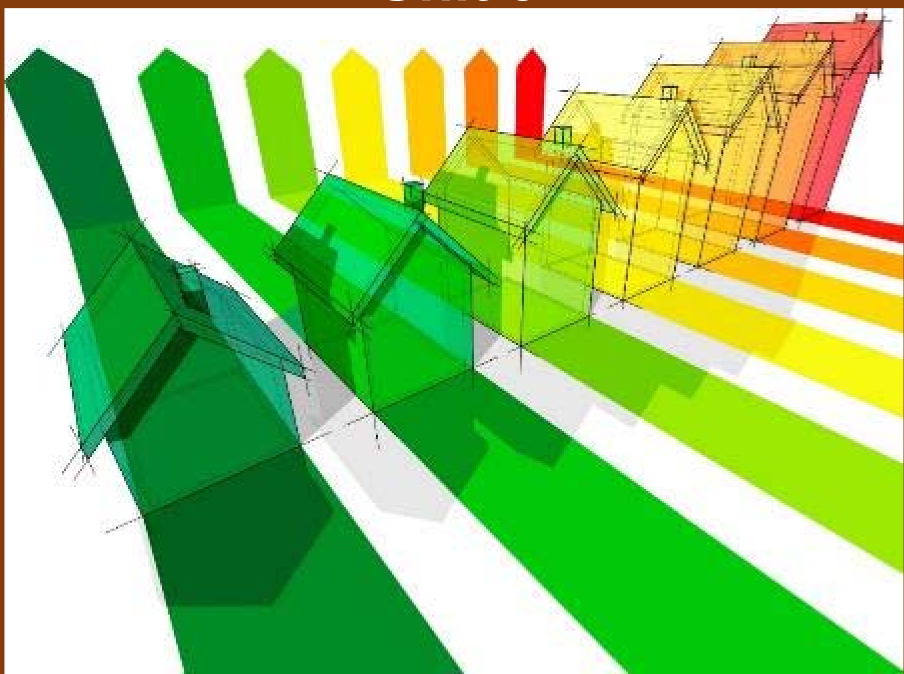
Department of Environment Community and Local Government, (2008) *Acceptable Construction Details*, Sections 1 - 6, Limiting Thermal Bridging and Air Infiltration, Dublin: Stationary Office. Available at: http://www.environ.ie/en/TGD/

Department of Environment Community and Local Government, (2014), *Code of Practice for Inspecting and Certifying Buildings and Works*, Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,38154,en.pdf

Energy Savings Trust, (2005), *Improving airtightness in dwellings*. Available at: http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/Refurbishment/Improving-airtightness-in-dwellings-2005-edition

QualiBuild

Unit 5



Heating and Ventilation

Unit 5: Heating and Ventilation

In the previous units, the importance of air tightness and continuous insulation within the envelope of the building have been discussed. However, whatever the performance of the building fabric, there is great potential for improving the energy efficiency of installed systems for space and Domestic Hot Water (DHW) heating.

We will look at how the installation and use of heating appliances and ventilation systems have an impact on energy efficiency and consumption, by looking at conventional and renewable systems.

Unit Overview

This Unit will cover the principles of efficient heating and ventilation systems

Heating Systems

This will describe conventional heating systems and renewable type systems available on the market and consider how these systems work within buildings using case studies.

Ventilation and Condensation

Once the building is air tight, it is essential to provide the correct ventilation system to prevent condensation and mould and to provide fresh air. Options are available for mechanical and natural ventilation systems and the positives and negatives of each will be outlined. These systems need to comply with regulations set out in TGD part F.

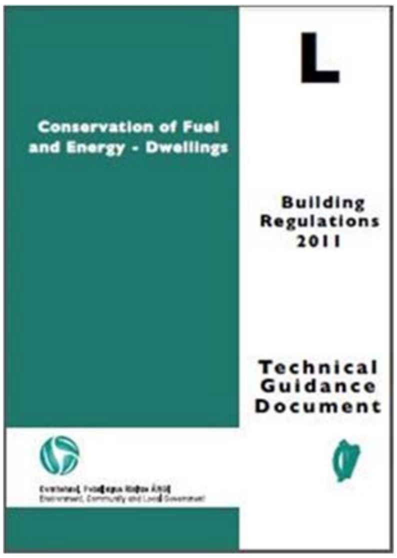
Learning Outcomes

The successful completion of this Unit, will help you to:

1. List and outline types of conventional and renewable heating systems and heat emitters.
2. Explain the importance of heating controls in low energy buildings.
3. Outline the principles of ventilation and the types of ventilation systems suitable for dwellings.
4. List the causes of condensation and mould growth within the building envelope and how they may be avoided.
5. Outline the main requirements of current building regulations for heating and ventilation.

Heating

In addition to many other matters, the building regulations have, in recent times, been paying more attention to improving the efficiency in heating. TGD Part L should be considered when choosing the heating system with matters around the energy performance of the building (this applies to residential and non-residential buildings).



L2 ***For existing dwellings***

(b) Controlling, as appropriate, the output of the space heating and hot water systems;

(c) Limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air;

(d) Providing that all oil and gas fired boilers installed as replacements in existing dwellings shall meet a minimum seasonal efficiency of 90% where practicable.

L3 ***For new dwellings***

(d) Providing and commissioning energy efficient space and water heating systems with efficient heat sources and effective controls;

(e) Providing that all oil and gas fired boilers shall meet a minimum seasonal efficiency of 90%;

(f) Providing to the dwelling owner sufficient information about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and energy than is reasonable.

The TGD part J relates to how the appliances should be installed and would be outside of the scope of this course. However you should be aware that this TGD exists and make sure that your actions on site do not affect compliance.

J1 *Air supply*

A heat producing appliance shall be so installed that there is an adequate supply of air to it for combustion, to prevent overheating and for the efficient working of any flue pipe or chimney serving the appliance.

Warning of release of Carbon Monoxide. J2(b)

Reasonable provision shall be made to avoid danger to the health and safety of the occupants of a dwelling caused by the release of carbon monoxide from heat producing appliances.

Heating Systems

It is not proposed to give a detailed account of heating systems and their installation in this manual. Instead this section will focus on the pros and cons of different types of heating systems and discuss the important factors which affect efficient and effective installation.

As previously explained in Unit 1, space heating accounts for the largest proportion of energy consumption across both the residential and non-residential building sectors in Ireland. It was noted that there were a number of factors that affected the amount of energy used (Figure 5.0).

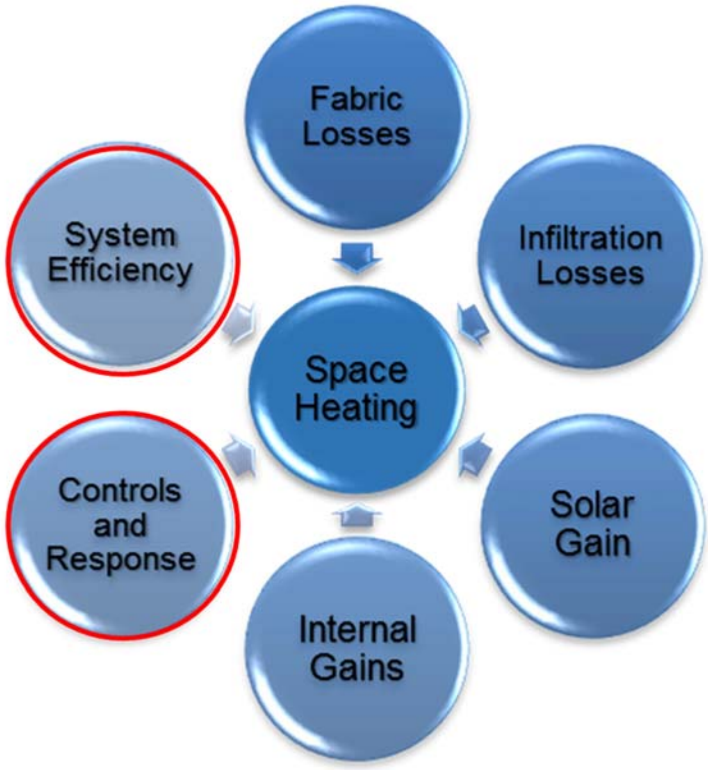


Figure 5.0 Factors affecting energy use for space heating

It has also been shown that domestic hot water (DHW) is also a high user of energy in residential buildings, partly due to distribution losses within pipework and hot water storage (Figure 5.1).

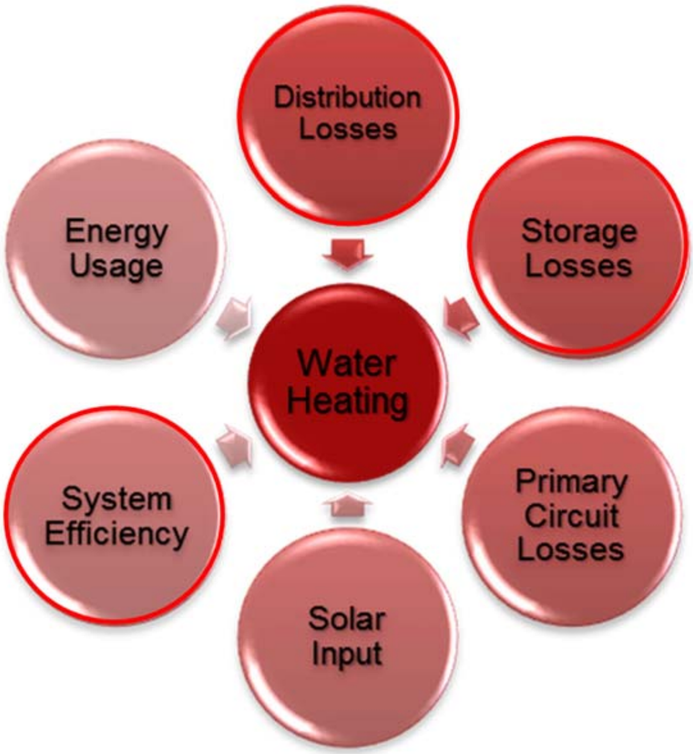


Figure 5.1 Factors affecting energy use for water heating

Careful design and installation of space heating and hot water systems with correct temperature and zoning controls can greatly improve efficiency and provide high levels of comfort for the building occupier.

There are a number of factors which impact on the efficiency of space heating and domestic hot water systems. These include:

1. The efficiency of the heating appliance.
2. The extent of the loss of heat in water and air-based systems in the distribution of the heat through pipework and ducts.
3. The efficiency of the heating control system and the way in which it is managed by the building users.

The level of efficiency of space and water heating in a building depends on:

- The efficiency of the heat producing appliance.
- The heat loss from distribution of the heat.
- The heat losses from hot water storage.
- The level of controls.

Heating Appliance Efficiency

Efficiency varies widely from appliance to appliance but some modern condensing boilers achieve 95% efficiency. By efficiency in this sense, we mean the amount of heat delivered to the building relative to the potential amount contained in the fuel source.

Conventional Heating Systems

In residential buildings the most popular space heating systems include open fires, gas and oil boilers, multi fuel stoves with back boilers and electric storage heaters.

Condensing boilers are highly efficient, with some modern systems achieving 95% efficiency (Figure 5.2). They use less fuel and have lower running costs than other boilers. Higher efficiency levels are made possible by recycling some of the heat contained in the combustion gases, which would otherwise have been lost through the flue to the atmosphere. All systems need to be sized correctly and vented. All condensing boilers require a drainage facility which should be considered and checked on site.

Figure 5.2 Gas Condensing Boiler

The domestic hot water (DHW) supply is usually provided as part of the space heating system, by a separate electric immersion heater or by a combination of these.

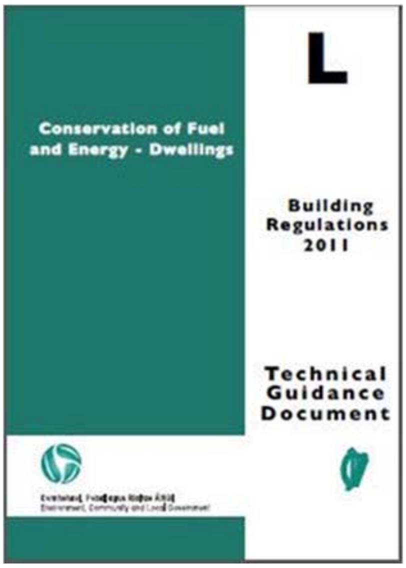
In non-residential buildings the most popular space heating systems include gas and oil boilers. The domestic hot water is generally supplied from the boilers or through individual water heaters located directly at sinks and wash hand basins.

It will be noted that most of these systems rely on fossil fuels and, as we have seen earlier, 89% of Ireland's energy requirements are provided by imported fossil fuels.

Renewable Heating Systems

Most of the building energy used in Ireland comes from fossil fuels which are imported. However, we are under obligation to reduce the amount of building energy that comes from fossil fuels. Space and water heating are two areas of energy use that have the biggest potential for meeting this requirement. There are a number of renewable systems that can be used for space and water heating which are becoming more and more popular.

The type of heating source used within the residential sector has changed over the years, as the need to reduce CO_2 emissions (climate change) has been pushed onto the agenda. This has meant that an alternative use to fossil fuels such as, using solar panels, wood and geothermal have increased over the years and has been driven by costs, EU policies and Irish building regulation amendments. There is now a minimum contribution from renewable systems required in the current regulations for dwellings.



TGD part L 2011 for dwellings states the following:

A minimum requirement for the contribution to energy provision from renewable technologies:

10 kWh/m^2 /annum contributing to energy use for domestic hot water heating, space heating or cooling

or

4 kWh/m^2 /annum of electrical energy

or

a combination of these which would have equivalent effect.

This includes solar thermal, biomass and heat pump systems along with other small-scale renewable systems.

Solar Panels

Solar collector panels can capture solar heat and transfer this heat into hot water production in solar thermal systems (Flat plate or Evacuated tube collectors) or collect the solar energy for electricity use (Photovoltaic panels, PV – Figure 5.3).

New technologies in this area are being developed all the time which include solar roof sheeting, night solar system and solar wall ventilation systems.

Figure 5.3 Solar PV Panels

Biomass

A modern biomass or wood burning stove can achieve efficiencies of up to 90% compared to only 20-30% for a traditional open fire. Wood can be a renewable energy if obtained from a sustainable source but needs to be dried correctly to 20% moisture content to provide an energy efficient option for heating the building.

Wood pellet burners can be sized to a particular building with industrial and domestic options available on the market (including stoves, Figure 5.4)

Wood pellets are available in bags or delivered loose for larger ventures. These are dried to below 20% moisture content and are therefore very efficient to use.

Other types of biomass burning systems include wood chip systems which require a large external area for storage of the chips and equipment.

Figure 5.4 Wood pellet stove

Geothermal

All geothermal systems have three main parts: a series of pipes, a heat pump and a heat distribution system. A heat pump extracts heat energy from low temperature sources (e.g., air, water, ground), and upgrades it to a higher temperature, and releases it where it is required for space and water heating. Heat pumps can also be operated in a reverse mode to generate or maintain cooling. The efficiency of these systems is represented as the coefficient of performance (CoP) of the pump and is based on the number of units of heat which can be obtained per unit of electricity.

There are 2 main types, ground to water systems (GHS) and air to water systems (AHS, Figure 5.5)). Both have pros and cons and are suited in different locations.

Geothermal is used for space heating and cooling, as well as for DHW and transfer heated water via pipes to low temperature radiators or under floor heating systems.

Figure 5.5 Geothermal Air to Water Units

Distribution and Storage

Heat can be transferred in various ways mainly by using systems which heat water or air. Both these systems are widely used in buildings for both residential and non-residential purposes.

Figure 5.6 Insulating pipes

The loss of heat whilst distributing the hot water through pipes in the building can be reduced by insulating the pipes especially within 2 metres of the hot water storage vessel (see Figure 5.6). It is good practice however to insulate all hot water pipes but also protect the cold water pipes in the attic space if it is an unheated space.

It is important to insulate the hot water storage vessel to ensure energy efficiency and installing factory insulated storage units is becoming standard practice (Figure 5.7). The temperature of the water can be better controlled and the water can stay hotter for longer at a steady temperature.

Figure 5.7 Factory Insulated hot water storage vessel

Controls

The energy performance of the building fabric and the efficiency of the heating systems dictate the energy use by the building. However this demand needs to be controlled using automatic controls and as well as manually by the end-user.

Controls play a large part in efficiency and the level of comfort for occupiers.

An efficient system is required to provide the correct amount of heat at the correct place at the correct time and burning the fuel in the most efficient way possible, by switching off the boiler when the demand is reached or not required.

You should be aware of how boilers, emitters (such as radiator, underfloor heating and radiant heater) and controls affect the efficiency of the heating system.

There are different types of heating system control. These include –

1. **Boiler controls** – those positioned in or at the boiler itself that improve its efficiency
2. **Local temperature controls** – these are positioned in rooms or zones to sense the temperature and switch off the heat when it is warm enough
3. **Timer controls** – these are switches or programmers that switch the boiler on and off

Boiler Controls

Whatever the age of the boiler, the right controls should be fitted to regulate the temperature for the heating and hot water.

Boiler Controls are specifically designed to maximise the efficiency of the new or existing boiler. What these controls do is ensure that the boiler operates only when it is needed and that it will supply additional heat to the area required, either for DHW or space heating.

Temperature Controls

The location of temperature controls is important as it needs to be in an area where the *real* temperature can be read.

Room Zoning Thermostats

These prevent the home from getting warmer than it needs to be: The thermostat will turn the heating on until the room reaches a certain temperature, and then turns off until the temperature drops, where it will turn on again.

Room Programmable Thermostats

A programmable room thermostat allows the easy adjustment of temperature controls and allows you to set different temperatures for different times of the day (Figure 5.8). It works in the same way as the zoning thermostat but may also be used for individual rooms rather than zoning areas.

Figure 5.8 Programmable Thermostat

Thermostatic Radiator Valves (TRVs)

Thermostatic radiator valves control the flow of water through the radiator so that a certain temperature can be reached. You can have different temperatures in individual rooms by installing thermostatic radiator valves (TRVs) on individual radiators.

Timer (and temperature) Controls

These control the times at which the boiler operates. They can be simple or more sophisticated and can take account of when the building is in use. There is little point in keeping a building fully heated when it is not occupied, for example:

The typical dial type timer, has now significantly improved and programmers are often installed in new houses similar to the one shown in Figure 5.9 as they not only provide a timing component but also regulate the temperatures for each room or zoning area.

Figure 5.9 Programmer

An effective heating control system is one that makes sure that the boiler only operates when there is demand for heating. It only provides heat where and when it is needed. Selecting the appropriate controls for a heating and DHW system ensures that the energy waste and running costs are kept to a minimum

Handover and Operation

When the works have been completed, the building user needs to live or work in the building comfortably and this means they need to know how to use the equipment, how to control this equipment and how to maintain/service this equipment. The same applies to maintaining and looking after all parts of the building, such as plaster, paint, windows, timber work, lighting, heating appliances and ventilation systems.

All this information should be available for the end user in a service/maintenance manual set out in a simple format so that these tasks can be carried out easily.

At handover stage, a demonstration on how to use the equipment and the controls should be carried out as this plays a large part in how efficient the heating system will be operated.

Communicate - Remember all these controls and systems need to be easy to use. At the end of the day it is the end-user who needs to know how to use them. Provide a step by step guide so that servicing and maintenance can be carried out.

What seems simple to you may not be simple to a non-expert!

Self-Test Seven

1. Identify a heating system with a renewable source suitable for installation in a dwelling?

2. Why are heating controls important within a building?

3. List three important factors which should be taken into account when a new heating system is being provided in a dwelling in order to achieve a low energy, air-tight, quality building.

   1)

   2)

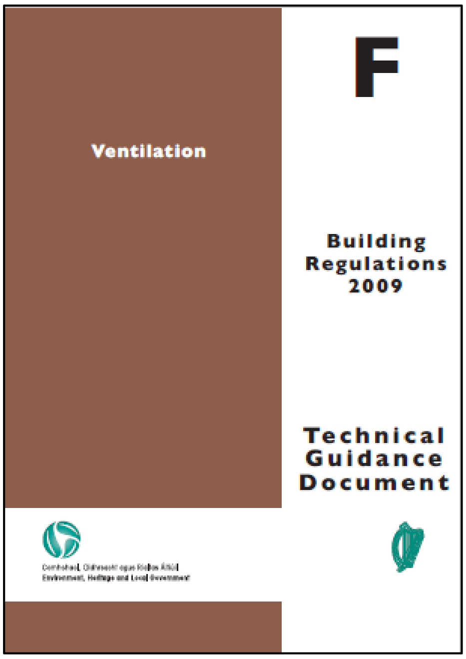
   3)

Ventilation

Ventilation is vital not just within the building structure, but also within the building itself. Stale air needs to be replaced and moist air needs to be removed.

For Residential Buildings, the TGD Part F requires that the chosen ventilation system should provide renewed air at a rate of 0.4 air changes per hour to all living areas. Moist air should also be extracted from wet rooms at a specified rate of: 50 m^3/hr in kitchens, 30 m^3/hr in bathrooms, 20 m^3/hr in WCs.

For Non-Residential Buildings, TGD Part F requires ongoing air renewal by the ventilation system. The rate of ventilation depends on the number of occupants and how the building is being used.



F1: Means of ventilation.
Adequate means of ventilation shall be provided for people in buildings. This shall be achieved by:
a) Limiting the moisture content of the air within the building so that it does not contribute to condensation and mould growth, and
b) Limiting the concentration of harmful pollutants in the air within the building.

A key aim of the provisions in relation to ventilation of occupied spaces is to minimise the risk of condensation, mould growth or other indoor air quality problems.

F2: Condensation in roofs
Adequate provision shall be made to prevent excessive condensation in a roof or in a roof void above an insulated ceiling.

The main ventilation requirements as listed in the Tables for Residential and Non-residential Buildings from TGD Part F (2009) – Ventilation.

Ventilation vs Air Infiltration

As we have seen in Unit 3, air infiltration is also referred to as draughts, exfiltration and air leakage or ***uncontrolled*** air movement, whilst ventilation refers to ***controlled*** air movement (see Figures 5.10 & 5.11).

Ventilation is viewed by many as causing draughts and energy loss, and ventilation systems are often sealed up after installation by the occupants or left out altogether by the builders. This could eventually cause problems for the building and occupants.

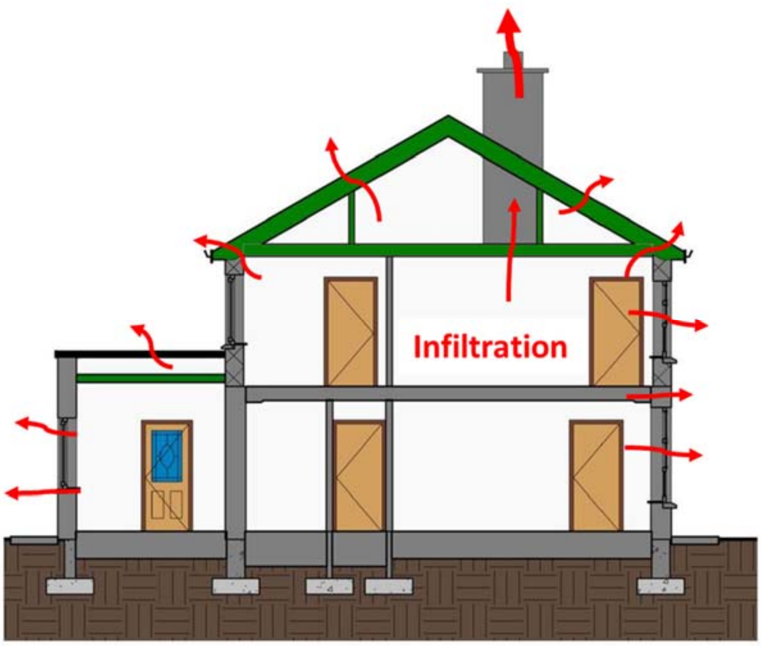


Figure 5.10 Diagram showing flows of uncontrolled air infiltration

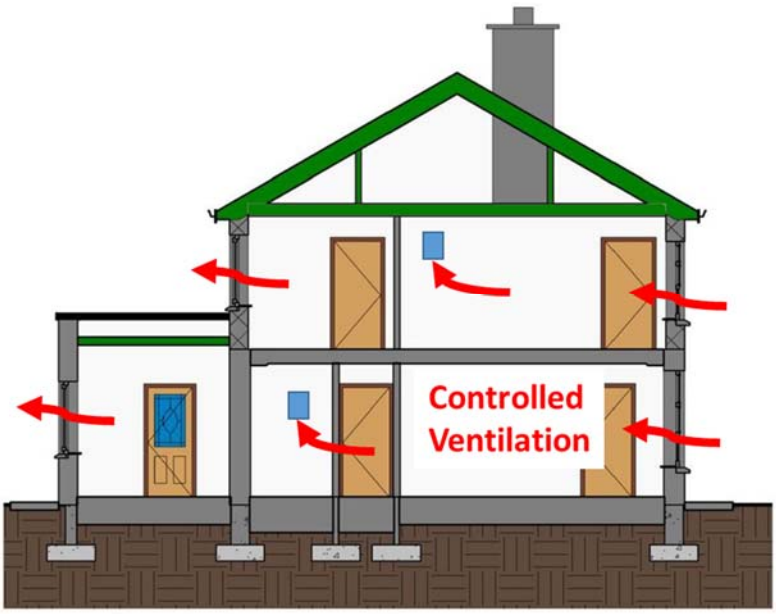


Figure 5.11 Diagram showing flows of controlled natural ventilation

Why Ventilate?

Ventilation is necessary to provide a healthy and comfortable internal environment for the building and its occupants. The most important reasons for providing adequate ventilation are as follows:

1. To remove unpleasant smells and odours.

2. To remove any excess moisture (steam) especially from wet rooms to prevent condensation and mould growth.
3. To provide fresh outside air to the interior of the building to prevent stagnation of the interior air and development of high levels of CO_2.
4. To prevent Carbon Monoxide build-up from heating combustion products.
5. To help prevent overheating, especially in south facing windows. This can be achieved simply by opening windows, open ventilation grilles or forcing air movement by the use of mechanical ventilation.
6. To comply with the building regulations TGD Part F.

Problems with Poor Ventilation

Issues can arise with condensation due to lack of air flow within the building which will cause mould and water damage. This condensation can happen within the structure and on the surface causing issues of mould, fungal growth, spurs and moisture and structural damage.

Surface Condensation

Surface condensation occurs with the collection of moisture on windows or walls and can lead to mould growth on the internal surfaces. Providing the correct levels of ventilation will help to prevent mould growth, but if a continual build-up of condensation occurs then it can lead to staining of the surfaces or even structural damage. Unventilated areas can lead to unhealthy living spaces with a development of mould and fungi growth.

Surface condensation is caused by one or more of the following factors:

- Lack of ventilation.
- Poor or incorrect levels of ventilation.
- Damp and water ingress.
- Cold surfaces e.g. Thermal Bridging.

Condensation on windows as shown in Figure 5.12 is usually due to heat loss through the windows and the incorrect levels of ventilation.

Figure 5.12 Surface Condensation on windows

Interstitial Condensation

Interstitial condensation has been previously explained in Unit 1 however it is an important issue to follow up on. When moisture is trapped within the structure then it can cause reduced energy performance of its materials, structural failure and even development of mould within the structure (see Figure 5.13).

This mould growth can have harmful consequences on the health of the occupants or other users of a building as the spores from the mould can get into the lungs and cause breathing and other difficulties.

Figure 5.13 Interstitial condensation resulting in mould through a wall.

Interstitial Condensation is generally caused by:

- Incorrect choice and use of insulation materials with no breathability properties
- Thermal Bridging
- Lack of ventilation to timbers
- No vapour barrier installed

If a building is not correctly ventilated then dampness can also occur in the roof space (see Figure 5.14).

Figure 5.14 Diagram showing problems in a building with no ventilation

Indoor Air Quality

Indoor air quality is dependent on the quality of fresh air and how often this is provided by controlled ventilation.

Ventilation is the process of "changing" or replacing air in any space to provide high indoor air quality (i.e. to control temperature, replenish oxygen, or remove moisture, odours, smoke, heat, dust, airborne bacteria, and carbon dioxide).

Proper ventilation has a huge impact on the conditions of a building:

***Improved indoor air quality*.**

Ventilation systems should supply fresh air to the working, living and sleeping areas of buildings while removing stale air.

***Improved comfort*.**

Buildings with air-tight construction and a highly insulated envelope will have fewer draughts and therefore a controlled fresh air supply will result in improved comfort levels.

Improved health.

Continuously providing controlled fresh air can result in the improved health and well-being of the occupants as stale air is removed automatically. Stale air can cause health problems such as headaches, drowsiness, and respiratory problems.

If levels of air infiltration have been greatly reduced due to high levels of insulation and air tightness, it is even more important that the levels of ventilation comply with building regulations in order to provide a healthy building.

Types of Ventilation Systems

Ventilation uses fresh air movements to supply fresh and remove stale air from buildings. This can be done by using natural, mechanical or a combination of ventilation methods.

There are various ways to provide ventilation

Background

Described as a small ventilation opening designed to provide controllable whole building ventilation. Background ventilation provides the building with controlled fresh air levels for healthy living. Background ventilation openings should be positioned 1.7m above floor level, to avoid noticeable draughts.

These openings include: holes in the wall with grilles, trickle vents in windows, demand controlled vents (DCV) with sensors or mechanical ventilation and should meet the requirements in the Irish Building Regulation TGD Part F – Ventilation.

Purge

An open-able window can provide purge ventilation which removes occasional build ups of pollutants such as smoke and smells from cooking or fumes from painting. Purge ventilation can also help with reducing the overheating of a building during warm summer periods.

Extraction

Extract ventilation is installed in rooms which encounter regular pollutants or excess water vapour i.e. kitchens or bathrooms. Extraction prevents the spread of fumes and pollutants throughout the building.

Natural ventilation

Wind-driven ventilation can be used whenever a building is exposed to the prevailing wind. In order for wind driven ventilation to operate properly, a pressure difference is required and this pressure difference is created by an air stream moving across a building facade. This is known as Cross ventilation.

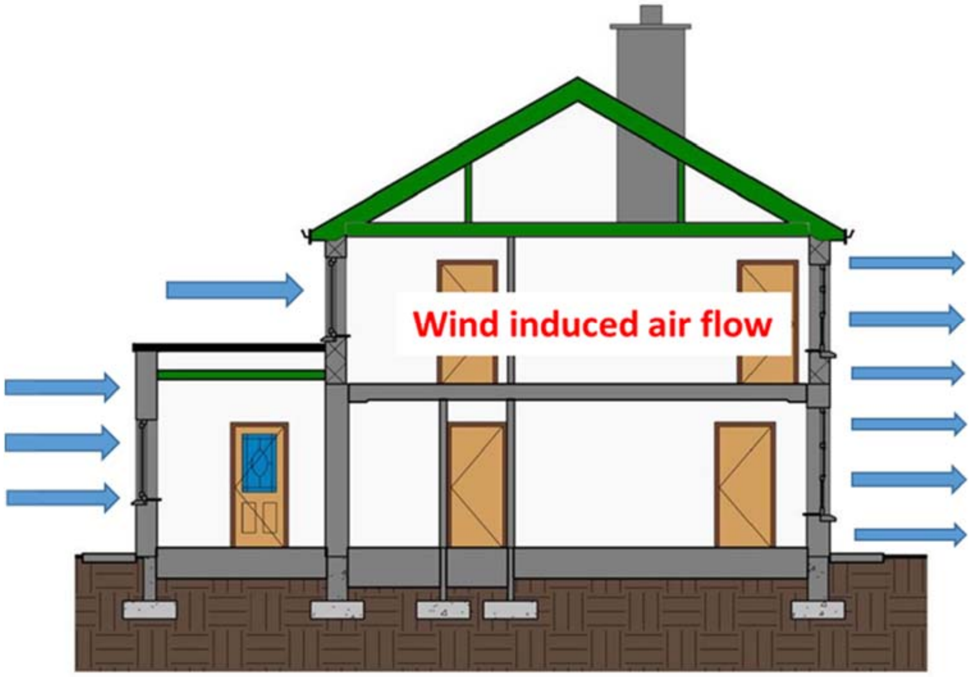


Figure 5.15 Diagram showing cross ventilation

Stack Ventilation

Stack ventilation is where air is driven through the building by vertical pressure differences. The warm air inside the building is less dense than colder air outside. As colder air enters the openings at lower level the temperature difference will force the hotter air to rise through a stack (atrium) and escape from openings at high level. These new technologies require ducting and should be considered before deciding on the installation.

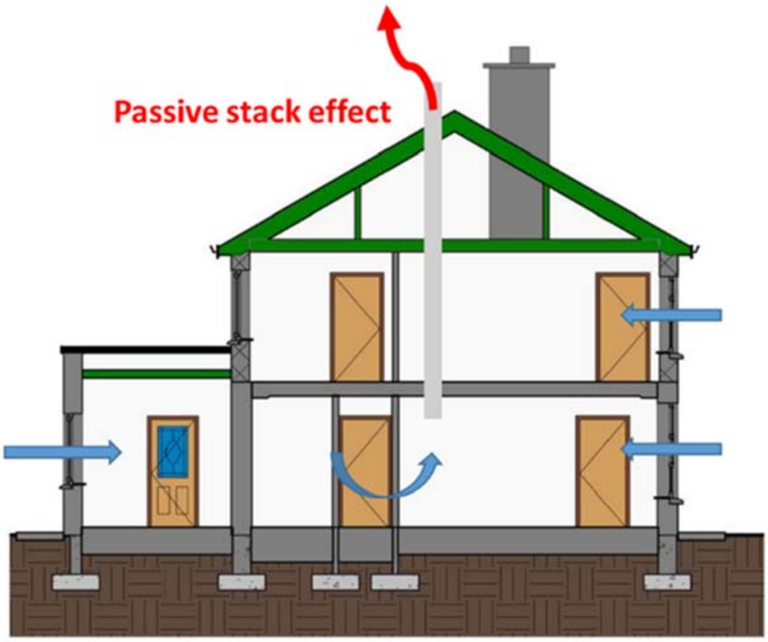


Figure 5.16 Diagram of Passive Stack Ventilation PSV

Mechanical Ventilation

Mechanical ventilation may be provided via rotating fans on the ceiling, grilles in the ceiling/walls or grilles in the floor. Fresh air is forced through the floor ducts and driven through the rooms and extracted at high level into an atrium or corridor area. "Mechanical" or "forced" ventilation is used to control indoor air quality, excess moisture content, odours and pollutants.

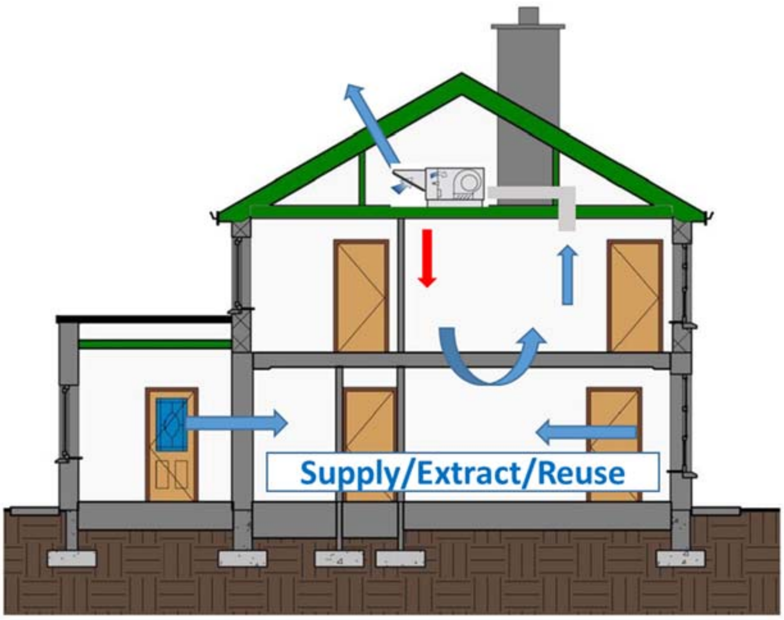


Figure 5.17 Diagram showing mechanical ventilation with heat recovery

Mechanical ventilation is forever evolving and alternative solutions are being developed. Positive Input Ventilation (PIV) includes a mechanical unit located in the roof space. The air needs to be drawn from the outside of the building to an internal central area such as a landing or hall space. This air is then gently dispersed around the building diluting and removing moisture through positive pressurisation.

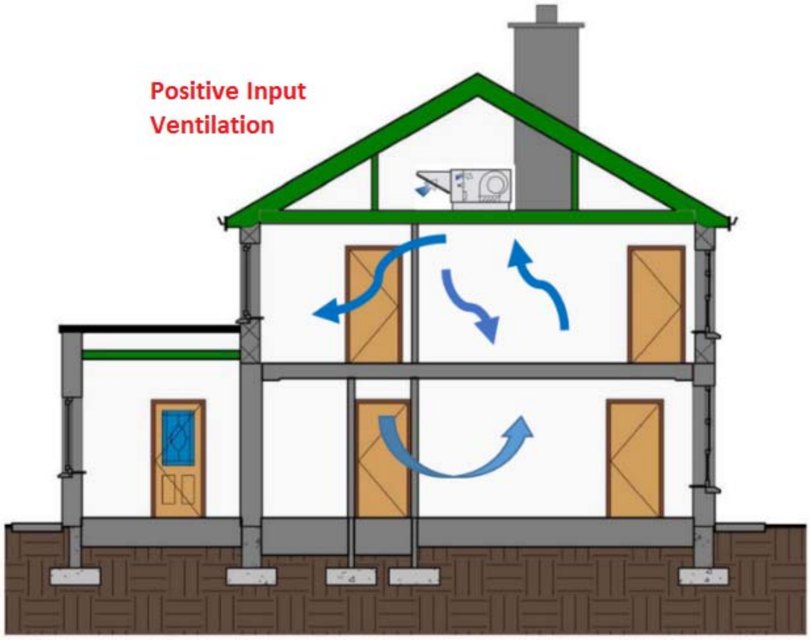


Figure 5.18 Diagram of Positive Input Ventilation PIV

We have now looked at what is ventilation and why and how we ventilate.

- **It is important to remember that it is necessary that all buildings are ventilated.**
- **From both a comfort and energy efficiency point of view it is necessary that this ventilation is controlled.**
- **If the insulation and air tightness of a building are improved and its heating systems upgraded, then particular attention needs to be paid to how the building will be ventilated**.

Summary

- Installing energy efficient heating systems with a percentage of renewable technologies will reduce energy waste and achieve compliance with Building Regulations.
- An efficient system is required to provide the correct amount of heat at the correct place at the correct time and burning the fuel in the most efficient way possible, by switching off the boiler when the demand is reached or not required.
- All boilers should be sized correctly and located centrally if possible as to reduce the length of pipe/ductwork and reduce distribution losses.
- Once the pipes and storage units are insulated the central heating controls such as programmable timers, thermostats and motorised valves are key to the success of any energy efficient central heating system.
- Ventilation refers to controlled air movement whilst air infiltration is uncontrolled air movement (also referred to as draughts, exfiltration and air leakage). Ventilation is used to:
- Remove unpleasant smells and odours.
    - Remove excess moisture (steam).
    - Provide controlled air movement if the insulation and air tightness of the building is improved.
    - Prevent stale air and development of high levels of CO_2.
    - Prevent Carbon Monoxide build-up from heating systems.
    - Prevent overheating.
    - Comply with the building regulations TGD Part F.
- This can be achieved by background, purge or extract ventilation.
- The traditional method of providing ventilation by opening windows is no longer acceptable. The correct strategy is to build an airtight envelope and ventilate with controllable openings **- "Build tight, Ventilate right".**
- There are various ways to ventilate using natural or mechanical systems or a mixture of the two. They all have their benefits and disadvantages.
- Surface condensation and mould is generally caused by thermal bridging and low levels of ventilation. Interstitial condensation is caused by the incorrect use of insulation resulting in damp within the structure. Rot in timbers in the roof can be caused by lack of ventilation between the timbers.
- In TGD Part F – Ventilation Guidelines are provided for background, purge and extract ventilation levels.

Self-Test Eight

1. What is the difference between air infiltration and ventilation?

   ____

   ____

   ____

2. List and describe 3 ways of providing ventilation in a dwelling.

   1) ____
   2) ____
   3) ____

3. List 4 reasons why buildings need to be ventilated?

   1) ____
   2) ____
   3) ____
   4) ____

4. List 4 common problems that can occur within a dwelling if ventilation levels are poor?

   1) ____
   2) ____
   3) ____
   4) ____

5. Briefly describe how surface condensation occurs

   ____

   ____

   ____

Useful Links

Heating

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit5-part1

SEAI (2014). Best practice guide for Photovoltaic. Available at: http://www.seai.ie/Publications/Renewables_Publications_/Solar_Power/Best_Practice_Guide_for_PV.pdf [Accessed 9 November 2014].

SEAI (2014). Domestic solar systems for hot water. Available at: http://www.seai.ie/Renewables/Solar_Energy/Domestic_solar_systems_for_hot_water_Consumer_Guide_2010.pdf [Accessed 15 October 2014].

SEAI (2014). Your guide to renewable energies in the home. Available at: http://www.seai.ie/Publications/Your_Home_Publications_/Heating/RE_guide_in_the_home.pdf [Accessed 25 November 2014].

SEAI (2014). Domestic wood burning stoves: A consumer guide. Available at: http://www.seai.ie/Renewables/Bioenergy/Domestic_wood_burning_stoves_Consumer_Guide_2010.pdf [Accessed 17 November 2014].

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part L: Conservation of Fuel and Energy – Dwellings.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part J: Heating Appliances.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Ventilation

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit5-part2

British Standard, BS 5250, (2002), *Code of practice for control of condensation in buildings*, BSI, Available at: http://www.commercialconnections.co.uk/Content/building_standards/BS5250%20-%20Code%20of%20Practise%20for%20condensation%20in%20buildings.pdf

Energy Saving Trust, (2005), *Energy efficient ventilation in dwellings – a guide for specifiers,* Available at:

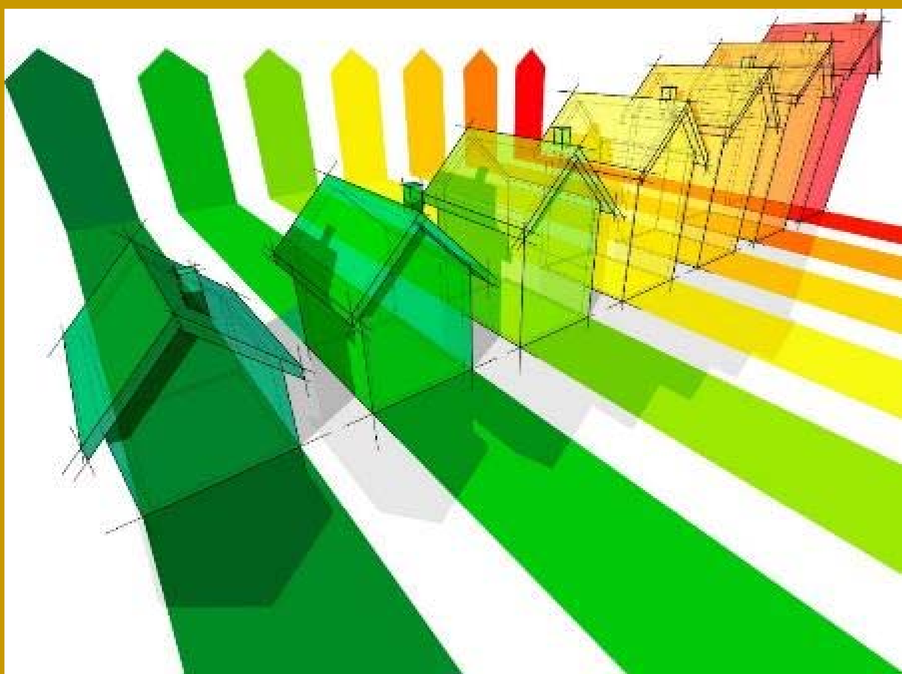
http://www.seai.ie/Archive1/Low_Carbon_Homes_Programme/Best_Practice_Guides/GPG268_-_Energy_efficient_ventilation_in_dwellings.pdf

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part F: Ventilation and Condensation.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Joseph Little - breaking the mould vol1, 2, 3, 4, 5 available on QualiBuild website

QualiBuild

Unit 6



Systems Thinking

Unit 6: System Thinking

In this Unit we will focus on the importance of collaboration and communication between all trades and crafts onsite to achieve low energy building standards. This includes an explanation of how the parts of a low energy building are interconnected and depend on the relationship between various workers onsite to perform efficiently.

Generally in the building sector, the greatest barrier that has been identified for delivery of quality low energy buildings is a lack of knowledge rather than skills. This knowledge of the basic principles of low energy buildings is essential for everyone involved. Even if you have many years of experience and excellent skills, there may be some new things for you to learn about the changes in how we are building now.

In the previous Units we have examined some of the new ways of thinking with regard to the construction of buildings and some of the ways of responding positively to this thinking. This Unit will bring together the principles covered and how to most effectively work together onsite to ensure a quality job.

Unit Overview

This final Unit considers the importance of working together onsite to achieve quality low energy buildings.

Working Together

In this section we concentrate on the process of Systems Thinking - communication, awareness, working together and the collaboration between all trades. This working together concept is essential for quality design, energy efficient construction, supervision and compliance with building regulations.

Importance of Communication

This section will look at the importance of good clear communication to eliminate any misunderstandings and errors during construction. Different types of communication are discussed to encourage best practice approaches to communication and awareness. The role of the builder on site and Building Regulations have changed greatly over the recent years and this needs to be understood. So an acceptance of the fact that every building construction worker is responsible for quality is important.

Learning Outcomes

Successful completion of this Unit will help you to:

- Describe how all building construction workers have a contribution to make to achieve low energy buildings
- Outline the principles of quality building and the correct sequence of works to construct low energy quality buildings.
- Outline how good communication can help to create low energy buildings.

Communication and Awareness for a Quality Building

Throughout the previous Units of the course we have seen examples of how all of those involved in the construction of a building have an impact on the quality of the final product. We have seen how this is particularly important with regard to the construction of air tight buildings, reducing thermal bridging and the installation of efficient heating and ventilation systems. We have seen that the way everyone carries out their work onsite can impact on the effectiveness of the work of others.

Fundamentally, it is important that everyone understands that they are part of a team working towards the same goal, a quality building.

Everyone on site should consider good workmanship, quality of care, improved communication, best practice and awareness of other trades.

An effective team, whether on the pitch, on a site, in an office or anywhere else, needs a number of things in order to work effectively. These include good communication, awareness of the work of others and of how all are inter-related.

When building, three basic principles should be considered, as outlined below in Figure 6.0, to make sure that **Quality of Build** is provided**.**

They are:

1. Systems Thinking
2. Communication
3. Quality Control

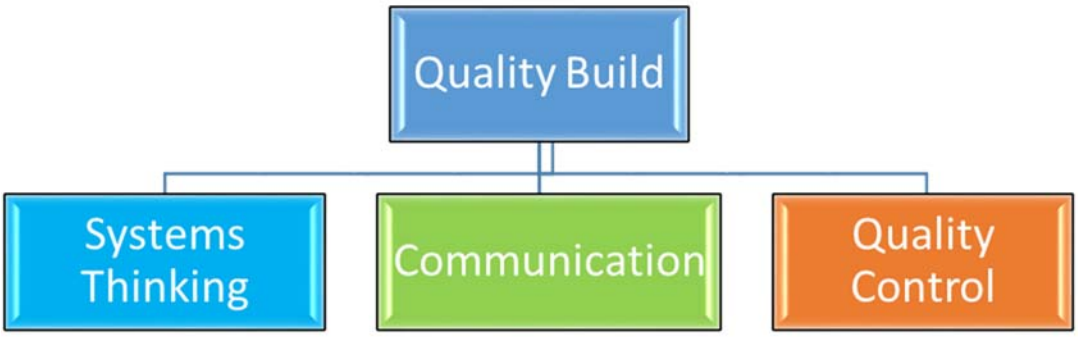


Figure 6.0 Principles of Quality Build

Let’s look at each principle in more detail.

Systems Thinking

Systems Thinking is 'an approach to building that focusses on the importance of collaboration and communication between all workers onsite to ensure a quality, high performing end product'

Systems Thinking involves:

- Consideration of all trades and their works - Working together
- Listening and Talking - Good Instructions and communication
- How other trades work - Awareness

A key element of systems thinking is to understand how your own work will affect the works of others and how important it is to communicate and changes amongst yourselves. The approach also considers how each individual affects the outcome of the final build and the standards that it achieves.

Working Together

A Team Approach to working together onsite is very important, just as it is for a football team if they are to be successful. A team might have a fantastically skilful midfield player. If he doesn't understand the team tactics and know how to play and fit in with the overall approach, then the team will not do so well. A team of average players working well together does better than a team of stars who do not co-operate. Of course a team of stars working to a team plan wins the All-Ireland or the European Cup!!

It is important to have good interaction between trades to ensure that quality low energy building is completed, making sure that continuous insulation, air-tightness and controlled ventilation are carried out.

In the context of building work it may be helpful to think of the building as a system rather than as a series of individual elements. In a system all the pieces work well together and reinforce the contribution of each element. We have seen how the walls, windows, doors, roof, insulation, heating and ventilation are all related from design through to the on-site build.

Instructions

Proper Instructions should be given to all trades on the site. However, this is often not the case. Correct instructions and directions are sometimes lost due to a breakdown in communication.

All building construction workers should highlight any difficulties and issues that they encounter, and if they are not sure about something, ask and get clarification on how to proceed.

If it doesn’t make sense to you it probably doesn’t make sense to everyone else!!

Awareness

Awareness is equally important. Being aware of how the other trades work on site is essential. The actions of each individual worker play an important part in providing low energy, high quality building and all need to work together. Take responsibility of your own actions.

Figure 6.1 Team work

BCWs can make a major contribution to the energy efficiency of a building by considering what impact their work will have on:

a) Other crafts/workers

b) The Building's Energy Rating or BER

Good Communication

Language in the energy and building sector is constantly changing. New words and definitions are introduced by EU legislation, National regulations, professional bodies and the general public on a regular basis. An important part of this course is to help you become familiar with the up-to-date terminology in the area of energy efficiency.

This section highlights the importance of good clear communication to prevent any misunderstandings and errors during construction. Different types of communication are explained to encourage best practice approaches to communication and awareness. It is highlighted that every building construction worker is responsible for the quality of the building and responsible for their own actions. The role of the builder to comply with Building Regulations has changed in the last year and this needs to be understood.

Nobody knows everything and as the Chinese proverb says:

"He who asks a question is a fool for five minutes; he who does not ask a question remains a fool forever"

Good communication includes the willingness to ask questions, to listen to the answer and to discuss anything that may not be understood. It is also important that all involved in the construction process are able to communicate what they require of others in order to enable them to do their work as effectively as possible.

Issues with communication between trades and professions, as well as between trades themselves, is often a stumbling block to achieving quality low energy buildings. Information is passed around in different ways i.e. drawings, written or verbal, but at all times there should be clear instructions to prevent any misunderstandings.

Remember:

If you don't understand or if the instruction is not clear
SAY SOMETHING – COMMUNICATE

Communication can be carried out in various ways; and all are useful depending on the situation.

Important communications onsite:

What does the customer/client say?

What does the Architect/Engineer say?

What do the other trades say?

What does the Specification/drawings say?

What does the Foreman or Supervisor say?

Quality Control

Quality Control is required and, although this may be carried out by a Foreman or Supervisor on site, success will depend on all trades working together and focussing on a common goal. Controlling the quality of the build involves clear communication within the workforce, as well as ensuring that works are carried out on time and on budget.

Although communication between some building construction workers and professionals may be carried out, it is important to realise that gaps in communication may exist between others involved in the building process.

This is understandable of course as it is the way in which things have tended to be done in the past. Construction was very much an individual exercise in which each trade carried out their own part of the process. This has become difficult to achieve as the complexity of buildings has increased, due to the call for energy-efficient buildings.

Managing the sequence of works and making sure each worker knows when and how to carry out their part of the overall process is important as it will prevent delays or problems down the line. The foreman or supervisor usually carries out this task but everyone involved needs to understand how the process works.

Finally, to achieve quality control, the workmanship, attention to detailing, choosing and fitting out of materials and setting out a sequence of works should all be considered.

The Sequence of Works

By following a correct sequence of works, the construction or re-modelling of a building will take place in an organised way with each step carried out in the correct order. This will help to ensure that each part of the process is in its appropriate place and that work will not have to be undone or modified because it has been implemented out of sequence.

It is important that all trades know the process of works, i.e. how the work will be carried out in a step by step programme. Works can then be carried out in the correct sequence and no work will be carried out before it should be. Everyone on site should be aware of this programme.

All trades should make sure that the insulation layer or air barrier is intact so that compliance with the Building Regulations can be achieved. ***All BCWs*** have a part to play in making sure that the person responsible can confirm compliance with Building Regulations and indeed Planning Permission.

It is important that the sequence of works is acceptable to all involved. Discuss all the works before starting on site and allow all trades to voice any issues.

An example of a sequence of works for the installation of external insulation is outlined in Figure 6.2.

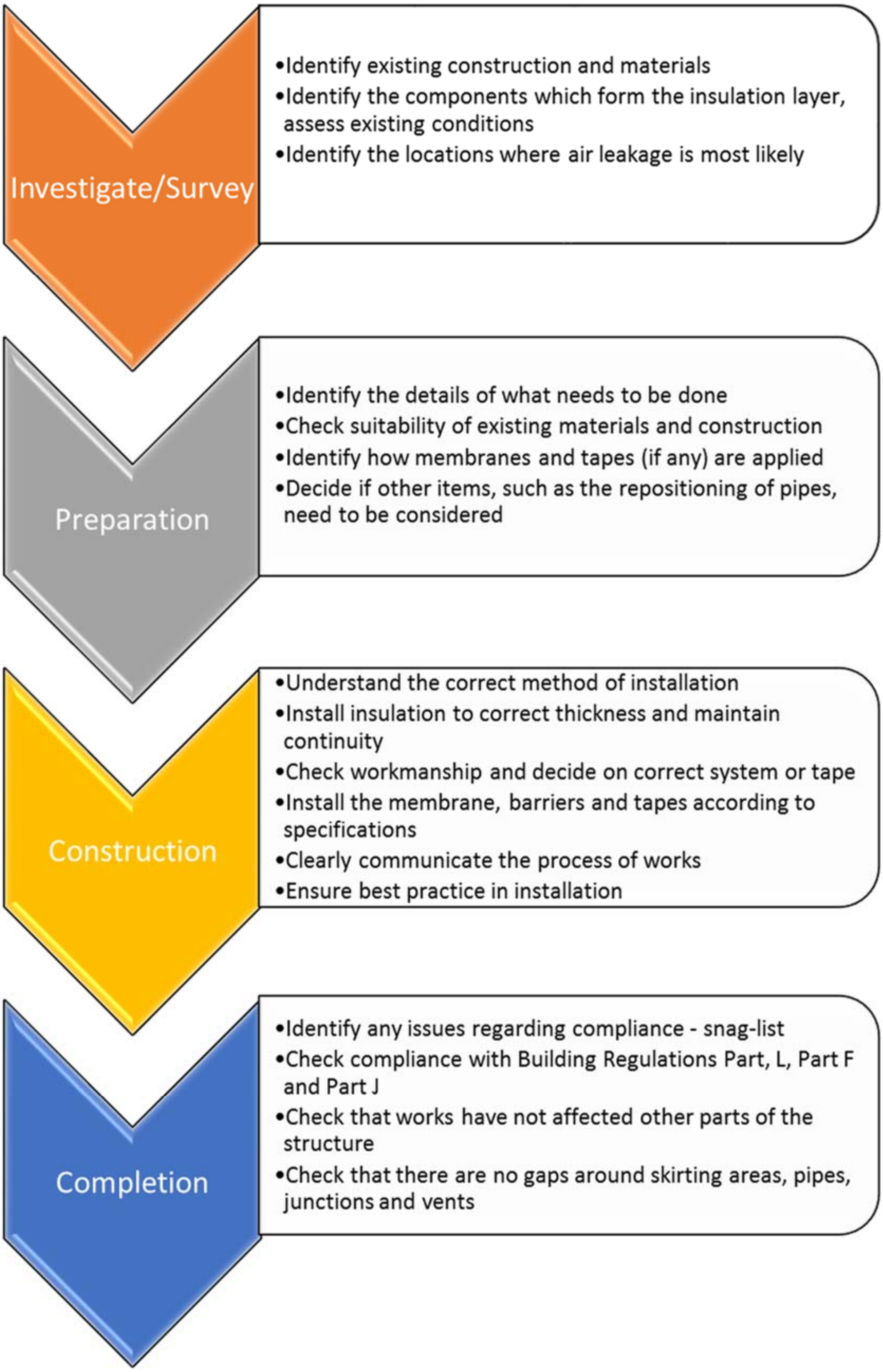


Figure 6.2 Sequence of Works for External insulation

Who is Responsible?

Everyone on site should consider:

- Good workmanship
- Quality of care
- Improved communication
- Best Practice
- Current Building Regulations

Asking questions is vital for success and ensuring best practice. If the situation is unclear or if it is not obvious who is taking responsibility for what, then discuss this with the site supervisor or foreman. Do not ignore it and expect someone else to deal with it.

Here are some common questions and comments that are often asked by different trades.

"Ma'am, I'm afraid the insulation in the walls of your gingerbread house contains dangerously high levels of cholesterol."

Question for the Plumber

I have passed a pipe through the external wall so who is responsible for making sure the wall is air tight and insulated properly?

Answer - It is the job of the person carrying out the works to complete/finish the job correctly. If they are unable to carry out some of the works then another trade needs to be brought in.

Remember providing quality low energy buildings require the provision of:

- Continuous insulation,
- Air-tightness
- Reduced thermal bridging
- Controlled ventilation.

Question for the Window installer

Is the window installer responsible for the air tightness and continuous insulation of the building?

Answer – If the building is being upgraded and retrofitted then it is the responsibility of ALL trades involved to improve the energy efficiency and Quality of the building. A new window needs to be installed to best practice. This means preventing heat loss, thermal bridging, condensation and mould growth.

Question for Insulation Installer

Should I complete other jobs (i.e. reposition gullies, extend the sills to the windows and ventilate rooms)?

Answer – When installing external insulation, the whole job needs to be assessed.

Consider the sequence of works and best practice.

Inform the client of the full extent of works and explain that certain works need to be completed such as relocating gullies, reforming window sills, etc.

Often the client just looks at and budgets for the insulation only and is unaware of the full extent of works. Write down the list of works in sequence so the client can understand the process and why it is important to complete all the works. Remember do not cut corners and exclude works that should be included.

Question for Site Supervisor/Foreman

Who is responsible for the quality of workmanship and compliance?

CERTIFICATE OF COMPLIANCE ON COMPLETION

Building Control Authority: **Unique Identifier:**________________
(for official use only)

1. This certificate relates to Commencement / 7 Day Notice reference no. __________ in respect of the following building or works: ______________________________

Part A — Certificate signed by Builder

2. I confirm that I am the Builder assigned by the owner to construct, supervise and certify the building or works.
3. I certify, having exercised reasonable skill, care and diligence, that the building or works as completed has been constructed in accordance with the plans, calculations, specifications, ancillary certificates and particulars as certified under the Form of Certificate of Compliance (Design) and listed in the schedule to the Commencement / 7 Day Notice relevant to the above building or works, together with such further plans, calculations, specifications, ancillary certificates and particulars, if any, as have been subsequently issued to me and certified and submitted to the Building Control Authority, and such other documents relevant to compliance with the requirements of the Second Schedule to the Building Regulations as shall be retained by me as outlined in the Code of Practice for Inspecting and Certifying Buildings and Works.
4. Reliant on the foregoing, I certify that the works are in compliance with the requirements of the Second Schedule to the Building Regulations insofar as they apply to the building or works concerned.

Signature: ____________________ **Date:** __________
(to be signed by a Principal or Director of a Building Company only)

Name: ______________________________

Address: ______________________________

Tel: __________ Fax: __________ Email: __________
Construction Industry Register Ireland registration number (where applicable): __________

Answer – Everyone on site

The quality of workmanship has always been the responsibility of the BCW and still is. Since March 2014 however this has become even more important with the introduction of the Building Control (Amendment) Regulations, BCAR.

A Certificate of Compliance (Undertaken by the Builder) is now required for works on buildings other than single dwellings and extensions, as shown above.

Changes to the Role of the Building Construction Worker

Recent changes have impacted greatly on the building industry across all sectors, including, clients, owners, building operatives, craft workers, technicians, Architects and Engineers.

The Building Control Act began in 1990 in an attempt to regulate the construction industry, apply the standard in construction and control how buildings are constructed. In 2007 all professionals such as Chartered Engineers, Chartered Surveyors and Architects were required to be registered and the Disability Access Certificate (DAC) was introduced.

In March 2014 the new Building Control (Amendments) Regulations (BC(A)R) came into law requiring all building construction workers to demonstrate competency and compliance with building regulations.

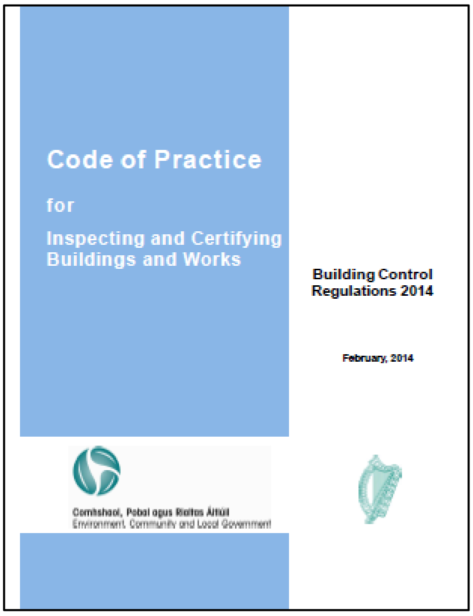
At present it is required to provide the following certificates during construction for buildings, except for single dwellings and domestic extensions:

- Certificate of Compliance (Design).
- Certificate of Compliance (Undertaking by Assigned Certifier).
- Certificate of Compliance (Undertaking by Builder).
- Certificate of Compliance on Completion.

To provide quality low energy buildings requires all parties in the construction sector to work together. The systems thinking approach is aimed at everyone on site and all workers need to be aware of the consequences of their actions or omissions as these can undo a high quality build and cause problems in the future.

Responsibility lies in everyone's hands.

As mentioned in Unit 1, The Code of Practice for inspecting and certifying buildings /and works, provides direction on certifying and assessing the quality of works.



This Code of Practice gives practical guidance on relevant statutory provisions for persons who undertake the role of Assigned Certifier as provided for in the Building Control Regulations and who are tasked with preparing an inspection plan to be implemented by themselves and others during construction in order that they are in a position to sign the Certificate of Compliance on Completion as Assigned Certifier.

The Code sets out standards and procedures that should be followed by:

- Building owners
- Designers
- Builders
- Certifiers
- Building Control Authorities
- Building materials and component manufacturers.

Link: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,38154,en.pdf or Qualibuild website: http://www.qualibuild.ie/useful-links/unit-1/ Code of Practice for Inspecting and Certifying Buildings and Works 2014

Achieving high standards of energy performance requires an effort from all involved in the construction industry towards a common goal.

This requires a 'Systems Thinking' approach and responsibility from everyone onsite where all workers understand how their actions will affect others on site.

And that's it in a nutshell!

Summary

- Achieving quality low energy building is not just down to the installation of airtight, insulated products and energy efficient heating systems, it is also down to good communication skills, management and quality control.
- Remember the 3 key elements of Systems Thinking:
  - Working together
  - Consideration of all trades and their works - Awareness
  - Listening and Talking – Good Instructions and Communication
- Before starting works think about what is required, how to achieve best practice, how will my actions affect other trades and what is the outcome of my actions.
- Understand the sequence of works and how to carry out works without interfering, delaying or causing problems for other members of the team.
- Finally check workmanship, attention to detailing, correct use and installation of products and compliance with current building regulations.
- Everyone on site should consider good workmanship, quality of care, improved communication, best practice and awareness of other trades.
- Everyone is responsible to achieve Quality Low Energy Buildings.

Self-Test Nine

1. List the 3 steps in achieving a Quality Build
   1) ______________________________
   2) ______________________________
   3) ______________________________

2. List the 5 things that everyone onsite should consider.
   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________
   5) ______________________________

3. There are many ways to improve communication on site. List 3 of these ways
   1) ______________________________
   2) ______________________________
   3) ______________________________

4. What are the 4 stages to consider to carry out the sequence of works?
   1) ______________________________
   2) ______________________________
   3) ______________________________
   4) ______________________________

5. List 2 reasons why the sequence of works/construction is important?
   1) ______________________________
   2) ______________________________
   ____

Useful Links

Link to QualiBuild Website http://www.qualibuild.ie/fes-training/useful-links/Unit6

Department of Environment Community and Local Government (2014). Retrofitting Code of Practice. Dublin, Ireland

Department of Environment Community and Local; Government; Building Regulations Technical Guidance Documents: http://www.environ.ie/en/TGD/

Department of Environment Community and Local; Government; Building Standards: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,38154,en.pdf

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part L: Conservation of Fuel and Energy – Dwellings.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part J: Heating Appliances.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Department of Environment Community and Local; Government, (2008) *Technical guidance Document Part F: Ventilation and Condensation.* Dublin: Stationary Office. Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

NSAI, (2014), S. R. 54: 2014, *Code of practice for the energy efficient retrofit of dwellings*, Available at: http://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx

Definitions

There are a lot of terms used in the construction sector. You will be familiar with many of these but some of them may be new to you. There is no need to learn all of these off by heart but have a read through them. You can also use this as a handy dictionary in case you come across some terms or language that you are not so sure about. One key term is the ’building envelope’. This is put at the start of the list since it appears in so many other definitions.

Building Envelope: The building envelope includes all the building components that separate the indoors from the outdoors. Building envelopes include the exterior walls, foundations, roof, windows and doors

Air Barrier: is the line within the envelope of the dwelling where the barrier to air leakage will be.

Air Leakage: is the uncontrolled flow of air through gaps and cracks in the external envelope/fabric of buildings (sometimes referred to as air infiltration, exfiltration or draughts).

Air Permeability: is the physical property used to measure the airtightness of the building fabric. It is defined as air leakage per hour per square metre of envelope area ($m^3/h/m^2$) at a test reference pressure difference across the building envelope of 50 Pascals (Pa) or ($50N/m^2$).

Climate Change: is the significant change in weather (i.e. regional temperature, precipitation, wind, etc.) caused by the increase in the greenhouse gases.

Condensing Appliance: is a boiler designed to make use of the latent heat released by the condensation of water vapour in the combustion flue products.

Delivered Energy: is the amount of usable energy arriving at a site or building, e.g. electricity or gas recorded at meter and is measured in Kilo joules (kJ) or Kilowatt hour (kWh).

Demand Controlled Ventilation: is a system that provides automatic regulation of the ventilation system by sensing the Indoor Air Quality (IAQ) and determining the required air change rate.

Final Energy: is the total primary energy minus the quantities of energy required to transform primary sources such as crude oil/transport into forms suitable for the end-users. This is measured in Kilo joules (KJ) or Kilowatt hour (KWh).

Greenhouse Gases: refers to gases (CO_2, Methane, Ozone, and Fluorocarbons) that contribute to the greenhouse effect by absorbing infra-red radiation (heat).

Interstitial Condensation: is the occurrence of condensation within building elements.

Mechanical Ventilation with heat recovery: (MVHR) is a ventilation system in which air is recycled using ducts and can be reused within the building for heating or cooling purposes.

Low Energy Buildings: are buildings using both passive and active measures to achieve significantly reduced energy consumption when compared to a conventional building.

Multi-fuel Appliance: is an appliance that is able to burn a range of different fuels.

Nearly Zero Energy Building: (NZEB) A building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. Directive 2010/31/EU

Power: is defined as the amount of energy consumed per unit time. Watts (W) or Joules per second (J/s)

Primary Energy: is the total amount of energy used in a given hour. It is the delivered energy plus an allowance for the energy used in extracting, generating or transporting the energy to the site or building. Primary energy can be non-renewable or renewable and is measured in Kilo joules (kJ) or Kilowatt hour (kWh).

Systems Thinking: is the collaboration and consideration of all trades and their workmanship on the entire build leading to a complete quality build.

Thermal Bridge: this occurs with a change or break in the thermal barrier of the building envelope. It occurs at gaps between insulation materials or junctions between materials with different insulating properties. Heat loss occurs at different rates between the materials which can lead to issues such as condensation and mould

Thermal Conductivity: (λ or k-value) is the quantity of heat transmitted through a unit thickness of a material.

Thermal Resistance: (R-value) is the measure of a material's ability to prevent heat from flowing through it, equal to the difference between the temperatures of opposite faces of the body divided by the rate of heat flow.

NOTES: