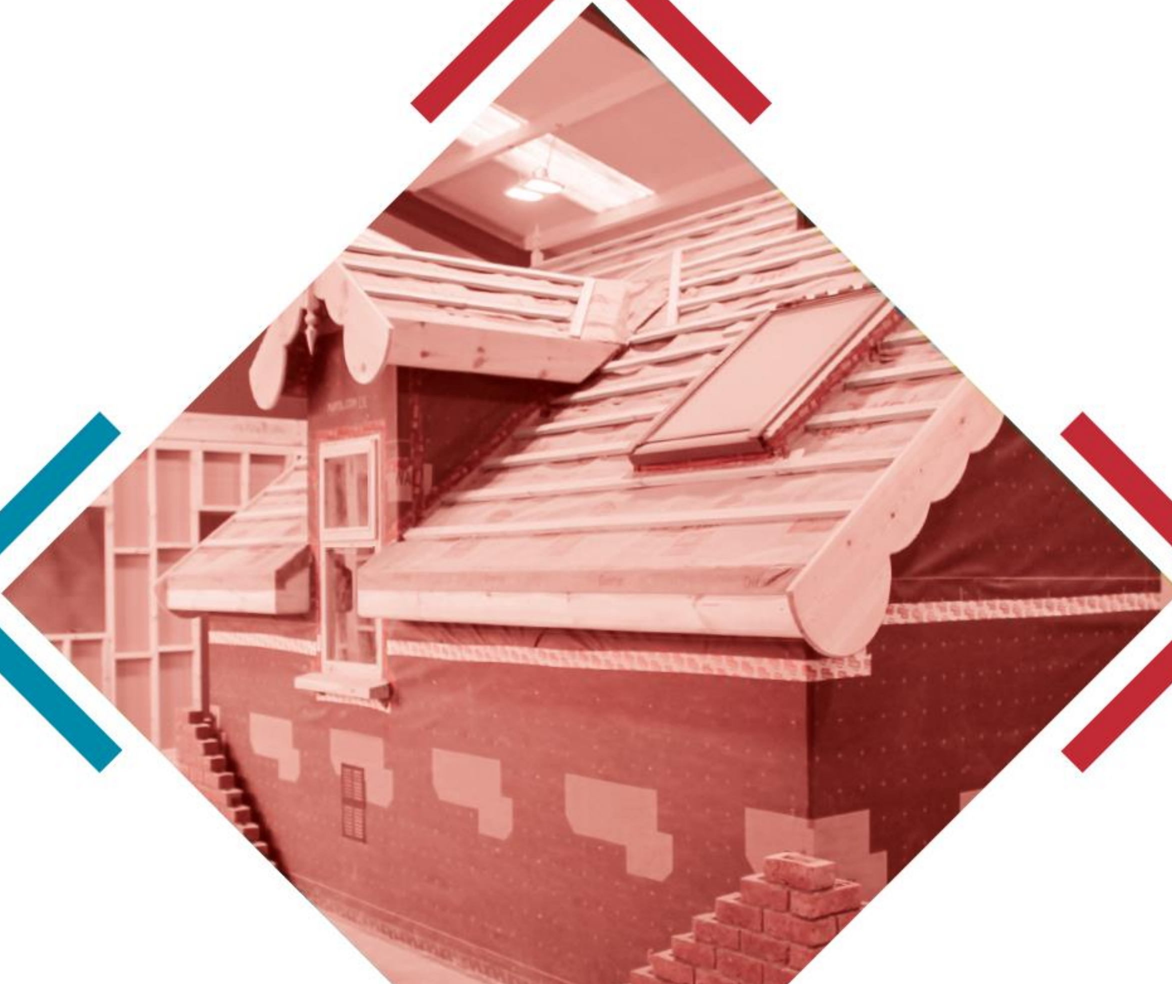


# LEARNER HANDBOOK
## NEARLY ZERO ENERGY BUILDING
# ELECTRICAL

# Table of Contents

# Introduction

Welcome to Nearly Zero Energy Building (NZEB) for Electricians for new dwellings. This learners' 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 NZEB or low energy buildings.

No matter how good we are at our job or how much information we have, we can always learn a little more. The aim of this course is provide Electrical Trades people with the knowledge, skills and competency in the principles and practices of Nearly Zero Energy Building (NZEB) for new build dwellings. The principle reasons for doing the course are so that:

- Everyone has the same understanding of what is involved in providing a quality nearly zero energy building
- Everyone understands the contribution which they can make to such a building
- Everyone understands the impact of his or her work on everyone else, who is trying to provide a quality nearly zero energy building.

This course 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 is to ensure that ALL craftworkers understand the NZEB reasoning through the development of this short NZEB training course to complement the existing apprenticeship process and to help craftworkers understand what makes a building energy efficient within their trade.

Irish Building Regulations, certifications and associated standards are constantly developing and improving, which means that understanding these changes are necessary to ensure all new buildings are constructed energy efficiently with comfort of the occupier in mind. This means 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 provide the background to the issues of energy efficiency and quality in dwellings, as well as best ways of achieving energy efficient, high-quality NZEB 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 quality NZEB buildings. As a craftworker or construction worker, you have a very important role to play with respect to many of these.

Generally, in the building sector, the greatest barrier identified for delivery of quality NZEB buildings is a lack of knowledge rather than skills. Knowledge of the basic principles of low energy building 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.

This handbook will take you through the why, the what and the how of low energy or NZEB 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 Quality Low Energy or NZEB 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, 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 an online session and 1 day practical workshop which includes both theoretical and practical elements.

The course is divided into 6 modules covering a number of learning units. These modules cover topics which will progressively improve your understanding of low energy or NZEB buildings.

Each Module is equivalent to a session, which is approximately 3.5 hours long.

Review the Course Structure diagram Figure 2 which gives a breakdown of each unit and the topics to be covered during the course.

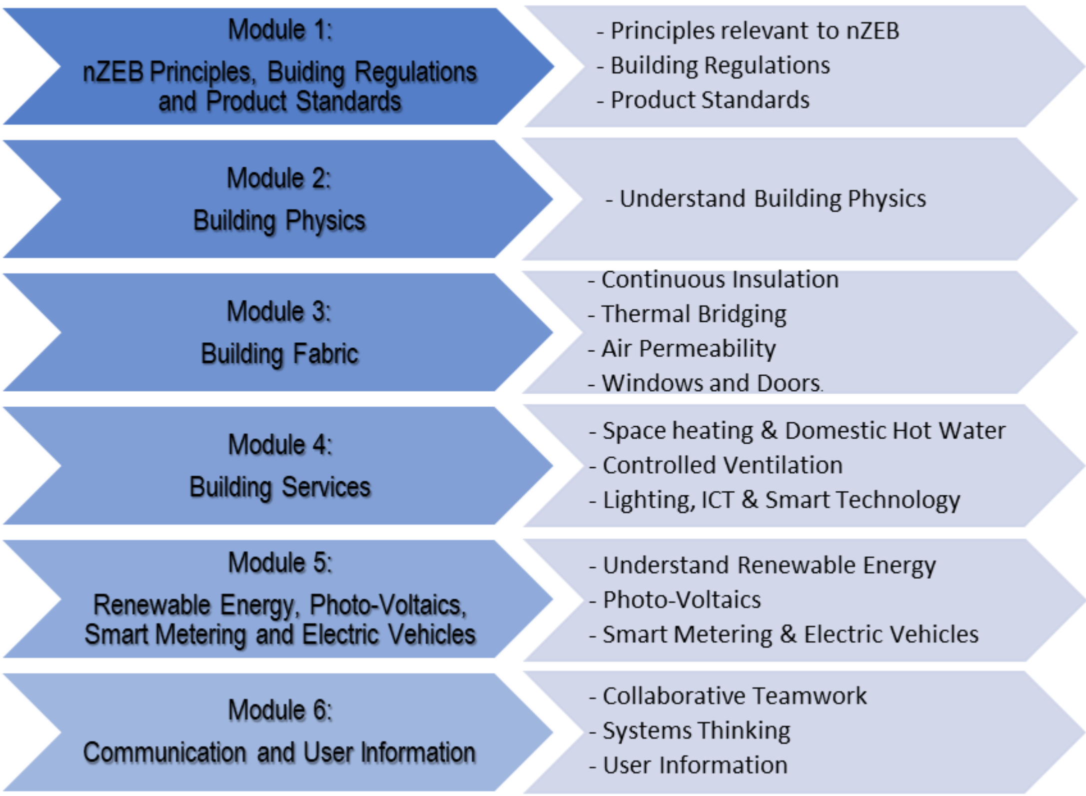



**Figure 2: Course structure and layout**

## Learning Outcomes for the Course

*Learning Outcomes* are the knowledge or skills which you should have developed by the end of the course and 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 required to achieve nearly zero energy buildings NZEB.

2. Explain the key energy terms and measurement units associated with NZEB buildings.

3. List and describe the key construction principles, techniques and products to achieve NZEB compliance. These principles include Continuous Insulation, Thermal Bridging and Air Permeability with special attention to Windows and Doors to achieve healthy buildings.

4. List and describe the key service techniques, methods and equipment needed to achieve NZEB compliance. These principles include energy performance of space heating, hot water installations and storage, ventilation systems and eco lighting with special attention to smart technology.

5. Identify best practice in a number of common construction methods and details relevant to NZEB compliance and be able to recognise work practices which fall below this standard.

6. Identify best practice for a number of renewable and service technologies relevant to NZEB compliance and be able to recognise work practices which fall below this standard.

7. Understand why there is need to talk and discuss with other trades in order to achieve NZEB compliance through collaborative teamwork.

8. Describe some key challenges of implementing high quality NZEB 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 Course Learners Handbook

We recommend the following:

- Work through the modules in order, as you need to learn some things in one part before you start the next part.
- 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.
- Complete the self-test at the end of the handbook.
  - 

If something is unclear make a note of it, so that you can discuss it with your trainer 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

**Key learning point**

Highlighting main points in text

**Activity**

Where you are asked to complete an activity

**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.

**Self-Test**

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

## Finally a reminder of the reasons for the NZEB 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 and comfort for the occupier. The following diagram, Figure 3, sets out these reasons and the way they are related.

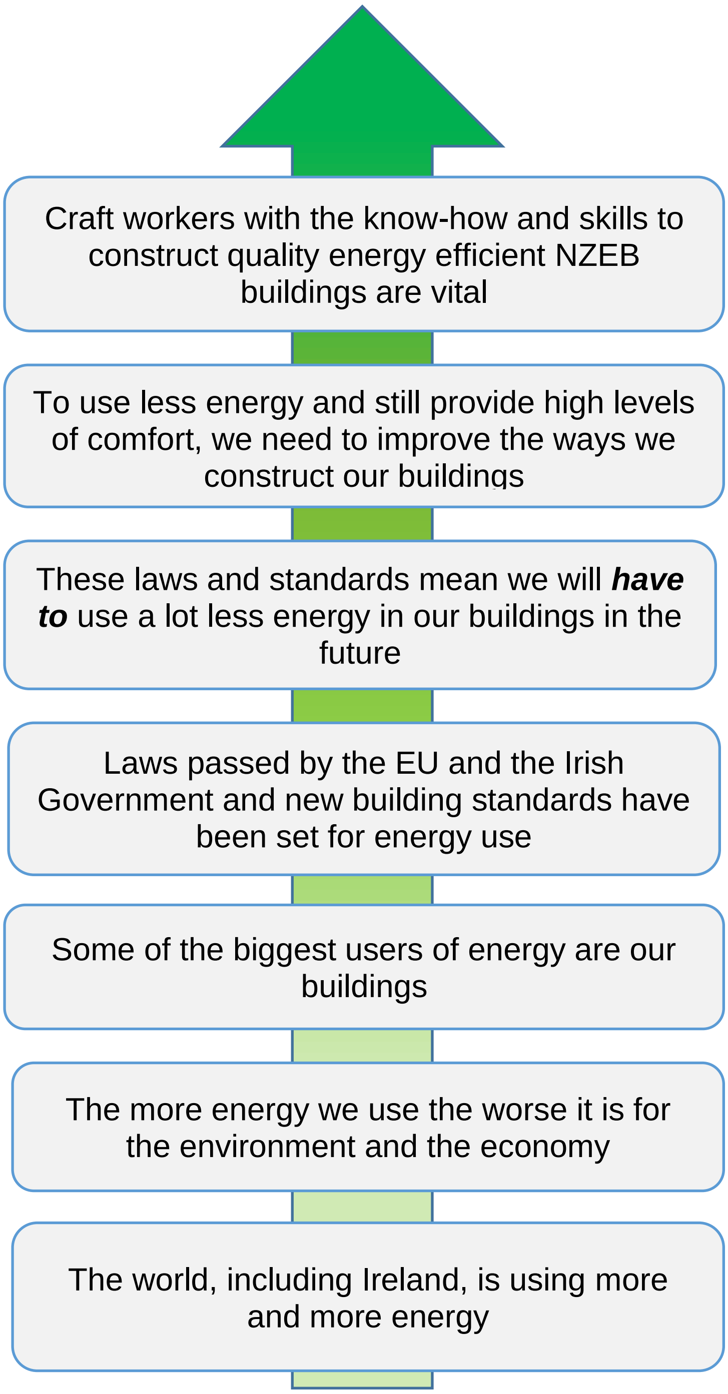


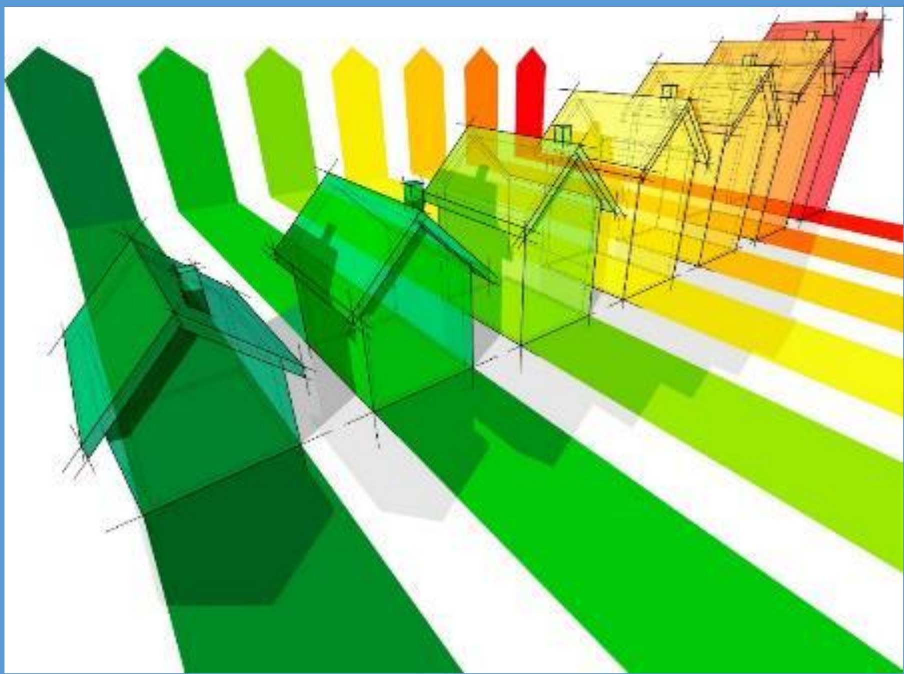

**Figure 3: The reasons for the NZEB Course**

## List of Abbreviations

As you probably know already, abbreviations are part and parcel of the construction industry. This list covers the main abbreviations common in energy efficient fields.

| | |
|---|---|
| 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 |

# Module 1



**NZEB PRINCIPLES, BUILDING REGULATIONS AND PRODUCT STANDARDS**

# Module 1: NZEB PRINCIPLES, BUILDING REGULATIONS AND PRODUCT STANDARDS

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

In Europe, buildings account for almost 40% of energy use as well as releasing 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 by reducing energy consumption and encourage the use of renewable energy sources.

Buildings 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 $CO_2$) contribute to global warming and changes in weather patterns, often resulting in extreme events such as hurricanes, floods and droughts.

## <u>Module Overview</u>

Module 1 provides the background and reasons to achieve Nearly Zero Energy Buildings (NZEB). This includes an overview of EU drivers for NZEB, how energy is used in the different sectors and within buildings, changes to the Building Regulations and key certified products relevant to NZEB construction.

### Unit 1.1: NZEB PRINCIPLES

This topic outlines the EPBD and EED drivers in NZEB and explores how energy is used in the sectors and buildings. It also describes how the construction of NZEB new builds can assist in the significant reduction in energy consumption and wastage.

### Unit 1.2: BUILDING REGULATIONS

Describes the current Building Regulations Technical Guidance Documents (TGDs) and the need for quality NZEB construction. Outline the key compliance terms, Acceptable Construction Details (ACDs) and software tools to achieve NZEB compliance

### Unit 1.3: PRODUCT STANDARDS

Provides a brief summary of key NSAI standards and certification schemes that are relevant to NZEB construction and certified products and equipment.

# Unit 1.1: NZEB PRINCIPLES

**What is NZEB?**

The idea of a Nearly Zero Energy Building (NZEB) is one which is being used more and more in the context of energy efficiency and energy performance in buildings and is now the basis of quality compliant construction.

The following is a definition of the term as given by the EU –

*"Nearly Zero Energy Buildings' means a building that has a very high energy performance, Annex 1 of the Directive and in which "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".*

- 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.

In Ireland, buildings make up over a third of all our energy usage, so they make a major contribution to Greenhouse/$CO_2$ emissions. In order to reduce these 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**.

It is agreed internationally that there is a need to reduce the production of energy from fossil fuels. It all started with the Kyoto Protocol in 1997, driving international efforts to reduce energy production from these sources. This led to further directives, policies and regulations which are now driving changes to our energy policies and building standards in Europe and Ireland.

In response to the Kyoto Protocol a number of EU laws were introduced. The Energy Performance of Buildings Directive (EPBD) 2010 and the Energy Efficiency Directive (EED) 2012 are the EU's main legislative instruments promoting the improvement of the energy performance of buildings within the EU.

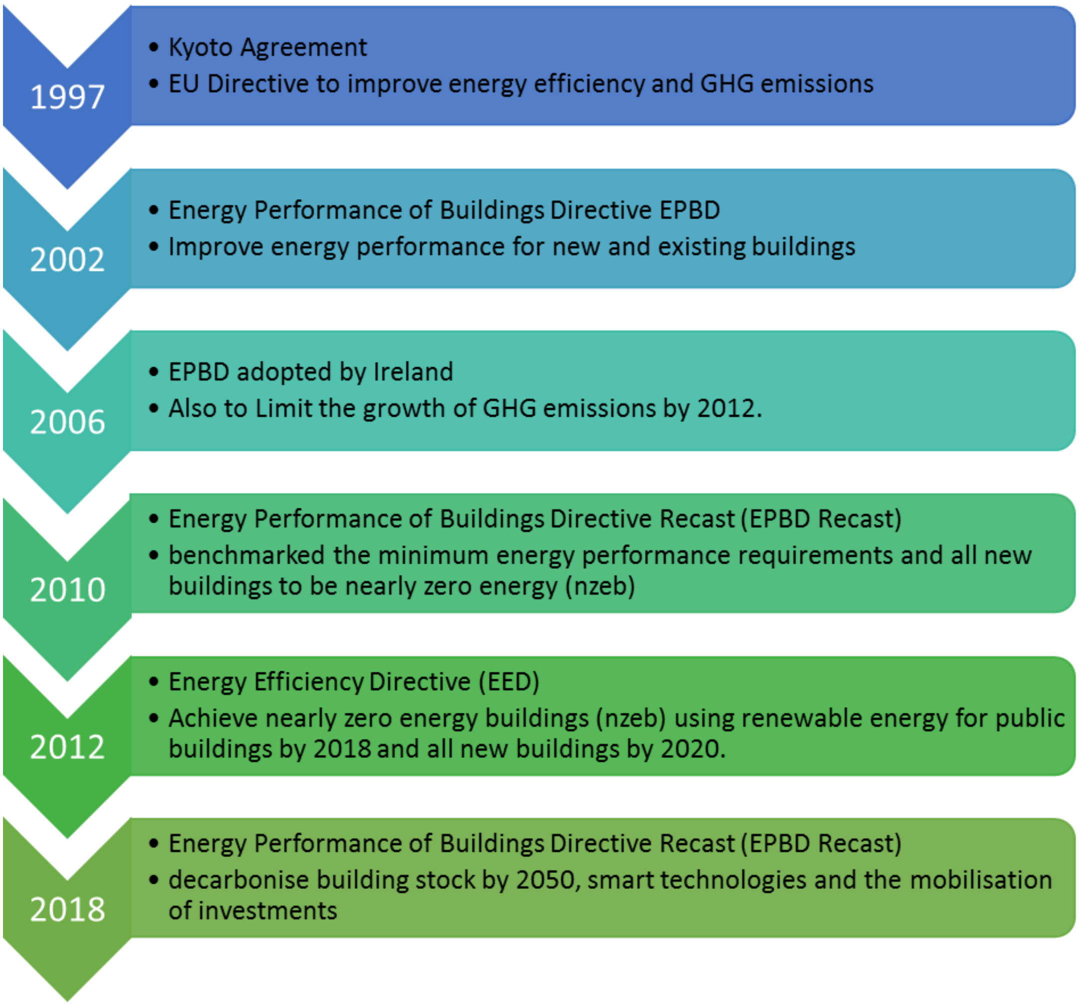



**Figure 1.0: Summary of Energy Directives since the Kyoto Agreement**

### Energy Performance of Buildings Directive, EPBD

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

In 2018, further amendments to the EPBD, aims at accelerating the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050 and the mobilisation of investments. It also supports e-mobility infrastructure deployment in buildings' car parks and introduces new ways to enhance smart technologies and technical building systems, including automation and consideration of health and well-being of the occupants with respect to air quality and ventilation.

The most relevant measures included in the EPBD Recast[1] are as follows:

[1] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

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

**Energy Efficiency Directive, EE**

The Energy Efficiency Directive (EED) established a set of 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 production to final consumption.

The measures most relevant are as follows:

- Energy distributors or 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.
- Energy consumers are encouraged to better manage consumption.
- Provide for and promote certification and/or accreditation schemes including suitable training programmes, for providers of energy services, energy audits, energy managers and installers of energy related building elements.

**How do these EU laws affect Ireland?**

In response to the EED, Ireland adopted a number of plans and strategies a few of these important strategies are as follows:

- 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.

Ireland’s policies have changed over the years to help improve the levels of energy efficiency and performance of buildings. In 2010, Ireland adopted the National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy Action Plan

(NREAP). These set down the main obligations for Ireland to reduce Greenhouse Gases/$CO_2$ emissions, reduce the amount of energy used and reduce fossil fuel generated energy.

| The National Energy Efficiency Action Plan (NEEAP)[2] | |
|---|---|
| 2010 | Ireland's committed to a 20% reduction in energy demand by 2020 |
| 2014 | An update was published called NEEAP 3<br>NEEAP 3 outlines the Nearly Zero Energy Building (NZEB) framework |

This set three key targets for the year 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 Renewable Energy Action Plan (NREAP)[3] | |
|---|---|
| 2010 | Ireland set out national targets for the share of energy from renewable sources to be consumed in transport, electricity and heating & cooling in 2020 |
| 2010 | Reporting every 2 years to EU |

This set out energy targets to be produced from renewable resources by 2020:

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

In 2016, the EU Commission reviewed the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED). They defined additional measures on energy efficiency in buildings needed to meet the 2030 targets. To move forward, the European Commission proposed a Roadmap to move to a low-carbon economy by 2050.
EU leaders have agreed to reduce emissions by at least 40% by 2030, with a 27% target for renewable energy penetration.

[2] https://www.dccae.gov.ie/en-ie/energy/publications/Pages/National-Energy-Efficiency-Action-Plan-3-(NEEAP).aspx

[3] https://www.dccae.gov.ie/documents/The%20National%20Renewable%20Energy%20Action%20Plan%20(PDF).pdf

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)
- At least 27% share for renewable energy
- At least 27% improvement in energy efficiency

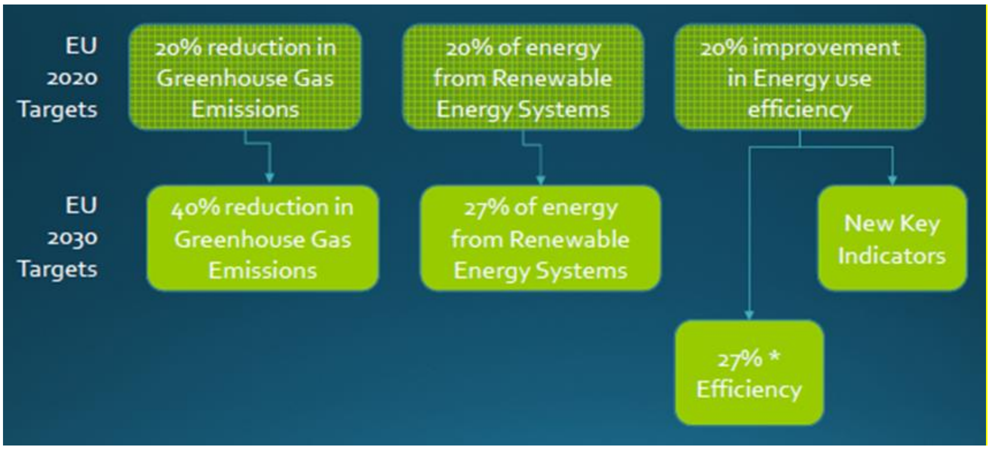



**Figure 1.1: Overview of agreed energy and emission targets for EU 2020 and EU 2030**

To move forward, the European Commission proposed a Roadmap to move to a low-carbon economy by 2050.

The amendments to the directive address energy performance - energy efficiency and on-site renewables more systematically, by improving the links between legal tools and financial support.

The roadmap sets out milestones for a 40% emissions reduction by 2030 and 60% emissions reduction by 2040 and for 2050 to reduce EU wide emissions by 80% to 95%, compared with 1990 levels.

So where does NZEB fit into all this?

**Figure 1.2: NZEB dwellings**

The EPBD Recast 2010 requires all new buildings to be nearly Zero Energy Buildings (NZEB). In Ireland the guidance proposes the following recommendation.

“A Nearly Zero Energy Buildings means 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”

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

- By 31st Dec 2018 - All new public buildings in the Ireland will have to consume 'nearly zero' energy.
- By 2020 - All new buildings need to achieve nearly zero energy status and be sourced 'to a very large extent' from renewable sources.

The European Energy Performance of Buildings Directive Recast 2010 (EPBD) requires all new buildings to be nearly Zero Energy Buildings (NZEB) by 31st December 2020 and all buildings acquired by public bodies by 31st December 2018.

This means that any buildings completed after these dates should achieve the standard irrespective of when they were started. This means that any new dwelling completed after these dates should achieve the standard irrespective of when they are started. Ireland carried out a cost optimal analysis in 2013 to define NZEB requirements. Technical Guidance Documents TGD Part L of the Building Regulations defines the requirements in legislation (For more details refer to Section 1.2).

**Energy use in different Sectors**

So how is energy used in each sector? 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, it is predicted that the energy use in all buildings is similar to the EU percentage of 40%.

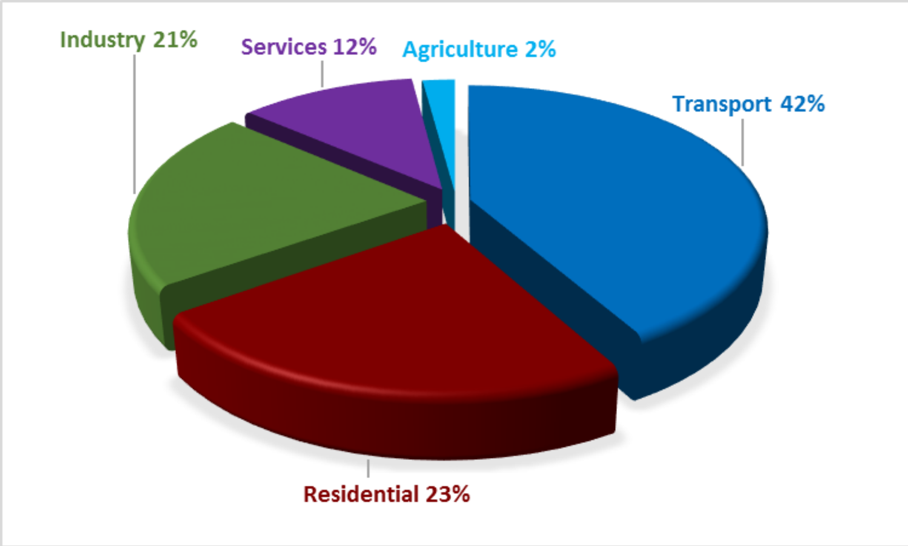



**Figure 1.3: Total final energy consumption in Ireland by sector in % of total Mtoe.**[4]

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.

**Where is all this energy being used in residential buildings?**

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 the residential sector in Ireland and these are outlined in Figure 1.4.

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

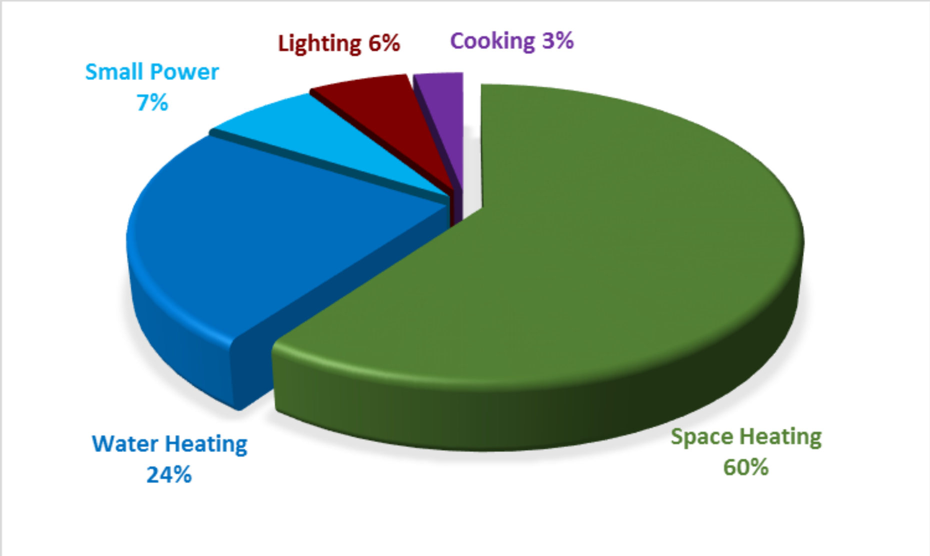



**Figure 1.4: Energy Use in the Residential Sector in Ireland**[5]

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 that total. It is no surprise that these areas have been the main target of amendments to recent laws and building regulations and should be targeted when carrying out new build (and retrofitting).

○

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?

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.

### Energy loss in Buildings

Continuing to waste energy is not sensible and buildings have a major contribution to make, by reducing energy consumption. So, NZEB buildings are good news for the environment and will lead to lower energy bills and more comfortable buildings for us all.

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

A lot of heat is lost through the fabric of many homes in Ireland. Figure 1.5 shows some of the most common parts of a dwelling through which heat is lost.

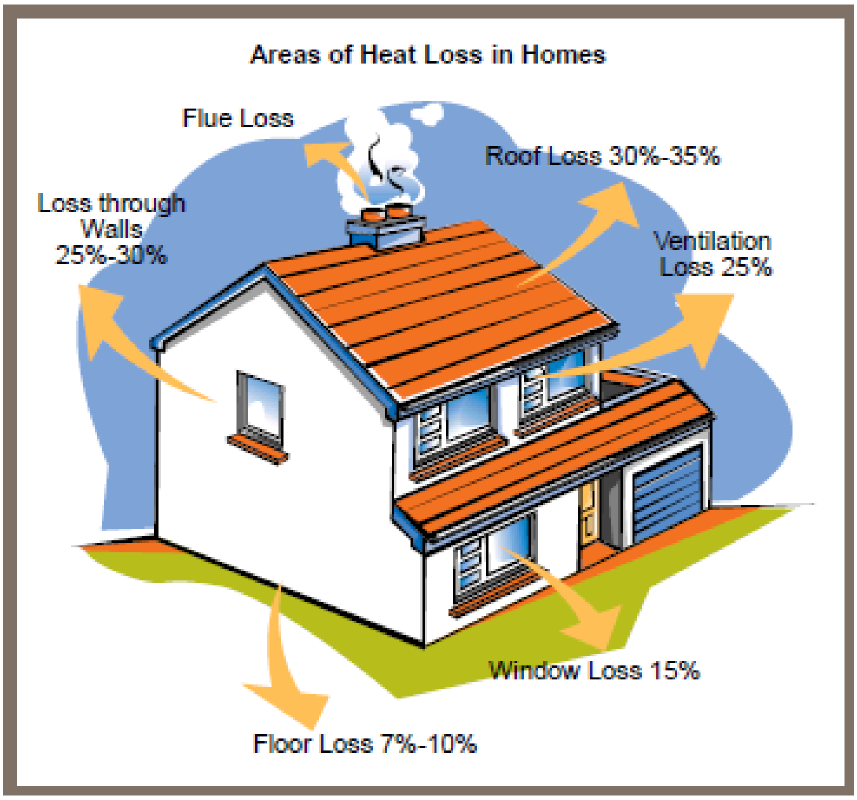



**Figure 1.5: Typical proportions of heat loss from dwellings (source: Tipperary Energy Agency)**

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 together 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 heat.

Improving the energy efficiency of buildings also generate other economic, social and environmental benefits. Better performing buildings provide higher levels of comfort and wellbeing for occupants, and improve health by reducing illnesses caused by a poor indoor climate. It also has a major impact on the affordability of housing and on the concept of energy poverty. Improvement of the energy performance of the housing stock and the energy savings it brings would enable many households to escape energy poverty.

## Unit 1.2: BUILDING REGULATIONS

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 and fit for purpose. It is not necessary for you to know all the details of policies and regulations but it is important that construction workers understand the principle ideas behind them.

**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 regulations apply to the design and construction of new buildings or an extension to an existing building. The minimum performance requirements that a building must achieve, are set out in the second schedule to the building regulations and the Technical Guidance Documents (TGD's).

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.


**Figure 1.20: Technical Guidance Documents (TGDs)**

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](http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents)

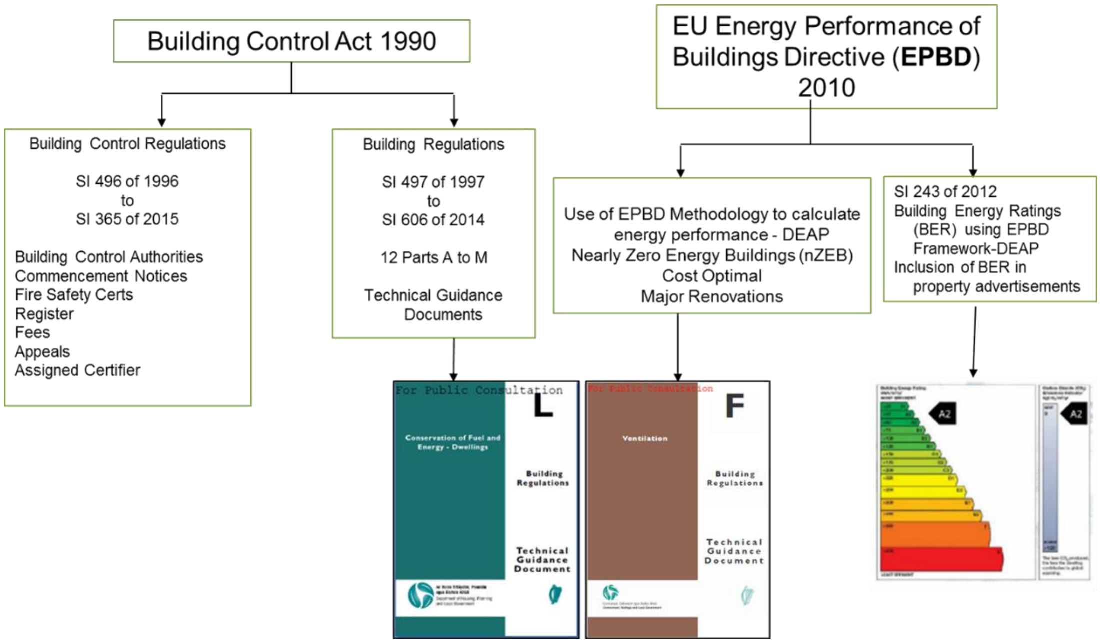



**Figure 1.20: Evolution of Building Regulations (Source: Sean Armstrong DHPLG)**

The Building Regulations Technical Guidance Documents (TGD's) are constantly being updated as improvements to building standards in the construction industry will continue and we will have to comply with Irish law. New rules and regulations are intended to ensure that our buildings perform well. It is not necessary for you to know all the details of building regulations but it is important that you understand the principle ideas behind them.

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.

Although compliance with all the TGDs is mandatory, it is important to ensure you are fully versed in **Part L**, Conservation of Fuel and Energy – Dwellings, **Part F**, Ventilation and **Part J**, Heat Producing Appliances. These are guidelines and express the minimum requirements, so as qualified electricians it is important to strive for higher standards.

Be aware that the Irish Building Regulations TGDs are continuously improving and should be checked periodically, especially in relation to the energy performance for buildings and NZEB in particular updating Technical Guidance Documents (TGD) Part L – Dwellings, Part F – Ventilation and Part J - Heat Producing Appliances.

**TGD Part L** - **Conservation of Fuel and Energy**

The Technical Guidance Document L - Conservation of Fuel and Energy – Dwellings 2011 (Amended 2017) ceases to have effect from ***31st March 2019***, and the new TGD Part L comes into force, with some significant changes to the requirements. The 2018 Part L Regulations set energy performance requirements to achieve Nearly Zero Energy Buildings performance as required by Article 4 (1) of the Directive 2010/31/EU for new dwellings

The requirements in Part L in 2019 include:

An application of a methodology for the calculation of the energy performance of buildings on the basis of a general framework set out in Annex I to the EPBD (recast).

The setting of minimum energy performance requirements for buildings and the application of these requirements to new buildings to achieve Nearly Zero Energy Buildings;

The guidance in this document also gives due regard to the cost-optimal levels of minimum energy performance requirements submitted in Ireland's report to the Commission under Article 5 of the EPBD Recast Directive 2010/31/EU of 19th May 2010.

The Second Schedule, insofar as it relates to works relating to dwellings, is amended to read as follows: -

L1 A building shall be designed and constructed so as to ensure that the energy performance of the building is such as to limit the amount of energy required for the operation of the building and the amount of carbon dioxide ($CO_2$) emissions associated with this energy use insofar as is reasonably practicable.

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 (CO2) emissions are calculated using the Dwelling Energy Assessment Procedure (DEAP) published by Sustainable Energy Authority of Ireland;
(b) providing that, the nearly zero or very low amount of energy required is covered to a very significant extent by energy from renewable sources including energy from renewable sources produced on-site or nearby;

(c) Limiting heat loss and, where appropriate, availing of heat gain through the fabric of the building;
(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) Ensuring that the building is appropriately designed to avoid the need for cooling
(g) 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.

## TGD Part F - Ventilation

The Technical Guidance Document F - Ventilation 2009 has been replaced with the ***new TGD Part F 2018***, with some significant changes to the requirements.

Part F of the Second Schedule to the Building Regulations 1997 is amended to read as follows:


**Means of ventilation F1 -** Adequate ***and effective*** 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

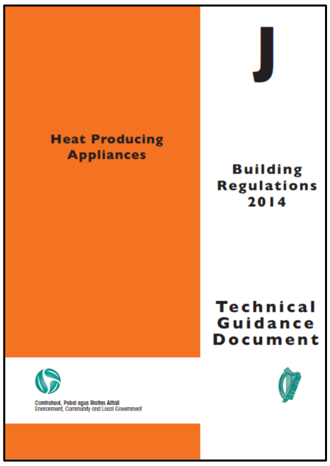
(b) limiting the concentration of harmful pollutants in the air within the building.

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

It is important to minimise the uncontrollable infiltration and supply sufficient purpose-provided ventilation. Air tightness measures to limit infiltration are covered in Part L of the Building Regulations. In general Technical Guidance Document F provides guidance on purpose-provided ventilation for buildings with an air permeability of $5m^3$ /($h.m^2$ ) at 50pa ***or less***. It is important as buildings become more airtight that adequate ventilation is maintained.

Ventilation may be achieved ***through the supply or extraction of air by mechanical means or by natural ventilation, or by a combination of these methods.***

## TGD Part J – Heat Producing Appliances




The Technical Guidance Document J - Heat Producing Appliances, 2014, sets out the Second Schedule to the Building Regulations with the aim to allow for the installation of heat producing appliances while giving adequate protection to the occupants from incomplete combustion or products of combustion and limiting the risk of fire to the building or fuel storage.

**Commissioning -** Heat producing appliances serving the total dwelling should be commissioned and tested at completion so that the systems and their controls are left in the intended working order and can operate effectively and efficiently.

## DEAP Software

The Dwelling Energy Assessment Procedure (DEAP) is a software package and methodology for demonstrating compliance with specific aspects of Part L for Dwellings of the Building Regulations.

DEAP is also used to generate the Building Energy Rating (BER) and advisory report for new and existing dwellings and calculates the energy consumption and $CO_2$ emissions associated with a standardised use of the dwelling. It considers space heating, ventilation, water heating, and lighting in a dwelling.

The current DEAP interface (v3.2.1, or DEAP3) and the recently launched DEAP4, a web-based technology accessed through your browser, will be amended to adopt the following proposed changes for the DEAP methodology for Part L 2018[6]:

1) Renewable Energy Ratio - It is proposed that the DEAP methodology shall be updated to include the Renewable Energy Ratio which is to be calculated in line with EN ISO 52000 -2017.

2) Primary Energy and $CO_2$ Factors of Electricity - The primary energy factor is based on the methodology outlined in EN ISO 52000 -2017. The DEAP 2018 is to base the primary energy on the projected energy use for the next 5 years. It will be reviewed before the end of the 5 year period.

3) Lighting Energy - The proposal is to update the Lighting Calculation to allow a more accurate representation of the energy use associated with the lighting within the dwelling.

4) Hot Water Demand - For buildings complying with NZEB requirements it was found that the hot water energy demand can be significantly larger than the space heating. To date the hot water demand was based on the number of people/ floor area and did not sufficiently account for the fittings or sources of hot water.

[6]https://www.housing.gov.ie/sites/default/files/public-consultation/files/part_l_public_consultation_deap_methodology_for_nzeb.pdf

Other changes cover the topics: Space Cooling, Main Heating Systems, High Heat Retention Storage Heaters, Heat Recovery Mechanical Ventilation, Occupancy, Waste Water Heat Recovery.

For residential buildings, compliance must be demonstrated using the SEAI DEAP methodology. For all new dwellings, NZEB will be equivalent to a 25% improvement in energy performance on the 2011 Building Regulations.

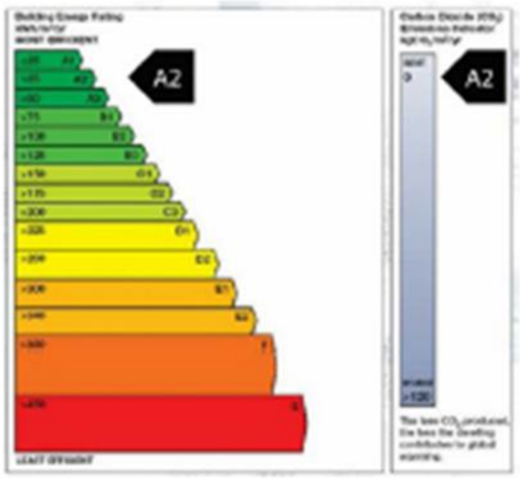



**Figure 1.19 Building Energy Rating Categories (source – SEAI)**

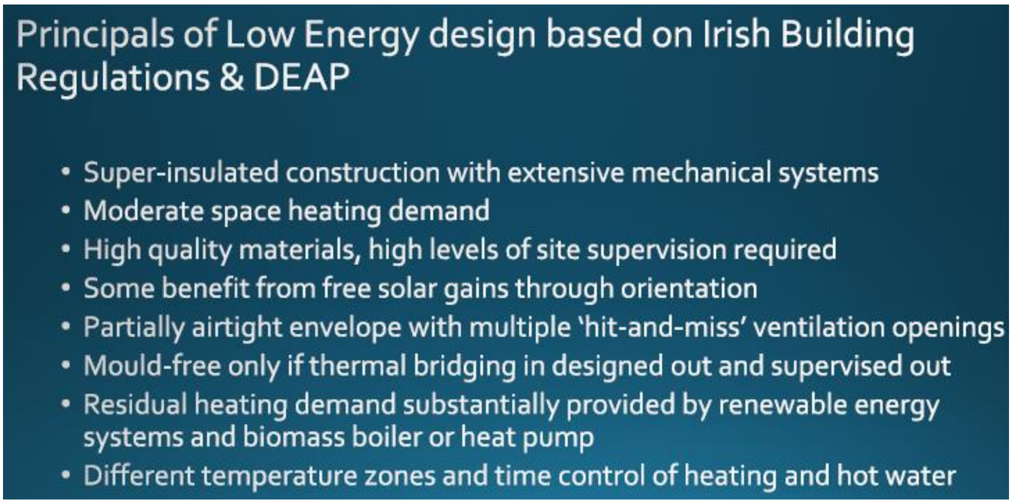
This means that for a typical dwelling, this equates to a Building Energy rating (BER) A2 rating with a primary energy value of 45 kWh/m$^2$/annum with a significant proportion of the energy demand being covered by renewable resources produced on-site or nearby. This takes account of the energy needed for space heating, water heating, fixed lighting and ventilation.

The progression to improved energy performance since 2005 of dwellings is summarised in Table 1.

| Year | 2005 | 2008 | 2100 | 2018 |
|---|---|---|---|---|
| Energy Improvement % | Baseline | 40% | 60% | 70% |
| Primary Energy Consumption (KWh/m$^2$/yr) | 150 | 90 | 60 | 45 |
| CO2 Emission Rate (KgCO$_2$/m$^2$/yr) | 30 | 18 | 12 | 10 |
| Maximum Permitted Energy Performance Co-efficient (MPEPC) | | 0.6 | 0.4 | 0.3 |
| Maximum Permitted Carbon Performance Co-efficient (MPCPC) | | 0.69 | 0,46 | 0.35 |
| BER | B3 | B1 | A3 | A2 |

**Table 1.0: Improved energy performance since 2005**

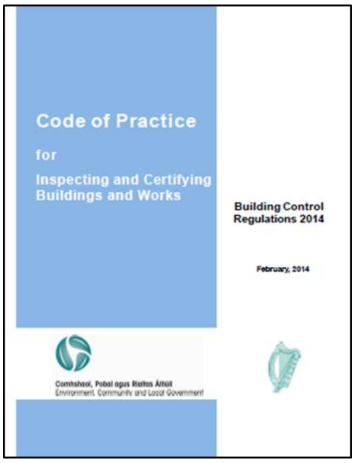
Not only is the compliance of the energy consumption required but to demonstrate NZEB compliance as calculated in the SEAI DEAP BER software, all new dwellings in Ireland must not exceed a maximum permitted energy performance co-efficient (MPEPC) of 0.302 and not exceed a maximum permitted carbon performance co-efficient (MPCPC) of 0.35.




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.

## Building Control - Regulations




The changes in March 2014, known as the Building Control (amendments) Regulations (BC(A)R) states that all building construction workers have to demonstrate competency, co-ordination and compliance with building regulations.

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.

**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).

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.

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

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.

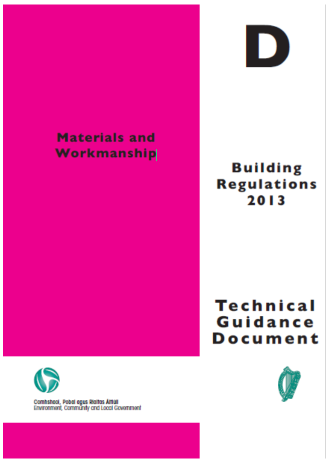
Some important ways for contributing to the achievement of these targets and objectives are:

- 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

## Unit 1.3: PRODUCT STANDARDS

### TGD Part D - Materials and Workmanship




Part D of the Second Schedule to the Building Regulations 2013 provides as follows:

Materials and workmanship D1 All works to which these Regulations apply shall be carried out with proper materials and in a workmanlike manner.

D3 “Proper materials” means materials which are fit for the use for which they are intended and for the conditions in which they are to be used, and includes materials which:

(a) bear a CE Marking in accordance with the provisions of the Construction Products Regulation;

(b) comply with an appropriate harmonised standard or European Technical Assessment in accordance with the provisions of the Construction Products Regulation; or

(c) comply with an appropriate Irish Standard or Irish Agrément Certificate or with an alternative national technical specification of any State which is a contracting party to the Agreement on the European Economic Area, which provides in use an equivalent level of safety and suitability.

**The National Standards Authority of Ireland (NSAI)** is Ireland's official standards body and provides a wide range of certification services to enable business demonstrate that Irish goods and services conform to applicable standards.

The following links provide information in relation to NSAI Agrément certified systems and installers: -

Agrément Search Page (external link) - National Standards Authority of Ireland

External Thermal Insulating Composite Systems (ETICS) Installers List (external link)- National Standards Authority of Ireland

Cavity Wall Insulation Installers List (external link) - National Standards Authority of Ireland

### The Eco Design Directive, EDD

The Ecodesign Directive (EDD) is a key instrument of the EU’s energy policy framework and is expected to have a substantial impact on energy efficiency and energy demand in the European economy.

Its scope currently covers more than 40 product groups; such as heating and cooling equipment, lightbulbs, TVs, IT, and kitchen appliances, energy-related products such as windows, insulation materials and certain water-using products which contribute to the greenhouse gas emissions.

The main aim of the Ecodesign Directive is to encourage manufacturers of energy-using products, at the design stage, to reduce the energy consumption and other negative environmental impacts of products. Whilst the Directive's primary aim is to reduce energy use, it is also aimed at enforcing other environmental considerations including: materials use; water use; polluting emissions; waste issues and recyclability.


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

## Summary

- Nearly Zero Energy Buildings' means a building that has a very high energy performance, Annex 1 of the Directive and in which "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".
- 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.
- 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 for 2020 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.
- Ireland's targets for 2030 are:
    - At least 40% cuts in greenhouse gas emissions (from 1990 levels)
    - At least 27% share for renewable energy
    - At least 27% improvement in energy efficiency
- 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.
- Irish definition of NZEB - "A Nearly Zero Energy Buildings means 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"
    - By 31st Dec 2018 - All new public buildings in the Ireland will have to consume 'nearly zero' energy.
    - By 2020 - All new buildings need to achieve nearly zero energy status and be sourced 'to a very large extent' from renewable sources.
- The Building Regulations are regularly updated as Ireland strives to reach these nearly zero energy buildings (NZEB) requirements.
    - The most relevant Building Regulation Technical Guidance Documents include:
    - Technical Guidance Documents (TGD) Part L 2011 (amended 2019)
    - Technical Guidance Documents (TGD) Part F 2009 (amended 2019)
    - Technical Guidance Documents (TGD) Part J 2014
- The Dwelling Energy Assessment Procedure (DEAP) is a software package and methodology for demonstrating compliance with specific aspects of Part L for Dwellings of the Building Regulations. DEAP4 has adopted significant changes.
- To comply with NZEB all new residential buildings must not exceed a Primary Energy Consumption of 45KWh/m$^2$/yr, a Maximum Permitted Energy Performance Co-efficient (MPEPC) of 0.3 and Maximum Permitted Carbon Performance Co-efficient (MPCPC) of 0.35.
- 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 BER rating for new residential buildings requires a rating of A2.
    - The Ecodesign Directive (EDD) is a key instrument of the EU's energy policy framework and is expected to have a substantial impact on energy efficiency and energy demand in the European economy
- The Irish Building Regulations, Part D 2013 requires all works to be carried out with proper materials and in a workmanlike manner, materials should be used which are fit for the use for which they are intended and for the conditions in which they are to be used, and to:

- (a) bear a CE Marking in accordance with the provisions of the Construction Products Regulation;
- (b) comply with an appropriate harmonised standard or European Technical Assessment in accordance with the provisions of the Construction Products Regulation; or
- (c) comply with an appropriate Irish Standard or Irish Agrément Certificate or with an alternative national technical specification of any State which is a contracting party to the Agreement on the European Economic Area, which provides in use an equivalent level of safety and suitability

## Useful Links

**Climate Change, NZEB,**

Energy Efficiency Directive (EED) implementation in Ireland and amendments 2016
https://www.dccae.gov.ie/en-ie/energy/consultations/Documents/18/consultations/Energy%20Efficiency%20Directive%20Consultation_FINAL.pdf

IBEC: A Guide to the Energy Efficiency Directive, National Energy Efficiency Action Plan and PAYS 2014 https://www.ibec.ie/IBEC/DFB.nsf/vPages/Energy~Resources~a-guide-to-the-energy-efficiency-directive,-national-energy-efficiency-action-plan-and-pays-14-08-2013/$file/A+Guide+to+the+Energy+Efficiency+Directive,+National+Energy+Efficiency+Action+Plan+and+PAYS.pdf

EU Directive on the Energy Performance of Buildings (2002/91/EC)
https://www.dccae.gov.ie/en-ie/energy/legislation/Documents/30/EU%20Directive%20on%20the%20Energy%20Performance%20of%20Buildings%202002%2091%20EC.pdf

Department of Communications, Climate Action and Environment: First National Mitigation Plan 2017
https://www.dccae.gov.ie/en-ie/climate-action/publications/Documents/7/National%20Mitigation%20Plan%202017.pdf

Department of Communications, Climate Action and Environment: National Energy Efficiency Action Plan https://www.dccae.gov.ie/en-ie/energy/publications/Documents/8/NEEAP%203.pdf

Check out Annex C on page 136 for Irelands' "National Plan for Nearly Zero Energy Buildings"
EC, (2009), Renewable Energy Sources Directive, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

Towards Nearly Zero Energy Buildings in Ireland: http://www.environ.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad%2C42487%2Cen.pdf

SEAI, National Energy Projections to 2030 - Understanding Ireland's energy transition

*https://www.seai.ie/resources/publications/National-Energy-Projections-to-2030.pdf*

## Building Regulations

The Irish Building Regulations Technical Guidance Documents (TGD's) are available to download at http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents

Sustainability Energy Authority of Ireland, January 2011. Dwelling Energy Assessment Procedure (DEAP) https://www.seai.ie/energy-in-business/ber-assessor-support/deap/deap4-software/

Proposed Changes to the DEAP Methodology for Part L 2018 Public Consultation https://www.housing.gov.ie/sites/default/files/public-consultation/files/part_l_public_consultation_deap_methodology_for_NZEB.pdf

## Product Codes

The Sustainable Energy Authority of Ireland at Home-heating Appliance Register of Performance (HARP) database (external link) -

SAP Appendix Q at Standard Assessment Procedure (SAP) Appendix Q Ventilation systems database (external link) -

National Standards Authority of Ireland at Windows Energy Performance scheme (WEPs) (external link)

National Standards Authority of Ireland at Product Certification for Air Tightness Testing (external link)

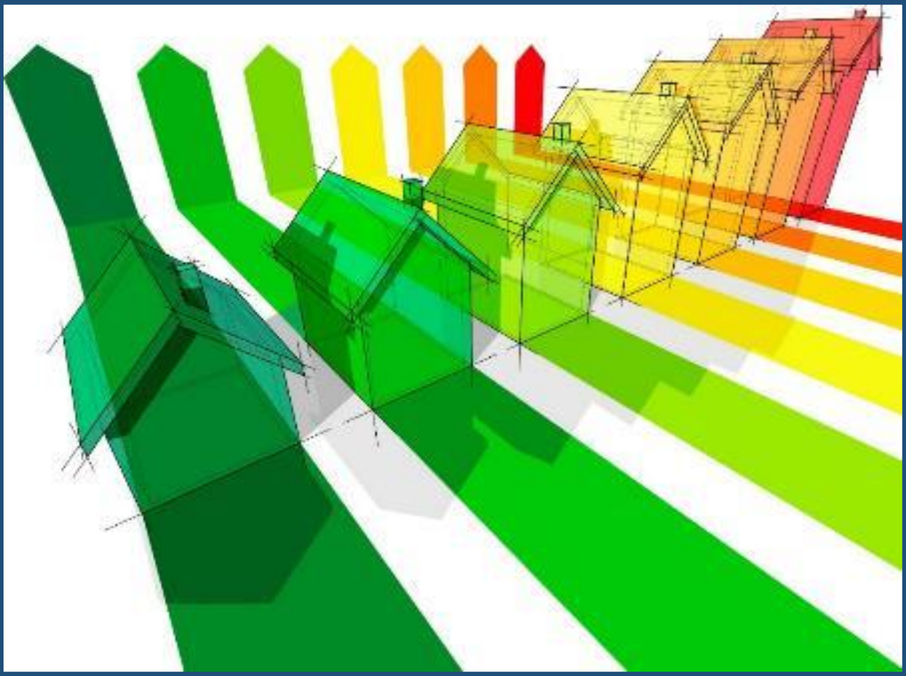
Sustainable Energy Authority of Ireland at To Account for Thermal Bridging in DEAP (external link)

National Standards Authority of Ireland at Agrément Search Page (external link)

National Standards Authority of Ireland at External Thermal Insulating Composite Systems (ETICS) Installers List (external link)

National Standards Authority of Ireland at Cavity Wall Insulation Installers List (external link)

# Module 2



# BUILDING PHYSICS

# Module 2: Building Physics

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

Compliance with NZEB and 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

## Basic understanding of Building Physics

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

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. A number of factors affect the rate of heat transfer through different building materials and it is important to know what these factors are and able to measure their effects. In this section, the units used for measuring heat transfer through building materials will be explained.

To understand this ***heat loss,*** it is necessary to remind you of 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.

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

**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.

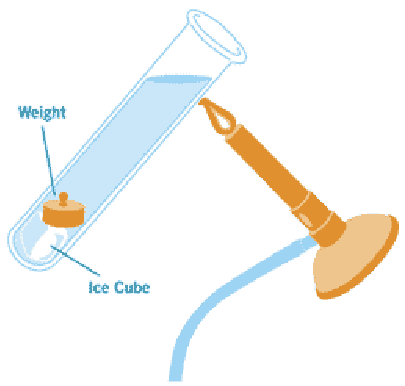



**Figure 2.0 Example of Conduction**[7]

**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

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

cooling effect on the surface temperature of the materials and therefore on the whole building.

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.

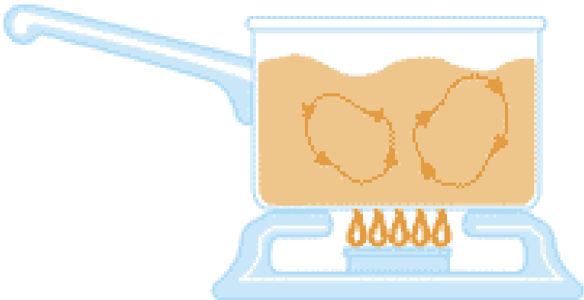


**Figure 2.1 Example of convection** [8]

## 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).

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.

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

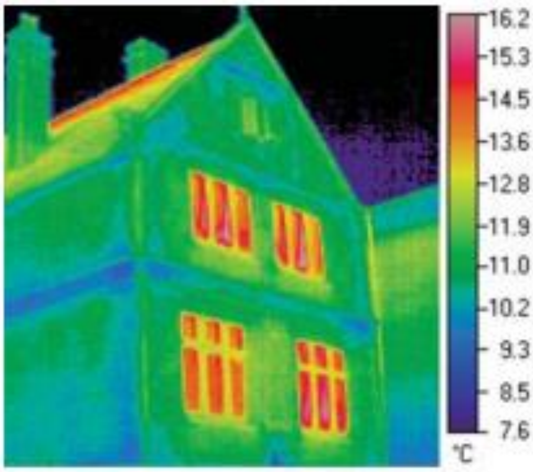



**Figure 2.2: Thermographic image illustrating heat loss through a building envelope (source: SEAI, 2007[9])**

### 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.

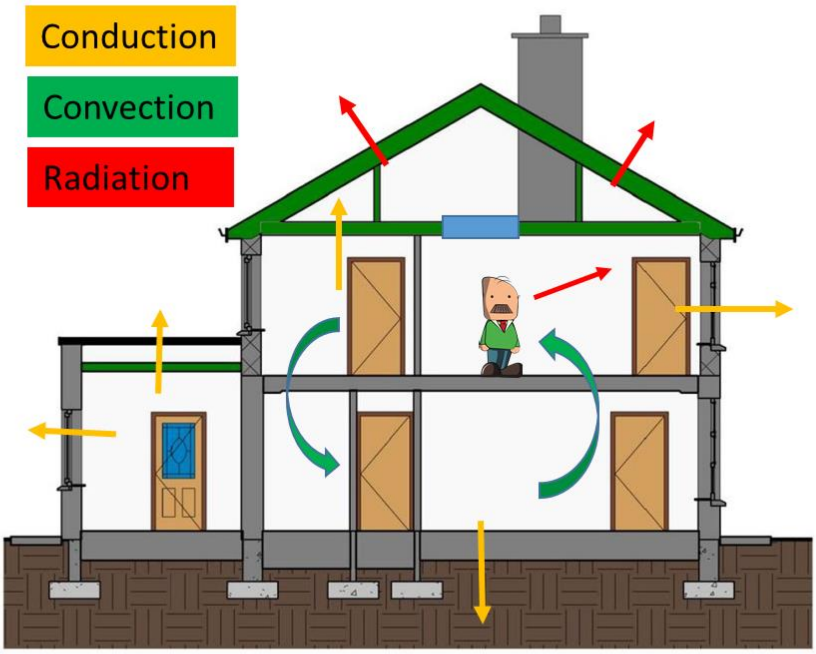



**Figure 2.3 Typical heat loss pathways from a house during winter**

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

Heat moves through the materials of the building envelope (wall, window, door, floor, ceiling and roof) by **conduction.** Since heat moves from the hotter to the colder areas, 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 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).

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.

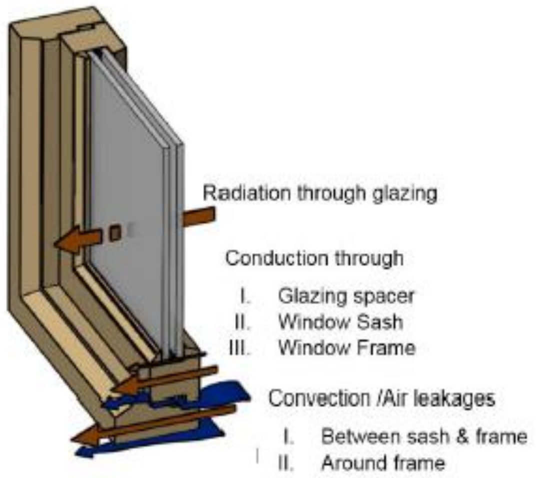



**Figure 2.4 Heat loss through a window**

So it is important to know
CONDUCTION: that heat transfers faster through some materials such as steel, faster than sheepswool
CONVECTION: that heat transfers through gaps from hot to cold areas
RADIATION: that heat transfers faster the hotter it is and radiates from the surface of materials

**Heat transfer in a typical 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.

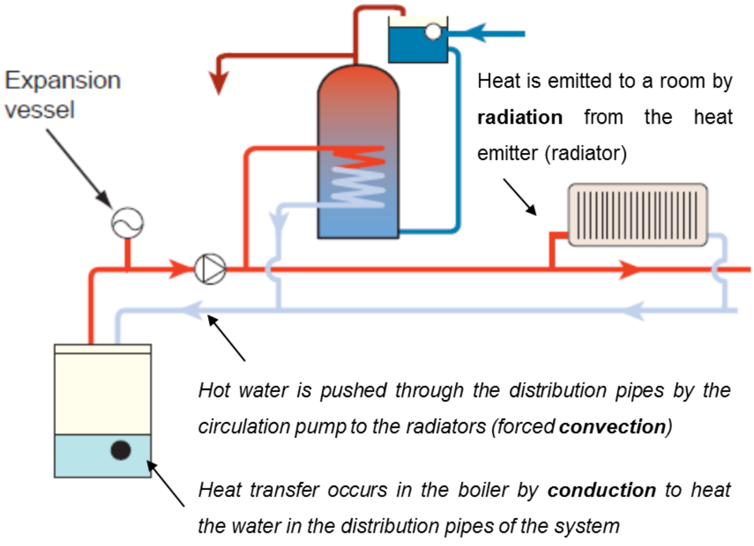



**Figure 2.5 Sealed wet central heating system (Source: SEAI)**

## Factors Affecting Heat Transfer in Buildings

There are many factors which affect the amount of heat losses and gains in a building and these are largely dependent on the following factors:

- The amount of surface area of building envelope exposed to the outside, e.g. a mid-terrace house only has two external walls, compared to a detached house with at least four walls.
- The thermal resistance of the building envelope
- The thermal compliance of heating storage and distribution services.
- The level of airtightness of the building.
- 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)

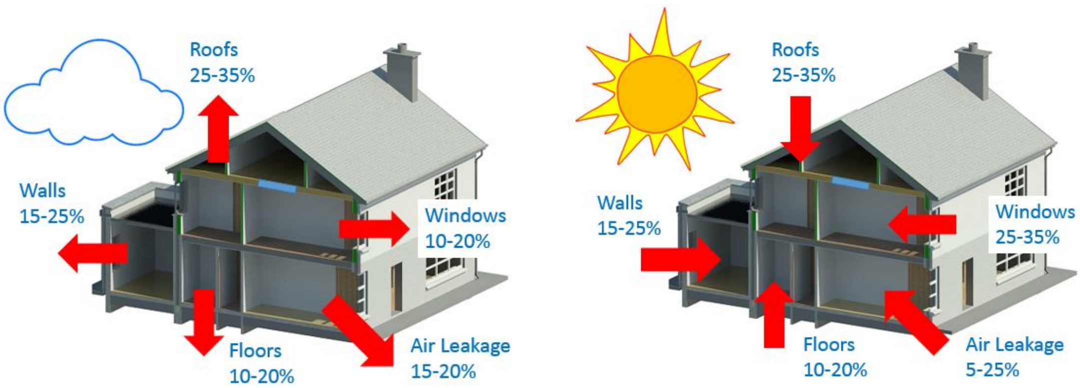



**Figure 2.6 Percentage of heat losses in winter time and heat gains in summer time**

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

As craftworkers, 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 and services.

**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, greatly increase the temperature internally through solar gain. (It should be noted that a lot of heat can also be lost through windows)

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.

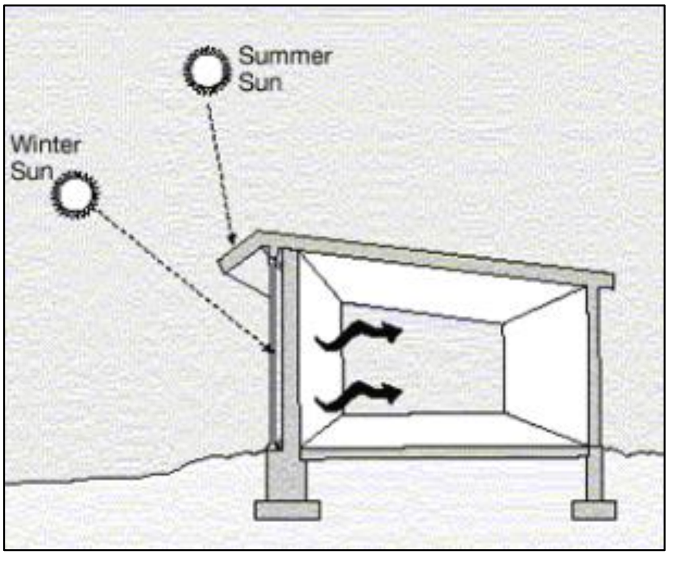



**Figure 2.7 External shading to the window preventing overheating of a building.**

**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 night time to keep internal air temperature down.

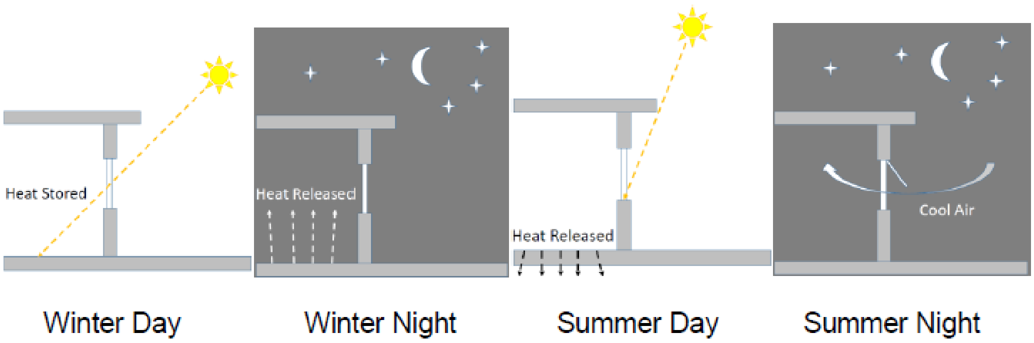



**Figure 2.8 Illustration of effect of thermal mass**

As Electricians, it is important to understand the principles of thermal mass and solar gain, and how these will affect heavy concrete or lightweight timber buildings so as to design and size heating and cooling services. The importance of shading to the internal space to provide good thermal comfort should also be considered.

## Simple Explanation of Energy Units

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.

**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)

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

**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.

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: **R = d/λ**

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.

**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 ($W/m^2K$).

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

To calculate the U value, it is the total thermal resistance of the layers of materials in a floor, wall, window or roof that give the U-value. Lower U-values lead to less heat transfer.

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.

Looking at the Technical Guidance Documents Part L – Conservation of Fuel and Energy for Dwellings (new build), it sets out U-Values of different building elements. The U-values have improved over the years and maximum U values to comply with building regulations and obtain NZEB compliance are required.

The following Figure 2.0 shows the U-values for each element of a *residential* building (dwelling) to comply with the proposed building regulations TGD Part L in 2019 to achieve NZEB compliance.

| **Maximum Elemental U-value (W/m2K)** | | | | |
|---|---|---|---|---|
| | 2011 | | 2019 | |
| Fabric Elements | Area weighted Average Elemental U-value (Um) | Average Elemental U-value individual element or section of element | Area weighted Average Elemental U-value (Um) | Average Elemental U-value individual element or section of element |
| Pitched Roof | 0.16 | | 0.16 | |
| Flat roof | 0.2 | | 0.2 | |
| Walls | 0.21 | 0.6 | **0.18** | 0.6 |
| Ground floor | 0.21 | 0.6 | **0.18** | 0.6 |
| Other exposed floors | 0.21 | 0.6 | **0.18** | 0.6 |
| External windows, doors and rooflights | 1.6 | 3.0 | **1.4** | 3.0 |

**Table 2.0 Maximum U-values – shows improvements for NZEB compliance.**

The next two figures clearly shows the required U values through each element. However it should be noted that when choosing the materials that these U-values should always be improved upon wherever possible.

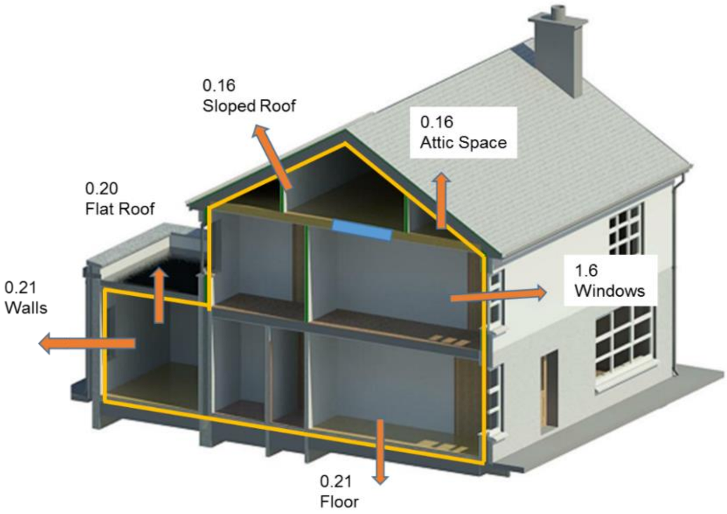



**Figure 2.9 Permitted U-values for Dwellings taken from TGD Part L, 2011**

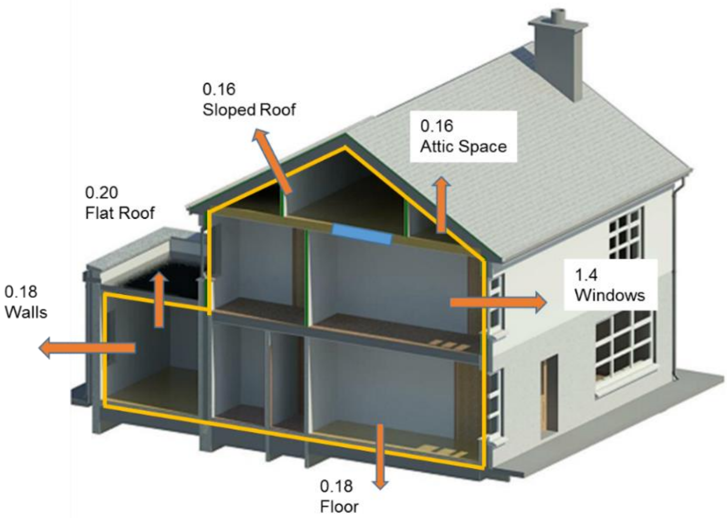



**Figure 2.10 Permitted U-values for Dwellings taken from TGD Part L, 2019**

These are the minimum, but we should always aim higher, as standards continue to improve. 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 were 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 Criteria of today.

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 (reduce fuel poverty) and improve comfort levels for the occupier.

To simplify:

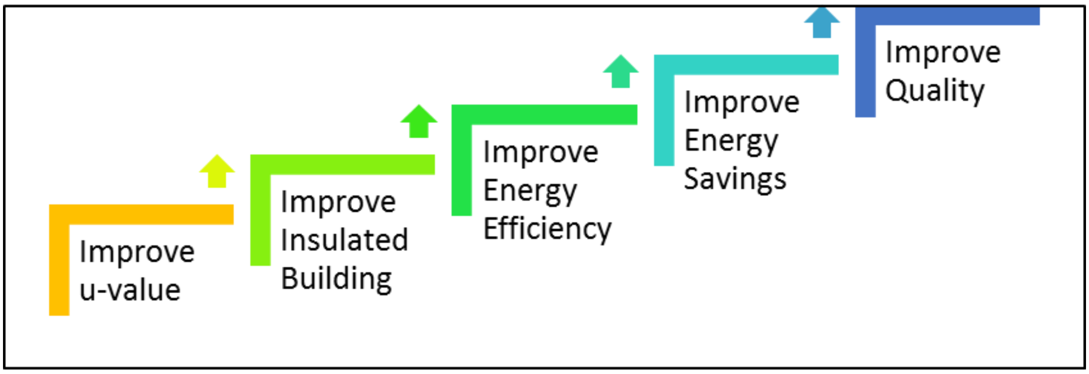



**Figure 2.11 Demonstrating the steps to achieving Quality**

## 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 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 2.12.

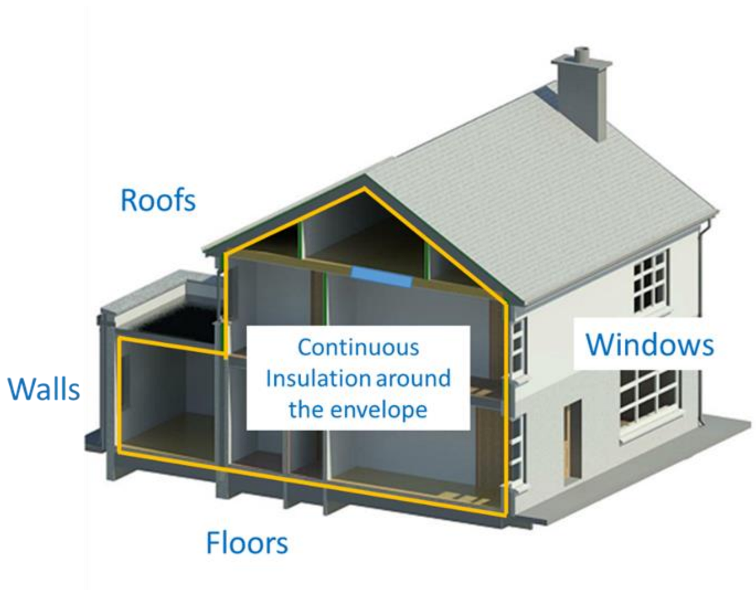



**Figure 2.12 Continuous Insulation shown by orange line – controlling heat flows through the envelope**

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

## 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.

Thermal bridging occurs at areas where:

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

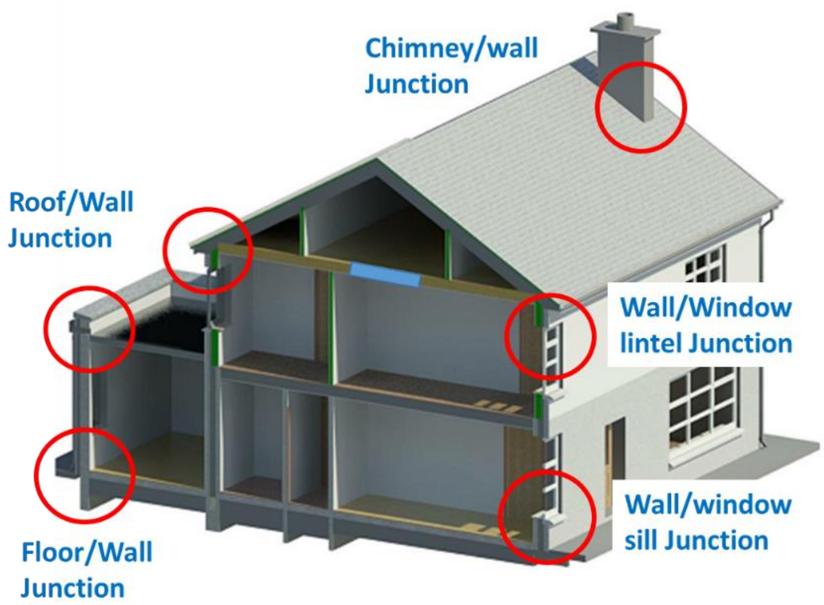



**Figure 2.13 Common areas where thermal bridging occurs in a dwelling**

## Air Permeability

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.

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).

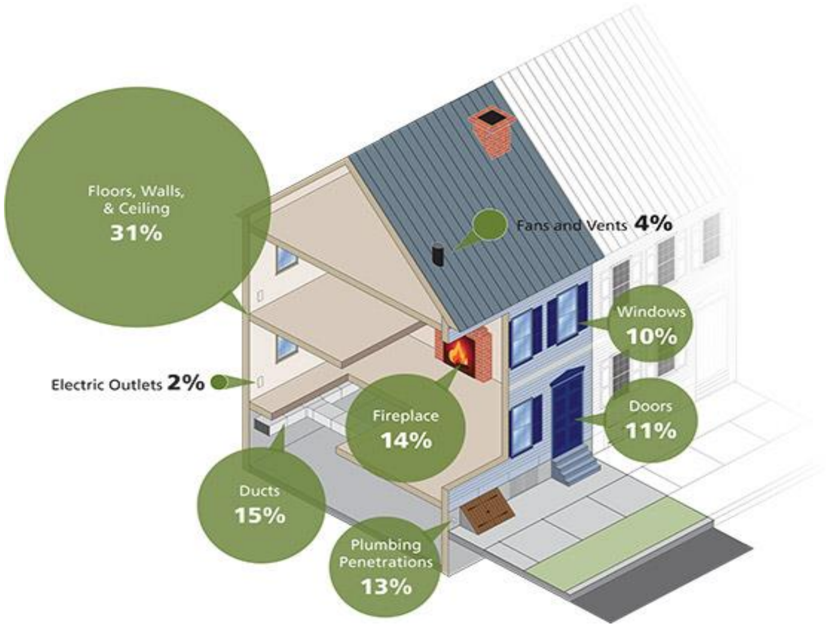
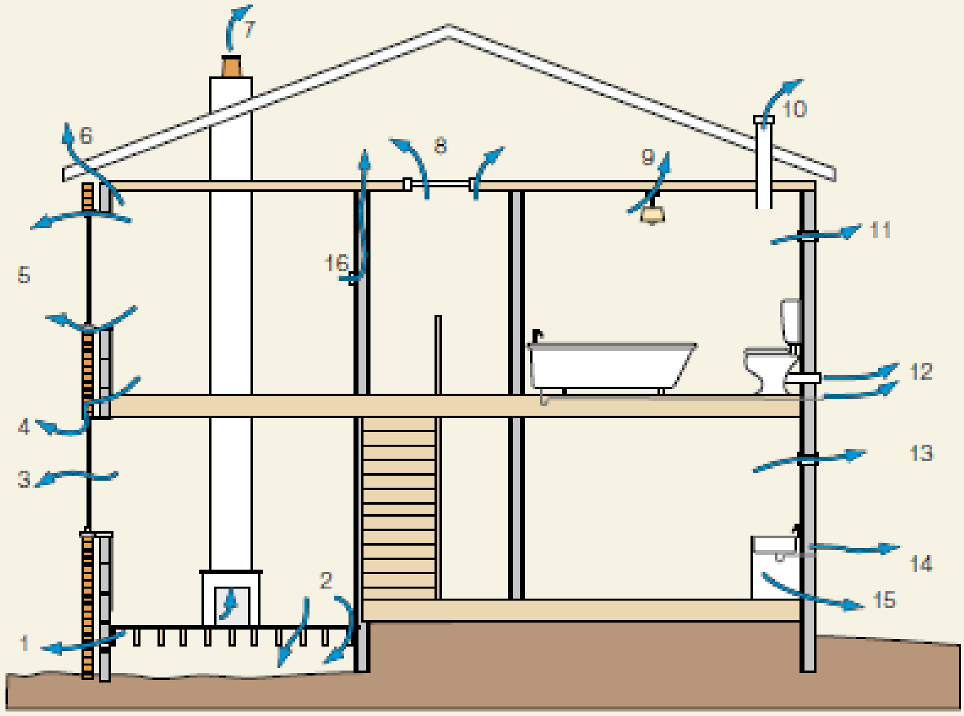



**Figure 2.14 Percentage of air leakage through a typical building**

Figures 2.14 and 2.15 illustrates some of the most common air leakage points in dwellings. You will note that air leakage is a result from both the fabric of the building and the installation of services.

It is important that every trade onsite takes responsibility for ensuring that their work does not leave these types of leaks in the building envelope. It is interesting to see where most of the leaks occur, with breaks in the construction of the walls of the building being the most common followed by the electrical and plumbing services.



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

To be discussed in more detail in Module 4, 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.

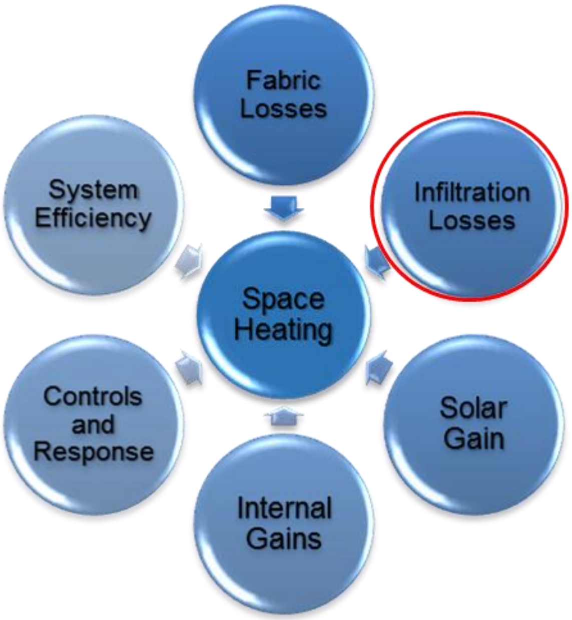



**Figure 2.16 Diagram- Infiltration losses affecting energy use for space heating.**

While air leakage is not desirable in an energy efficient building, controlled air movement is necessary known as ***Controlled Ventilation*** which will be discussed in Module 4

## 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.
- As craftworkers, 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 and services.
- As Electricians, it is important to understand the principles of thermal mass and solar gain, and how these will affect heavy concrete or lightweight timber buildings so as to design and size heating and cooling services.
- Continuous Insulation is defined as insulation that is continuous across all structural members other than fasteners and service openings. These openings should be kept to a minimum.
- A thermal bridge is any break in the thermal barrier of the building envelope. These occur where:
    - Two different materials with different thermal properties lie next to each other
    - At junctions within the building envelope, and where service pipes and wires are installed.

- 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.
- 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.
- All buildings, whether for extensions or new buildings should comply with the most current building regulations. However, remember these U-values are minimum figures.
- Thermal comfort is the level of comfort that a person experiences. This experience can vary depending on the person and the conditions.

## Useful Links

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

The Irish Building Regulations Technical Guidance Documents (TGD's) are available to download at http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents

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

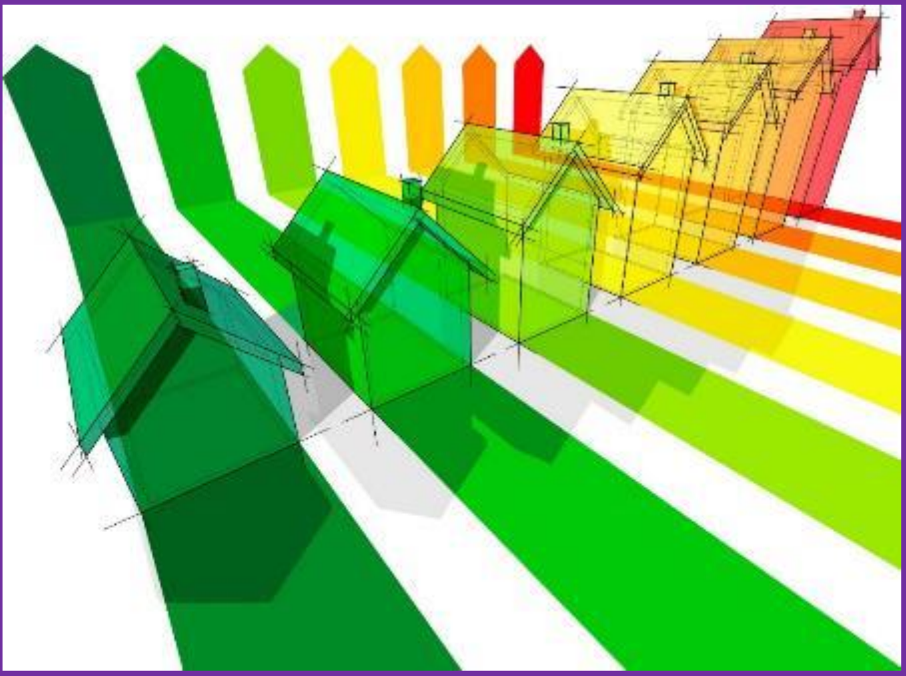
See links below to videos illustrating heat loss principles and calculations:

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

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

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

# Module 3



# BUILDING FABRIC

## Module 3: Building Fabric

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, continuous insulation and airtightness need to be included and maintained at all stages of design and construction.

In this module we will consider the concept of continuous insulation, how heat loss and other problems can occur due to thermal bridging at junctions and the importance of air and wind tightness, in relation to all parts of the envelope but with special emphasis on doors and windows.

**Unit 3.1 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.

**Unit 3.2 Thermal Bridging**

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.

**Unit 3.3 Air Permeability**

How airtightness can be achieved and how air leakage and heat-loss can be minimised before carrying out an air permeability test, including wind tightness to the external envelope of buildings.

**Unit 3.4 Doors and Windows**

Special emphasis on the choice and installation of windows and doors.

## Unit 3.1 Continuous Insulation

**How important is insulation?**

As long as the insulation is maintained around the building then heat loss and air leakage is minimised.

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 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).

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 NZEB 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. As long as the insulation is maintained around the building then heat loss and air leakage is minimised.

Recall how you wrap a blanket around you to keep warm and any hole in your blanket will provide a draught, discomfort and loss of heat. This also applies to a building. The workmanship of installing insulation should be of high quality and all insulation slabs/rolls should be overlapped or interlocked. Think about installing insulation inside a cavity blockwork wall, all the insulation slabs need to interlock leaving no gaps otherwise heat loss will occur at this point and lead to other problems such as mould growth.

**Properties of Materials**

It is important to consider the properties and characteristics of the material when choosing insulation products and systems. 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.

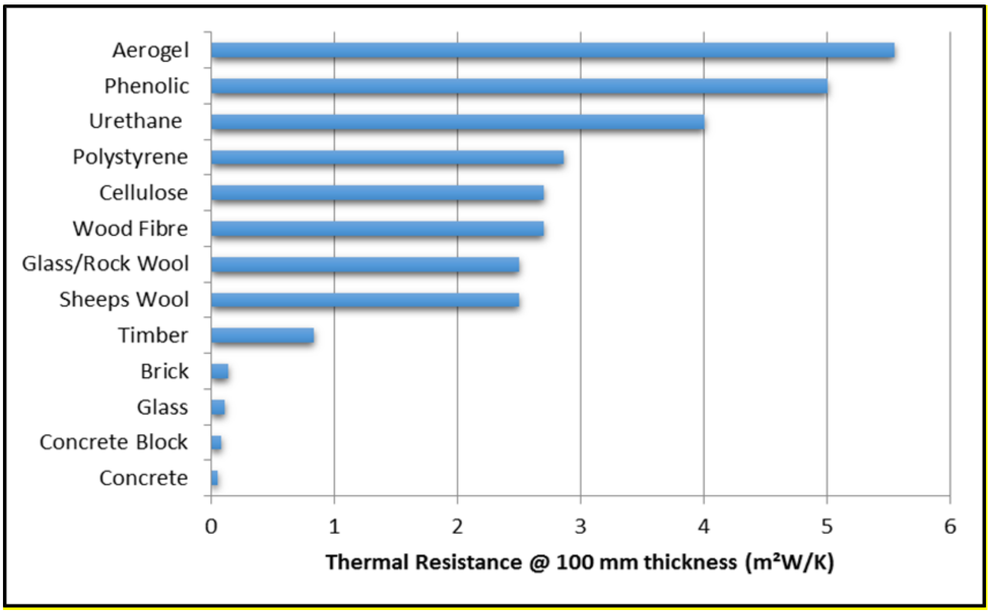



**Figure 3.0 Chart comparing the thermal resistance for materials of 100mm thickness**

Although the thermal resistance of the material is important to achieve NZEB compliance, it is equally important to make sure that the materials used and how they are used is “fit for purpose”.

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. 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.

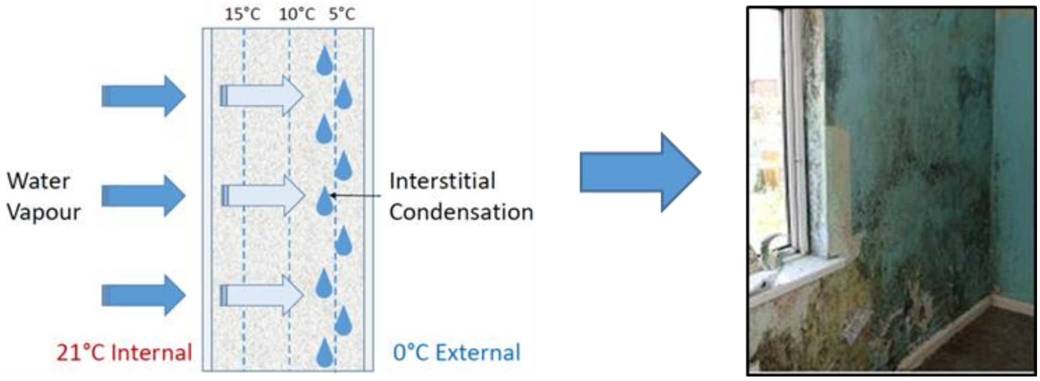



**Figure 3.1 Interstitial Condensation leading to mould growth**

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.

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

As the Building Standards and NZEB compliance 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 NZEB quality building.

○

## Unit 3.2 Thermal Bridging

As continuous insulation is important to reduce heat loss, thermal bridging which commonly occur at junctions (roof/ wall/ window/ floor) or penetrations caused by services (plumbing/ electrical/ IT) need to be detailed correctly to maintain continuous insulation. However, in some cases this is not so simple and accurate detailing to prevent thermal bridging is needed. Remember a thermal bridge is any break in the thermal barrier of the building envelope.

**Figure 3.2  Examples of continuous insulation in the wall and roof**

Thermal bridging occurs at many places within the building envelope and we will look at the construction of the timber framed wall. The detailing here can be easily replicated throughout the construction of the roof structure.

**Timber frame wall 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 3.3), 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.

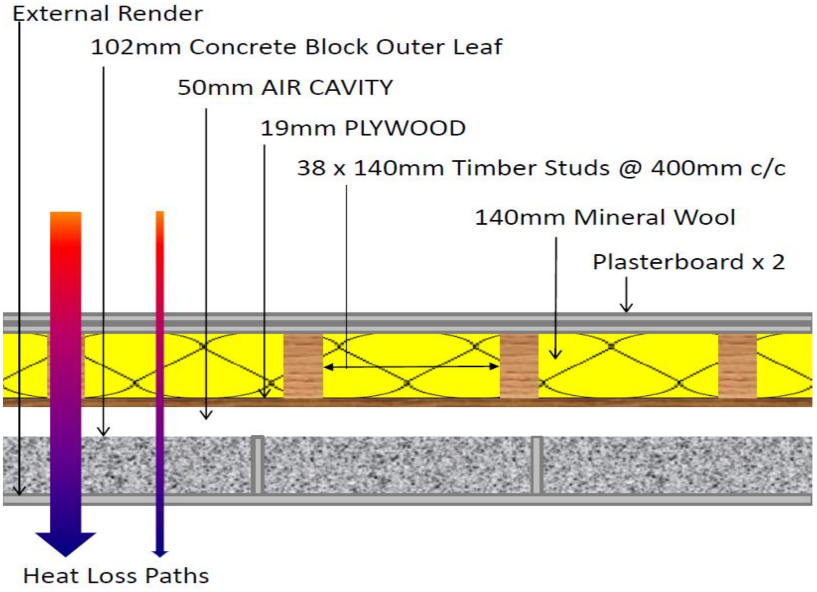



**Figure 3.3 Typical timber frame external wall construction showing Thermal Bridging**

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.

To minimise the impact of the thermal bridge, additional insulation can be laid in front of the timber frame (Figure 3.3). This will provide a continuous layer of insulation and therefore reduce the impact of heat flow through the timber studs.

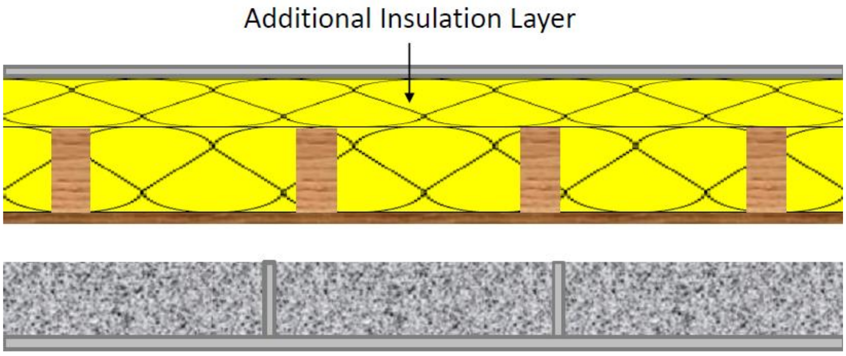



**Figure 3.3 Addition of Insulation Layer to Counteract Thermal Bridging Affect**

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.

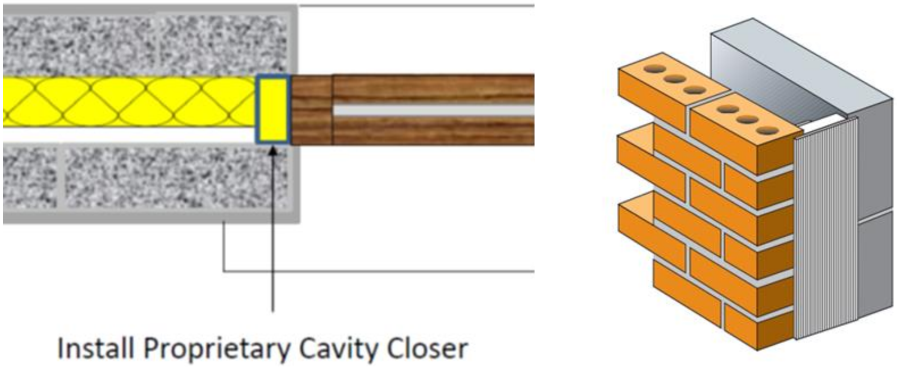



**Figure 3.4 Proprietary Cavity Closer installed at Window opening**

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.

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, if at any location a thermal bridge occurs there is a risk of the following:

- Condensation
- Structural damage due to moisture
- Mould and Fungus Growth
- Health problems
- Extra Heat Loss – Higher Space Heat Demand and Heat Load

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

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

A selection of demonstration models are available to clearly see how thermal bridging can be minimised or removed through a number of different constructions.


**Figure 3.5 Addition of Insulation Layer to Counteract Thermal Bridging**

The proportion of the overall heat loss due to thermal bridging in an average dwelling built in 2008 can be as much as 15%. As this is so significant, the Building Regulations TGD Part L 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.

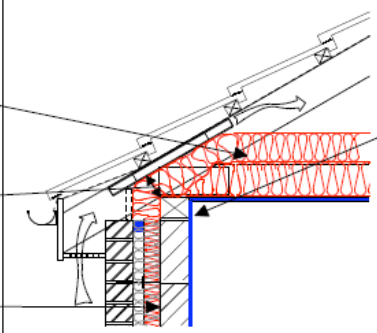
(I) WALLS:- INSULATION IN CAVITY **Eaves - Ventilated Attic** DETAIL 1.09, JULY 2008

**THERMAL PERFORMANCE**

CHECKLIST (TICK ALL)

- ☐ Ensure continuity of insulation throughout junction
- ☐ Ensure full depth of insulation between and over joists abuts eaves insulation
- ☐ Ensure gap between wall plate and proprietary eaves vent is completely filled with insulation having a min. R-value across the insulation thickness of 1.2 m²K/W
- ☐ Ensure partial fill insulation is secured firmly against inner leaf of cavity wall. If using partial fill insulation, tuck compressible insulation down into the head of the cavity

*Complying with checklist qualifies builder to claim ψ value in Table 3 of IP 1/06 and Table K1 of DEAP 2006*



**AIR BARRIER - CONTINUITY**

CHECKLIST (TICK ALL)

- ☐ Bed wall plate on continuous mortar bed
- ☐ Fix ceiling first, and seal all gaps between ceiling and masonry wall with either plaster, adhesive or flexible sealant
- ☐ Seal all penetrations through air barrier using a flexible sealant

*Complying with checklist will help achieve design air permeability*

GENERAL NOTES

Thermal performance of junction can be improved by incorporating an eaves wind barrier (plywood, OSB, softboard or other suitable material) around insulation to be sealed to connect with the ventilator strip thereby mitigating wind chill from the vent inlet in the eaves

Keep cavities clean of mortar snots and other debris during construction

Use of over joist insulation is considered best practice, as it eliminates the cold bridge caused by the joist

Use a proprietary eaves ventilator to ensure ventilation in accordance with BS5250. Installation of the eaves ventilator must not prevent free water drainage below the tiling battens

Ensure cavity is closed with firestopping insulant or proprietary cavity barrier

Read this detail in conjunction with detail 1-15, Roof at Attic Floor Level

OPTION (TICK ONE) **AIR BARRIER - OPTIONS**

- ☐ Masonry inner leaf with wet-finish plaster, or
- ☐ Masonry inner leaf with scratch coat, and finished with plasterboard, or
- ☐ Inner leaf with plasterboard on dabs, with continuous ribbon of adhesive tape around all openings, along top and bottom of wall, and at internal and external corners, or
- ☐ Airtightness membrane and tapes

ACCEPTABLE CONSTRUCTION DETAIL **Eaves - Ventilated Attic**

**Figure 3.6 ACD at the junction of a cavity blockwork wall and a pitched roof**

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

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

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. It is important that these details are approved and understood before works start.

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

- Good workmanship.
- Care and attention.
- Responsibility.
- Good communication between <u>all</u> trades.

Insulate first:

- Prevent any unnecessary breaks. Quality of works.
- Minimise number of service openings
- Specify correct insulation for the construction type
- Know how to detail

## Unit 3.3 Air Permeability

**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. There is nothing worse than having a draught on your back when you are trying to relax at home.

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 Module 2, 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.

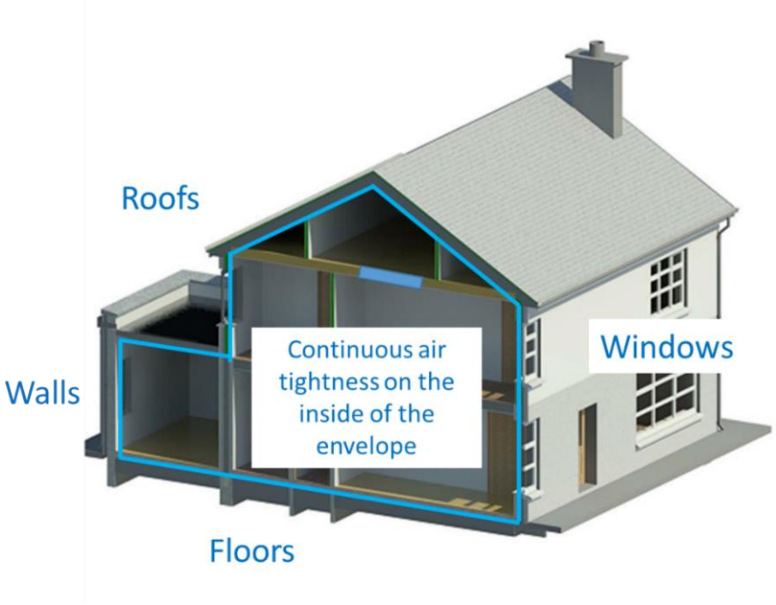



**Figure 3.7 Air Tightness barrier in a building envelope**

Figure 3.3 shows the position of a continuous air tight barrier as it should be formed on the inside of 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, such as fiberglass, rockwool or sheep's wool. This occurs because the wind cools the insulation thereby reducing their thermal performance.

Figure 3.8 shows the position of a wind tight barrier in a building envelope.

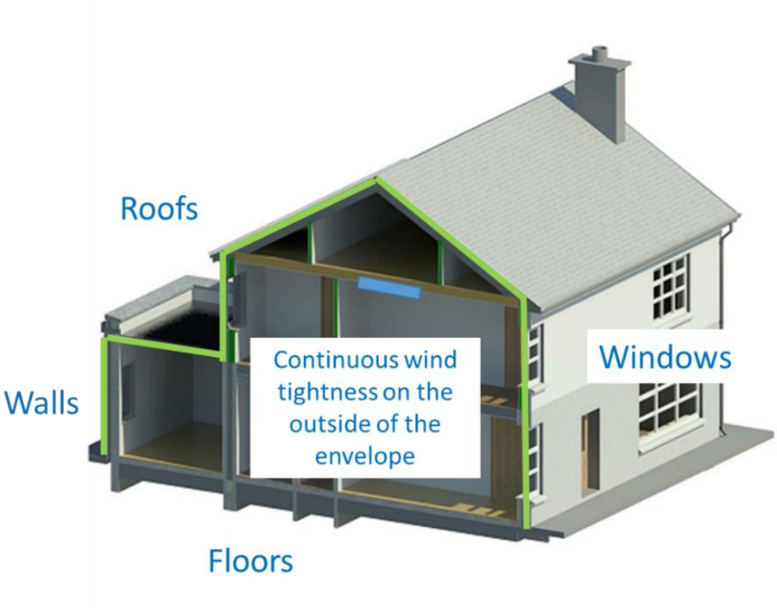



**Figure 3.8 Wind Tightness barrier around a building**.

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.

To achieve NZEB compliance and the required air permeability test (discussed in next section) it is important to set up an air tightness strategy should be in place before work starts. Positioning and choosing the correct air tightness and wind-tightness membranes/tapes is important and each tradesperson on site should be aware of this airtightness strategy and understand the importance of not breaking these barriers.

**Achieving Air and Wind-Tightness**

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

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

**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 sheeting | |
| 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 and wind tightness are:

- Correct use of air/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 3.9 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.

**Figure 3.9 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 3.10.

**Figure 3.10 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 3.11. Other areas of weakness occur at skirting levels so the air tight barrier should be continued and sealed at ground level.

**Figure 3.11 Wind tight membrane fitted at floor joist penetrations**

### 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 3.12). 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 3.12 Air tightness grommet detailing for pipes and electrical services**

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

## 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.

The 2019 Building Regulations TGD Part L – for dwellings, sets a requirement for air pressure testing of new dwellings.

The permitted maximum air permeability level is **5 m³/hr/m².**

The Building Regulations require that an air permeability test should be carried out on **all** dwellings on all development sites to provide NZEB.

When tested in accordance with the procedure I.S. EN ISO 9972:201513829: 2000 "Thermal performance of buildings: determination of air permeability of buildings: fan pressurization method", the permitted maximum air permeability is **5 $m^3$/h.$m^2$**. Where levels of air permeability are achieved it is important that ventilation is provided.

To ensure that this air permeability rate of less than 5 $m^3$/h.$m^2$ is met, and hence NZEB compliance, it is important to check that the air tightness is maintained through out the build and certainly before finishes are put in place. The airtightness strategy (mentioned in the previous section) will ensure that the air permeability test is successful and that works will not require additional fixing or amendments, causing delays and additional use of labour. Each trade record their work in relation to air tightness thus ensuring that the barriers/membranes are not punctured or removed.


**FIG 3.13: Recording air tightness testing at intervals to ensure compliance with NZEB**

It is useful to carry out the airtightness test at strategic timeframes and 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 3.14 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 3.14 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 *Building Regulations* 2019 TGD-L (Dwellings) indicates that maximum provision for airtightness is to achieve a pressure test result of no worse than $5m^3/(hr.m^2)$@50Pa.
*Best Practice* aims for $3m^3/(hr.m^2)$@50Pa.

## Unit 3.4 Windows and Doors

Special attention should be drawn to the choice of windows and doors and how they are installed to ensure the energy performance of the NZEB dwelling. It is important to choose high quality passive house rated windows or “A+” equivalent to keep the heat loss out of the building to a minimum. Why construct a highly insulated wall and roof, if the windows do not provide high levels of insulation?

The data and certification of the windows is required for the DEAP system, choosing highly insulated double or triple glazed windows is essential for NZEB compliance.

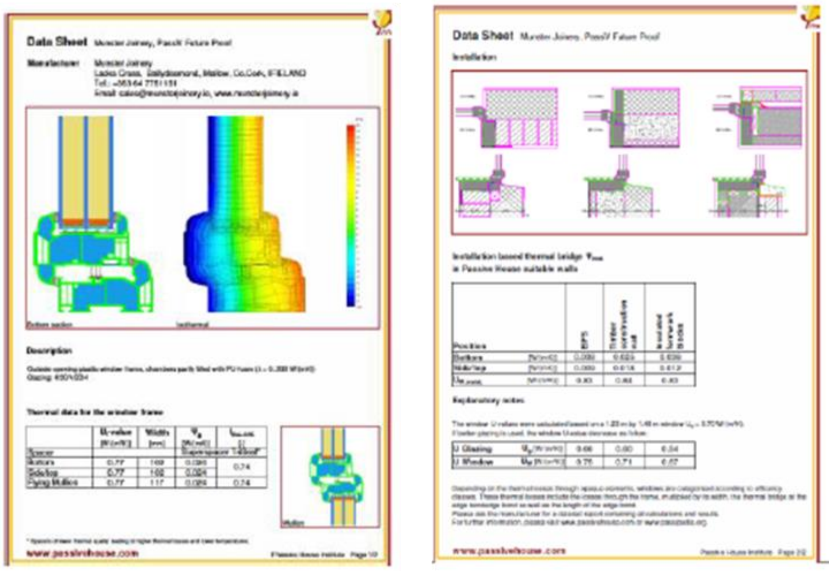


**Figure 3.15 Data sheets setting out relevant information on Passive windows**

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 3.16. 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.

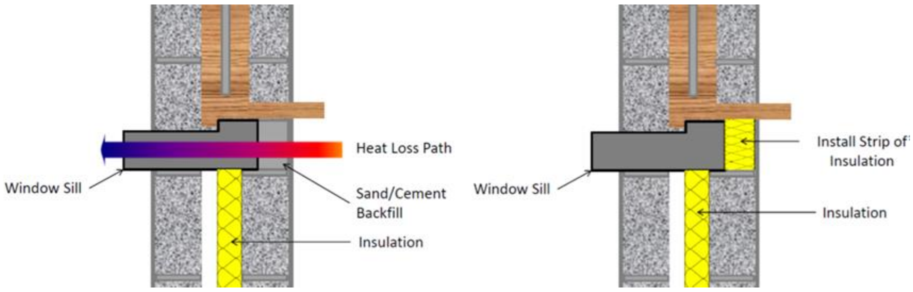



**Figure 3.16 Cavity Wall Sill Detail showing Thermal Bridging and solution**

It is good practice that concrete sills are backed with insulation, as illustrated in Figure 3.17. 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

Always install the windows in line with the insulation layer to eliminate thermal bridging. 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 3.17 Thermal break detailing and air-tightness taping around windows**

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. In Figure 3.18 shows how heat loss is eliminated from the building on the right at the window junctions indicated with the colour blue (no heat loss) and viewing the building to the left heat loss is shown with red, orange and yellow (heat escaping from the building).

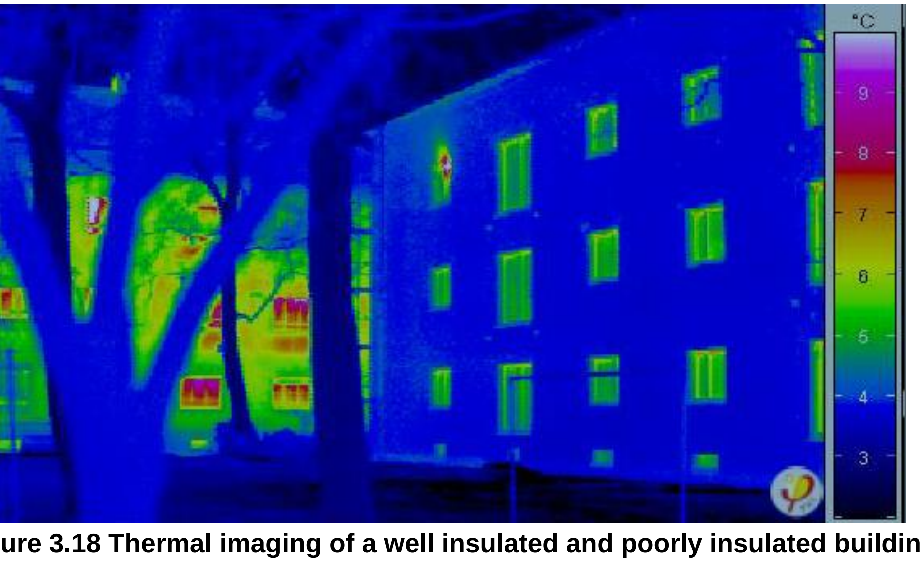



**Figure 3.18 Thermal imaging of a well insulated and poorly insulated building**

## Summary

- The three important points to remember when achieving continuous insulation are:
  - Properties of Materials - choose adequate and correct insulation on all parts of the external building envelope.
  - Detailing - Eliminate what is called thermal bridging, (as far as possible).
  - Best Practice - Eliminate any gaps and holes in the insulation (as far as possible).
- Choosing materials and products that are fit for purpose, suitable thermal conductivity and thermal breaks should prevent:
  - Surface condensation and mould growth
  - Deterioration of the building fabric caused by interstitial condensation
  - Cold surface temperatures which affect occupant comfort levels
  - Health problems for the occupants
  - Extra Heat Loss – Higher Space Heat Demand and Heat Load
- 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. Rule of thumb 1:2 ratio.
- Air and wind tightness can be achieved by using air and wind tight materials including membranes, tapes and sealants at strategic locations.
- As an electrician you should record your work in relation to air tightness, thus ensuring that the barriers/membranes are not punctured or removed when carrying out your work.
- Fitting quality, high performance continuous insulation and air tightness membranes/tapes have the following advantages:
  - Reduce heat loss or control heat gain.
  - Reduce energy costs (Space Heating or Cooling) by reducing energy usage and waste.
  - Improve thermal performance of the structure.
  - Minimise uncontrolled movement of air
  - Improve thermal comfort of the occupant (A steady temperature is maintained throughout the building) by reducing the transfer of heat and removing draughts.
  - Improve BER rating and the value of the property.
- The building regulations TGD Part L 2019 – for dwellings, set a maximum requirement for air pressure testing (air permeability test) for new dwellings of 5 $m^3/hr/m^2$ at 50 Pascal. Best practice should aim for 3 $m^3/hr/m^2$ at 50 Pascal
- Future revisions of the regulations are likely to require better standards of air tightness to achieve compliance.
- Continuous insulation and wind/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.

## Useful Links

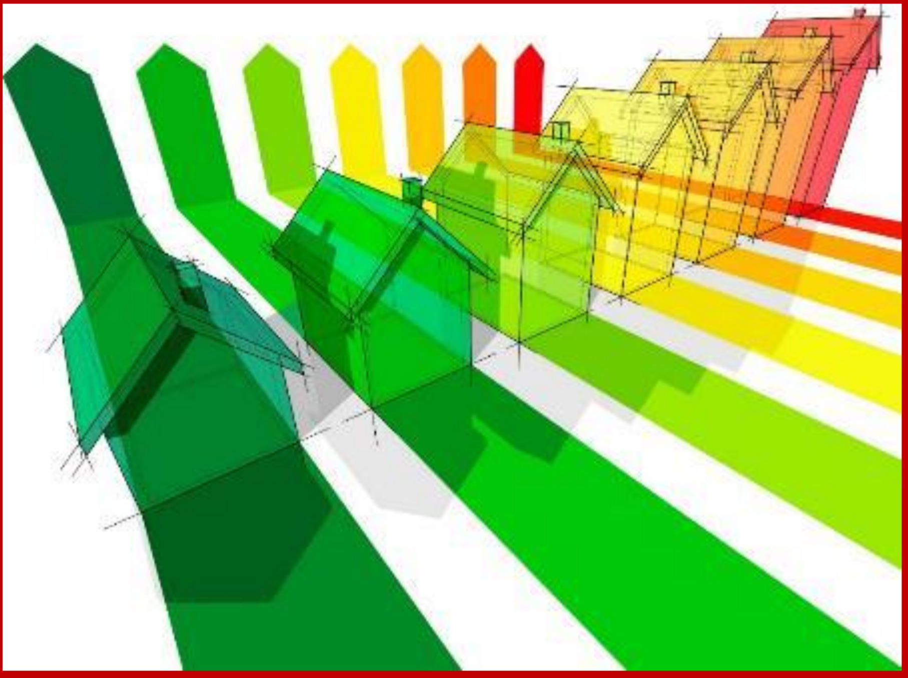
Department of Environment Community and Local Government, (2014), *Code of Practice for Inspecting and Certifying Buildings and Works*, Available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,38154,en.pdf

The Irish Building Regulations Technical Guidance Documents (TGD's) are available to download at http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents

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

# Module 4



# BUILDING SERVICES

# Module 4: Building Services

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.

In the previous modules, 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.

This module will cover energy efficient heating, ventilation and lighting provision and how these can be chosen, sized, installed and certified for use in an NZEB dwelling.

**Unit 4.1 Space Heating and Domestic Hot Water**

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.

**Unit 4.2 Controlled Ventilation**

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, natural and combined ventilation systems. These systems need to comply with regulations set out in TGD part F.

**Unit 4.3 Lighting, ICT and Smart Technology**

Installing energy efficient lighting is one of the easiest and cheapest way to reducing energy costs in a dwelling and introducing controls through smart technology can not only reduce energy consumption further but provide higher comfort levels

## Unit 4.1 Space Heating and Domestic Hot Water

In addition to the thermal performance of a building, the building regulations have, in recent times been paying more attention to improving the efficiency in heating. NZEB compliance will require stringent measures to achieve a BER A2 rated dwelling (45kWhr/m$^2$/yr) not only by insulating but also by using energy efficient heating and renewable sources.

TGD Part L – conservation of fuel and energy and TGD Part J – heat producing appliances should be referred to when choosing and installing the heating system with matters around the energy performance of the building.

Approximately one third of the Irelands primary energy consumption is used for space heating and hot water production. Space heating and Domestic Hot Water production account for approximately 60% and 24% of Irelands Residential Energy Consumption alone, and is thereby a major source of carbon emissions from dwellings. These areas have been the main target of amendments to recent building regulations and should also be targeted when carrying out retrofitting works.

Space heating, water heating and lighting account for over 90% of energy usage, with space heating accounting for 60% of that total. It is no surprise that these areas have been the main target of amendments to recent building regulations and introduction of NZEB.

Space heating is defined as the heating of spaces especially for human comfort. Space heating systems are designed to satisfy the thermal comfort requirements of building occupants. Table 4.1 outlines the typical design temperatures required for thermal comfort.

| *Type of Building* | *Design Temperature* |
|---|---|
| Domestic | |
| Living rooms | 21 |
| Bedrooms | 18 |
| Bathrooms | 22 |
| Offices | 20 |
| Classrooms | 18 |
| Shops | 18 |
| Restaurants | 18 |
| Hotel Bedrooms | 22 |
| Factories (light Work) | 16 |

**Table 4.1 Typical Design Temperatures for Thermal Comfort**

## Space Heating System Design & Classification

The design of the heating system is based on the steady state heat loss of the building, or the heat output required to maintain comfort conditions within the building with an accepted external design temperature. The amount of energy required for space heating of buildings is affected by the following:

- 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.

As stated in the second schedule of the TGD Part L:

"A building shall be designed and constructed so as to ensure that the energy performance of the building is such as to limit the amount of energy required for the operation of the building and the amount of carbon dioxide ($CO_2$) emissions associated with this energy use insofar as is reasonably practicable."

Types of Space Heating System:

In general, space heating systems can be classified as:

1. Centralised Wet systems – these use water (or sometimes steam) to transfer heat from a source (such as a boiler) to a heat 'emitter' (typically radiators or underfloor heating). This is the most common type of heating system used in the residential sector and is dealt with in detail below.

2. Centralised Warm air systems – these use warmed air to transfer heat from a heat source to the building (usually via air ducts although some warm air systems provide heat directly through stand-alone units).

3. Electric storage and panel systems – direct resistance electrical heating of space and water is provided using on-peak and off-peak electricity. It should be noted that direct resistance electric heating, although considered to be 100% efficient, is more expensive and environmentally damaging than heat produced by combustion appliances (boilers) or heat pumps.

Heating systems can be can also be classified as direct or indirect acting heating:

- Direct heating systems convert fuel to heat within the space to be heated. For example, open coal fires, gas radiant or convective heaters and the majority of electric heating systems.
- Indirect systems, convert the fuel energy into heat in a central position from where it is distributed around the building by water via a network of pipes (wet system) or ducts (warm air system) and finally emitted to the space by a heat emitter. An example is a radiator or underfloor heating system served by a boiler or heat pump.

Heat Sources:

Heating appliances/generators or boilers can be defined as a solid, liquid, gas fuelled appliance designed to provide hot water for space and domestic hot water heating. The appliance or appliances provided to service space heating and hot water systems should be as efficient in use as reasonably practicable. Building Regulations Technical Guidance Document Part L section 1.4.2 sets out the minimum requirements in terms of heating appliance/generator efficiency.

Fuels:

Selection of the appropriate fuel is likely to depend on a number of factors including:

- Installation or capital cost of the system
- Cost to run based on current and projected fuel costs
- System design requirements and user/installer preferences
- Aftercare, maintenance and replacement costs
- Regulatory requirements
- Availability of fuel
- Space requirements
- Adaptability to automatic control

There are various systems available from traditional boilers (condensed oil and gas), biomass boilers to heat pumps (air source), but all must be sized and commissioned correctly to provide energy efficient space and water heating with efficient heat sources and effective controls.

## Heat appliances/generators:

Heat appliances/generators convert the energy in the fuel to heat energy in the form of hot water. There is a vast range of boiler types, each of which is suited to particular applications. Some common boiler classifications are described below. Building regulations now require boiler efficiency to be expressed as a seasonal figure, to reflect the efficiency likely to be achieved over a full heating season.

Oil & Gas Boilers

Burn fuel (oil or gas) to produce heat that is transferred via a heat exchanger to the water circulating in the primary circuit. This hot water is distributed to the heating system via the primary hot water. Combustion gasses exhaust to the atmosphere via a flue or chimney. Any condensate leaves the boiler via a drain. To prevent heat loss from the boiler, the whole mechanism is contained within an insulated metal enclosure. TGD part L outlines that for fully pumped hot water-based central heating systems utilising oil or gas, the boiler seasonal efficiency should be not less than 90% as specified in the DEAP manual and the associated Home-heating Appliance Register of Performance (HARP) database maintained by the SEAI (www.seai.ie/harp). Boiler efficiency depends on good combustion of fuel, good heat transfer to the hot water and low standing losses (achieved by compact, well-insulated boilers). Condensing boilers are the most efficient designs available. These use large heat exchangers to extract as much heat from the waste flue gases as possible. With a large enough heat exchanger, the temperature of the flue gases can be reduced to below 60ºC (the point at which the water vapour in the flue gases starts to condense). This releases the latent heat from the water vapour, significantly boosting the boiler's efficiency. Condensing boilers can give a seasonal efficiency of over 90%, compared to around 80% for modern, non-condensing designs. Boilers more than 20 years old have seasonal efficiencies of 70% or less. Now all oil and gas fired boilers must now meet a minimum seasonal efficiency of 90%.

Heat Pumps:

A heat pump is a device which absorbs heat from the ground, air, or water outside a building and releases it inside the building. Heat pumps generally use the vapour-compression refrigeration cycle – the same process used by most fridges, freezers and air conditioning systems. Electrical energy is used to drive the compressor, however the heating effect is far greater than the electrical input.

Heat pumps are most efficient when the temperature of the heat distribution medium is low, for example with underfloor heating systems. All heat pump systems, excluding those providing warm air to the home, can supply all of the hot water needed for baths, showers and sinks, however heat pumps operate most efficiently when the temperature lift is low.

TGD part L requires that fully pumped hot water-based central heating systems utilising electric heat pumps, the seasonal performance factor should be not less than 3.0 for space heating and 1.5 for domestic hot water generation when calculated in accordance with ecodesign regulation.

Biomass:

Biomass boilers use materials such as wood chips or wood pellets as a fuel source. These are considered to be virtually carbon neutral because the $CO_2$ released to the atmosphere during combustion is offset by the growth of new biomass. The operational characteristics of biomass boilers differ significantly from traditional boilers (such as gas-fired). Start-up and shutdown times are longer, and they are not suited to frequent modulation (changes in heat output) and are therefore often installed with a buffer/accumulation tank that will absorb fluctuations in heat demand. Biomass boilers tend to have a larger footprint than traditional boilers, and space requirements for fuel storage and delivery can be considerable.

TGD part L requires that fully pumped hot water-based central heating systems utilising a biomass independent boiler, the boiler seasonal efficiency should not be less than 77% as specified in the DEAP manual and the associated Home-heating Appliance Register of performance (HARP) database

Combined heat and power (CHP):

Combined heat and power (CHP), also known as co-generation, is the simultaneous generation of heat and electrical power from the same source. A CHP unit includes a prime mover/engine which runs on gas (or in some cases diesel or biofuels), an electric generator and a heat exchanger. The mechanical power produced by the prime mover/engine is used to generate electricity and the waste heat is used to provide space heating or hot water. In order to realise the environmental benefits, full use of the generated heat and electricity should be made. Also, to be cost-effective, CHP units should run continuously for at least half the year. For these reasons, CHP is best suited to buildings with predictable and relatively constant heat demand.

## Heat Emitters:

1. Radiators

   *Key Points*

   - Provide convective and radiant heat (See figure 4.2).
   - Should be placed in coldest part of room to aid natural convection (E.G. Under windows).
   - Require relatively high temperatures to operate >60ºC, therefore work better with boilers.
   - Simple and compact.
   - Occupants familiar with their operation.
   - Low maintenance.
   - Can be fitted with thermostatic radiator valves (TRVs) to provide good local control.
   - Wide range of styles and sizes provide flexible layout and appearance.

   *Limitations*

   - Heat output is mostly convective which can lead to an uneven temperature gradient in the space (See figure 4.3).
   - Furniture must be positioned sympathetically to avoid obstructing heat output.
   - The combination of windows that can be opened and perimeter radiators can result in excessive heat loss if the windows are of a poor design or used incorrectly.

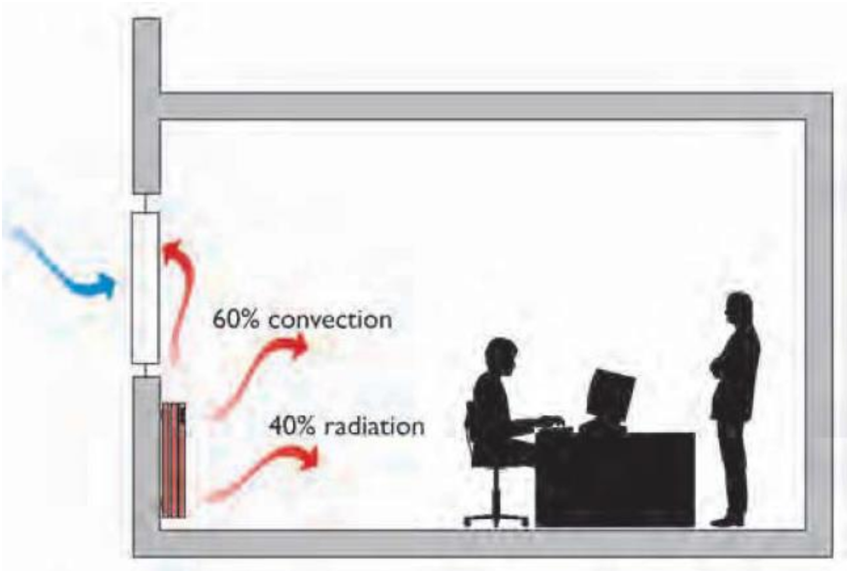



**Figure 4.2 How Radiators Heat Space (Source www.bsria.co.uk)**

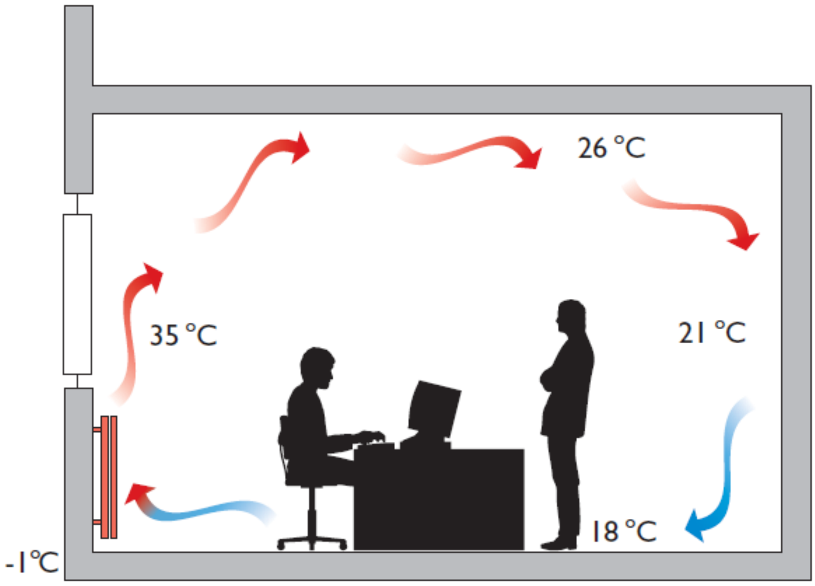



**Figure 4.3 Typical temperature variation in a space heated by radiators (Source www.bsria.co.uk)**

2. Convectors

Natural convectors generally consist of a casing with top and bottom openings, and a finned hot water pipe at low level. The hot water pipe creates an upward convection current of hot air within the casing, pulling room air in at the bottom and pushing hot air out at the top (Figure 4.4). Some units incorporate a damper to regulate output. Low level convectors are also available (Figure 4.5) which are ideal for placing below full-height windows to counter cold downdraughts. A similar type of unit can also be placed in a trench below the window, leaving only the top grille visible. The main benefit of convectors in comparison to radiators is their greater heat output per unit size and their quicker warm up time. Convectors can also incorporate one or more fans which increase the heat output per unit size and improve air movement in a space. Fan speed can be controlled to suit requirements and can include a boost setting for the rapid warming up of a space.

*Key Points*

- Quicker warm-up time in comparison to radiators.
- Fan convectors provide a high heat output for the unit size.
- Casing can be designed by the architect to achieve a particular appearance, and constructed as part of the builder's work.
- Low level/trench convectors are ideal where glazing extends to floor level, such as a shop window.
- Convection current created by unit provides good air movement.
- The casing can reduce the risk of burning, which can occur with radiators.

- Fan convectors provide greatly enhanced heat output and air movement and consequently can be used in conjunction with lower temperature heat sources such as heat pumps.

*Limitations*

- Dust/dirt may collect in the casing necessitating periodic cleaning.
- Trench convectors tend to accumulate dirt and the grille can become covered by furniture.
- Fan convectors incorporate many components and lack the simplicity of radiators and natural convectors. As a consequence, they have an increased maintenance requirement.
- Fan convectors require a power supply.

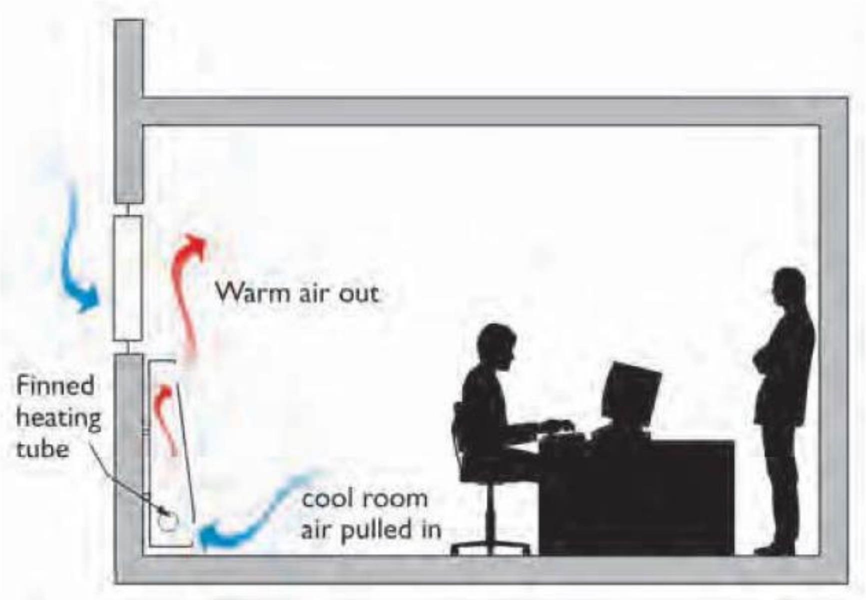



**Figure 4.4 How Convectors Heat Space (Source www.bsria.co.uk)**

**Figure 4.5 Compact low-level convector (Picture courtesy of Hudevad Ltd.)**

3. Underfloor Heating

There are two basic forms of underfloor heating:

1. Low temperature hot water systems
2. Embedded electric element systems.

Both forms of underfloor heating system comprise of a matrix of either plastic pipework or heating cable embedded between a top layer of concrete screed/slab and the layer of insulation below (figure 4.6 & figure 4.7). This form of underfloor heating has a relatively slow warm up and cool down cycle due to the thermal mass of the concrete screed/slab and needs to be carefully controlled for optimal performance.

Low temperature hot water underfloor heating systems radiate heat from a continuous network of reinforced polyethylene piping which is laid in loops underneath the entire floor area (figure 4.6). The floor area is typically divided into zones to provide the most efficient layout. Each zone is controlled by a zone thermostat. When the required room temperature is achieved a signal is sent to the motorised zone valve and this shuts off the supply of hot water to that particular zone. A manifold (figure 4.8) is located above floor level to which the under floor heating loops for each zone is connected is supplied with low temperature hot water from the boiler or heat pump via a circulating pump. Water can enter the manifold at temperatures between 35-60°C (ideally suited to a heat pump system). The water entering the manifold may be mixed with the return water to reduce the temperature travelling through the underfloor heating loops to approximately 35-40$^{O}$C. This in turn heats the floor surface to a temperature in the range of 18-23°C. The floor becomes one large thermal store giving off heat evenly throughout the room.

Other combinations of floor coverings can also be used, such as chipboard and carpet which, when used with electrical heating, provide a relatively quick warm up and cool down cycle. This makes it particularly well suited to buildings used intermittently and for short periods.

*Key Points*

- Form of space heating is suited to certain types of public spaces, foyers, shopping complexes, churches, commercial buildings and buildings with tall spaces.
- Overcomes the problem of a cold surface normally associated with stone floors and other such coverings.
- Provides an invisible heating system which leaves the floor space virtually free from heating services.
- Heat output is largely self-regulating - as the air temperature in the room increases towards that of the floor, heat output diminishes naturally.
- Relatively even temperature distribution though-out space, with minimal or no stratification.
- Thermal comfort can be achieved with lower energy use than the equivalent radiator or convector systems.

- Electric systems are particularly convenient for use in small areas such as bathrooms and kitchens where tiling is required, however, they carry an environmental penalty due to the energy loss associated with the generation and distribution of electricity.

*Limitations*

- Not suited to buildings such as offices which require underfloor services, such as power and data systems.
- Heat output is limited and may not be suited to spaces with a high heat loss.
- Slow response to changes in temperature setting.
- Not suited to intermittently occupied spaces.

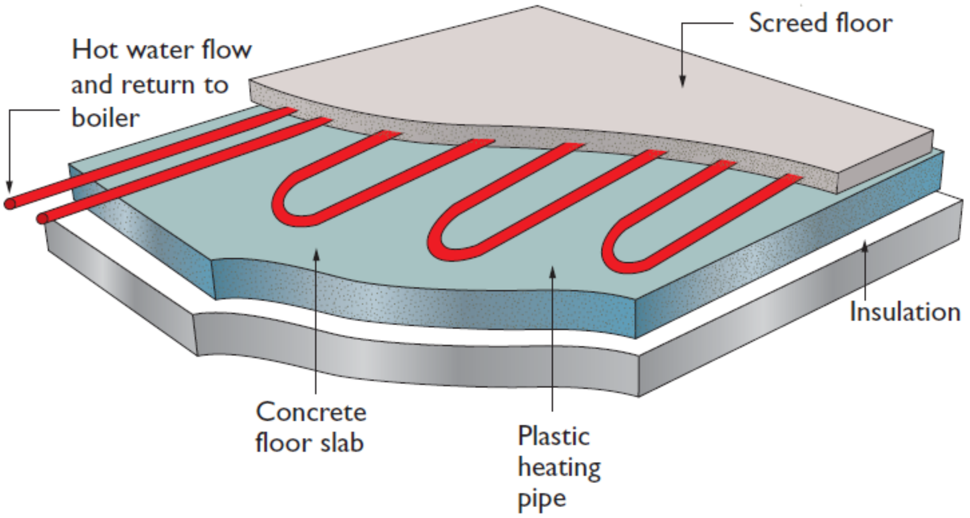



**Figure 4.6 Water Based Underfloor Heating (Source www.bsria.co.uk)**

**Figure 4.7 Electric underfloor heating elements prior to receiving a layer of screed (Source www.bsria.co.uk)**

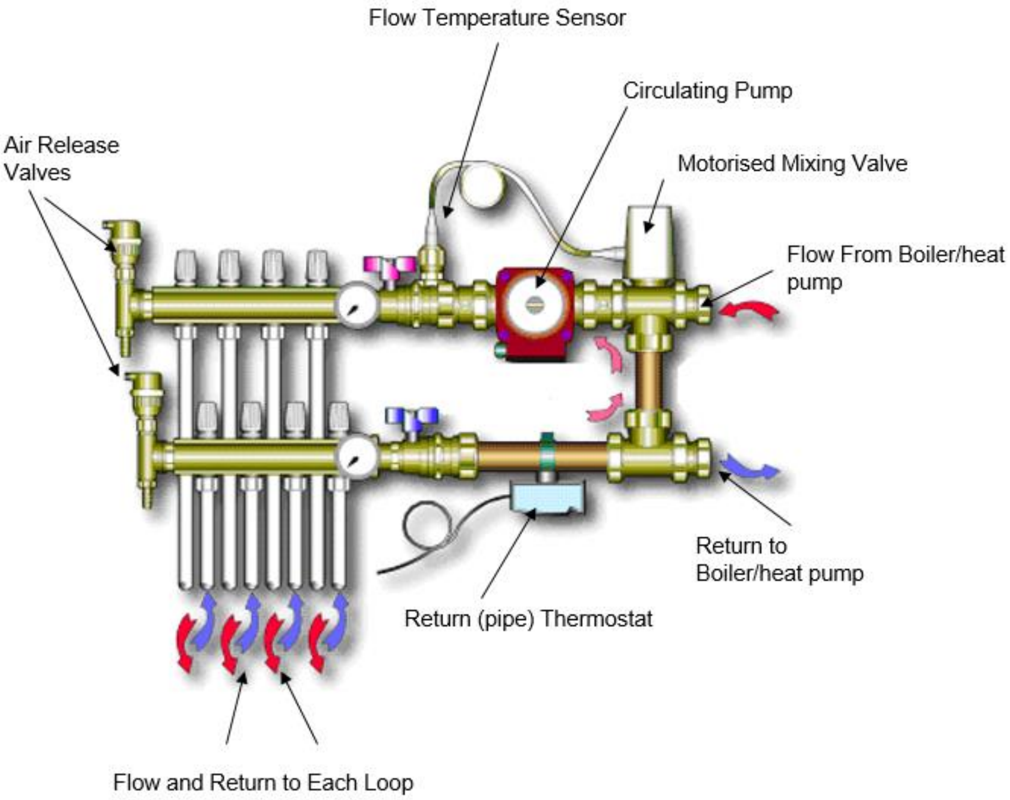
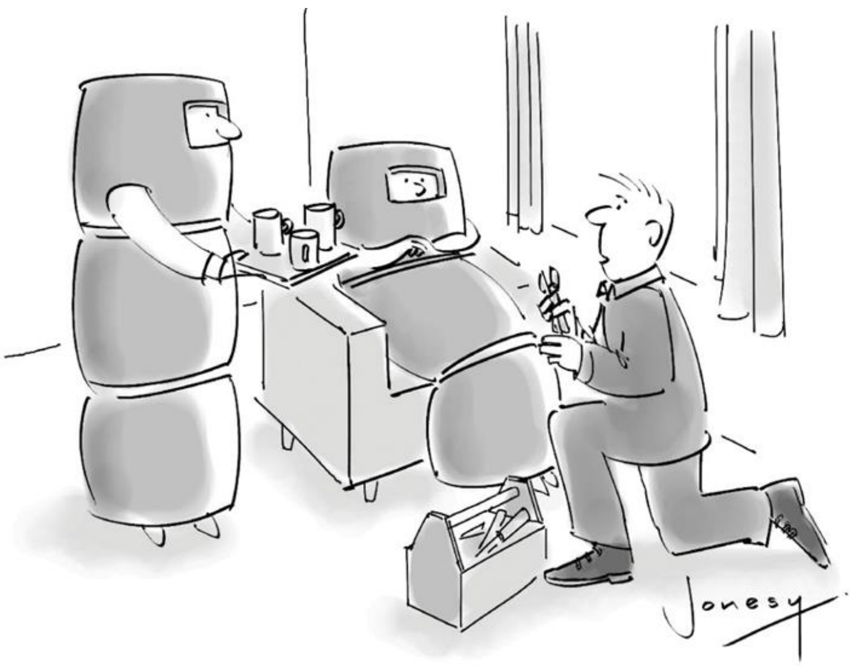



**Figure 4.8 Underfloor heating manifold**




"You're the fourth couple I've lagged this week."

## Domestic Hot Water (DHW) Provision:

Domestic hot water (DHW) can be defined as the water used principally for domestic purposes such as food preparation, sanitation, and personal hygiene, in any type of building. There are two ways of providing hot water to the home:

1. Using a hot water cylinder to give a store of hot water.
2. Using a combination boiler or instantaneous water heater to give instant hot water.

Table 4.2 below outlines the advantages and disadvantages associated with stored DHW and Instantaneous DHW.

| Stored hot water | Instantaneous hot water |
|---|---|
| Advantages | |
| Can deal with high demand more easily | Can be cheaper to run as water is heated only when used |
| Water can be heated by green sources of energy like solar or biomass | Hot water is produced very fast from cold |
| Allows the connection of different types of water heating methods | Can be cheaper to install than a storage system |
| Emergency backup heat source can be fitted to allow hot water if boiler fails | No chance of water growing harmful bacteria |
| Disadvantages | |
| Can be more expensive to run as water is heated even when not used | Cannot deal easily with high demand |
| Can take much longer to get hot water from cold | Can be very hard to connect alternate sources of hot water heating methods |
| Can be more expensive to install | Water can only be heated by non green sources: gas, oil or electricity |
| Greater chance of the water growing harmful bacteria | If the boiler fails there is no emergency backup heat source |

**Table 4.2 Store & Instantaneous DHW (Source www.aphc.co.uk)**

Types of DHW system

There are three main types of DHW system;

1. Open vented hot water systems (stored hot water).
2. Unvented pressurised (stored hot water).
3. Instantaneous (hot water on demand).

*1. <u>Open vented hot water systems</u>*

These systems produce DHW that is stored in a hot water cylinder. Cold water from a storage cistern (tank) is fed into the bottom of the cylinder where it is heated either directly or indirectly. DHW can be drawn from the top of the hot water cylinder. An open vent/expansion pipe allows the water to expand safely as it is heated.

Direct heating of DHW

Figure 4.9 illustrates how the DHW is heated directly from the heat source either by an immersion heater or by the boiler.

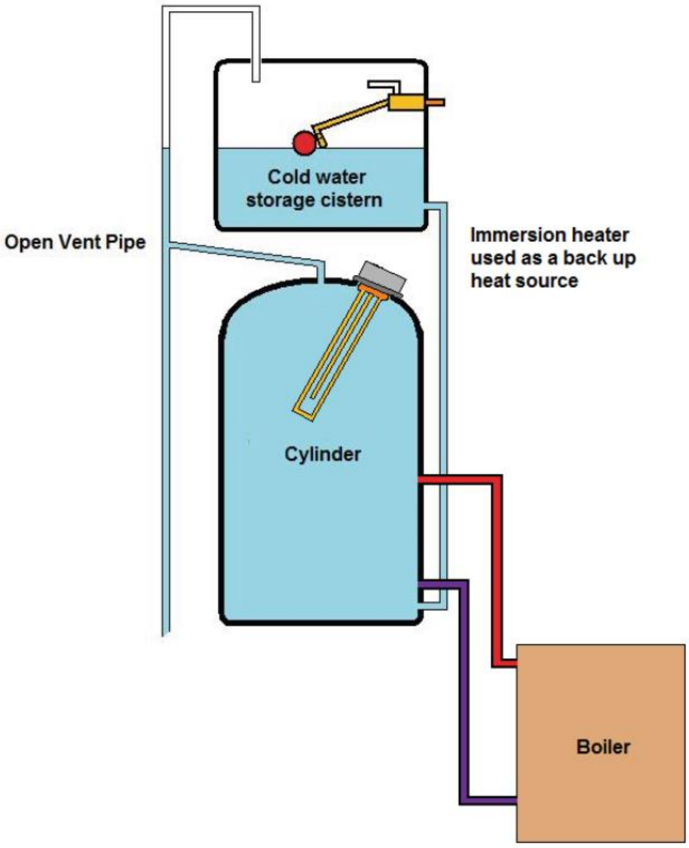



**Figure 4.9. Open Vented Direct hot Water Provision (Source www.aphc.co.uk)**

Cold water is heated in the boiler. The heated water rises through natural convection currents and is replaced by cold water coming from the bottom of the hot water cylinder. A circulation is thereby set-up (circulation may be assisted with a circulation pump). DHW is drawn from the top of cylinder and replaced by cold water from the cold water storage tank (in attic). An open vent/expansion pipe connects to the horizontal pipe at the top of the hot water cylinder and runs vertically from the hot water distribution pipe to the cold water storage tank. In the direct hot water system the water that is heated in the boiler and subsequently stored in the cylinder is the same water that is drawn-off for domestic use. This makes this system unsuitable for supplying a central heating circuit. The constant introduction of fresh water to the system means that in hard water areas there is likely to be a build-up of fur or lime scale in the entire system potentially blocking pipes and reducing the efficiency of the system. There is also an increased likelihood of air being introduced to the system which will increase the potential for corrosion.

Indirect Heating of DHW (most common)

In this system (Figure 4.10) the central heating and the DHW are separate. The water in the cylinder is heated indirectly via a coil (heat exchanger) from a boiler. This allows heat emitters (radiators/underfloor heating) to also be connected to the boiler. In the case of radiators water in the central heating system can potentially become contaminated by iron residues from the radiators which would make the hot water unusable for washing. As with the direct system cold water from the storage tank is fed into the bottom of the cylinder where it is heated indirectly from a boiler using a coil fitted inside the cylinder. Indirectly heated cylinders generally come with an electric immersion heater back up to heat the DHW at times when space heating isn't necessary and the boiler is shut down.

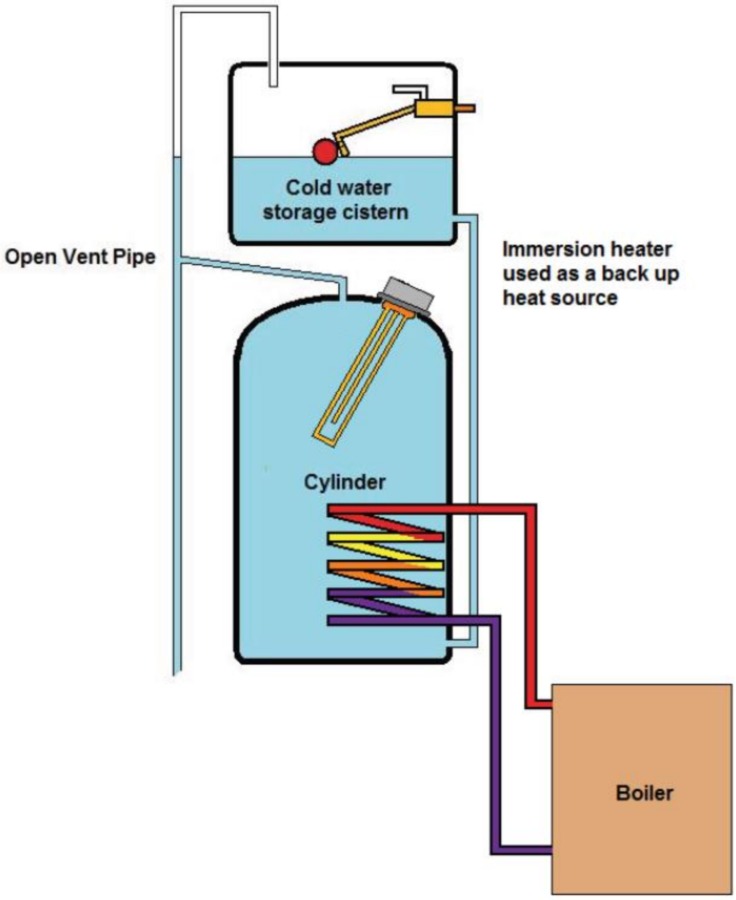



**Figure 4.10 Open Vented indirect hot Water Provision (Source www.aphc.co.uk)**

In the primary circuit of the indirect system the hot water circulates between the boiler and the indirect hot water cylinder coil in a closed circuit. This water does not mix with stored water in cylinder. The hot water travelling through coil raises the temperature of the stored water in the cylinder. As the same water is circulating continuously in this primary circuit the potential for lime scale and corrosion is dramatically reduced. The central heating loop can also be connected to the primary circuit. The cylinder coil (heat exchanger) - is the tube that is fitted to the cylinder to indirectly heat up water using the water from the central heating system.

2. Unvented (pressurised)

Unvented hot water systems (Figure 4.11) are more complicated, but do allow higher pressure (near mains pressure) hot water supply for better appliance performance.

Unvented systems do not have an expansion pipe or cold water storage cistern. Unvented systems employ series of safety devices are that regulate the temperature and pressure of the stored water.

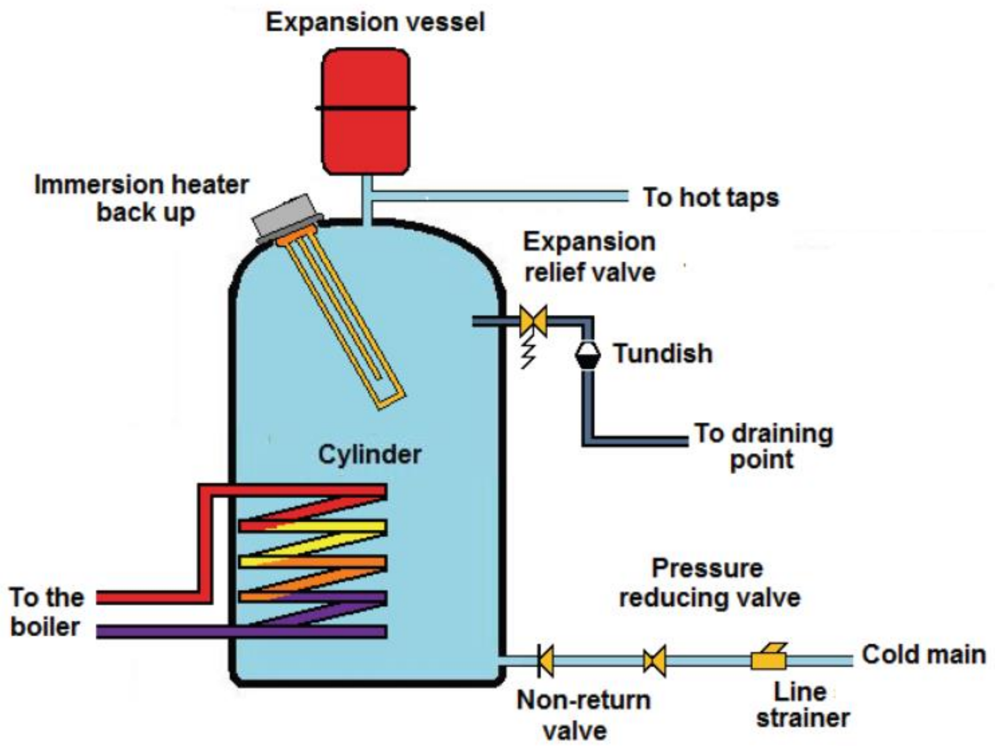



**Figure 4.11. Unvented/pressurised hot Water Provision (Source www.aphc.co.uk)**

The DHW in the unvented system is heated in the same manner as the indirect system. The unvented system has a number of additional components to allow for the safe heating and storage of DHW, including:

- Pressure reducing valve -This is placed on the incoming cold water main pipe to the hot water system to reduce the water pressure slightly and keep it at a constant level of pressure.
- Line strainer - This is placed on the incoming cold water main pipe to filter out any particles that might come from the cold water system, because of the sensitive nature of some of the components (a small piece of grit could cause them to malfunction), the strainer keeps them clear.
- Expansion vessel - This allows for the expansion of the water in the system as it is heated.
- Temperature and expansion relief valve - This valve is also part of the 'sealed' heating system. It is designed to relieve pressure from the system.

- The tundish - This is connected to the pipe coming from the relief valve. This device is placed in the pipeline to alert you to a fault in the system, as you will be able to see the water flowing out of the safety valve(s).

3. <u>Instantaneous hot water heating systems</u>

This method of DHW production involves using gas or electricity to heat the water to a useable temperature without the need to store the water in a cylinder. The electric versions (Figure 4.12) use a coiled heating element to heat the water rapidly in a similar way to a kettle or immersion heater. DHW may be provided by these individual localised units (boilers) mounted over/under sinks, basins, etc. and fuelled by gas burner or an electrical immersion heater. These units are inexpensive to install for a small facility, but it would be uneconomical to provide several of these throughout a building. Therefore, it is usual to provide a centralised heat source in the form of a boiler to heat water indirectly via a storage cylinder and to provide sufficient hot water to circulate through the space heating system simultaneously when required.


**Figure 4.12 Examples of instantaneous electric water heaters**

Another common method of heating water instantaneously is the use of a combination boiler, this type of boiler works by using the primary circuit that powers the central heating and diverting it to 'water to water' heat exchanger (heat swapping). This part swaps out the heat from the primary circuits heating water in to the DHW supply. The boiler combination boiler illustrated in the diagram (figure 4.13) below operates by heating the central heating water and pumping it around to the diverter valve. This is then diverted from the central heating circuit to go into the water to the heat exchanger where it passes the heat from the central heating water to the cold water feed coming into the boiler.

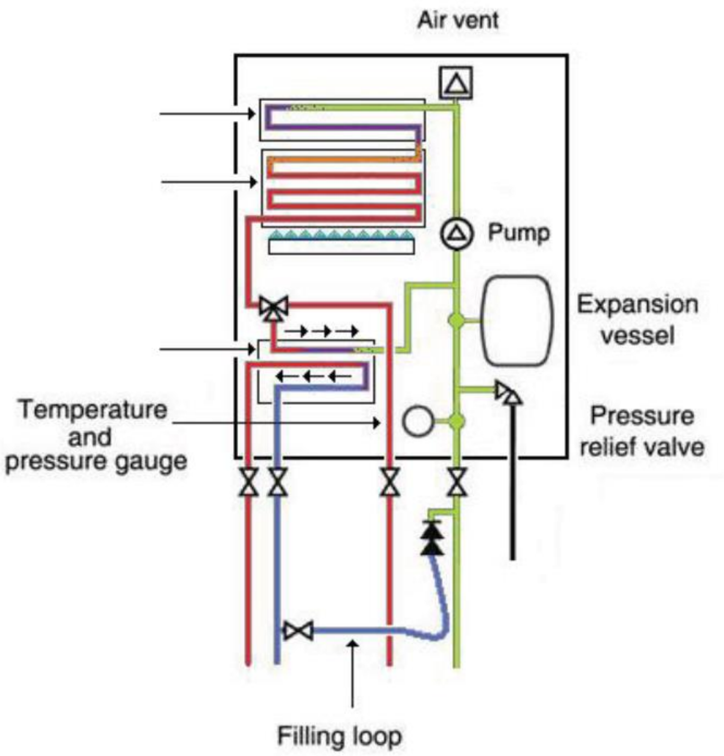



**Figure 4.13 Example of DHW production from a combination boiler (Source www.aphc.co.uk)**

## Storage of hot water:

The hot water storage cylinder (also known as a calorifier) shown in figure 4.14 incorporates a coil that is attached to the primary pipework. This enables water to circulate between the boiler and coil transferring its heat energy the water stored in the cylinder. An electric immersion heater can also be used to heat the stored water. 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 4.14). Insulation of the storage cylinder reduces energy loss and allows for better control of the water temperature by enabling the stored water to stay at an increased temperature for longer.

Building Regulations Technical Guidance Document Part L sets out the minimum standard of insulation required for hot water pipes and vessels. It states that all hot water storage vessels, pipes and ducts associated with the provision of heating and hot water in a dwelling should be insulated to prevent heat loss.

Adequate insulation of hot water storage vessels can be achieved by the use of a storage vessel with factory applied insulation of such characteristics that, when tested on a 120 litre cylinder complying with I.S. 161: 1975 using the method specified in BS 1566, Part 1: 2002, Appendix B, standing heat losses are restricted to 0.8 W/litre. Use of a storage vessel with 50 mm, factory applied coating of PU-foam having zero ozone depletion potential and a minimum density of 30 kg/m$^3$ satisfies this criterion when installed within the normally heated area of the dwelling. It should be noted that water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in Technical Guidance Document G and Report BR 262, Thermal insulation: avoiding risks, published by BRE.

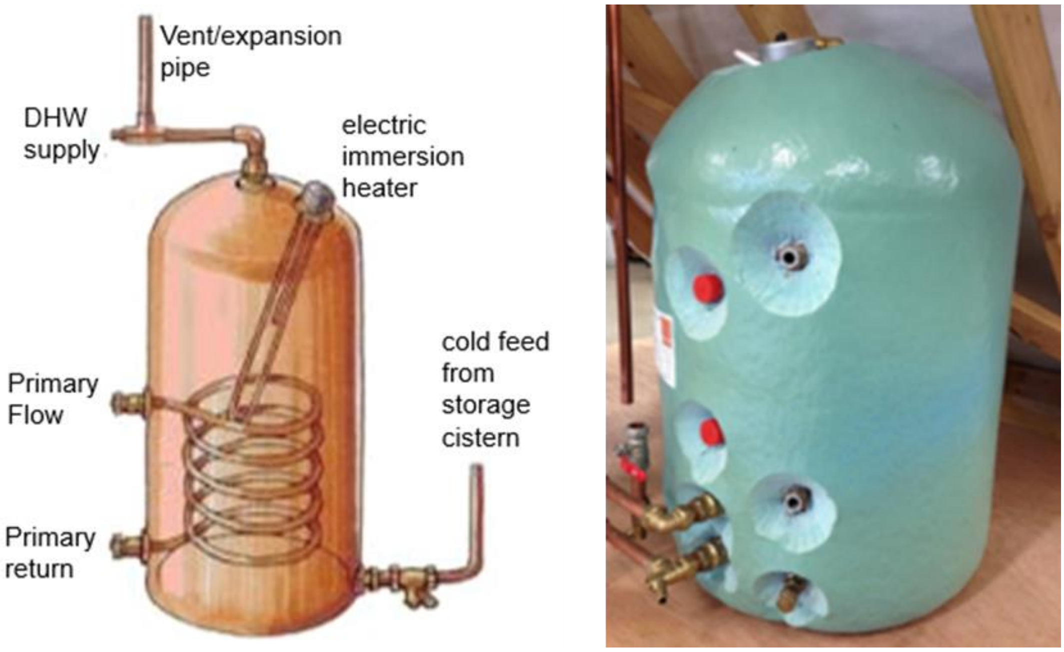



**Figure 4.14 Indirect DHW storage cylinder with factory fitted insulation**

Immersion heaters

Immersion heaters can be used to heat the water in the DHW cylinder at any time. They are commonly used to provide DHW during the summer months when the primary heat source (boiler) is switched off. Immersion heaters are an insulated electric element. Some Immersion heaters have two heating elements and are known as a dual immersions (Figure 4.15). The shorter element heats a small volume in the upper part of the cylinder this is adequate for sink & basin use. The longer element heats a larger volume of water for when a bath is required.

**Figure 4.15 Dual Immersion Heater**

Both time and temperature controls of installed immersion heaters should be provided to allow householders to set the time period required for water heating and the temperature to which water is heated. This means that water need not be heated for longer than required or to higher temperatures than required. Temperatures for hot water should be set to a maximum of 60°C.

It should be noted that the electric resistance heating provided by immersion heaters is considered 100% energy efficient in the sense that all of the delivered energy (incoming electricity) is converted to useful energy (heat). However, most of our electricity is produced in fossil fuel burning power stations that convert approximately 35% of the fuel's primary energy into electricity. Because of electricity generation and transmission losses, electric resistance heating is more expensive and environmentally damaging than heat produced by combustion appliances (boilers) or heat pumps.

## Thermal Properties of Water

Water expands in volume when heated. A given volume of cold water (10°c) when heated (80°c), volume increases by 4%. Heating systems must be designed to accommodate this increase in volume. Vent pipes on both the primary and secondary circuits in vented systems and expansion vessels in unvented systems allow for the safe thermal expansion of water. An expansion vessel, utilised instead of a feed and expansion tank in a sealed/pressurised system, is a pressure vessel containing a flexible diaphragm that accommodates the expansion of the water in a system as the temperature rises. For safety purposes, pressure and temperature relief valves are also fitted to unvented/pressurised systems. The pressure/temperature relief valve allows for the safe discharge of water should the system become over pressurised.

## Water storage and Legionella

Domestic hot water is generally produced and stored in the hot water cylinder. Stored hot water must be heated to a minimum of 60ºC to prevent the growth/spread of Legionella bacteria. Legionella pneumophila bacteria causes Legionnaires disease an acute and potentially fatal respiratory infection. People may get infected when they breathe in tiny water droplets (aerosols) or droplet nuclei (particles left after the water has evaporated) contaminated with elevated concentrations of Legionella bacteria. Any water system with an operating temperature between 20.5ºC and 45ºC is a potential legionella source. Legionella bacteria are always present in water systems. Legionella bacteria can survive in low temperatures, but thrive in stagnant water at temperatures between 35˚C and 45˚C. Legionella cannot survive in high temperatures, water heated to 60˚C for 2mins will kill Legionella bacteria (water heated to 50˚C for 2 hours will kill up to 90% of legionella contained in a cylinder) for this reason it is important that the water stored in DHW cylinders is heated to a minimum of 60ºC. It should be noted that temperature control of DHW is generally considered the preferred means of reducing the risk of legionella bacteria growth. DHW calorifiers and their associated control systems should be designed to ensure compliance with specified temperature regimes.

*DHW Distribution System design – avoidance of long pipe runs*

In particular for new build, and also for deep retrofit, careful consideration should be given to location of DHW heating system components with a view to avoid excessive pipe runs for DHW supply.  In particular, for high DHW demand locations (kitchen, bathroom and showers) designers should consider the impact of pipe runs on energy losses and well as water use.  Excessive pipe runs will result in

***DHW Heating Control***

Time and temperature control of DHW systems allow householders to pre-set the time period required for water heating and the temperature to which water is heated. This means that water need not be heated for longer than required or to higher temperatures than required. In general the temperatures for stored DHW should be set to approximately 60°C in order to kill Legionella bacteria. However, heating water above this temperature, only to add cold water to it afterwards, is a waste of energy.

Building Regulations Technical Guidance Document Part L sets out the minimum requirements for the control of DHW heating. TGD Part L states that DHW heating should be effectively controlled so as to ensure the efficient use of energy by limiting the provision of heat energy use to that required to satisfy user requirements, insofar as reasonably practicable.

The aim should be to provide the following minimum level of control for DHW systems:

- Automatic control of heat input to stored hot water on the basis of stored water temperature.
- Separate and independent automatic time control of DHW heating.
- Automatic shut down of boiler or other heat source when there is no demand for either space or water heating from that source.

The following components are typically employed to meet the above requirements:

1. Programmer / timer - This device is used to turn the heating source (boiler/immersion) on or off at user defined times thus controlling when space and DHW heating occurs.
2. Cylinder thermostat - This device is usually strapped to the side of the hot water cylinder about 1/3 from the top. It is commonly used with a motorised valve to provide close control of DHW temperature. It senses the temperature of the water in the cylinder and will turn on or off the supply of heat to the DHW cylinder based in the temperature of the stored water. It should be adjusted to around 60°C.
3. Boiler Interlock - Cylinder controls should not be used unless they also operate an electrical switch to provide boiler interlock, otherwise the boiler will cycle unnecessarily. Boiler interlock is a wiring arrangement to prevent the boiler firing when there is no demand for heat.

*Centralised (Wet) Space and DHW Heating Systems*

This is the provision of space and DHW heating from a boiler/heat pump using the medium of water. Water is heated in the boiler/heat pump. The water leaving the boiler/heat pump is pumped through the primary circuit to the various heat emitters for space heating and to the coil in the indirect DHW cylinder for DHW production.

There are two main adaptations of central heating system design:

1. Open-Vented
2. Sealed/pressurised

Open vented refers to the separate vent pipe, which is open to the atmosphere. The system uses a feed-and-expansion cistern to allow for changes in water volume with temperature. Figure 4.16 below shows the typical layout of an open vented space heating and domestic hot water system.

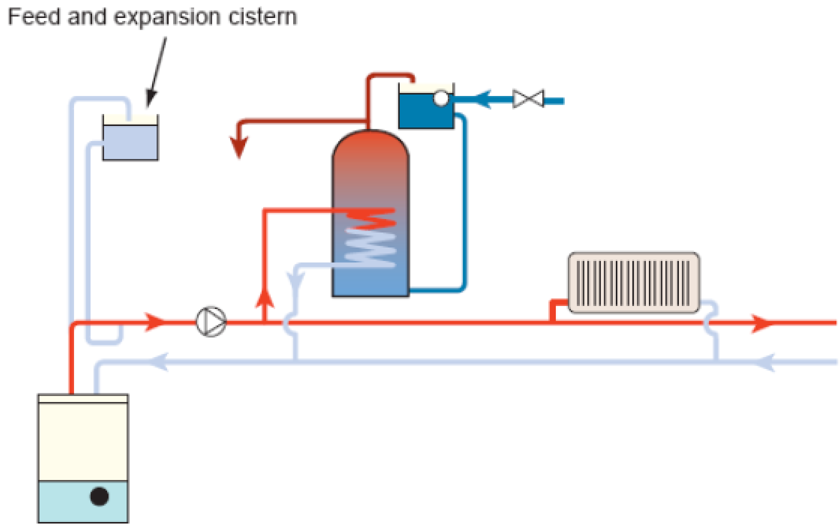



**Figure 4.16 Open-Vented central heating system**

In the sealed/pressurised the feed-and-expansion cistern is replaced by an expansion vessel incorporating a diaphragm to accommodate variations in water volume. The boiler, primary pipes, heat emitters, and coil in the storage cylinder are filled from a mains fed temporary filling connection consisting of a filling valve, hose, and double check valve to prevent potential contamination of the mains water system. Figure 4.17 below shows the typical layout of a sealed/pressurised space heating and domestic hot water system.

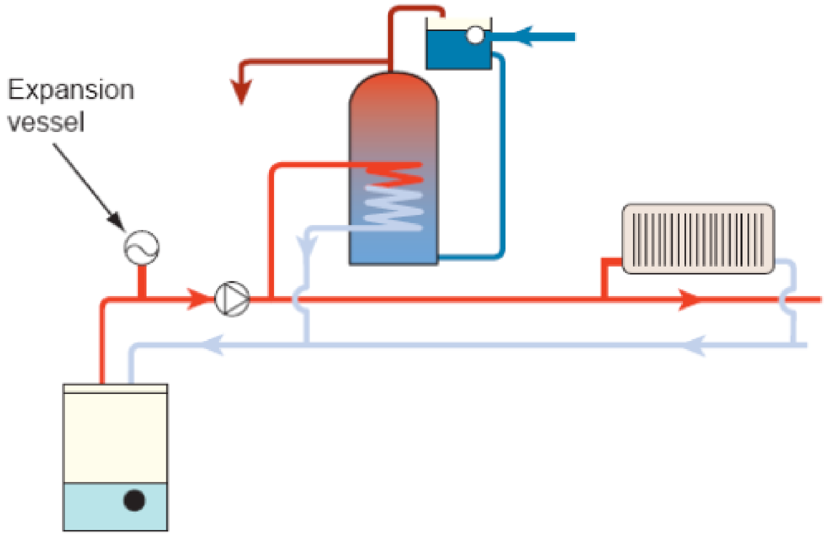



**Figure 4.17 Sealed/pressurised central heating system**

Heating System Energy Use

Space heating in homes represents a large energy demand, consumption for space heating in the European Union represents approximately 60% of the total energy consumption in residential sector buildings. That makes the heating sector an obvious target for reduction in fossil fuel use. The EU have carefully considered best courses of action to achieve their goals of reducing fossil fuel dependency, reducing overall energy consumption, and reducing $CO_2$ greenhouse gas emissions.

The EU's overall heating policy strategy highlights that a reduction of heat demand for dwellings would reduce the consumption of fossil fuels while switching to renewable fuels would achieve the remaining reduction.

Optimising heating system performance in new buildings:

- Size and select the most efficient heat generation system possible
- Site and design the most sustainable building possible
- Ensure the building is insulated and sealed efficiently
- Size and select the most efficient heat generation system possible
- Select the most efficient and practical heat emission system
- Ensure efficient control of both space heating and Domestic Hot Water (DHW)

Optimising heating system performance in existing buildings:

When householders decide to improve the thermal performance and comfort conditions within an existing dwelling, it is important that a comprehensive assessment is carried out on the dwelling to ensure their finances are invested wisely. Chart 4.1 below shows how best to optimise these improvements in relation to payback.

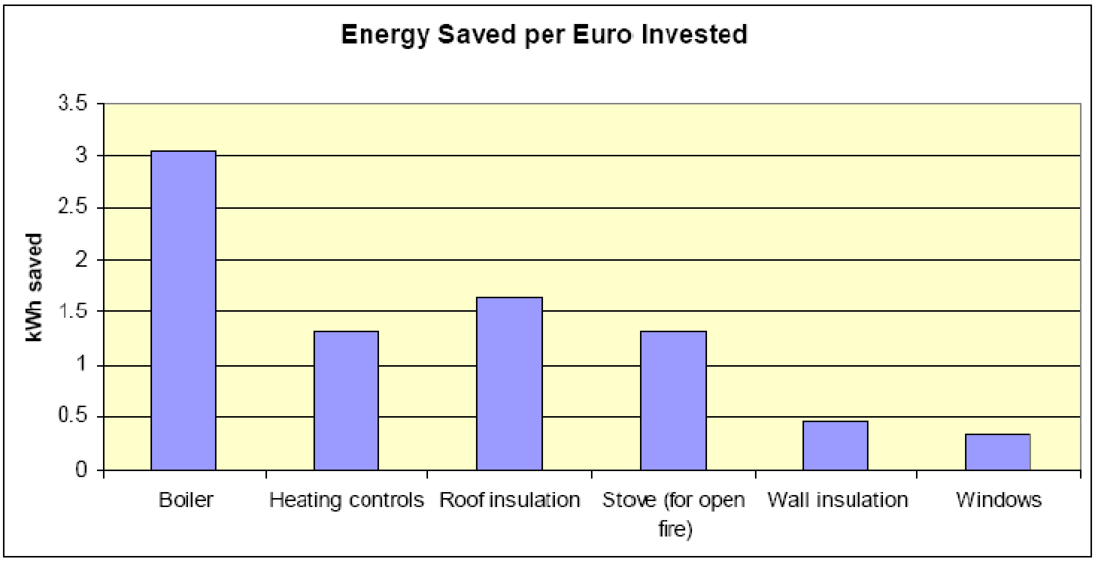



**Chart 4.1 Energy saved per Euro invested in existing buildings (Source – Trainenergy - Efficiency in Domestic Heating Systems. The Retrofitting Challenge. Paul Kenny Tipperary Energy Agency SERVE© Project, 2008)**

*Heating Controls*

Heating controls are required to ensure that heating systems operate safely and efficiently. They also protect buildings, heating plants and other machinery from frost and condensation damage.

The essence of good heating control is to operate a heating system only when it is required and to the minimum acceptable temperature. There are a variety of controls to help achieve this and the main types affect time, temperature and the operation of the boiler.

Poor control of heating and hot water services is the cause of excessive energy consumption in many small commercial and multi-residential buildings. In premises with well-controlled systems, heating fuel consumption is typically 15-30% lower (CTG065 www.carbontrust.co.uk). Good control not only saves energy, but also maintains a consistently comfortable environment for building occupants, as well as reducing plant maintenance costs.

Overheating is a sign of poor control. It wastes money and energy and creates uncomfortable working conditions. By controlling your heating better, you will not only be saving money, but also improving overall comfort levels for staff.

The cost benefits of controls should not be underestimated. Upgrading controls on older heating systems, for example, can save over 15% on energy bills when fitting a full set of controls to a system which previously had none (CTG065 www.carbontrust.co.uk).

Controls can impact on energy use in two different ways:

1) they reduce heating requirements
2) increase heating and hot water system efficiency.

Reducing heating requirements has by far the biggest impact on energy consumption. This can be achieved by reducing the heating 'on' time and set temperature so that they better match occupant requirements and times of use. It is important to ensure that suitable controls are specified which allow for adjustments according to energy demand.

The installation of effective heating controls has a major impact on the energy consumption of heating and hot water systems. The correct selection, installation, and commissioning, of heating controls will ultimately lead to:

- Improved energy efficiency
- Reduced running costs
- Lower carbon dioxide ($CO_2$) emissions.

*Building Regulation requirements:*

The Building Regulations, TGD Part L, set out the minimum requirements for space heating and hot water supply system controls. Part L, states that space and water heating systems should be effectively controlled so as to ensure the efficient use of energy by limiting the provision of heat energy use to that required to satisfy user requirements, insofar as reasonably practicable.

The aim should be to provide the following minimum level of control: -

- Automatic control of space heating on the basis of room temperature.
- Automatic control of heat input to store hot water on the basis of stored water temperature.
- Separate and independent automatic time control of space heating and hot water.
- Shut down of boiler or other heat source when there is no demand for either space or water heating from that source.

The minimum controls for DHW and space heating with heat pump systems, as set out in the 2019, TGD Part L for public consultation, is outlined in table 4.2 below.

| Minimum standard of controls for heat pumps | |
|---|---|
| **3.0 Domestic Hot Water (DHW)** | a. For full heating, the heat pump and any supplementary domestic hot water heating should be capable of supplying water in the range 60°C to 65°C. This is applicable to ground -to-water, water-to-water and air-to-water type heat pumps.<br><br>b. If the heat pump is not capable of supplying water at these temperatures, supplementary heating should be provided and controlled as described in other sections of this guide. Controls should include an auxiliary heating regime to 60°C or more for disinfection purposes.<br><br>c. The domestic hot water system should have temperature control (e.g. a tank thermostat) and time control to optimise the time taken to heat the water<br><br>d. The heat pump may be utilised for all or part of the DHW load. During the DHW heating period the heat pump may not necessarily be providing heated water to the space heating system |
| **4.0 Controls** | <u>a. Heat pump unit controls should include:</u><br>i. control of water pump operation (internal and external as appropriate)<br>ii. Control of water temperature for the distribution system.<br>iii. Control of outdoor fan operation for air-to-water units.<br>iv. Defrost control of external airside heat exchanger for air-to-water systems.<br>v. Protection for water flow failure<br>vi. Protection for water high temperature<br>vii. Protection for high refrigerant pressure<br>viii. Protection of air flow failure on air-to-water units.<br><u>b. External controls should include: FOR PUBLIC CONSULTATION</u><br>i. weather compensation or internal temperature control<br>ii. timer or programmer for space heating.<br><br><u>c. Minimum heat pump flow rates or volume requirements should be met. If all zones are thermostatically controlled, then a buffer would be an acceptable method of compliance.</u> |

**Table 4.2- Minimum Controls for DHW and space heating Heat Pump Systems (Source; Draft TGD L 2018)**

Individual heating Controls:

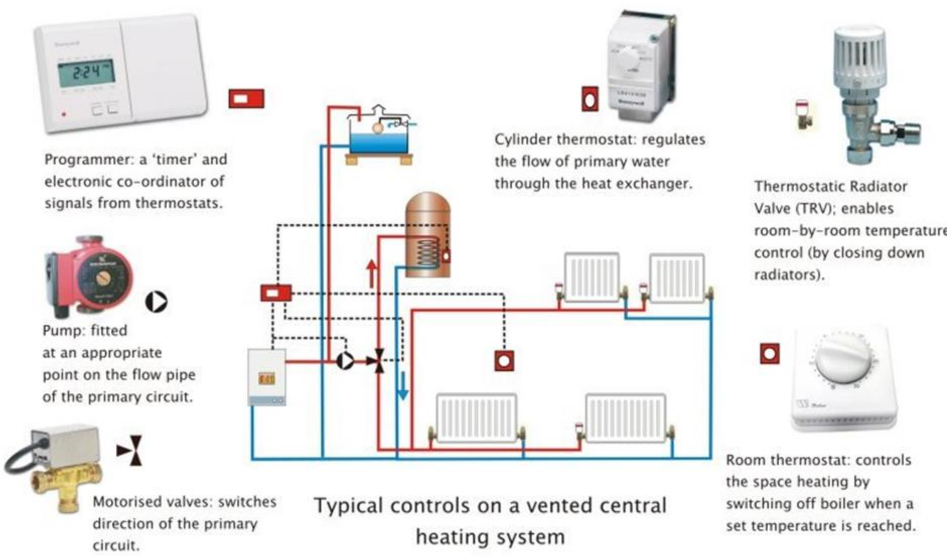



**Figure 4.19 Schematic of Typical Central Heating Controls (www.homeenergysaving.ie)**

Time Controls:
Time controls are fundamental to any efficient heating system – they specify when the heating should come on and for how long. Set correctly, they ensure the system operates at the best times in terms of building occupancy and requirements. Most heating systems have some sort of time control and understanding how they work and how to set them up is essential in order to achieve significant cost savings. Time controls come in a variety of shapes and sizes, makes and models. They will often be located near the boiler or hot water storage. Below are some common types:

24-hour dial time switch
Simple time control of a system that will only switch one circuit. There are usually two dials: the outer dial is of a higher resolution and shows the minutes past the hour that the heating is switched on and off. The inner dial shows just the hour.


**Figure 4.20 Twenty-four hour time switch (Source: www.davies.ie)**

Seven-day time switch
Gives greater flexibility allowing different time programmes for each day. Modern electronic time switches come in a variety of forms and can be set remotely using a phone app, thereby providing excellent control flexibility.

Programmer
A programmer can switch multiple circuits separately (usually heating zones and hot water). There are three basic types:

- a mini-programmer allows space heating and hot water to be on together, or hot water alone, but not heating alone
- a standard programmer uses the same time settings for space heating and hot water
- a full programmer allows the time settings for space heating zones and hot water to be fully independent.

Room Thermostat

Room thermostats provide simple temperature control by sensing the air temperature and switching the heating off/on when the air temperature rises/falls above or below the thermostat setting. Room Thermostats are designed to give automatic temperature control of space heating systems. Most room thermostats include an accelerator (or anticipator), which has the effect of smoothing out the temperature cycle, so that on and off periods are not too long. Room Thermostats can be used to directly switch Electric heaters, circulating pumps or boiler, or to operate spring return and motor open/motor close zone valves. A wide range of Room Thermostats are available from modern digital models (figure 4.21) to simple dial operated control. Wireless units are now available that provide increased flexibility in positioning and eliminate visible wiring.


***Figure 4.21 Digital Room Thermostat (Source: www.danfoss.com)***

Programmable Room Thermostat

Allows different temperatures to be set for different periods in the day or week, providing a better match to the business working pattern. This is important if occupancy is varied over the day or week. These can also provide a 'night setback feature' where a minimum temperature can be maintained at night. Many are battery operated and can replace a conventional thermostat without the need for additional cabling. Many also allow time control of hot water. A programmable room thermostat (figure 4.22), with its greater flexibility in setting temperatures and times, has the capability to provide greater savings than a 'standard' room thermostat.


**Figure 4.22 Programmable Room Thermostat (Source: www.danfoss.com)**

**Positioning of Room Thermostats**

Room thermostats should be positioned and wired as per manufacturers' instructions. In general room thermostats should not be influenced by draughts or heat sources such as sunlight, radiators or office equipment. These factors create a 'false local temperature' and may result in heating systems over or under heating a building. Thermostats should be placed on a flat internal wall, at approximately 1.5m height. This helps to provide a more representative temperature (figure 4.23).

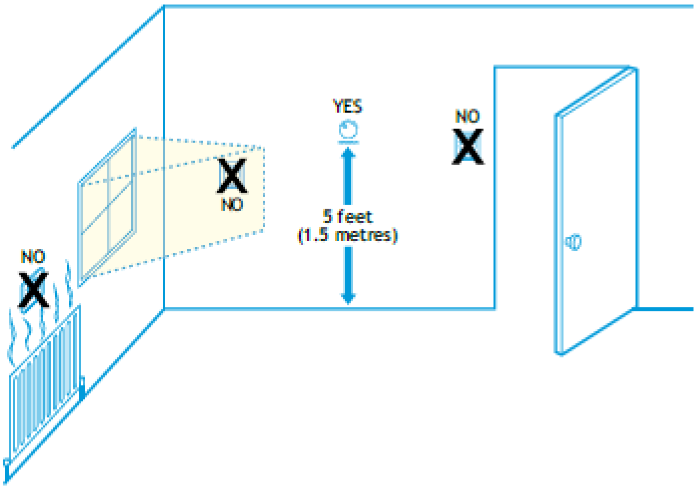



**Figure 4.23 Positioning of Room Thermostats (Source: www.carbontrust.co.uk)**

<u>Cylinder Thermostat</u>

Simple control of stored hot water temperature, usually strapped to the side of the hot water cylinder about 1/3 from the top (figure 4.24). It is commonly used with a motorised valve to provide close control of DHW temperature. It senses the temperature of the water in the cylinder and will turn on or off the supply of heat to the DHW cylinder based in the temperature of the stored water. It should be adjusted to 60°C – 65°C to kill off bacteria in the stored water.


**Figure 4.24 DHW Cylinder Thermostat (www.draytoncontrols.co.uk)**

Frost Thermostat

A frost thermostat (figure 4.25) is a simple override control used to avoid frost damage to the dwelling and/or boiler and system. A frost air thermostat should be fitted in a suitable place inside the dwelling (e.g. loft space, floor voids, garages etc.) so that a minimum temperature is always maintained.


**Figure 4.25 Frost Thermostat (www.honeywelluk.com)**

Pipe Thermostat

A pipe thermostat (designed to be strapped on to pipes, figure 4.26), provides high or low limit or frost protection in heating and hot water systems.

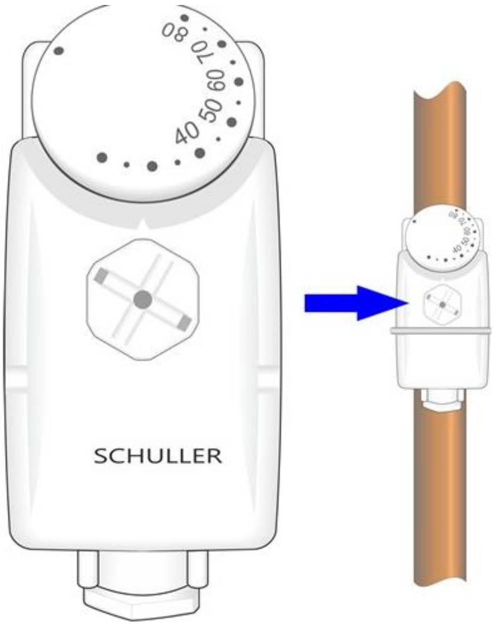



**Figure 4.26 Pipe Thermostat (Source: www.topline.ie)**

Thermostatic Radiator Valve (TRV)

Used to limit temperatures in individual rooms and so reduce energy consumption. Typically the thermostatic radiator valve contains a plug, made of wax, which expands or contracts with the surrounding temperature. This plug is connected to a pin which in turn is connected to a valve. The valve gradually closes as the temperature of the surrounding area increases, limiting the amount of hot water entering the radiator. TRV's (figure 4.27) allow a maximum temperature to be set for each room can therefore usefully prevent overheating of individual rooms due to solar and incidental gains.

**Figure 4.27 Thermostatic Radiator Valve (www.draytoncontrols.co.uk)**

Zone Controls/Motorised Valves:

Used to control water flow from boiler to heating and hot water circuits. Two & three-port motorised valves can be used to provide zone control, such as lower temperatures in unoccupied areas or different heating times. This allows these zones to be controlled separately and avoids heating areas which may not be used for large parts of the day. Residential dwellings are generally divided into zones, for example living quarters and sleeping quarters or upstairs and downstairs. DHW heating can be controlled separately from the space heating system using motorised valves. Zone and DHW heating control is provided by motorised valves, linked to a timer (or programmer) and thermostat, that directs the heated water to wherever the heat is required. Auxiliary switches on valves are wired to switch the boiler/pump off when there is no demand for heat or hot water.

Two-port valve operation for zoning of DHW and Space heating

Two port Motorised Valves have a wide range of flow control applications in domestic and light commercial central heating systems. Most models have end switches for electrical control of pump and/or boiler. Two port motorised valves are spring loaded and in the case of a power failure can, depending on the model, default to either "normally open" or "normally closed". The normally open model is particularly applicable to control of solid fuel systems, since it will always fail-safe in the event of a power failure.

**Figure 4.28 Two-port Motorised Valve (www.honeywelluk.com)**

Three-port valve operation for zoning of DHW and Space heating

When DHW heating is called for (time programme & cylinder thermostat) the three port valve allows water to flow from the boiler to the cylinder (AB to B in Figure 4.29). When space heating and DHW heating are both calling for heat the valve move to a mid-position allowing water to flow from the boiler to both the DHW and space heating circuits. If the DHW demand is satisfied, (either by the programmer or cylinder thermostat) the motorised valve directs water only to the space heating circuit A (see figure 4.29). When both Space and DHW demands are satisfied the boiler switches off (boiler interlock).

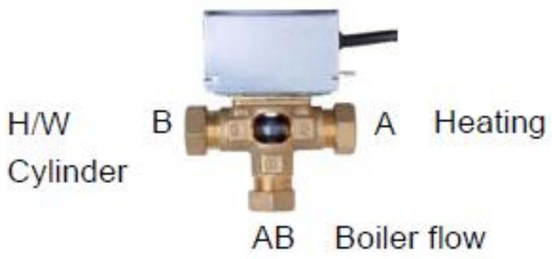



**Figure 4.29 Three-port valve operation for zoning of DHW and Space heating ([www.honeywelluk.com](www.honeywelluk.com))**

Boiler Interlock

Boiler interlock is the automatic shutdown of the boiler or other heat source (and pumps etc.) when there is no demand for either space or water heating from that source. This is not a control device but a wiring arrangement to prevent the boiler firing when there is no demand for heat (figure 4.30). The boiler can be said to be 'interlocked' when the boiler is switched 'on' and 'off' by the operation of a room or cylinder thermostat (or a boiler energy manager). In many cases the interlock will also apply to the pump operation but any requirements for pump overrun must be observed. Without an interlock, the boiler is likely to cycle on and off regularly and waste energy by keeping the boiler hot when it is not necessary. For regular boiler systems, the interlock is usually arranged so that the room or cylinder thermostat switches the power supply to the boiler (and sometimes the pump) through the motorised valve 'end' switches. For combi boilers interlock is usually achieved by using a room thermostat.

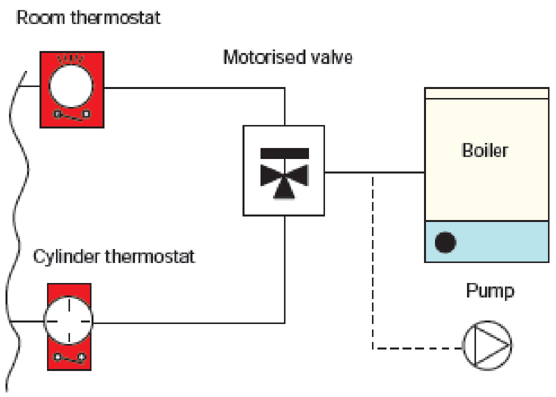
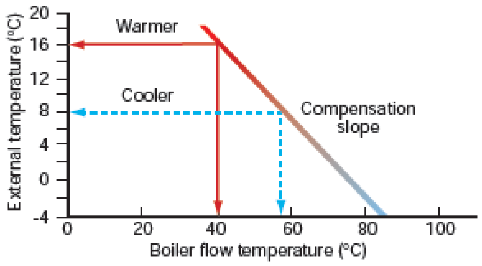



**Figure 4.30 Boiler Interlock through Motorised Valve (Source: BISRA GPG302)**

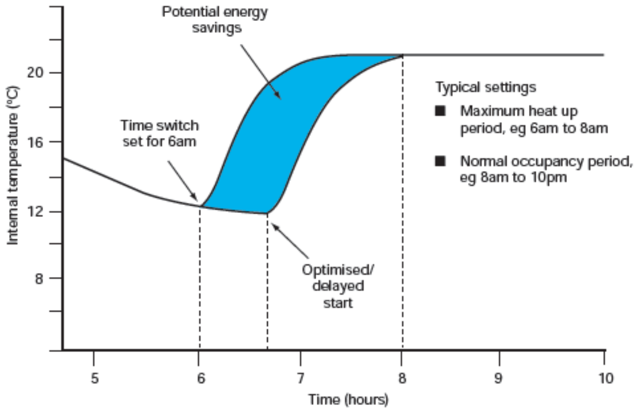
## Boiler Energy Manager:

These controls are self-contained devices (figure 4.31) that include (but are not limited to) the boiler control functions described below:

Compensator
Reduces boiler water temperature for space heating according to internal/external air temperature and should increase the efficiency of condensing boilers by reducing the average return water temperature of the system.




*Delayed Start* - Reduces energy use by delaying boiler start time when the weather is mild.
*Optimum Start* - Adjusts the heating start time to give the required dwelling comfort temperature at a chosen time.




*Night Setback* - Allows a low temperature to be maintained at night. Provides improved comfort and reduced dwelling warm-up time in cold weather. A programmable room thermostat can provide this facility.

*Self-adaptive function* - Reduces appliance ‘on’ time by learning from previous temperature characteristics.


**Figure 4.31 Vaillant Boiler Energy Manger (www.vaillant.co.uk)**

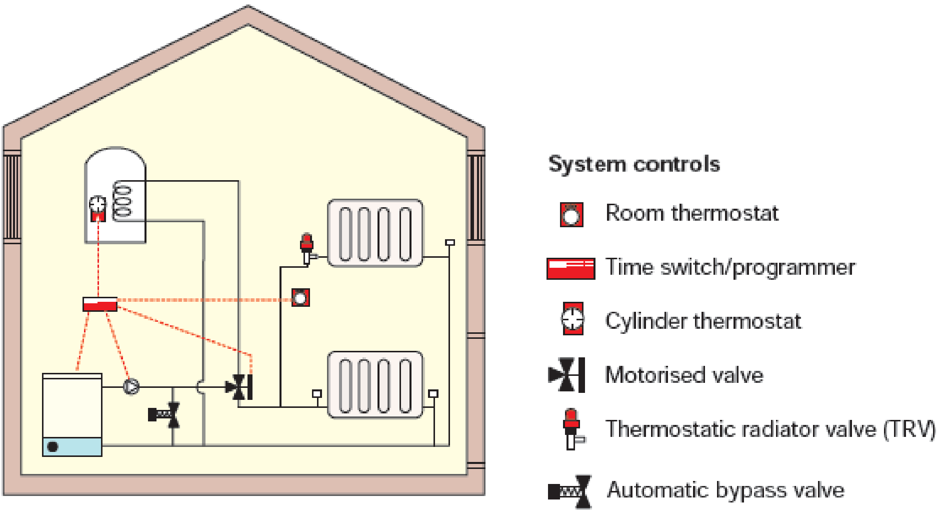
Heating System Controls:

Heating controls are required to ensure that heating systems operate safely and efficiently. They also protect buildings, heating systems and other machinery from frost and condensation damage.

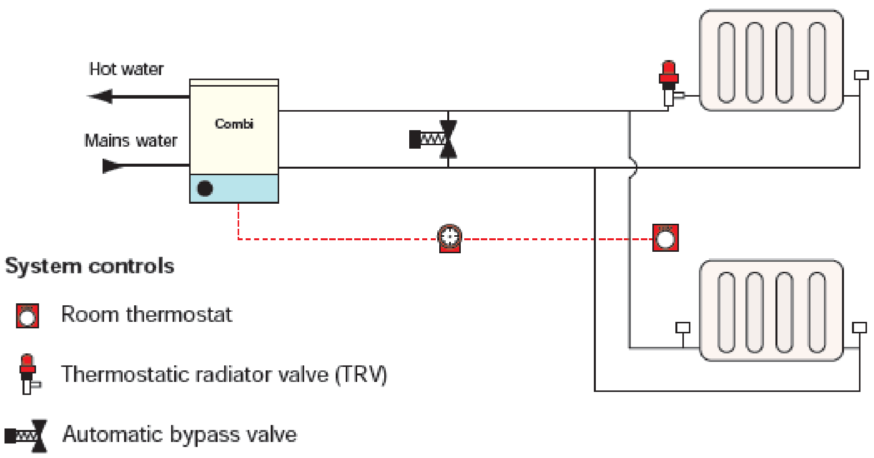
The essence of good heating control is to operate a heating system only when it is required and to the minimum acceptable temperature. There are a variety of controls to help achieve this and the main types affect time, temperature and the operation of the boiler.

Heating systems should be provided with controls that (at a minimum) meet the requirements of Part L of the Building Regulations as previously outlined. Below are some examples of heating system controls.

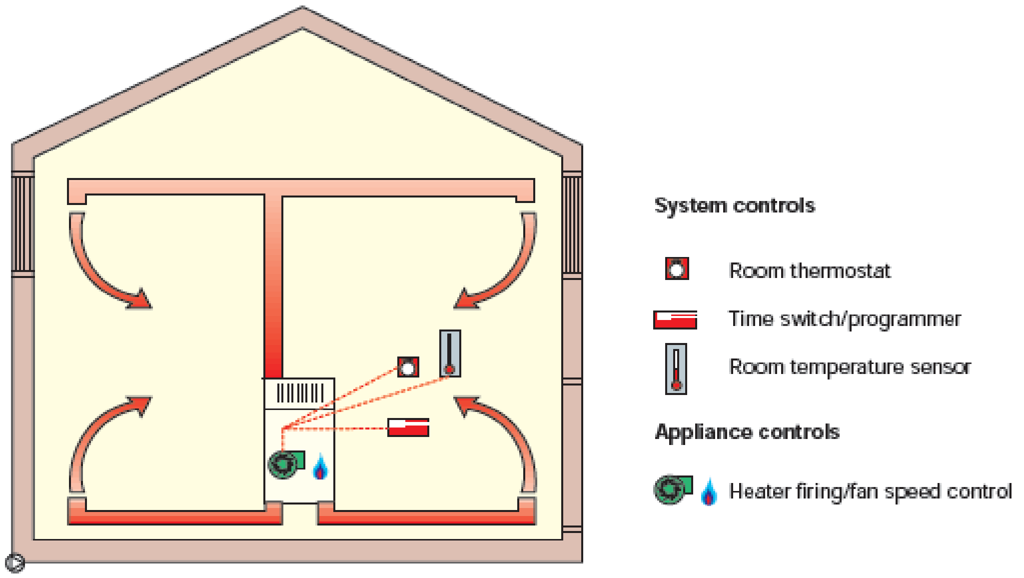
*Typical 'wet' system control of Space and DHW heating (Source: BISRA GPG302)*




*Typical 'combi' system control for Space heating (Source: BISRA GPG302)*

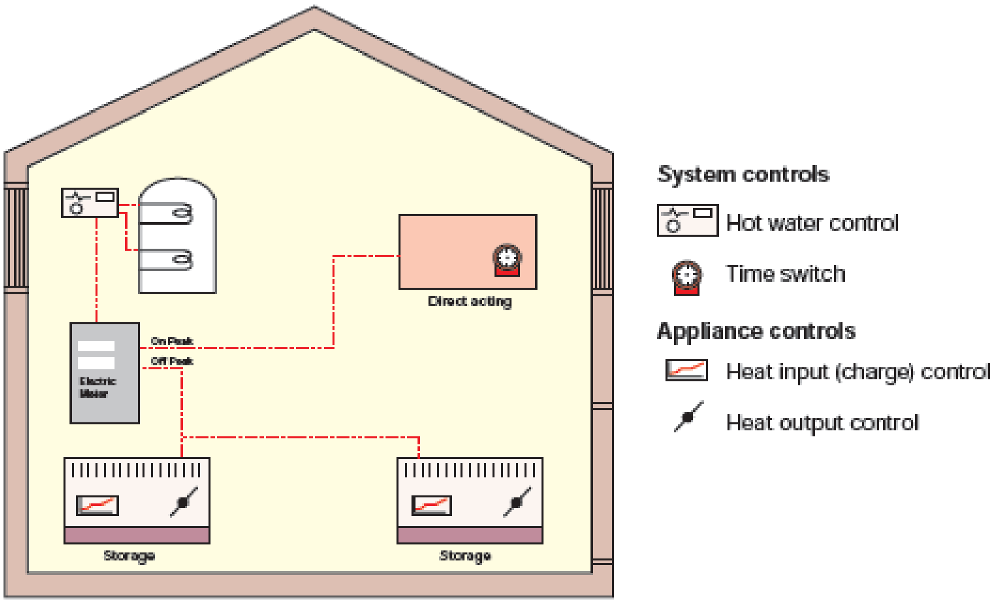


*Warm Air Heating System Control (Source: BISRA GPG302)*




*Electric Space & DHW Heating System Control (Source: BISRA GPG302)*

Electric resistance heating is considered 100% energy efficient in the sense that all of the delivered energy (incoming electricity) is converted to useful energy (heat). However, most of our electricity is produced in fossil fuel burning power stations that convert approximately 35% of the fuel's primary energy into electricity. Because of electricity generation and transmission losses, electric resistance heating is more expensive and environmentally damaging than heat produced by combustion appliances (boilers) or heat pumps.



## Insulation of water storage vessels, pipes & ducts

Insulation of Water storage vessels:

Hot water cylinders should be insulated to ensure energy efficiency. Installation of factory insulated DHW cylinders units is becoming standard practice (Figure 4.32).

Insulation of the storage cylinder reduces energy loss and allows for better control of the water temperature by enabling the stored water to stay at an increased temperature for longer. Adequate insulation of hot water storage vessels can be achieved by the use of a storage vessel with factory applied insulation of such characteristics that, when tested on a 120 litre cylinder complying with I.S. 161: 1975 using the method specified in BS 1566, Part 1: 2002, Appendix B, standing heat losses are restricted to 0.8 W/litre. Use of a storage vessel with 50 mm, factory applied coating of PU-foam having zero ozone depletion potential and a minimum density of 30 kg/m$^3$ satisfies this criterion when installed within the normally heated area of the dwelling.

**Figure 4.32 Factory Fitted DHW Cylinder Insulation**

It should be noted that water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in Technical Guidance Document G and Report BR 262, Thermal insulation: avoiding risks, published by BRE.

Cold water storage cisterns, when located in an unheated space (attic), should be insulated on the top and sides. The area underneath the cistern should be left un-insulated and continuity of tank and ceiling insulation should be ensured (Figure 4.33). Where raised tanks are used, to aid head pressure, the ceiling should be insulated as normal and all surfaces of the tank insulated separately.

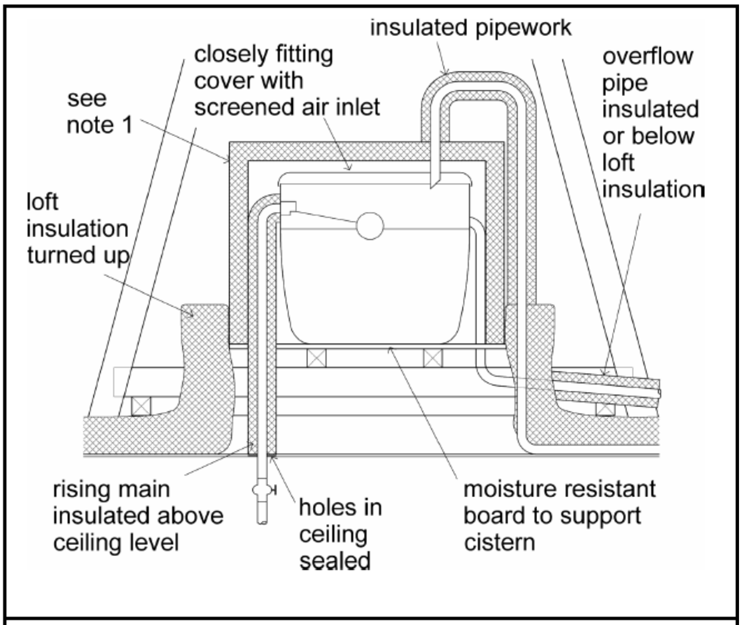



Diagram for clarification only.

Note 1: Insulation U-value to be not less than 0.3 $W/m^2K$ as per TGD L Table 1.

**Figure 4.33 Insulation of Cold Water Storage Cistern (Source: TGD Part G)**

Insulation of Water Pipes

Hot and cold water distribution pipework in buildings other than dwellings is generally insulated up to the point of use. The practical reasons for this are:

1. Energy conservation (hot water pipework).
2. Avoidance of temperature changes during distribution, for water quality and legionella control purposes.
3. Avoidance of condensation (cold water pipework).
4. Avoidance of freezing where pipes pass through unheated spaces or outside.

<u>Building Regulation requirements:</u>

Building Regulations Technical Guidance Document Part L sets out the minimum standard of insulation required for hot water pipes. It states that all hot water pipes and ducts associated with the provision of heating and hot water in a dwelling should be insulated to prevent heat loss.

Pipes and ducts which are incorporated into wall, floor or roof construction (unheated spaces) should be insulated to prevent heat loss. The following standard of pipe insulation is specified in TGD Part L:

- With pipe or duct insulation meeting the recommendations of BS 5422: 2009 Methods of specifying thermal insulating materials for pipes, ductwork and equipment (in the temperature range - 40ºC to + 700ºC); or
- With insulation with material of such thickness as gives an equivalent reduction in heat loss as that achieved using material having a thermal conductivity at 40ºC of 0.035 W/mK and a thickness equal to the outside diameter of the pipe, for pipes up to 40 mm diameter, and a thickness of 40 mm for larger pipes.

Hot water pipes and ducts within the normally heated area of the dwelling that contribute to the space heat requirement of the dwelling do not require insulation, as any heat lost will inevitably contribute to the heated space (except for pipework relating to the production of DHW).

The hot water pipes connected to DHW storage vessels, including the vent pipe and the primary flow and return to the heat exchanger, where fitted, should be insulated to the standard outlined above, for at least one metre from their point of connection.

The insulation of pipes relating to the production and distribution of DHW will limit unnecessary heat loss to the heated space.

It should be noted that cold water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in Technical Guidance Document G and Report BR 262, Thermal insulation: avoiding risks, published by BRE.

*Condensation Risk:*

Condensation occurs when warm moist air meets a cold surface and is thus cooled below its dew point temperature. The vapour close to the cold surface becomes saturated and turns to liquid.

Condensation can occur when warm air in heated spaces comes into contact with exposed cold water pipes or cold water storage cisterns. This can be prevented by insulating exposed cold water pipework and storage cisterns.

*Heating Controls*

Heating controls are required to ensure that heating systems operate safely and efficiently. They also protect buildings, heating systems and other machinery from frost and condensation damage.

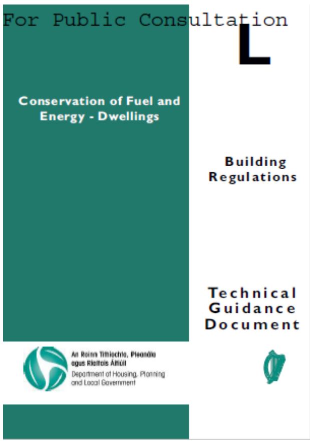
The essence of good heating control is to operate a heating system only when it is required and to the minimum acceptable temperature. There are a variety of controls to help achieve this and the main types affect time, temperature and the operation of the boiler.

Poor control of heating and hot water services is the cause of excessive energy consumption in many residential buildings. In premises with well-controlled systems, heating fuel consumption is typically 15-30% lower (CTG065 www.carbontrust.co.uk). Good control not only saves energy, but also maintains a consistently comfortable environment for building occupants, as well as reducing equipment maintenance costs.

The installation of effective heating controls has a major impact on the energy consumption of heating and hot water systems. The correct selection, installation, and commissioning, of heating controls will ultimately lead to:

- Improved energy efficiency
- Reduced running costs
- Lower carbon dioxide ($CO_2$) emissions.

Although many apartments or smaller dwellings use instant hot water supply, the larger dwellings are often installed with a hot water storage cylinder. It is necessary to insulate the hot water storage vessel to ensure energy efficiency and installing factory insulated storage units is becoming standard practice




Insulation of the storage cylinder reduces energy loss and allows for better control of the water temperature by enabling the stored water to stay at an increased temperature for longer. Building Regulations Technical Guidance Document Part L sets out the minimum standard of insulation required for hot water pipes and vessels. It states that all hot water storage vessels, pipes and ducts associated with the provision of heating and hot water in a dwelling should be insulated to prevent heat loss.

Hot and cold water distribution pipework in buildings other than dwellings is generally insulated up to the point of use. The practical reasons for this are:

1. Energy conservation (hot water pipework).
2. Avoidance of temperature changes during distribution, for water quality and legionella control purposes.
3. Avoidance of condensation (cold water pipework).
4. Avoidance of freezing where pipes pass through unheated spaces or outside.

It should be noted that cold water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in Technical Guidance Document G and Report BR 262, Thermal insulation: avoiding risks, published by BRE.

Condensation occurs when warm moist air meets a cold surface and is thus cooled below its dew point temperature. The vapour close to the cold surface becomes saturated and turns to liquid. Condensation can occur when warm air in heated spaces comes into contact with exposed cold water pipes or cold water storage cisterns. This can be prevented by insulating exposed cold water pipework and storage cisterns.

*Space Heating, DHW and Renewable Energy Systems*

Through appropriate design and standards the space heating demand and DHW demand should be reduced to levels achieving or exceeding the requirements in relevant building standards. The energy transition also demands that building maximise the use of renewable energy systems for the supply of energy. Critically, in terms of compliance with building standards this refers primarily to on-site generation of renewable energy rather than renewable energy which may be purchased from an external supplier e.g. electricity supplier from a green electricity utility.

The technical solutions which can be utilised to delivery renewable energy heating and DHW within buildings are described in detail in Section 4.3. Technologies for on-site generation include

- *Heat Pumps:* Air Source, Ground Source and Hydrothermal – supplying space and DHW
- *Photovoltaics:* Suppling electricity which can be utilised for DHW and building electricity loads
- *Biomass/Bioenergy Systems:* Typically supplying heating but can be utilised with CHP technology to provide power also.
- *Wind Energy Systems:* Suppling electricity which can be utilised for DHW and building electricity loads
- *District Heating:* Centralised heating systems supplying heat and DHW to a group of buildings
- *Combined Heat and Power:* Supplying heating and power for the building energy demands.

Critically renewable energy which is produced on site through relevant technologies <u>does not</u> contribute to the total building delivered/primary energy. As renewable energy technologies generally are characterised by zero, or greatly reduced, $CO_2$ emissions, the buildings EPC and CPC are reduced by the extent that they replace traditional fossil fuels.

Compliance with the renewable energy contribution requirements is done within DEAP and as the reference dwelling is not affected by the incorporation of these technologies in a dwelling being assessed, it has the effect of making it easier to achieve compliance.

There is a requirement to calculate the Renewable Energy Ratio (RER) for buildings based on:

- Renewable Energy Ratio (RER) = EPren (Primary Energy of the Renewables) / EPtot (Total Primary Energy)

*Low Temperature Space Heating, DHW and Renewable Energy Systems – Design Considerations*

For a number of RES technologies consideration has to be given to the fact that a number of these systems, such as Heat Pumps and District Heating, typically operate at lower operating temperatures than traditional heating systems e.g. oil/gas boilers. This needs to be considered in the context of the sizing of the RES technology itself but also the distribution and emitter systems which will be used.  Low temperature emitters e.g. aluminium radiators may need to be considered in terms of the design and specification of the distribution and heating system.

Also, for such low-temperature heating systems careful consideration of heating control strategies is required as normal practice, which a homeowner might be accustomed to with a high temperature boiler system, is unlikely to result in comfort levels being achieved and inefficient operation of the heating system

## Unit 4.2 Controlled Ventilation

Ventilation rate is the rate at which air within a building is replaced by fresh air. It may be expressed as:

- Number of times the volume of air within a space is changed in one hour (air changes per hour or ach).
- Rate of air change in volume and time, e.g. litres per second (l/s).

Ventilation is simply the removal of 'stale' inside air from a building and its replacement with 'fresh' outside air thereby creating a healthy and comfortable internal environment for the occupants of a building.

Ventilation of buildings:

- Provides fresh air for breathing.
- Dilutes and removes airborne pollutants, including odours.
- Controls excess humidity arising from water vapour in the inside air.
- Provides oxygen for fuel burning appliances.

**Ventilation vs Air Infiltration:**

Air infiltration can be referred to as draughts, exfiltration and air leakage or uncontrolled air movement, whilst ventilation refers to controlled air movement (see figures 4.34 & 4.35).

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.

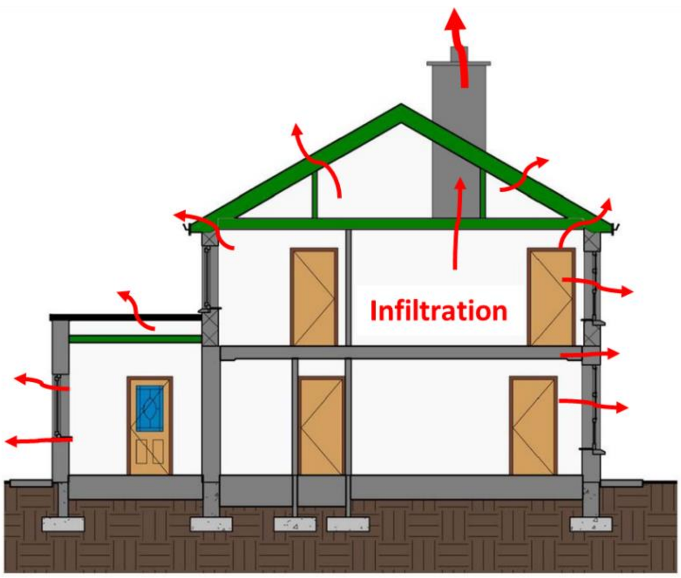



**Figure 4.34 Diagram showing flows of uncontrolled air infiltration**

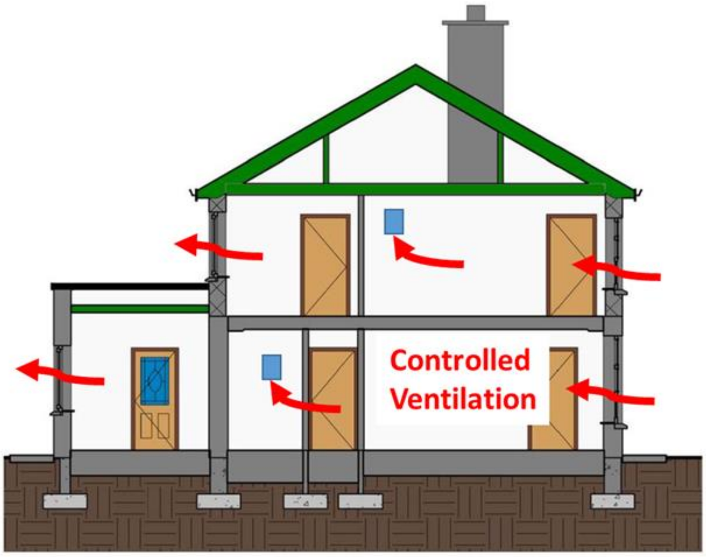



**Figure 4.35 Diagram showing flows of controlled natural ventilation**

### Ventilation and heat loss:

Figure 4.36 below shows that as insulation standards have improved, ventilation heat losses have increased as a percentage of total heat loss. In well-insulated dwellings, the ventilation losses can be responsible for around one third of the total heat loss.

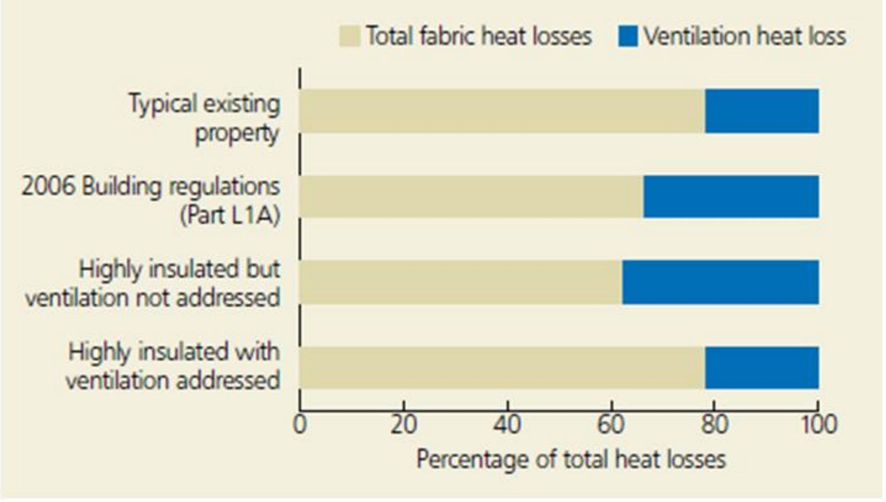



**Figure 4.36 Comparison of ventilation and fabric heat losses for a semi-detached house (Source: GPG268)**

There are two types of natural ventilation heat loss:

1. Infiltration: Cold air entering IN the building
2. Exfiltration: Air leakage OUT from the building

Leakage occurs through openings and cracks in the structure, badly fitted windows and doors and openings such as chimneys. Permeability is a measure of air tightness and hence ventilation loss. Airtightness is characterised by air leakage through the external building envelope and it is a key component of energy efficient buildings. Undesirable and uncontrolled leakage of air from the inside through the building envelope to the outside will reduce efficiency of the thermal insulation, reduce heat resistance of the structure and increase heat losses by ventilation. The prevention of draughts due to uncontrolled air leakage leads to better living comfort and increased energy efficiency, which in turn leads to lower heating costs.

Additionally modern energy efficient buildings often employ forced mechanical ventilation with heat recovery to provide fresh air supplies and to fulfil the ventilation requirements for the energy efficient buildings. Efficient regulated indoor air ventilation can only be achieved if the building shell is airtight. Thus for these systems to operate effectively buildings are required to have reduced air permeability levels. Ensuring excellent air quality in buildings requires a combination of high levels of airtightness and controlled ventilation to provide a constant supply of fresh, oxygen-rich air.

There two main problems arising from Poor Ventilation:

- Condensation (Surface and Interstitial)
- Poor air quality

## Condensation

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 4.37 is usually due to heat loss through the windows and the incorrect levels of ventilation.

**Figure 4.37 Surface Condensation on windows**

<u>Interstitial Condensation</u>

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 4.38).

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 4.38 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 4.39).


**Figure 4.39 Diagram showing problems in a building with no ventilation**

As required in TGD Part F: Adequate provision shall be made to prevent excessive condensation in a roof or in a roof void above an insulated ceiling.
Provision of ventilation openings may be continuous or distributed along the full length of the eaves and may be fitted with a screen, fascia, baffle, etc. Further guidance in relation to condensation in roofs is contained in BS 5250: 2002: Code of Practice for Control of Condensation in Buildings. Additional guidance is given in DEHLG publication Acceptable Construction Details and the BRE publication "Thermal Insulation - avoiding risks".

<u>Indoor Air Quality</u>

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:

1) *Improved indoor air quality* - Ventilation systems should supply fresh air to the working, living and sleeping areas of buildings while removing stale air.
2) *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.
3) *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

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

Background/General Ventilation

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/Rapid Ventilation

An open-able window (minimum 1/20th of room floor area) 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 excess water vapour, fumes and pollutants throughout the building. Extract ventilation can be provided mechanically or naturally with passive stack ventilation. Local mechanical extract fans are installed in 'wet' rooms (Figure 4.40) and provide rapid extraction of moisture and other pollutants. They operate intermittently under either occupant or automatic control. The fans can be either mounted in a window, ceiling or external wall. When ceiling-mounted, the extract should be ducted to outside. Replacement dry air is provided via background ventilators (e.g. trickle ventilators) and air leakage. In addition, as these fans do not run continuously, the background ventilators should be

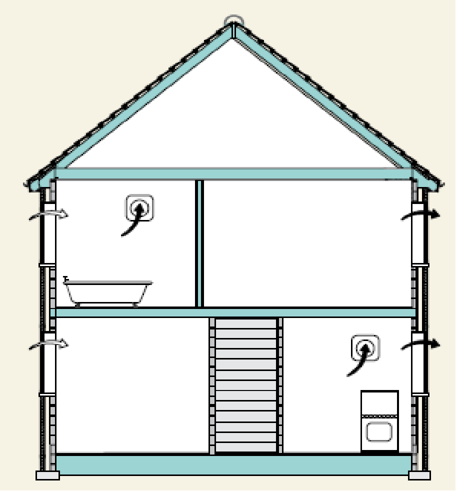


**Figure 4.40 Intermittent Mechanical Extract Fans (Source: GPG268)**

sized to provide adequate continuous whole house ventilation. Providing a gap at the bottom of the internal doors will allow the free passage of air through the property.

Advantages of Mechanical Extract

- Easy to install.
- Provide rapid extraction of pollutants.
- Operation is easy to understand.

Disadvantages of Mechanical Extract

- Noise.
- If occupant controlled, may not be used.
- Prone to occupant tampering.

## Natural Ventilation Systems

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 4.41).

Ventilation is viewed by many as causing draughts and energy loss, and trickle vents (in windows) or traditional ventilation systems (hole in the wall) 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 especially in a well-insulated dwelling. Alternatively Demand Controlled Ventilation (DCV) grilles are installed on the windows or installed strategically in the envelope.

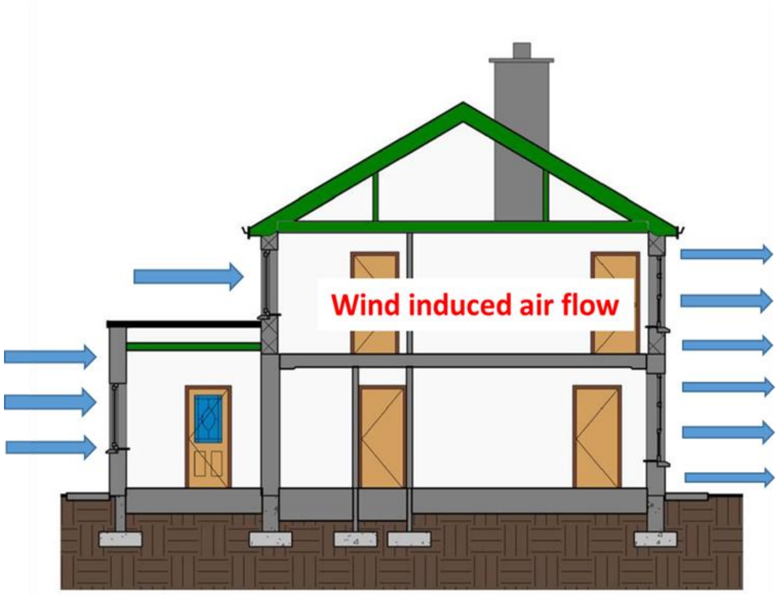
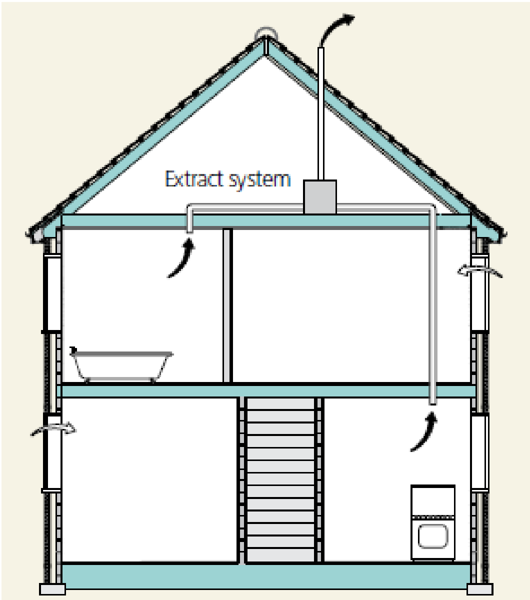



**Figure 4.41 Diagram showing cross ventilation**

Positive Input Ventilation (PIV)




A fan, typically mounted in the roof space, supplies air into the dwelling via central hallway or landing (figure 4.3). This creates a slight positive pressure in the dwelling. With these systems, excess water vapour is not directly extracted from kitchens or bathrooms, etc. but has to find its way out by means of either background ventilator openings or air leakage routes. Fans typically run continuously at low speeds with a manual or humidity controlled boost option. These systems are often recommended for dealing with radon problems.

**Figure 4.42 Positive Input Ventilation (Source: GPG268)**

Passive Stack Ventilation (PSV)

Passive 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.

*Operation of PSV systems* - PSV systems comprise of vents located in ‘wet’ rooms, connected via near-vertical ducts to ridge or other roof terminals. Warm, moist air is drawn up the ducts by a combination of the stack effect and wind effect. Replacement fresh ‘dry’ air is drawn into the property via background ventilators (e.g. trickle ventilators) located in the habitable rooms, and by air leakage. Providing a gap at the bottom of the internal doors will allow the free passage of air through the property.

*Controls* - PSV systems can be controlled with humidity-sensitive inlets that provide increased flows when humidity is high (e.g. during periods of moisture production). These give enhanced energy performance because air extraction is minimised when moisture production is low, and are necessary if the good practice standard is to be achieved.
*Sound attenuation* - Acoustic treatment of the systems to reduce external noise ingress is possible where external noise levels are likely to be a problem.
*Fire Control* - Fire dampers are available for ducts that pass through a fire separating floors.

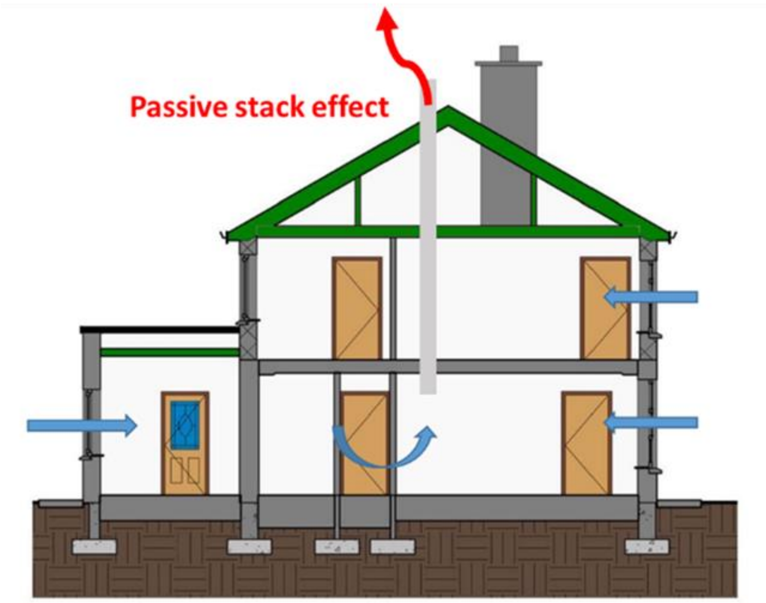



**Figure 4.43 Diagram of Passive Stack Ventilation**

Advantages of PSV Systems

- No direct running costs associated with the system.
- No electrical connection required.
- Silent in operation.
- Provides continuous extract ventilation.

Disadvantages of PSV Systems

- Existing house layouts can make it difficult to accommodate vertical ducting from ground floors.
- As low pressure differences are involved, systems are more sensitive to proper installation and must be installed correctly to ensure that design performance is achieved.
- The air flow through a passive stack is weather dependant. In particular, additional ventilation may be required (e.g. opening of windows) during warmer weather.

**Mechanical Ventilation Systems:**

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.

Mechanical ventilation systems are generally installed in conjunction with low permeability ‘air-tight’ buildings and should be carefully controlled to ensure adequate ventilation to these buildings.

Mechanical ventilation is forever evolving and alternative solutions are being developed, below are a number of alternative mechanical ventilation systems.

Single Room (Heat Recovery) Ventilators

Single room (heat recovery) ventilators are a development of the extract fan. They provide a balanced flow of supply and extract air into ‘wet’ rooms. A heat exchanger can be incorporated to recover heat from the outgoing air in order to pre-heat the incoming air. The unit can be operated intermittently (on/off), or continuously (dual speed) providing low-speed continuous ‘trickle’ ventilation, and high-speed ‘boost’ flow.

*Controls* - The Single room (heat recovery) ventilator can be controlled with:

1. manual switching
2. automatic on demand switching using a humidistat sensor

**Figure 4.44 Single Room Heat Recovery Ventilator (www.renergise.ie)**

Advantages of Single Room (Heat Recovery) Ventilators

- Easy to install.
- Provides continuous ‘low-level’ background ventilation.
- Heat recovery from extracted air.
- Almost silent in operation at trickle-speed.

Disadvantages of Single Room (Heat Recovery) Ventilators

- Some recirculation possible due to close proximity of supply and extract grilles.

Centralised Continuous Mechanical Extract Ventilation Systems (MEV)

A centralised continuous mechanical extract ventilation (MEV) system (figure 4.45) continually extracts air from ‘wet’ rooms. It usually consists of a central ventilation unit positioned in a cupboard or loft space and ducted throughout the dwelling to extract air from the wet rooms. The system is typically dual speed, providing low speed continuous ‘trickle’ ventilation, and high-speed ‘boost’ flow. Replacement dry air is drawn into the property via background ventilators (e.g. trickle ventilators) located in the habitable rooms, and by air leakage. Providing a gap at the bottom of the internal doors will allow the free passage of air through the property.

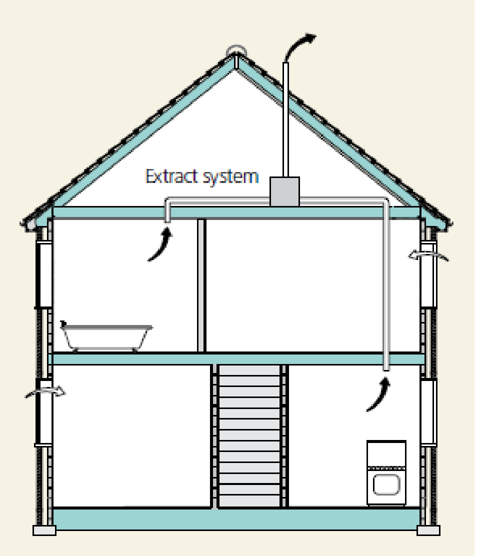



**Figure 4.45 Mechanical Extract Ventilation (Source: GPG268)**

*Controls* - The system's boost setting can be operated automatically (e.g. using a humidistat sensor), or via manual switching.

Advantages of MEV

- Easy to install.
- Provides continuous 'low-level' background ventilation.
- Operation is easy to understand.

Disadvantages of MEV

- Requires ducting from wet rooms.
- Requires commissioning.

<u>Whole house Mechanical Ventilation with Heat Recovery (MVHR)</u>

A whole house mechanical ventilation system (Figure 4.46) usually combines supply and extract ventilation in one system. Systems can also incorporate a heat exchanger. Typically, warm, moist air is extracted from 'wet' rooms via a system of ducting and is passed through a heat exchanger before being exhausted to outside. Fresh incoming air is preheated via the heat exchanger and ducted to the living room and other habitable rooms.

MVHR system are typically variable speed, providing low-speed continuous 'trickle' ventilation, and high-speed 'boost' on demand for increased extract flow.

*Control of MVHR Systems*

- Manual control with variable speed switches
- Automatic control using humidity sensors in 'wet rooms' that boost or increase the air flow during times of high moisture production.

*Sound attenuation* - Acoustic treatment of the systems to reduce external noise ingress is possible where external noise levels are likely to be a problem.

*Fire Control* - Fire dampers are available for ducts that pass through a fire separating walls or floors.

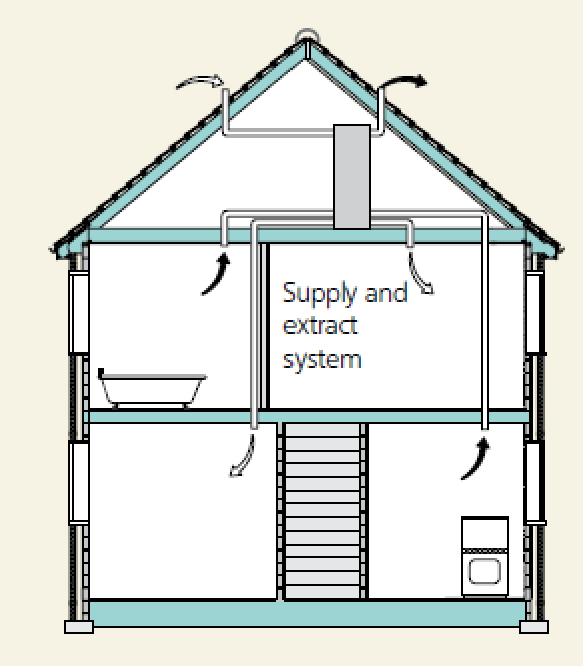



**Figure 4.46 Whole House Mechanical Ventilation with Heat Recovery (Source: GPG268)**

Advantages of MVHR

- These systems provide controlled, preheated fresh air throughout the house almost independently of the weather conditions.
- These systems save energy, the utilisation of heat recovery reduces the demand for space heating. However, the energy saving benefits are only realised for airtight properties (<5m$^3$/hr/m$^2$ at 50Pa) when almost all ventilation air passes through the heat exchanger.
- These systems are particularly effective at reducing the risk of condensation, and as a consequence of the airtight structure and controlled ventilation rate, reducing cold air draughts.
- Systems are normally supplied with air filters which can be useful, particularly in more polluted areas, although the most effective filters do result in a need for greater energy use for the fans to overcome the increased air flow resistance.

Disadvantages of MVHR

- Initial costs are high.
- For optimum performance, an adequate level of airtightness must be achieved, which can be difficult in existing dwellings.
- Complexity of installation and commissioning.

Positive Input Ventilation (PIV)

A fan, typically mounted in the roof space, supplies air into the dwelling via central hallway or landing (figure 4.47). This creates a slight positive pressure in the dwelling. With these systems, excess water vapour is not directly extracted from kitchens or bathrooms, etc. but has to find its way out by means of either background ventilator openings or air leakage routes. Fans typically run continuously at low speeds with a manual or humidity controlled boost option. These systems are often recommended for dealing with radon problems.

*Controls* - The systems deliver a continuous flow of air to the dwelling. Fan speed can be increased by occupant, or automatic switching.

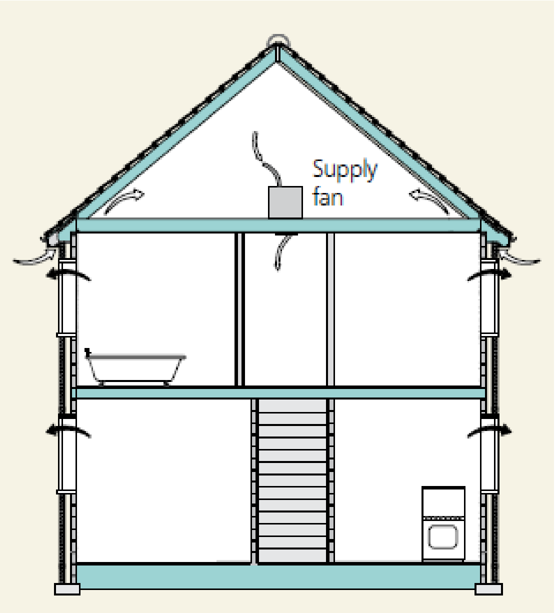



**Figure 4.47 Positive Input Ventilation (Source: GPG268)**

Advantages of Positive Input Ventilation

- Easy to install.
- Operation is easy to understand.
- Heat gain to loft space is utilised.

Disadvantages of Positive Input Ventilation

- Limited research into their use.
- Some additional enhancement measures may be needed, dependent on building shape and layout

**Building Regulations - Ventilation**

For Residential Buildings, the TGD Part F (2018) 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.

The main ventilation requirements as listed in the Table for Residential Buildings from TGD Part F (2009) – Ventilation:

*F1: Means of ventilation.*
Adequate and effective 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.

*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.

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.

*TGD F - Guidance for Ventilation Systems*
TGD Part F gives specific guidance on approaches to meeting the ventilation regulations through the use of; continuous mechanical extract ventilation, mechanical ventilation with heat recovery, and natural ventilation with specific provision for extract ventilation.

**TGD F - Continuous Mechanical Extract Ventilation**
Table 1 below outlines the minimum extract rates required from centralised continuous mechanical extract ventilation systems. These systems should also be able to provide a boost capacity of at least 25% of the minimum rate. The minimum extract rates outlined below may need to be increased to achieve the general ventilation rate required. As an alternative, an opening window provided for purge ventilation may be relied on for extract purposes also.

| Wet rooms | Minimum extract rate (l/s) |
|---|---|
| Kitchen | 13 |
| Utility room | 8 |
| Bathroom | 8 |
| Sanitary accommodation (no bath or shower) | 6[1] |

**TGD F - Mechanical Ventilation With Heat Recovery (MVHR)**
Mechanical Ventilation with Heat Recovery system should be capable of providing adequate general ventilation at all times and of meeting requirements for extract ventilation that may need to be met from time to time. These systems should also be able to provide a boost capacity of at least 25% of the minimum rate.

The calculated general ventilation rate for MVHR is determined as the greater of:

1. 5 l/s plus 4 l/s per person, e.g. 25 l/s for a five person dwelling. This is based on two occupants in the main bedroom and a single occupant in all other bedrooms. This should be used as the default value if a greater level of occupancy is expected, then add 4 l/s per occupant.
   **Or**
2. 0.3 l/s per $m^2$ internal floor area, e.g. 30 l/s for a 100 $m^2$ dwelling.

The minimum ventilation rate should be at least the minimum capacity (as calculated above) or the minimum extract rate outlined in Table 2 below, whichever is higher.

| Wet rooms | Minimum extract rate (l/s) |
|---|---|
| Kitchen | 13 |
| Utility room | 8 |
| Bathroom | 8 |
| Sanitary accommodation (no bath or shower) | 6[1] |
| Notes:<br>1. As an alternative, an opening window provided for purge ventilation may be relied on for extract. | |

**TGD F - Natural Ventilation with Specific Provision for Extract Ventilation**
Table 3 below outlines the requirements for natural/basic ventilation provision using background ventilators and specific provision for extract and purge ventilation for $5m^3/hr/m^2$> air permeability > $3m^3/hr/m^2$

| Room or Space | General Ventilation<br>Minimum equivalent area of background ventilator[a] ($mm^2$) | Extract ventilation<br>Extract fan[b] - Minimum intermittent extract rate (l/s)[i] | Purge ventilation<br>Opening window or external door - Minimum provision[h] |
|---|---|---|---|
| **Habitable Room** | *7000[c, d, g]* | - | *1/20th of room floor area* |
| **Kitchen** | *3500[c, d, e, g]* | *60l/s generally 30l/s if immediately adjacent to cooker (e.g. cooker-hood not recirculating)* | *Window opening section (no size requirement)[e]* |
| **Utility Room** | *3500[c, d, e]* | *30 l/s* | *Window opening section (no size requirement)[e]* |
| **Bathroom** | *3500[c, d, e]* | *15 l/s* | *Window opening section (no size requirement)[e]* |
| **Sanitary Accommodation (no bath or shower)** | *3500[c, d, e]* | *6 l/s[f]* | *Window opening section (no size requirement)[e]* |

**Design and Installation of Ventilation Systems**
Ventilation systems should be designed by competent designers. Systems should be installed, balanced and commissioned by competent installers eg Quality and Qualifications Ireland accredited or Education Training Board or equivalent. Systems when commissioned and balanced should then be validated to ensure that they achieve the design flow rates by an independent competent person eg NSAI certified or equivalent

Controls of Mechanical Ventilation Systems:

1. Continuous ventilation systems should not allow the occupier to turn off the fan, other than at the local isolator. Provision of an on/off function will result in the fans being operated intermittently and the required continuous air flow ventilation rates not being achieved.
2. Where sensors are not pre-installed within the fan unit, or additional optional sensors can be installed, only the sensors specified by the manufacturer of the fan unit should be installed.
3. If sensors are duct mounted, their location should be noted and provisions for access for maintenance or replacement made.
4. If control of the fan speed is undertaken manually, the operation of the fan in boost mode should be made obvious. This will minimise the likelihood of it being left in this mode unnecessarily.
5. Humidity control should not be the only control used in sanitary accommodation, as odour is the main pollutant.

Location and configuration of controls:

1. Installation of manual controls for the system must meet the requirements of Part M of the Building Regulations.
2. Installation of room sensors should follow the manufacturer’s guidance on positioning.
3. Where control of the fan speed is undertaken manually, switching should be provided locally to the spaces being served, i.e. bathrooms and kitchen. Provision of a single centrally located switch is insufficient and will result in fans being left in inappropriate modes of operation.

**Ventilation Ducts & Fire Safety**

Where ventilation ducts pass between fire resisting elements (floors, protected stairwells etc.), they should be protected in accordance with the recommendations contained in Part B of the 2017 Building Regulations (TGD B).

TGD B 2017 states that where a ducted warm air heating system or a Mechanical Ventilation with Heat Recovery system or similar is provided in a dwelling house, precautions should be taken to ensure that it will not contribute to fire spread or endanger the enclosure to any stairway, particularly with regard to protected stairways, BS 9991: 2015 *Fire Safety in the Design, Management and use of Residential Buildings: Section 6, paragraph 35*, contains appropriate guidance on these measures. (see also S3- Internal Fire Spread).

It is also not recommended to connect cooker hoods to Mechanical Ventilation with Heat Recovery systems. Where cooker hoods are connected the guidance under fire precautions in BRE Digest 398 "*Continuous mechanical ventilation in dwellings*" should be followed.

*Fire Dampers*

Fire dampers (figure 4.48) are passive fire protection products used in heating, ventilation, and air conditioning (HVAC) ducts to prevent the spread of fire inside the ductwork through fire-resistance rated walls and floors. Fire damper prevents smoke and fire propagation through the air ducts of ventilation and air conditioning systems in case of fire. Mounted in the ventilation ducts laid through fireproof walls and floors.

**Figure 4.48 Ventilation Duct Fire Damper (www.ventilation-system.com)**

*Fire Damper Design*

Fire dampers (figure 4.49 below) typically consist of a galvanized steel casing (1), blades from insulation material (calcium silicate) and fireproof material (2), thermic release mechanism (3) activated at 70°C, silicone seal (4) and spring (5).

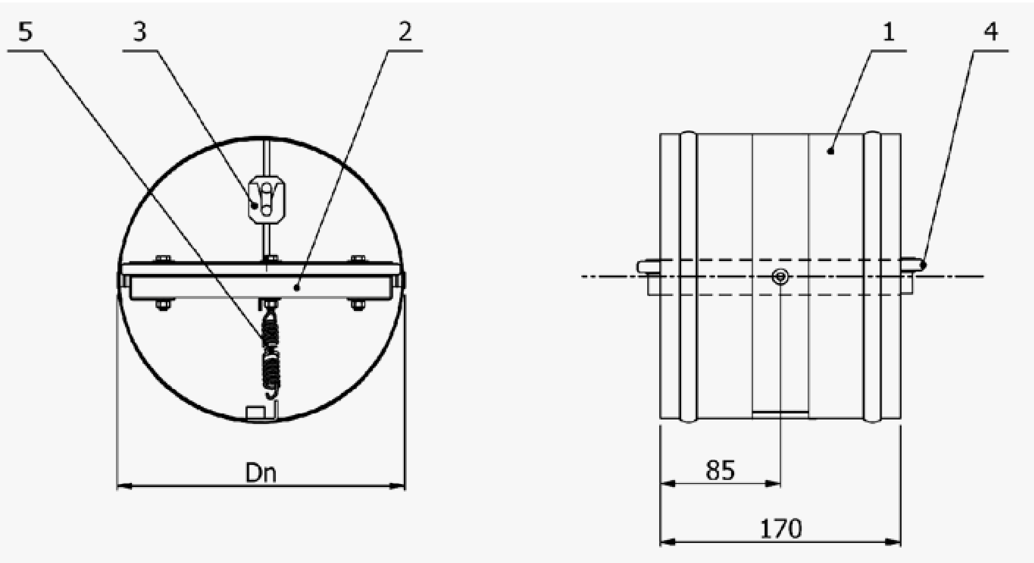



**Figure 4.49 Fire Damper Design (www.ventilation-system.com)**

*Noise from Mechanical Ventilation Systems:*

Noise from domestic ventilation systems is a poorly understood problem. Noise from mechanical ventilation systems, is a factor that is often not considered during their design. However, noise can be a significant constraint to the use of ventilation systems. Evidence from many countries indicates that when people find the noise from ventilation systems to be objectionable, they turn the ventilation down or off entirely, and suffer the adverse effects of poor air quality.

Installation of sound attenuators in ductwork may be used to reduce noise levels from equipment.
The average A-weighted sound pressure level in noise sensitive rooms such as bedrooms and living rooms should not exceed 30 dB LAeqT. In less sensitive rooms such as kitchens and bathrooms noise level should not exceed 35 dB LAeqT. Noise from a continuously running mechanical ventilation system on its minimum low rate should not normally exceed these levels.

*Noise Minimisation* - should be considered through the specification of quieter products, the correct design of ductwork and fittings and installation and mounting of units to manufacturers' instructions. Further Guidance is available in BS 8233 "Sound Insulation and Noise Reduction for Buildings Code of Practice".

Issues that can lead to excessive noise for occupants are noted under the following headings of design, installation, commissioning and maintenance.

Design issues:

- Centralised MEV or MVHR unit located in inappropriate place for break out or structure borne noise, e.g. bedroom cupboard or on rafters in loft above a bedroom.
- Poor ductwork layout – too many bends can lead to additional fan pressure requirement and regenerated noise
- Specification of flexible ductwork
- Inadequate attenuation of duct borne noise

Installation issues:

- Ductwork kinked or damaged inhibiting flow
- Ducts not connected up to supply or extract valves (which will inhibit flow and require higher fan setting)
- Wrong type of outlet fitted (using extract outlets for supply air can lead
- to regenerated noise)
- No anti-vibration mounts used
- Failure to ensure ductwork is clean when installed prior to commissioning
- Use of flexible ductwork where not specified

Commissioning issues:

- The standard practice of commissioning with non-compensating flow measurement devices means that flows are not generally well balanced or indeed correctly set.

Maintenance issues:

- Failure to replace filters at appropriate intervals (the market for replacement filters clearly indicates that very few users replace filters at appropriate intervals).

The Building Engineering Services Association, Guide to Good Practice Low Energy Ventilation for Residential Buildings, TR/35, Section 5 provides guidance on good practice for sizing and installation of ductwork.

The owner of the building should be provided with sufficient information about the centralized continuous mechanical extract ventilation system, its continuous operation and maintenance requirements so that it can be operated in an efficient and effective manner. A way of complying would be to provide a suitable set of operating and maintenance instructions on the centralised continuous mechanical extract ventilation system in a way the householder can understand. This is covered in Module 6 of this handbook.

# Unit 4.3 Lighting, ICT and Smart Technology

Lighting is an essential building service – it is also a major energy user in most buildings. As awareness of energy issues has increased in recent years, more emphasis has been placed on efficient light sources, controls, and the use of daylight. After space and DHW heating lighting is the next significant energy user in dwellings. An average household can attribute approximately 6% of its total energy consumption to lighting. In commercial buildings, lighting can in some cases account for up to 40% of total energy consumption, although this figure has reduced dramatically with the introduction of energy efficient lighting technologies (Replacing traditional legacy light sources with LED technology can reduce lighting energy consumption by 70% - CTV049 v2).

When considering compliance with Irish Building energy performance standards lighting needs to be considered in the context of both direct electrical energy consumption (and its impact on primary energy demand), daylighting and its contribution to internal gains. Within DEAP lighting electricity consumption is based on the proportion of fixed low energy lighting outlets installed, and on the contribution of daylight. For Irish dwellings a standard figure of 9.3 kWh/m$^2$/yr is assumed and a correction factor applied to account for the proportion of lighting provided by low energy lights (defined in Appendix L). Heat gains from lighting are calculated and added to the other gains.

<u>Lighting Energy Use</u>

The following factors effect light energy use:

- *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.
- *Controls:* including; occupancy sensors, daylight sensors, time switches, manual and automatic dimming devices, are used in lighting design projects to provide high quality energy efficient lighting systems.

It may be the role of the lighting 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 obtain information about different types of lighting as these play a huge part on the energy use and operational running costs of the building to the end user.

Just replacing existing inefficient light bulbs with modern energy efficient products can drastically reduce the energy usage in the building. However, factors such as making use of natural light, carrying out maintenance, and utilising energy efficient lighting controls are also important factors to consider.

Light Quality

Low lighting levels can cause discomfort for employees if they are insufficient to easily complete the tasks required. Glare and flicker can have an even more disruptive effect, including triggering headaches and eyestrain, especially for desk-based tasks. Lighting levels also have an impact on health and safety at work. This is especially pertinent for sectors where risk of accidents is high, such as the manufacturing, construction and catering industries. The quality of artificial lighting is one of the most important influences on performance in the work place. Some 80% of our sensory input at work comes through our eyes; compromising our vision is therefore not an option when considering energy efficiency measures (CTV049 v2).

Lighting levels

The demand for light varies according to the people who are in the space and what tasks they are completing. Table 1 below can be used as a guideline to determine required lighting levels.

| Illuminance (lux) | Activity | Area |
|---|---|---|
| 100 | Casual seeing | Corridors, changing rooms, stores |
| 150 | Some perception of detail | Loading bays, switch rooms, plant rooms |
| 200 | Continuously occupied | Foyers, entrance halls, dining rooms |
| 300 | Visual tasks easy/moderate | Libraries, sports halls, lecture theatres |
| 500 | Visual tasks moderate/difficult | General offices, kitchens, laboratories, retail |
| 750 | Visual tasks difficult | Drawing offices, meat inspection, chain stores |
| 1,000 | Visual tasks very difficult | General inspection, electronic assembly, paintwork, supermarkets |
| 1,500 | Visual tasks extremely difficult | Fine work and inspection, precision assembly |
| 2,000 | Visual tasks exceptionally difficult | Assembly of minute items, finished fabric inpsection |

**Table 5.0 Required lighting levels for various activities (Source: www.carbontrust.co.uk)**

Lighting Terminology:

1. *Luminous flux* (lumens; lm) - The amount of light produced by a lamp.
2. *Efficacy* (lumens per watt; lm/W) - The ratio of light emitted by a lamp to the power consumed by it, that is, lumens per Watt.
3. *Illuminance* (lux; lx) - The amount of light falling on an area, measured in lux. One lux is equal to one lumen per square metre.
4. *Colour temperature* (Kelvin; K) - Also known as colour appearance, the colour temperature is the colour of ‘white’ the light appears. It is measured in Kelvin, and ranges from 1800K (very warm, amber) to 8,000K (cool). 6500K is daylight. For general use these are: a warm white (2,600 to 2,700 degrees Kelvin), a medium white (3,000 to 3,500 degrees Kelvin) and a cool white (4,000 degrees

Kelvin). The colour temperature of a light can have a significant effect on the space: higher colour temperatures feel more clinical, whereas lower colour temperatures create a more ambient environment. Figure 4.50 below illustrates the colour temperature scale.

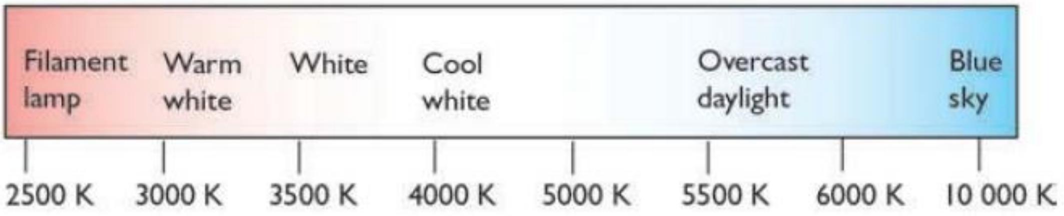



**Figure 4.50 Colour Temperature (Source: www.bsria.co.uk)**

**5.** *Colour Rendering Index* (CRI) - The colour rendering index determines how accurately colours are represented by a light source. Good colour rendering equates to a high CRI (CRI 100 = daylight), poor colour rendering equates to low CRI. A practical example of CRI is the low colour rendering of street lighting. Conventional low pressure sodium street lighting has a low CRI, meaning that even bright red objects appear a dull brown or yellow colour. Examples of the effect of different CRI (Ra) levels on the appearance of various colours is shown in figure 2 below.

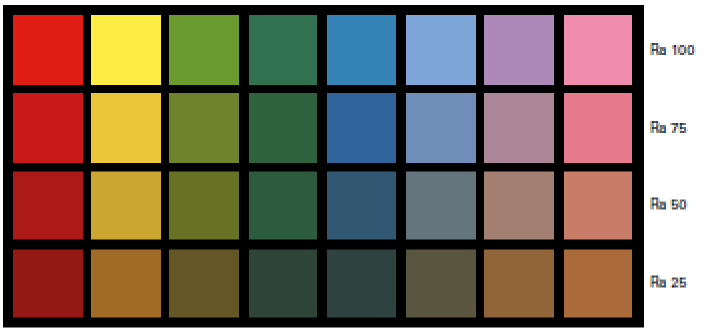



**Figure 4.51 Colour Rendering Index (Source: www.carbontrust.co.uk)**

6. *Glare* - is caused by extreme contrasts in luminance – for example extremely bright objects in the same vicinity as extremely dark objects. Glare can take two basic forms: discomfort glare and disability glare.
7. *Lamps* - Light sources are called lamps, rather than light bulbs, and each lamp type has different characteristics which affect where and when they should be used. The most important three characteristics of lamps are the efficacy (how efficient the lamp is), its expected lifetime and its colour rendering ability.

8. *Luminaire* - Light fittings, or luminaires, provide a housing and electrical connections for one or more electric lamps. They usually incorporate reflectors,

lenses or diffusers to direct light to where it is needed, and to control glare. Most types of lamp require a ballast or control gear, and this is generally contained within the luminaire.

Lamp Types

Artificial light can be produced in different ways:

1. Thermal Radiation (Incandescent lamps)
   Where light is created by passing an electrical current through a wire so that it glows white hot (e.g. Tungsten).
2. Discharge
   The generation of light occurs within a gas filled envelope that is driven by an electric circuit (e.g. Fluorescent).
3. Semiconductor
4. Light is generated at the junction of a semi-conductor (e.g. LED).

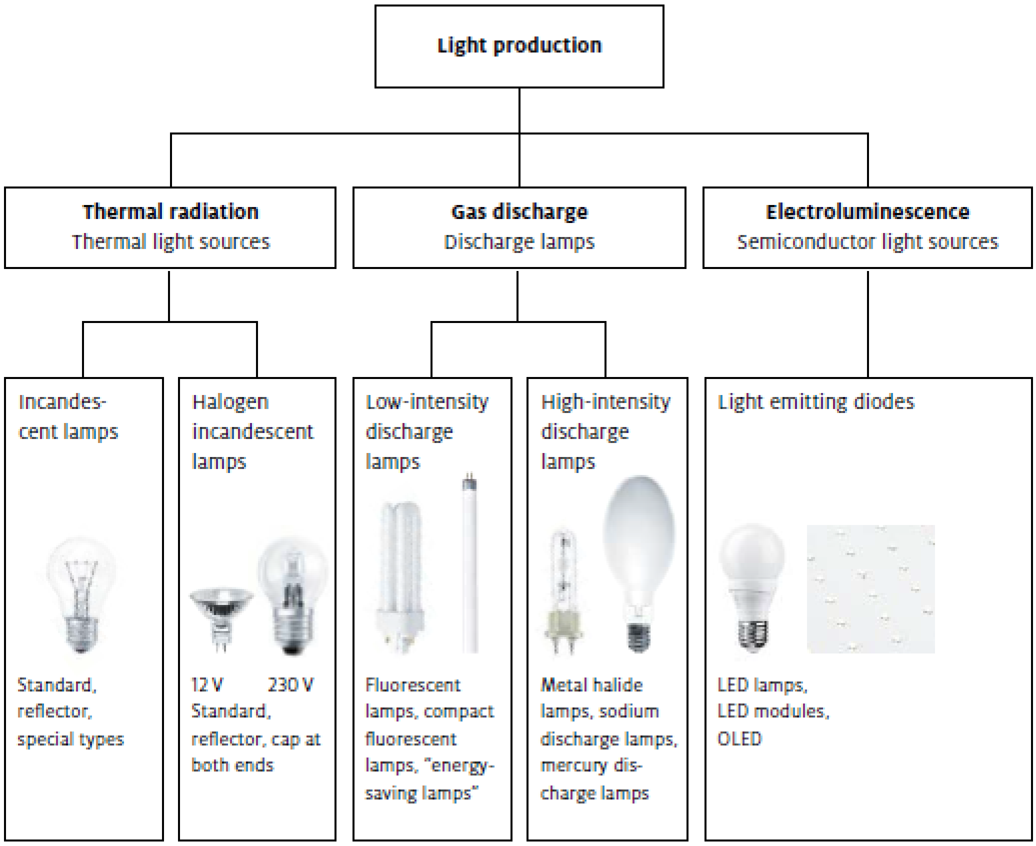



**Figure 4.52 Light Production (Source: www.zumtobel.com)**

1. Incandescent Tungsten Filament Lamps

Thomas Alva Edison invented the incandescent lamp in 1879. Light is produced when an electric current is passed through a tungsten filament causing it to glow white-hot. Incandescent tungsten filament lamps (figure 4) are currently being phased out of the market because they are inefficient, generate unwanted heat and are expensive to run. These lamps have a short lifetime but do offer good colour rendering. They are also – in the most part – easily dimmed.

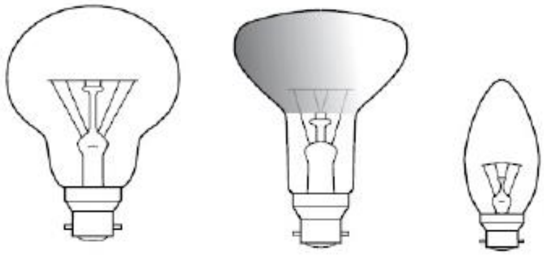


***Figure 4.53 Incandescent Tungsten Filament Lamps (*****Source: www.carbontrust.co.uk)**

Application of Incandescent tungsten filament Lamps: Traditional 'legacy' light source used extensively throughout homes and businesses. Due to inefficiency, incandescent tungsten lamps and halogen lamps are being phased out, as stipulated by EU Directive. More efficient alternatives include compact fluorescent lamps with built-in electronic ballasts or LED lamps.

Operational Characteristics of Incandescent tungsten filament Lamps:

- CCT (K) 2500-3000
- CRI (Ra) 100
- Efficacy (lm/W) 5-20
- Lamp Life (hours) 1000

2. Halogen Incandescent Lamps

Current flows through a filament and heats it up in exactly the same way as in an incandescent lamp. This is why these lamps release relatively large amounts of heat. The halogen gas and the tungsten filament produces a halogen cycle chemical reaction which re-deposits evaporated tungsten back onto the filament, increasing its life and maintaining the clarity of the envelope. The efficacy is increased slightly through this process, though all other key characteristics remain the same. Low-voltage lamps are very compact and therefore ideally suitable for directing light precisely, but they do need a transformer.

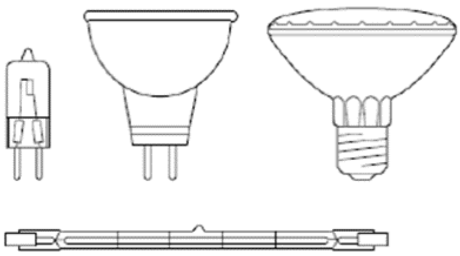


***Figure 4.54 Tungsten Halogen Incandescent Lamps (*****Source: www.carbontrust.co.uk)**

Application of Halogen Incandescent Lamps: Widely used in hospitality, retail, display areas. Due to European legislation, only the most energy-efficient versions of this lamp group are permitted. More efficient alternatives include compact fluorescent lamps with built-in electronic ballasts or LED lamps.

Operational Characteristics of Halogen Incandescent Lamps:

- CCT (K) 3200
- CRI (Ra) 100
- Efficacy (lm/W) 15-24
- Lamp Life (hours) 2000

3. Discharge Lamps - Tubular fluorescent lamps

A low pressure mercury-vapour gas-discharge lamp that uses fluorescence to produce visible light. An electric current in the gas excites mercury vapour and produces short-wave ultraviolet light that causes a phosphor coating on the inside of the bulb to emit photons.

The spectral power distribution is improved through use of multiple phosphors. These lamps need ignitors and current limiting; these functions are combined in an electronic ballast. Three types of fluorescent tube exist: T12, T8 and T5, increasing in efficacy as they decrease in diameter.

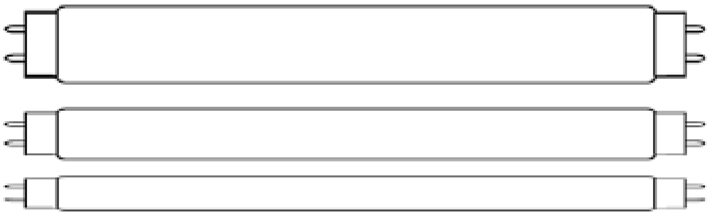


***Figure 4.55 Tubular fluorescent lamps (*****Source: www.carbontrust.co.uk)**

Application of Tubular fluorescent lamps: Commonly used in offices, commercial buildings & low bay industrial buildings.

Operational Characteristics of Tubular fluorescent lamps

- CCT (K) 2700-6500
- CRI (Ra) >80
- Efficacy (lm/W) 60-105
- Lamp Life (hours) 10000-20000

4. Discharge Lamps - Compact fluorescent lamps (CFLs)

Designed to replace incandescent lamps; some types of CFLs fit into light fixtures formerly used for incandescent lamps. Most require a few minutes of warm-up time to reach full output. Integrated lamps combine the tube and ballast in a single unit and non-integrated

CFLs have the ballast permanently installed in the luminaire.

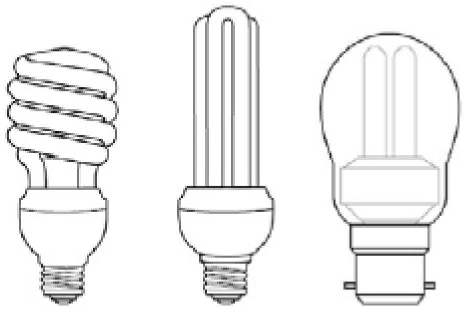


*Figure 4.56 Compact fluorescent lamps (***Source: [www.carbontrust.co.uk](www.carbontrust.co.uk))**

Application of Compact fluorescent lamps: Commonly used in offices, commercial buildings & low bay industrial buildings.
Operational Characteristics of Compact fluorescent lamps

- CCT (K) 2700-4000
- CRI (Ra) >85
- Efficacy (lm/W) 45-80
- Lamp Life (hours) 6000-15000

5. Light Emitting Diodes (LEDs)

Over the last ten years LEDs have become the light source of choice, providing illumination at a fraction of the cost of traditional sources. LEDs have the highest efficacy and lamp life of all widely used lighting types, are easy to control, and have no warm up period. The cost of LEDs has reduced significantly in recent years and technological developments have improved light output, efficacy and reliability.

As can be seen in figure 4.57 below, LED lights generally integrate all components into a sealed single luminaire. The LED chip is often mounted directly on to the heat sink, with the LED driver providing the power supply to the chip. The lens and housing then focuses the light output for the required application.

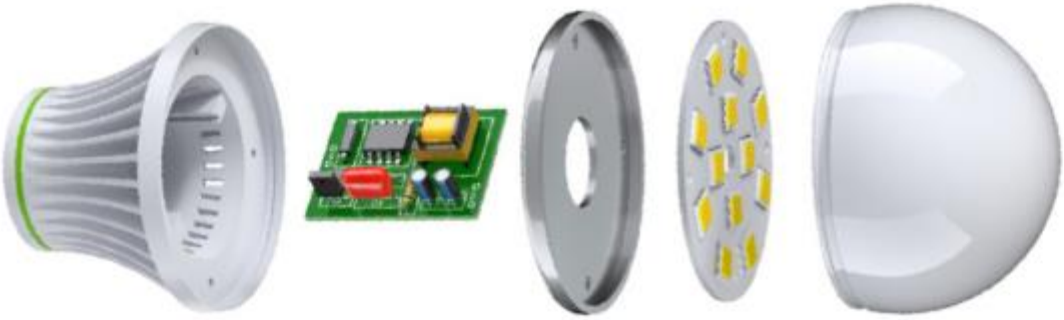


**Figure 4.57 Components of LED Lighting (Source: www.carbontrust.co.uk)**

Application of LEDs:

Due to their high efficiency rating and long life, LED lighting is now considered the light source of choice for the vast majority of sectors and applications.

Operational Characteristics of LEDs:

- CCT (K) 2700-8000
- CRI (Ra) 65-97
- Efficacy (lm/W) 70-150+
- Lamp Life (hours) 25000-75000+

The table below outlines the relative performance characteristics of the lamp technologies described above. It should be noted that in order to comply with NZEB standards residential lighting have to conform to the following specification:

- All lighting to be provided by low energy lighting.
- A+ Rated Bulbs with efficacy or 94 lumen/W or greater.

| | Lamp Life | Colour Temperature | Colour Rendering | Efficacy |
|---|---|---|---|---|
| Standard Incandescent | 2,000 - 3,000 Hours | 2,500 - 3,000K | 100 Ra | 5 - 20 lm/W |
| Tungsten Halogen | 2,000 Hours | 3,200K | 100 Ra | 15 - 24 lm/W |
| Tubular Fluorescent | 10,000 - 12,000 Hours | 2,700 - 6,500K | >85 Ra | 60 - 105 lm/W |
| Compact Fluorescent | 6,000 - 15,000 Hours | 2,700 - 4000K | > 85 Ra | 45 - 80 lm /W |
| LED | 25,000 - 75,000+ Hours | 2,700 - 8,000K | 65 - 97 Ra | 70 - 150+ lm/W |

**Table 4.1 Relative performance of light sources (Source: www.carbontrust.co.uk)**

## Energy Labelling of Lamps

A household appliance energy consumption labelling directive was set out by the European Council in September 1992. The EU Directive 92/75/EC was replaced by Directive 2010/30/EU[3] which has applied since 31 July 2011. This directive requires white goods including light bulb packaging to clearly display an EU Energy Label when offered for sale. The energy efficiency of the Lamp is rated in terms of a set of energy efficiency classes from A to G on the label, A being the most energy efficient, G the least efficient.

In an attempt to keep up with advances in energy efficiency, A+, A++ grades were introduced for various products. Since 2010, a new type of label exists that makes use of pictograms rather than words, to allow manufacturers to use a single label for products sold in different countries. The labels also give other useful information to the customer as they choose between various models. This information should also be given in catalogues and included by internet retailers on their websites.

Every label of light bulbs and tubes (including incandescent light bulbs, fluorescent lamps, LED lamps) now contains the following information:

- The energy efficiency category from A+++ to G.
- The luminous flux of the bulb in lumens.
- The electricity consumption of the lamp in watts.
- The average lamp life length in hours.

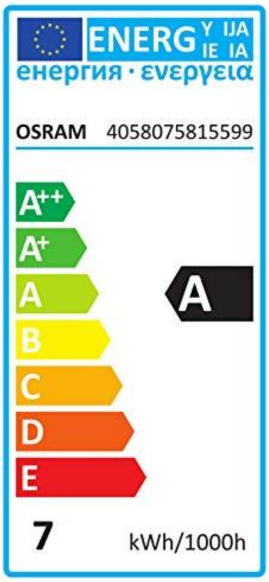



**Figure 4.58 Example of Energy Label (Source: OSRAM)**

Lighting Controls

Put simply, switching lights off or dimming them saves energy – not only lighting energy, but also the energy used by cooling systems to reject heat from lighting.

Providing appropriate controls can help building owners and occupiers reduce energy bills, in addition to giving better control over their environment. No matter how efficient a luminaire is, if its use is uncontrolled there will still be waste, avoidable costs and unnecessary $CO_2$ emissions.

Lighting controls are the key to managing the use of light and to ensure that the right light is provided in the right place and at the right time.

Artificial lighting is often manually switched off or dimmed according to the needs of a task or activity, when there is sufficient daylight or when an area is unoccupied. Properly applied lighting controls facilitate this and ensure that there is no unnecessary use of electricity, eliminating the risk of human error (e.g. forgetting to switch off the lights).

Automatic lighting controls generally react to three main stimuli:

1. Movement sensor – occupancy control
2. Time clock – timed schedule
3. Light sensor – daylight harvesting (dimming).

There are additional functions in some lighting control systems but these are the principle techniques for reducing electricity use. Automated controls should always be combined with manual override options, as we all like to be able to make decisions for ourselves.

These user controls or manual override options must be easily understood and conveniently located. Wherever there might be doubt then clear labelling should be employed. The principle of combining user controls with automatic management is to have an environment where users switch lighting on but it is switched off automatically when it is no longer required.

There is clear evidence that giving people more control of their lighting conditions also contributes to their perception of comfort. And in those buildings where there is a high ratio of local switches to lights less electricity is used. Comfort and lighting energy efficiency have been shown to go hand-in-hand.

Lighting controls can make huge reductions in energy use, usually between 30% and 50% in a typical office environment (www.carbontrust.co.uk).

*1. Movement Sensor – occupancy control*

Motion sensors monitor occupancy. They rely on three technologies to detect presence:

1. Passive infra red – PIR
2. Ultrasonic detection
3. Microwave detection.

PIR sensors are the most common type used in office spaces because they offer a good compromise between value and sensitivity. They can generally monitor smaller areas than the other two methods, which can be beneficial.

The location of a motion sensor is important; it must be able to ‘see’ the activity that requires the light but not beyond that area. Many sensors do not work effectively because people passing close by trigger.

**Figure 4.59: Some typical motion sensors (Source: [www.carbontrust.co.uk](www.carbontrust.co.uk))**

*2. Time control*

Lights can be set to come on and go off at set times. 24-hour and 7-day timers are available. Whilst timed operation can be an effective method to control lighting for buildings where occupancy levels are predictable (e.g. 9am to 6pm working day). Time control doesn’t fit well with, flexible working practices as there needs to be a very large number of local overrides that are easily found and used. Time control does, however, remain vital in exterior lighting so lights are only on when it is dark outside.

**Figure 4.60: Illustrating the effect of time controls (Source: www.carbontrust.co.uk)**

*3. Light Sensors*

Light sensors can be used in spaces to provide dimming or switching control that allows the integration of artificial and natural lighting. As daylight increases the sensor automatically dims or turns off the artificial light. Dimming controls can be used to deliver the correct light level whenever the lights are switched on. This light level tuning can be carried out either at initial occupancy, or periodically during the life of the building.

**Figure 4.61 Light Sensor (Source: www.zumtobel.com)**

Centralised lighting control:
Various systems are available which enable functions such as time settings and light level tuning to be programmed centrally. Programming can occur at circuit level, or if addressable luminaires are used, at the individual luminaire level. One of the most commonly used protocols for lighting control is DALI (Digital Addressable Lighting Interface). Such systems can provide additional functions such as monitoring of emergency luminaires, and monitoring of lamp and ballast failures.


**Figure 4.62 A digital interface for a lighting control system (Image courtesy of ERCO - Source: www.bsria.co.uk)**

## Summary

- The majority of energy used in residential buildings is used for space heating and water heating.
- Space heating, water heating and lighting account for over 90% of energy usage, with space heating accounting for 60% of that total.
- The amount of energy required for space heating of buildings is affected by:
    - 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
- As stated in the second schedule of the TGD Part L:
    - A building shall be designed and constructed so as to ensure that the energy performance of the building is such as to limit the amount of energy required for the operation of the building and the amount of carbon dioxide (CO2) emissions associated with this energy use insofar as is reasonably practicable.
- All heating equipment should be sized correctly and located centrally if possible as to reduce the length of pipe/ductwork and reduce distribution losses.
- All hot water storage units, distribution pipes and ducting should be continuously insulated to prevent condensation and heat loss.
- 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).
- Controlled Ventilation is used to:

- Remove unpleasant smells and odours.
- Remove excess moisture (steam) and reduce risk of condensation.
- 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 and better comfort levels.
- Comply with the building regulations TGD Part F and DEAP.

- 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 combination of both. It is important to consider heat recovery when installing ventilation systems.
- In TGD Part F – Ventilation Guidelines are provided for background, purge and extract ventilation levels and minimum levels of ventilation rates.
- 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.
- Automatic lighting controls generally react to three main stimuli:
    - Movement sensor – occupancy control
    - Time clock – timed schedule
    - Light sensor – daylight harvesting (dimming).

## Useful Links

Energy Savings Trust: Good Practice Guide 302: Controls for domestic central heating and hot water – guidance for specifiers and installers: https://www.cibse.org/getmedia/1c033bb2-0eba-418c-8c83-3da4fe0cb236/GPG302-Controls-for-Domestic-Central-Heating-and-Hot-Water.pdf.aspx

Carbon Trust: Heating Control: Maximising comfort, minimising energy consumption: https://www.carbontrust.com/media/10361/ctg065_heating_control.pdf

Department of Housing Planning and Local Government; The Irish Building Regulations Technical Guidance Document Part L (2018); Consultation: https://www.housing.gov.ie/sites/default/files/public-consultation/files/technical_guidance_document_l_-_dwellings_2018_for_public_consultation.pdf

BSRIA; Illustrated Guide to Electrical Building Services 3rd Edition (BG 32/2014): https://www.bsria.co.uk/information-membership/bookshop/publication/illustrated-guide-to-electrical-building-services-3rd-edition/

Department of Housing Planning and Local Government; Installation and Commissioning of Ventilation Systems for Dwellings - Achieving Compliance with Part F (2018) https://www.housing.gov.ie/sites/default/files/public-consultation/files/installation_and_commissioning_of_ventilation_systems_for_dwellings_achieving_compliance_with_part_f.pdf

Department of Housing Planning and Local Government; The Irish Building Regulations Technical Guidance Document Part F (2018); Consultation https://www.housing.gov.ie/sites/default/files/public-consultation/files/technical_guidance_document_f-_ventilation_2018_for_public_consultation.pdf

Sustainable Energy Authority of Ireland SEAI Home Owners Guide to Ventilation: https://www.seai.ie/resources/publications/Homeowners-Guide-To-Ventilation.pdf

Energy Savings Trust: Energy efficient ventilation in dwellings – a guide for specifiers (2006): https://www.envirovent.com/images/uploads/files/GPG268-Energy-efficient-ventilation-in-dwellings.pdf

CIBSE: DETR Environment Transport Regions: Good Practice Guide 257; Energy-efficient mechanical ventilation systems: https://www.cibse.org/getmedia/d9c6311e-3191-4d93-91f3-79f80824a951/GPG257-Energy-Efficient-Mechanical-Ventilation-Systems-1998.pdf.aspx

Train Energy Project: Module 4 Ventilation: https://tippenergy.ie/wp-content/uploads/2011/09/Module-4-Ventilation.pdf

Department of Housing Planning and Local Government; The Irish Building Regulations Technical Guidance Document (2017) Part B Fire Safety Dwelling Houses Volume 2: https://www.iaosb.com/technical_guidance_document_b-_fire_safety_-_volume_2_dwelling_houses-1.pdf

Department of Housing Planning and Local Government; The Irish Building Regulations Technical Guidance Document (2014) Part E Sound: https://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad%2C39956%2Cen.pdf

Carbon Trust: Lighting; Energy efficient lighting advice for your organisation, including guidance on energy-saving LED lighting (2017). https://www.carbontrust.com/resources/guides/energy-efficiency/lighting/

Zumtobel: The Lighting handbook; Your choice reference book (2018) https://www.zumtobel.com/PDB/teaser/EN/lichthandbuch.pdf

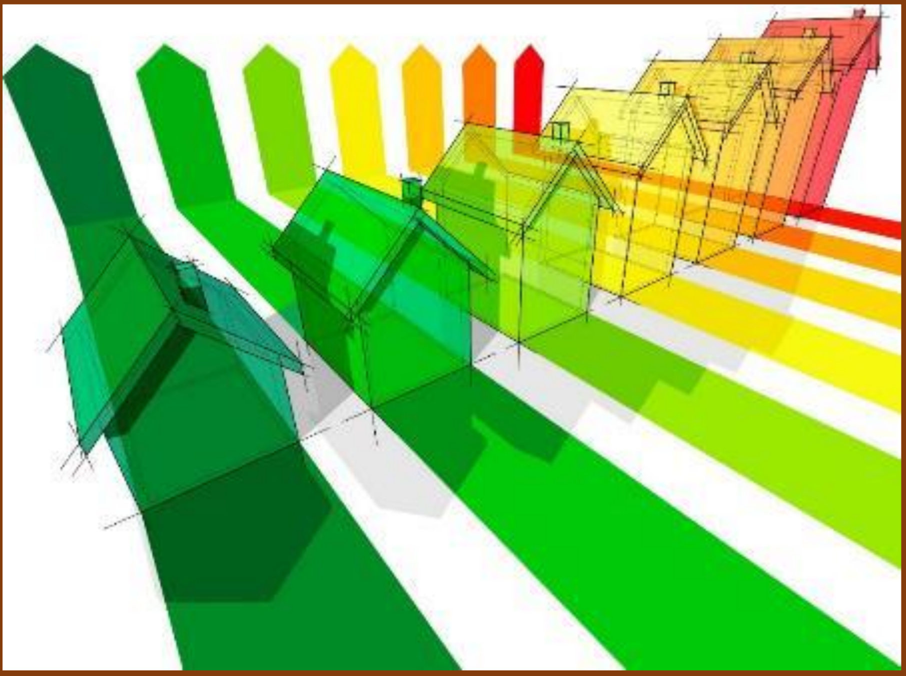
I.S. EN 13141-4:20042010 Ventilation for buildings. Performance testing of components/products for residential ventilation. Fans used in residential ventilation systems

I.S. EN 13141-7:2004 2011 Ventilation for buildings. Performance testing of components/products for residential ventilation. Performance testing of a mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for single family dwellings

BS 5250: 20022011+A12016 Code of practice for control of condensation in buildings

BS 8233:2014 Sound insulation and noise reduction for buildings Code of Practice.

# Module 5



**RENEWABLE ENERGY, PHOTO-VOLTAICS, SMART METERING AND ELECTRIC VEHICLES**

# Module 5: Renewable Energy, Smart Metering and Electric Vehicles

In this module we will outline the Renewable Energy Technologies, including Heat Pumps, Wind, Biomass systems and Photo-Voltaic, which can be utilised in NZEB buildings. It also provides an overview of Smart Metering and Electric Vehicles in relation to an NZEB dwelling.

## Unit 5.1 Renewable Energy

The nearly zero or very low amount of energy required in a building should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby (Department of Housing, Planning, Community and Local Government, TGD L, 2017). The use of renewables will impact on both the Energy Performance Coefficient (EPC) and the Carbon Performance Coefficient (CPC) of the building.

In order to achieve the acceptable primary energy consumption rate for a nearly zero energy dwelling, the Maximum Permitted Energy Performance Coefficient (MPEPC) for a nearly zero energy dwelling is 0.30.
The Maximum Permitted Carbon Performance Coefficient (MPCPC) for a nearly zero energy dwelling is 0.35.

Remember, renewable energy which is produced on site through relevant technologies does not contribute to the total building delivered/primary energy. As renewable energy technologies generally are characterised by zero, or greatly reduced, $CO_2$ emissions, the buildings EPC and CPC are reduced by the extent that they replace traditional fossil fuels. Compliance with the renewable energy contribution requirements is carried out using DEAP and as the reference dwelling is not affected by the incorporation of these technologies in a dwelling being assessed, it has the effect of making it easier to achieve compliance.

Solar Photovoltaic (PV), wind, solar thermal, biomass, combined heat and power (CHP) or heat pumps, can be utilised to provide the 20% (or 10%) requirement for energy provision from renewable sources. For most buildings, it is likely that the most practical option will be a combination of PV and heat pumps.

### Energy Definitions

As we are considering the production and use of energy from renewables it is important to identify the critical terminology and definitions which arise

Energy:
Energy is the capacity to do work, the scientific unit of energy is the Joule (J). We measure electrical energy in Kilo Watt Hours (KWh), where 1kWh = 3,600,000Joules. Heat energy from e.g. heat pumps, is also measured in kWh

Energy (kWh) = Power (kW) x Time (h)

Energy cannot be created or destroyed, only transferred from one form to another. Energy can be stored, for example electricity can be stored in a battery.

Power:

Power is the rate of doing work, or the rate of using energy. The scientific unit of energy is the Watt (1 Watt = 1J/S). Power also called load or demand is measured in watts (W) or kilo Watts (kW) where 1kW = 1000W. For example designers may specify a 3kW Photovoltaic system for a building.

Fossil Fuel Energy

Fuels such as Coal, Oil, Peat, & Gas that were formed by the decomposition and pressurisation of prehistoric organisms over millions of years. Fossil fuel energy can also be termed non-renewable energy. Fossil hydrocarbon based fuels have to date been our traditional source of energy, these fuels give off harmful pollutants when burnt.

Renewable Energy

Comes from sources that are replenishable. Sources of renewable energy include solar thermal, solar photovoltaic, wind, bioenergy, hydro, wave, tidal, & geothermal energy.

Low Carbon Technologies

Low carbon technologies are not completely renewable as they may still have carbon emissions associated with it albeit much smaller than conventional fossil fuel burning technologies. Heat pump and combined heat and power (CHP) are two low carbon technologies that are used for heating buildings in order to reduce the operational costs and $CO_2$ emissions. Heat pump and CHP technologies can be utilised to provide the 20% (or 10%) requirement for energy provision from renewable sources. Electrical heat pumps use grid electricity to extract heat from a heat source. Most CHP units are fuelled by mains gas and generate heat and electricity simultaneously, although biomass CHP are also available.

Primary Energy

Primary energy is a term applied to the energy “contained” within in a resource. Primary energy is energy that has not been subjected to any conversion or transformation process. Primary energy is energy contained in raw fuels and the resource energy of renewable energy sources.

Delivered energy

Delivered energy is the energy content as it is received by the consumer. For example, the amount of electricity delivered to the consumer after generation and distribution losses.

Conversion of Energy

Energy conversion is the process of transforming energy from one form into another. There will always be some waste (heat). For example a solar cell converts solar radiation into electrical energy.

DRAFT

Energy Efficiency

Very few devices can transform energy from one form into another without wasting some energy in the process. The ratio of useful power output to power input is the efficiency of that device, machine or engine. Efficiency of conversion can be expressed as a percentage (boilers) or as a coefficient (heat pumps).

- % Efficiency = (output energy/input energy) x 100
- Coefficient of performance (COP) = (output energy/input energy)

## Overview of Renewable and Low Carbon Technologies

In order to comply with NZEB standards, all new buildings will be required to provide 20% (or 10%) requirement for energy provision from renewable sources. The compliant renewable technologies are as follows:

1. Solar Photovoltaic
2. Heat pump
3. Solar Thermal
4. Wind
5. CHP
6. Biomass boiler

### 1. Solar Photovoltaic (PV)

Photovoltaic (PV) installations convert sunlight into dc electricity. PV electricity generation uses the energy in the light from the sun to causes an electrical current to flow between different atomic energy levels in specially processed materials. Solar PV, like solar thermal, is a truly intermittent renewable energy technology and requires the user to obtain electricity from an alternative source during the night when it cannot generate electricity. Alternatively a battery can be used to provide back-up, where energy generated can be stored during the day, for use at night.

The Photovoltaic Effect:

This is the basic process by which a PV cell converts solar radiation into electricity. The most common PV devices at present are based on silicon. In crystalline silicon cells a p-n junction (‘p’ for positive, ‘n’ for negative) is formed (figure 5.1) by diffusing phosphorous into the silicon and introducing a small quantity of boron. This results in an electric field being formed. When photons, ‘particles’ of solar energy, are absorbed by a PV cell, electrons under the influence of the field move out towards the surface. This flow or current is ‘harnessed’ by an external circuit with a load.

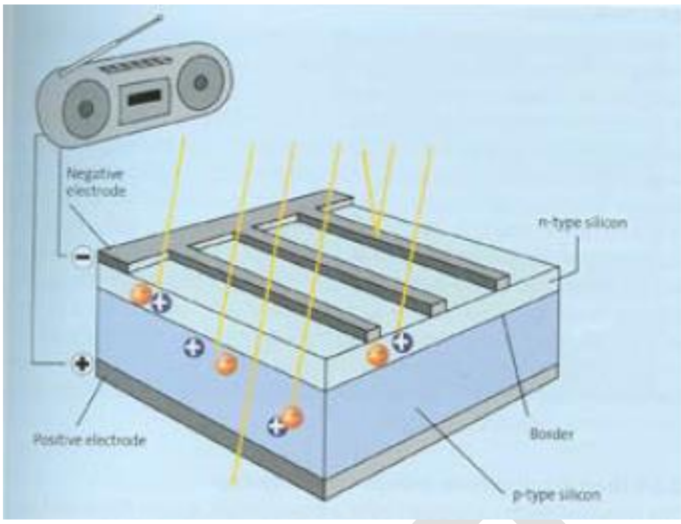



**Figure 5.1 Photovoltaic Effect (Source: www.seai.ie)**

PVs respond to both direct and diffuse radiation (figure 5.2) and their output increases with increasing sunshine or, more technically, irradiance, or solar “power”, which is measured in W/m$^2$.

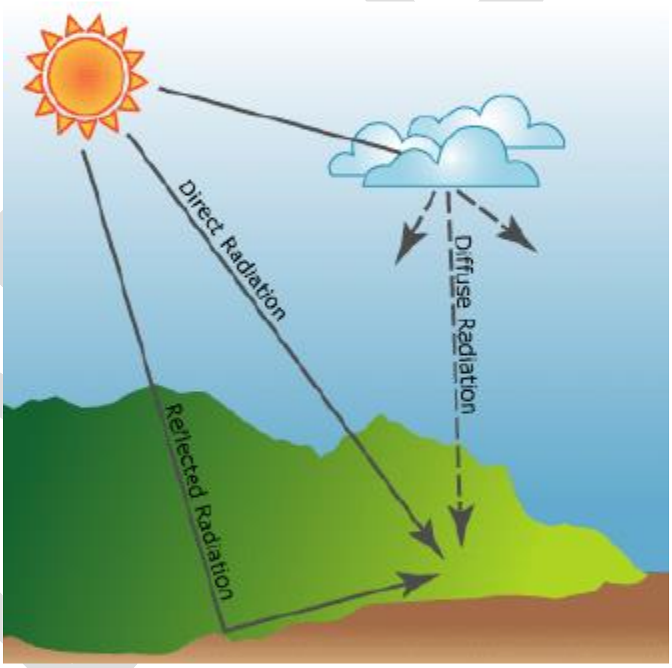



**Figure 5.2 Direct and diffuseradiation (Source: www.seai.ie)**

Efficiencies of Common Types of PV:
The original Solar Cell was a 1% efficient Selenium based cell invented by Charles Edgar Fritts in 1883. The first Silicon based Solar cells were invented in the 1950s by Scientists in Bell Labs and had an efficiency of approximately 6%. Today theoretical maximum efficiencies are about 30%. Actual efficiencies are improving. In solar car races, PVs with efficiencies of about 25% are being used. Novel approaches such as producing multi-junction cells, which use a wider part of the solar spectrum, are another aspect of a drive to increase efficiency. Table 5.1 shows the typical

efficiencies of common types of PV cell. Efficiencies are determined under standard testing conditions (STC: 25ºC, 1,000 W/$m^2$).

| Cell material | Module efficiency [1] | Surface area needed for 1 kWp |
|---|---|---|
| Mono-Si | 13-15% | c.7 m2 |
| Poly-Si | 12-14% | c.8 m2 |
| Thin-film (CIS) | 10-11% | c.10 m2 |

**Table 5.1 Typical PV efficiencies (source: www.seai.ie)**

Configuration of Solar PV Systems:
Solar cells, which produce low voltage direct current (DC), are joined in series to form a solar module of a higher, more useful voltage. Solar modules are connected together to form solar panels. Solar panels that are connected together are often referred to as an array. An array is a generic term for any grouping of panels connected in series and/or parallel. Figure 5.3 shows the build up of a solar PV array from cell to module to panel to final array.

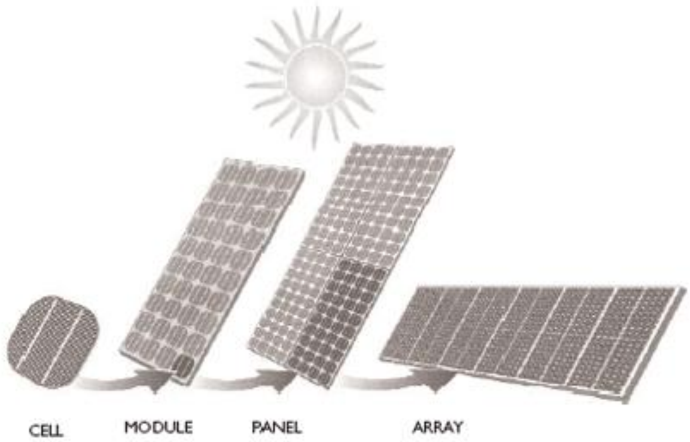



**Figure 5.3 Build-up of Cell-Module-Panel-Array (source: www.seai.ie)**

Power from the array goes to a Power Conditioning Unit (PCU). PCU is a general term for the device (or devices) which converts the low voltage DC electrical output from the PV array into higher voltage synchronised AC electricity for use in the building. The principle component of the PCU is the inverter. Inverters are the devices to convert the DC electricity generated by the PV modules into AC electricity for connection to the consumer load and grid. The PCU may also contain associated control and protection equipment required under ETCI regulation. The AC output from the PCU goes to a distribution board in the building or to the grid if supply exceeds demand (figure 5.4).

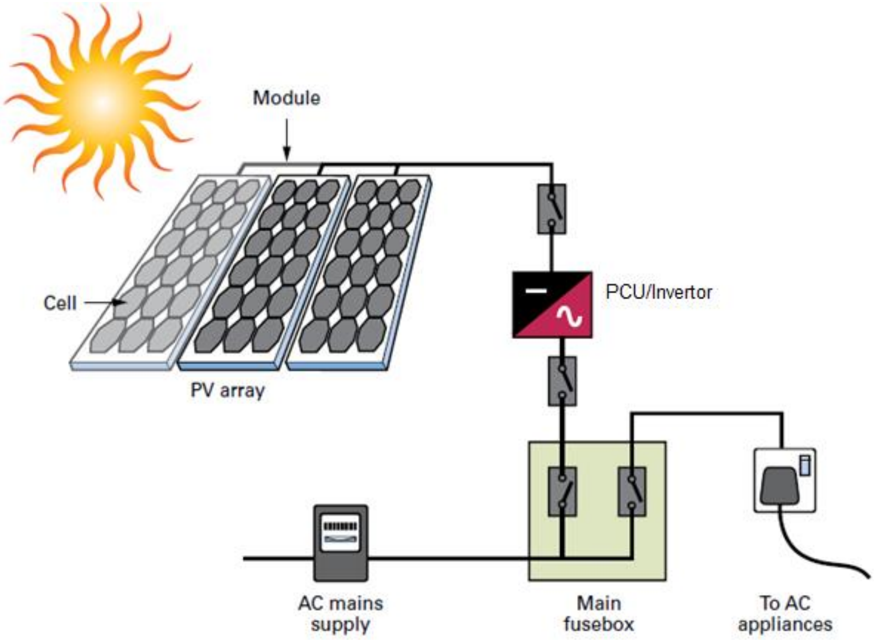



**Figure 5.4 Typical grid connected PV System Configuration (Source: www.carbontrust.co.uk)**

Location and orientation:

Solar PV systems function best when positioned in an optimum location. The maximum annual incident solar radiation (and hence output) is achieved at an orientation of due south and at a tilt from the horizontal of 30º. Slight deviations from these optimums will not have a significant effect on the solar availability. An encouraging aspect is that the total annual output is of the order of 95% of maximum over a surprisingly wide range of orientations and tilts. Table 5.2 below can be used for estimating available solar radiation in Ireland.

| Tilt of Collector | Orientation of Collector | | | | |
|---|---|---|---|---|---|
| | S | SE/SW | E/W | NE/NW | N |
| Horizontal | 963 | 963 | 963 | 963 | 963 |
| 15º | 1036 | 1005 | 929 | 848 | 813 |
| 30º | 1074 | 1021 | 886 | 736 | 676 |
| 45º | 1072 | 1005 | 837 | 644 | 556 |
| 60º | 1027 | 956 | 778 | 574 | 463 |
| 75º | 942 | 879 | 708 | 515 | 416 |
| Vertical | 822 | 773 | 628 | 461 | 380 |

**Table 5.2 Irelands Average Annual Solar Radiation ($kWh/m^2$) (Source: www.seai.ie)**

Estimating the Annual Output of a Solar PV Array:

The output of a solar PV array can be approximated using the following formula:

Output (kWh) = 0.8 x kWp x S x Zpv

*Where:*

*KWp = installed peak power*

*S = annual solar radiation (from Table 2.2)*

*Zpv = over shading factor (typically a value of 1 where placed on a roof with no shading)*

Worked example:
For an array of 8 monocrystalline silicon panels (approx. 1.3 m2 per panel) each with a peak power of 170 Wp, mounted on a roof with a 45° pitch facing directly south with no overshading:

Total installed capacity:
0.170 x 8 = 1.36 kWp

The annual output would be:
0.8 x 1.36 x 1,072 x 1 = 1,166 kWh

In July 2018 the SEAI published a code of practice for installers of domestic solar photovoltaic systems that should be followed. This is available at: https://www.seai.ie/resources/publications/Code-of-Practice-Solar-PV-Grant.pdf

## 2. Heat Pumps

A Heat pump is a device that takes heat from a source at a certain temperature and releases it at a higher temperature. The main components of a heat pump system are the collector, the heat pump, and the distribution system. The heat pump extracts heat energy from low temperature sources (e.g. air, ground, water), and upgrades it to a higher temperature, and releases it where it is required for space and water heating. The efficiency of a heat pump is represented as its coefficient of performance (CoP) and is based on the number of units of heat energy which can be obtained per unit of electricity. Heat pumps can also be used to provide cooling.

Heat Pump efficiency is the ratio of the heating or cooling delivered to the electrical energy required to operate the system using a refrigerant.

The ratios are given in two ways:

1. Coefficient of Performance (COP) – the ratio of heating delivered to the electrical energy input
2. Energy Efficiency Ratio (EER) – the ratio of cooling delivered to the electrical energy input

The higher the COP or EER, the greater is the efficiency of the heating or cooling system. COP data is available on the appliance certificate or energy label and should be provided by the manufacturer.

Seasonal Coefficient of Performance or Seasonal Performance Factor (SCOP or SPF) is also often used when referring to Heat Pumps. This is the ratio of heating delivered to the electrical energy input on an annual basis. While the COP reflects the efficiency of the heat pump under relevant laboratory testing conditions the SCOP/SPF looks at the annual efficiency of the heat pump and takes in account the variation of the outdoor temperature throughout the year. Normally the COP is greater than the SCOP/SPF, but the lather is more of a true reflection of the efficiency of the heat pump.

There are a few important things to be considered when designing the system and sizing the heat pump, in accordance with NSAI recommendations the system "should be designed and constructed in accordance with the Building Regulations, Irish Standards, the EU Energy Performance of Buildings Directive (EPBD) and the Building Energy Rating scheme (BER)":
Heat loss calculations in accordance with NSAI SR50-1 should be done for the proposed dwelling, either for new, renovation or retrofit project and the heat pump should be sized in accordance with this and in-line with current recommendations from SEAI regarding "Heat Pump Tool for DEAP 2016".

Almost all heat pumps are based on a vapour compression cycle as outlined in figure 5.12 below.

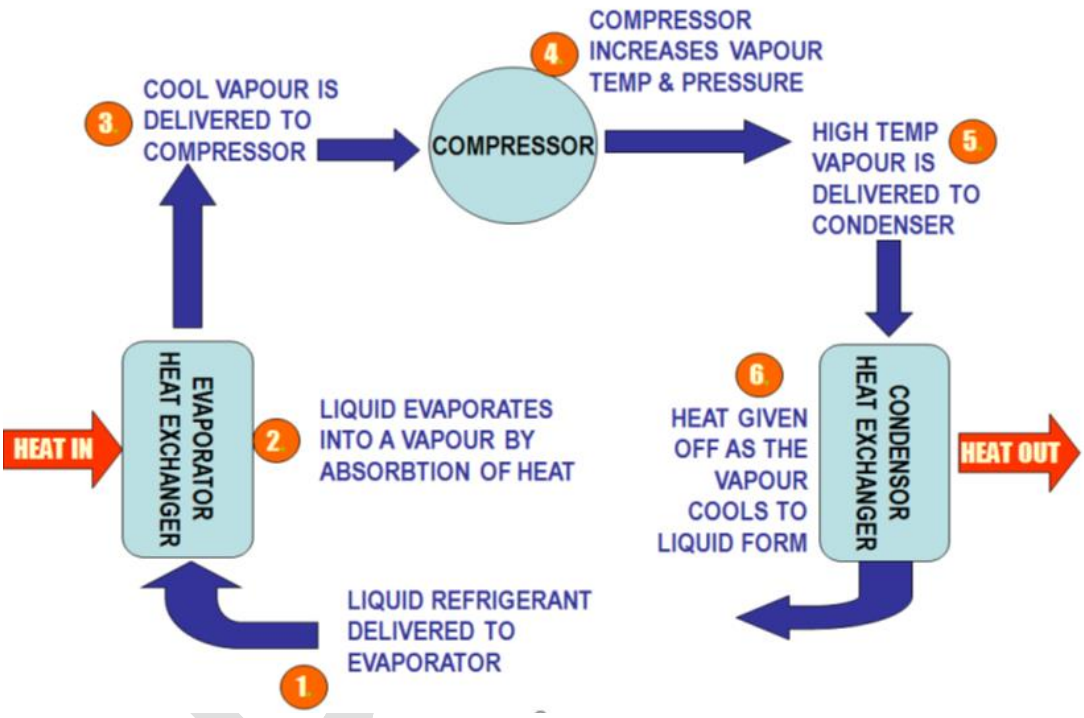



**Figure 5.12. The Vapour Compression Cycle**

System Types:

Heat pump systems can be categorised depending on where the heat is sourced from. The most common sources are used in the residential sector in Ireland are; Ground Source Heat Pumps (GSHP) and Air Source Heat Pumps (A2W).

*Ground-Source Heat Pumps:*

Ground-source heat pumps (GSHPs) take low-level heat from solar energy stored in the earth and convert it to high-grade heat by using an electrically heat pump (figure 5.13). There are three main GSHP types

- Brine to Water – the most commonly used type takes heat energy from closed loops buried in the soil, placed in a lake or through a borehole probe.
- Water to Water –Open-Loop System This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the geothermal heat pump system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is practical only with an adequate supply of relatively clean water, and if all local codes and regulations regarding groundwater discharge is met.
- DX (direct exchange) or Direct Evaporation These heat pumps use copper or aluminium pipes filled with the refrigerant gas and normally coated with a PE plastic layer to directly absorb heat energy from the earth in horizontal arrays

Specific requirements need to be met for the installation of the ground source collectors.

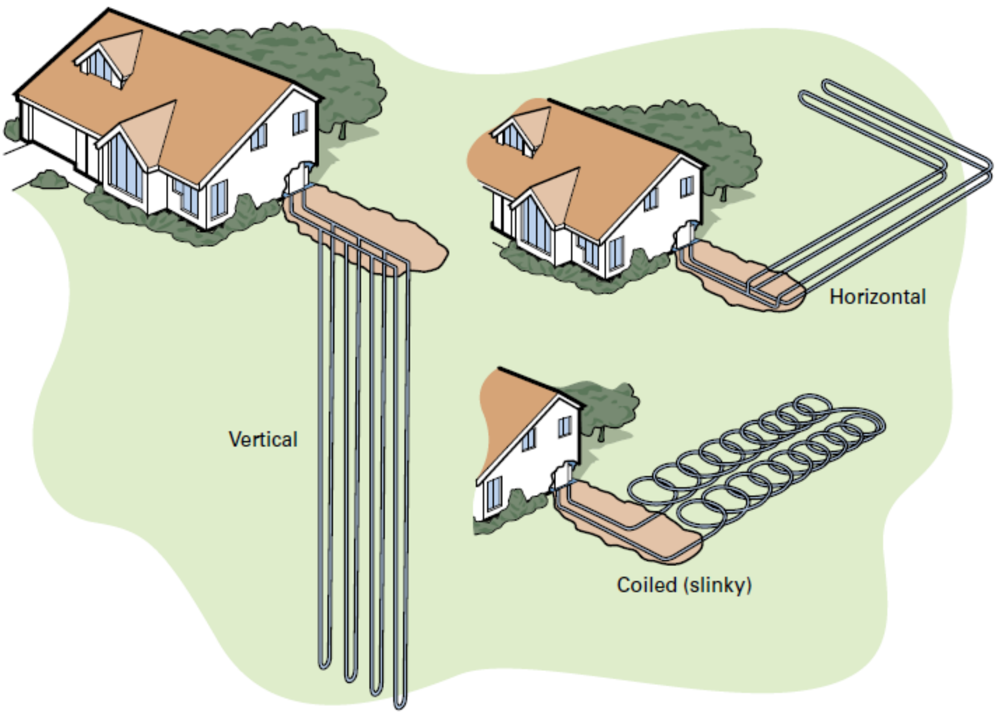



**Figure 5.13 Ground Source Heat Pump Collector Layouts (Source: www.carbontrust.co.uk)**

*Air-Source Heat Pumps:*

Air-source heat pumps (ASHPs) work on a similar principle to GSHPs, but source the low-level heat from the air, using an air-source collector, located outside of the building. ASHP come in three forms

- AIR-TO-WATER where the extracted energy from the outside air is being transferred through a heat exchanger to water; these systems can provide full Heating & DHW production
- AIR-TO-AIR Heat Pumps where the extracted energy from the outside air is being transferred through a heat exchanger to air; these systems can provide full Heating.
- EXHAUST AIR Heat Pumps where extracts heat from the exhaust air of a building and transfers the heat to the supply air, hot water and/or hydronic heating system

ASHPs are an alternative to GSHPs where the cost and access to the required space for the collector is an issue. Installation of an ASHP (figure 5.14) involves siting an external collector. ASHPs tend to be cheaper and easier to install than GSHPs. The performance of an ASHP varies with the external air temperature and this should be taken into account when considering the use of such a system.

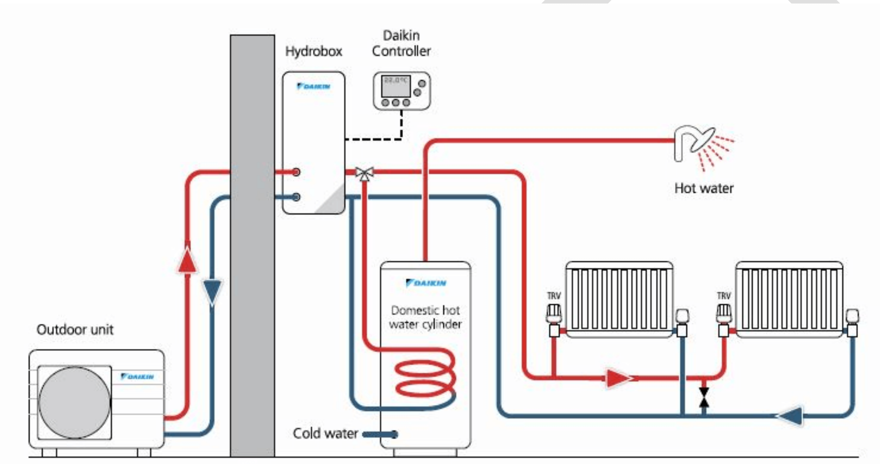



**Figure 5.14 Air to Water Heat Pump System (Source: Daikin)**

*Water to Water Collector:*
A Water to Water collector uses ground water from a conventional well as a heat source. A well must be able to deliver about 6 litres of fresh water per minute per kW installed. Water source systems can offer better efficiency and lower installation cost than ground source systems but are limited to where a suitable ground water source is available.

Benefits of Heat Pumps:

- Low carbon technology that can be used for space & DHW heating.
- Cheaper to run than traditional heat sources.
- Proven technology.
- Works well with low temperature space heating systems such as under floor heating.

Limitations of Heat Pumps:



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- To achieve high COPs the temperature lift from source to output needs to be kept small.
- Careful consideration required to achieve high COPs when used with high temperature space heating systems (traditional radiators).
- Some heat pump systems are more expensive than traditional heat sources.

### 3. Solar Thermal (Water Heating)

The principle function of solar thermal systems is to heat domestic hot water. Solar Thermal hot water systems are generally designed to meet a percentage (50-60%) of the overall annual hot water requirement. Solar thermal collectors are designed to collect the heat in the most efficient, but cost effective way. The collected heat is transferred using a heat transfer fluid (water and antifreeze mix) via a coil to the water in DHW storage cylinder. The two main types of collector are: flat plate panels and evacuated tubes (figure 5.5). Tube-based systems are about 20% more expensive, but can give up to 10% higher heating output.


**Figure 5.5 Solar Thermal Collectors (Source: www.seai.ie)**

How the technology works:

The sun's radiation heats the water in the solar collectors. An electronic controller measures the temperature differential between water in the collectors and water in the cylinder using resistance temperature sensors (RTDs). When the water in the collectors is hotter than that in the cylinder, the controller switches on the system's circulating pump. Heat transfer fluid is then circulated through the collectors and the cylinder's heat exchanger, heating the DHW in the cylinder (figure 5.6).

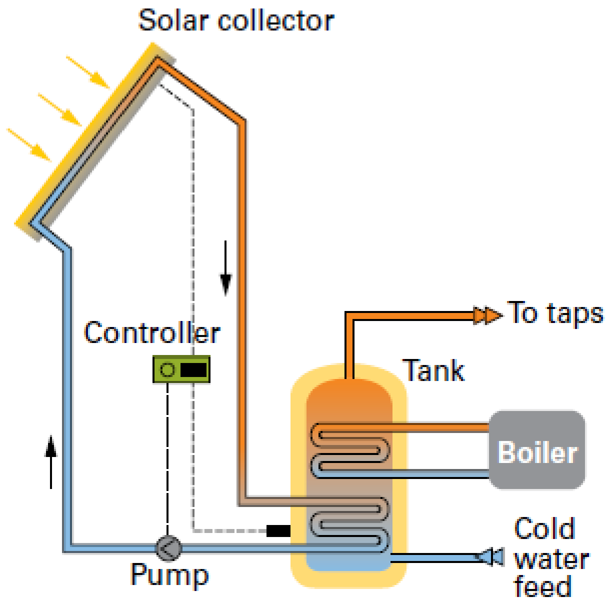


**Figure 5.6 Solar Thermal System (Source: www.carbontrust.co.uk)**

Location and orientation:
Solar thermal systems function best when positioned in an optimum location. The optimum location for a solar thermal collector is an unshaded area facing due south with a tilt angle between angle of 30-45 degrees. Where it is not possible to have collectors facing directly south, you may face them southeast/southwest and this will only affect output by approximately 5%. East/west systems are also feasible, i.e. where collectors are located on both east and west facing surfaces of the roof.

## 4. Wind Power

Wind turbines produce electricity by capturing the natural power of the wind to drive a generator.
There are many sizes of turbine ranging from micro turbines for domestic use to large-scale turbines, which can be over 120m tall (to the blade tip). Wind turbines for domestic use can be free standing or mounted on a building. Wind Turbines with a mast height of 10 metres or less and a rotor diameter of 6 meters or less are exempt from planning permission requirements subject to certain conditions. Residential micro generation wind turbines are usually pole-mounted in an unobstructed area and are available as single phase (up to 5.75kW) and three phase (up to 11kW) generators. Small wind turbines can generate either AC electricity or DC electricity (requiring an inverter). They can be used 'off grid', incorporate battery storage or they can be connected to the national grid (figure 5.7).

The output of a wind turbine is affected by its Capacity Factor. The capacity factor describes the productivity of the turbine over time. A turbine will not operate at full capacity every hour of every day during the year as the wind speed and duration will vary through the year. Knowing the typical capacity factor for wind energy sites in a location can give an indication of performance. In Ireland, typical sites for large scale wind farms have capacity factors between 30-35%. However, for micro-generation the capacity factors are much lower and can be less than 15%.

The annual energy output from a wind turbine can be calculated from
Annual Energy Output (kWh) = h x Pt x F x T

Where:
H = number of hours per year (8760)
Pt = rate power of each turbine
F = annual capacity factor
T = Number of turbines

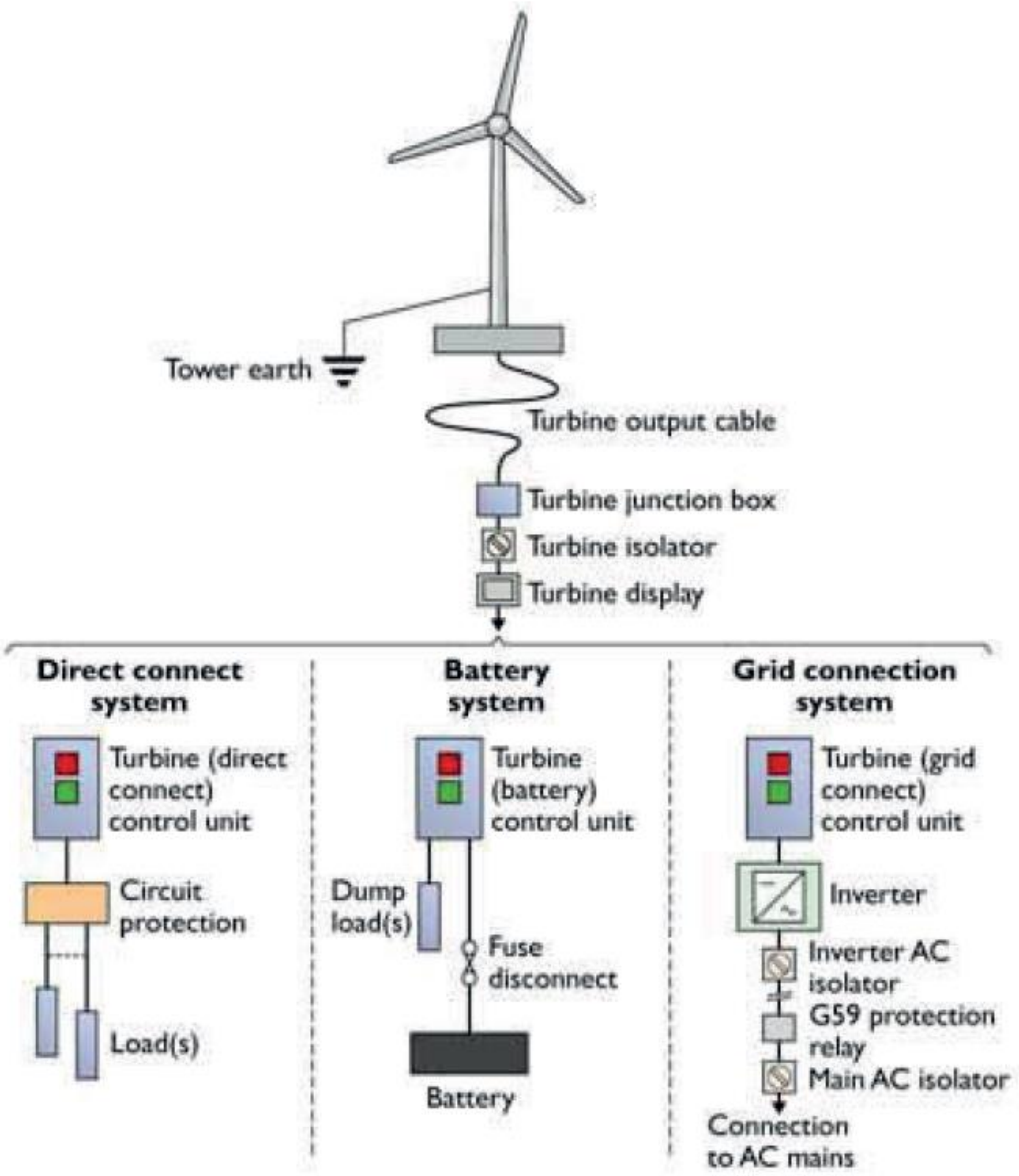


**Figure 5.7 Small Scale Wind Power System (Source: www.bisra.co.uk)**

Limitations of small scale wind:

- Will only produce electricity when there is wind (4-5m/s minimum).
- Wind velocity greatly effects the power produced (Power is proportional to $V^3$).
- Actual performance is dependent on wind profile of site and may vary considerable from the rated output of the turbine generator.
- Best performance will be obtained in non-urban locations where the air turbulence is less likely.
- Building mounted turbines may cause structural vibration, noise, & damage.
- Turbines require maintenance.
- Capital costs can be high in relation to the amount of electricity generated.

## 5. **Combined Heat and Power (CHP)**

Combined heat and power (CHP) is the simultaneous generation of both useable heat and electrical power from the same source (gas or biogas). A CHP unit comprised of a prime mover (engine) in which the fuel is combusted. The mechanical power produced by the engine is used to generate electricity using an integral generator. The heat emitted from the engine (waste heat) is captured and used to provide heat for space heating or DHW. The environmental benefits of CHP stem from the increased energy efficiency resulting from the use of the heat produced by the CHP unit. In conventional power stations the heat produced is wasted. By using this waste heat CHP units can achieve efficiencies in excess of 80%. Also because the electricity is generated on site, transmission losses via the grid do not occur. Micro CHP units for the domestic market have an electrical output in the region of 1kW and a heat output of 6kW. Domestic micro-CHP systems are currently powered by mains gas, LPG or bio-liquids. Although gas and LPG are fossil fuels rather than renewable energy sources, the technology is still considered to be a 'low carbon technology' because it can be more efficient than just burning a fossil fuel for heat and getting electricity from the national grid.

Micro CHP System design:
Micro-CHP systems (figure 5.8) are similar in size and shape to ordinary, domestic boilers and like them can be wall hung or floor standing. The only difference to a standard boiler is that they are able to generate electricity while they are heating water. CHP systems should be suitable for the building application (simultaneous electrical and thermal profile requirements) and not oversized. The optimum size of the CHP plant should maximise the running hours without requiring the shutdown of the unit or rejection of surplus heat or electricity.

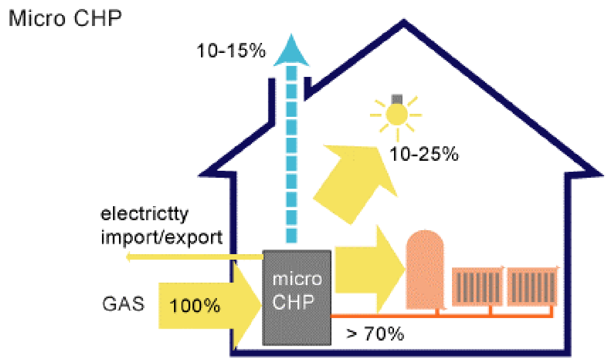


**Figure 5.8 Micro-CHP System (image courtesy of four seasons architecture)**

Benefits of Micro-CHP

- Electricity generation as a by-product of heat. When the micro-CHP is generating heat, the unit will also generate electricity to be used in your home.
- Carbon savings. By generating electricity on-site you could be saving carbon dioxide compared with using grid electricity and a standard heating boiler.

Limitations of Micro-CHP

- Systems must be correctly sized
- Requires full use of generated heat and electricity for optimum efficiency
- Requires specialist maintenance

## 6. Biomass

Biomass energy is the use of organic materials such as wood, straw and dedicated energy crops, for the generation of heat, electricity or motive power. In residential buildings biomass fuel is most commonly used to produce heat. Wood is by far the most popular fuel and is available in many forms. Wood can be considered a carbon neutral renewable form of energy if obtained from a sustainable source. The most common varieties of wood fuel on the market are; logs, pellets, and woodchips (figure 5.9).

**Figure 5.9 Example of Wood Pellets & Wood Chips**

Biomass boilers can range from simple wood burning stoves to highly efficient and fully automated wood chip (figure 5.10) or pellet boilers. Modern biomass boilers can achieve efficiencies of up to 90%. Wood biomass needs to be dried to approximately 20% moisture content to provide an energy efficient option for heating the building.

Operation of Biomass Boilers:
Biomass boilers (figure 5.10) operate differently to traditional (oil & gas) boilers. Start-up times are longer (the wood has to ignite) and heat retention within the boiler means that heat is transferred to the heating medium for a considerable period after boiler shut down. For efficient, low emission combustion, biomass needs to be burnt rapidly and at a high temperature. Therefore biomass boilers are not suited to rapid cycling (on/off) and generally do not allow for significant modulation. To prevent cycling and negate the need for modulation a buffer tank can be incorporated into the system. The buffer tank (figure 5.11) provides a large volume of water that acts as a thermal store/buffer between the boiler and the load side of the system. When the demand decreased the temperature of the store/buffer increases and when the load subsequently increases there is a reserve/store of hot water to satisfy demand until the boiler output rises.

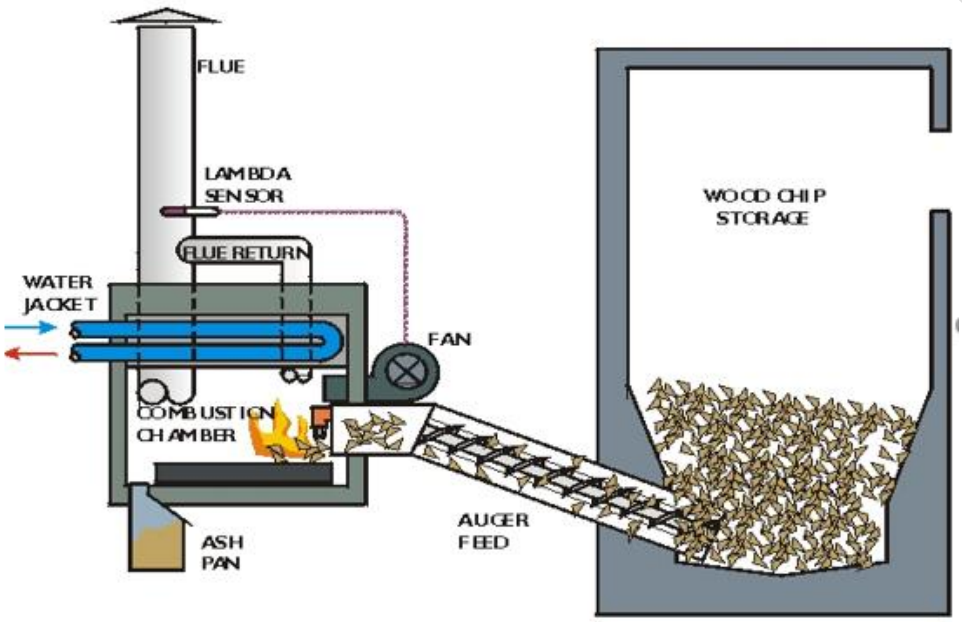


**Figure 5.10 Schematic of a Biomass Wood Chip Boiler**

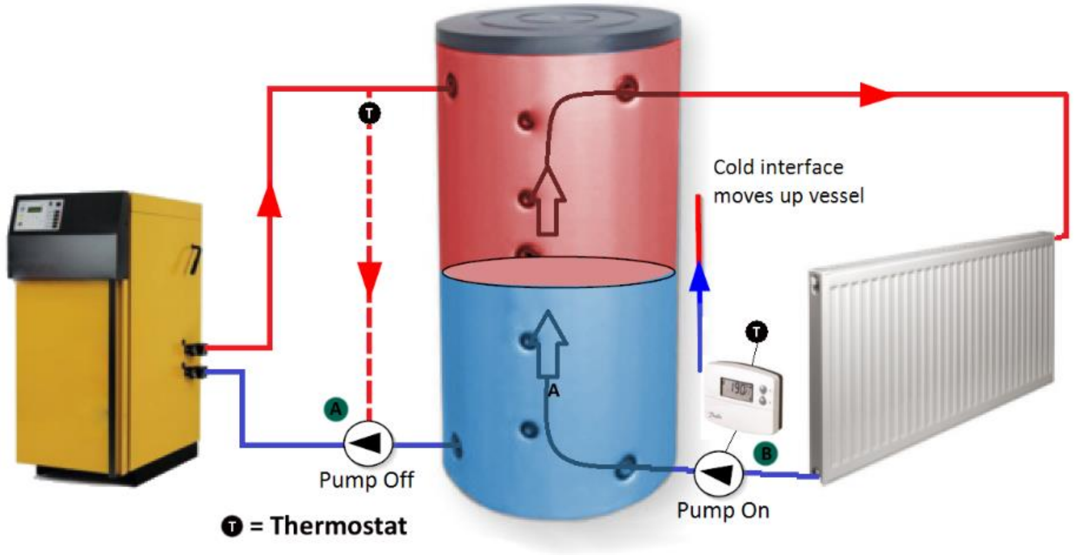

**Figure 5.11 Biomass Boiler & Buffer/Thermal Store (www.renewableenergyhub.co.uk)**

Benefits of Biomass

- Biomass fuels can be considered renewable and carbon neutral.
- Biomass fuels are cheaper than traditional fossil fuels.
- Biomass fuels can be grown and sourced locally

Limitations of Biomass

- Biomass fuels have a lower energy density than fossil fuels and therefore require a larger storage space.
- Biomass systems can be less convenient than traditional oil and gas systems and require more maintenance, ash removal etc.
- Sources of good quality (dry) biomass can fluctuate.

### Selection of Renewable Energy Technologies

The selection of any renewable energy technology requires considerable thought. Before you investing in renewable or low carbon technologies, it's essential to find out how much energy is currently being consumed and to do as much as possible to reduce it. In most scenarios, it is likely that current energy use is greater than necessary and that some energy is being wasted. Implementing some basic energy efficiency measures (Insulation, LED lights) will not only help cut down the amount of energy consumed but will also influence the type and size of the most suitable system. The less energy required, the easier it is to provide a significant proportion from a renewable or low carbon source.

- A lower energy requirement means a smaller and therefore cheaper renewable or low carbon energy system can be installed.
- Accurately assessing energy use will enable the identification of the most cost effective renewable or low carbon solution.

It is important to remember that while renewable energy technologies have many benefits there are some limitations in its use. Renewable Energy by its nature is intermittent, for example wind turbines will not produce electricity when there is no wind. Similarly Solar PV panels will not produce electricity at night. For this reason, a grid connection is required to provide backup and power storage.

Batteries are also sometimes used for storage, although this is less common. Prior to the design and implementation of any renewable energy system a number of key questions need to be asked.

- What is the current mix of energy use, is it mainly electricity or mainly heat or a mixture of both?
    - wind and photovoltaics produce electricity
    - Biomass & Solar water heating produce heat
    - heat pumps provide heating and cooling
    - CHP provides heat & electricity
- Is energy demand constant, or does it fluctuate between night and day and between seasons?
- Is there access to the resource?
    - Does the location have a good wind resource?
    - Is there space for a biomass boiler and fuel store?
    - Is the location or close to a river?
    - Is there adequate south facing space (roof) for solar panels?
- Is a Renewable Energy Feed In Tariff available (REFIT) and is grid upgrading needed to transfer power in and out?

### Energy Storage Systems

Energy storage systems allow you to capture heat or electricity when it is available (for example, electricity from a solar PV system during daylight or from a wind turbine when it's windy, or heat from a log boiler when burning batches of logs), and then save it until a time when it can be useful to you. Heat can be stored in 'thermal stores' like hot-water cylinders or larger 'buffer' or 'accumulator' tanks. Heat can also be stored in phase-change materials (similar to gel hand warmers) in the form of 'heat batteries'. Electricity is stored in electrical battery units (including electric cars). Batteries for electricity storage are made from various chemicals common examples include lead-acid or lithium-ion.

Domestic energy storage systems make the most of renewable electricity and heat by managing the time difference between when the energy is available and when it is needed. Energy storage system can reduce fuel bills and carbon emissions by allowing consumers to make the most of free renewable energy by storing it until it is required.

Energy storage systems can also be upgraded with smart operation and control. This allows consumers to track energy use online and to charge storage devices with low rate electricity from the grid at off peak times when the supply tariff is cheaper. It is becoming more likely that people with energy storage devices will benefit from payments or reduced tariffs in the future for providing smart services to the grid – for example, allowing their energy storage device, including electric cars and hot water cylinders, to be used to store excess electricity on the grid.



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Electric Battery storage

Renewable energy sources, particularly solar and wind may generate electricity at a time when it's not needed or the electricity may not be available when you want to use it. Electricity batteries help to make the most of renewable electricity from a solar PV system or wind or hydro turbine. For example, a solar PV system will generate electricity during the day when the consumer may be out at work, and this can be stored in the electric battery for use when the consumer is home in the evening. Battery technology is becoming more advanced and affordable. A number of systems exist on the market

- AC connected: where the battery is connected on the AC side of the PV inverter

- DC connected: where the battery is connected on the DC side of the PV inverter

Systems use a number of different battery chemistries including, gel lead acid (NOT flooded lead acid), lithium-ion, lithium-ion polymer, NiCad, NiMH, lithium ferro phosphate (LiFePO4), and nickel manganese phosphate

EU Standards which apply to battery storage systems include EN 62133 and EN 62619, and should also comply with other relevant standards e.g. weather protection where appropriate. Typical installation requires the battery to be installed on a flat vertical surface, according to manufacturer's recommendations, with adequate surrounding space to allow for ventilation. This is necessary of such systems generate a certain amount of heat. Similarly for floor mounted systems they should be mounted on a flat horizontal surface. Systems should be mounted on a fire resistance surface, and if not a fire-resistant substrate which extends to a minimum of 150mm beyond the edge of the inverter should be installed.

Building owners and installers are recommended to review current requirements through consultation standards & terms and conditions of ESB Networks and where relevant (where grant supports may apply) SEAI.

Thermal stores

Thermal stores are highly insulated tanks that can store heat as hot water for many hours. Thermal stores can vary in size from a common domestic hot water cylinder of around 120 litres up to very large buffer stores of 500 litres or more. Thermal stores can have a single heating input or can have multiple heat inputs.

Thermal stores can increase the efficiency of wood-fuelled heating systems, particularly log boilers which are designed to burn logs in larger batches rather than small quantities throughout the day. Thermal stores store hot water from the last time the stove or boiler was lit, so you don't need to wait as long for water to heat up.

Thermal stores will store the heat captured by solar thermal panels and can also be used to allow excess solar heat to be used for heating rooms as well as heating water. They can be designed and controlled to prioritise solar heating above all other sources.

An air source heat pump or ground source heat pump can also be linked to a thermal store. This allows the heat pump to work more efficiently, with less wear on the pump and compressor, by removing the need for it to continually 'short cycle' on and off when the demand for heat is low.

When combined with a diverter (smart controller), thermal stores can work with renewable electricity generation systems, such as wind turbines or solar PV systems. Instead of exporting excess unused electricity to the grid, the spare electricity is diverted to power a heat pump or immersion heater generating hot water in the thermal store.

Diverters (Smart Controllers)

Diverters are employed to prioritize the use of excess electricity from renewable sources. Diverters can be programmed to send excess electricity to a variety of end uses in order of the consumers priority (generally whichever is the most economically advantages) including; Battery storage, Thermal Storage, Electric Car Chargers, or back to the grid.

Diverters can be used to send excess renewable electricity to a heat pump or immersion heater to provide hot water domestic hot water cylinder, thus using the DHW cylinder as an energy store. This has the benefit of producing free (renewable) domestic hot water. A 'smart diverter' can do more than just divert excess electricity into heat generation. Smart diverters can also control electricity storage in via charge controllers for battery units or electric cars.

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## Micro Generation Connection Process – Inform and Fit

ESB Networks have developed a dedicated connection process for "one-off" micro-generators; this is detailed in figure 5.15 below.

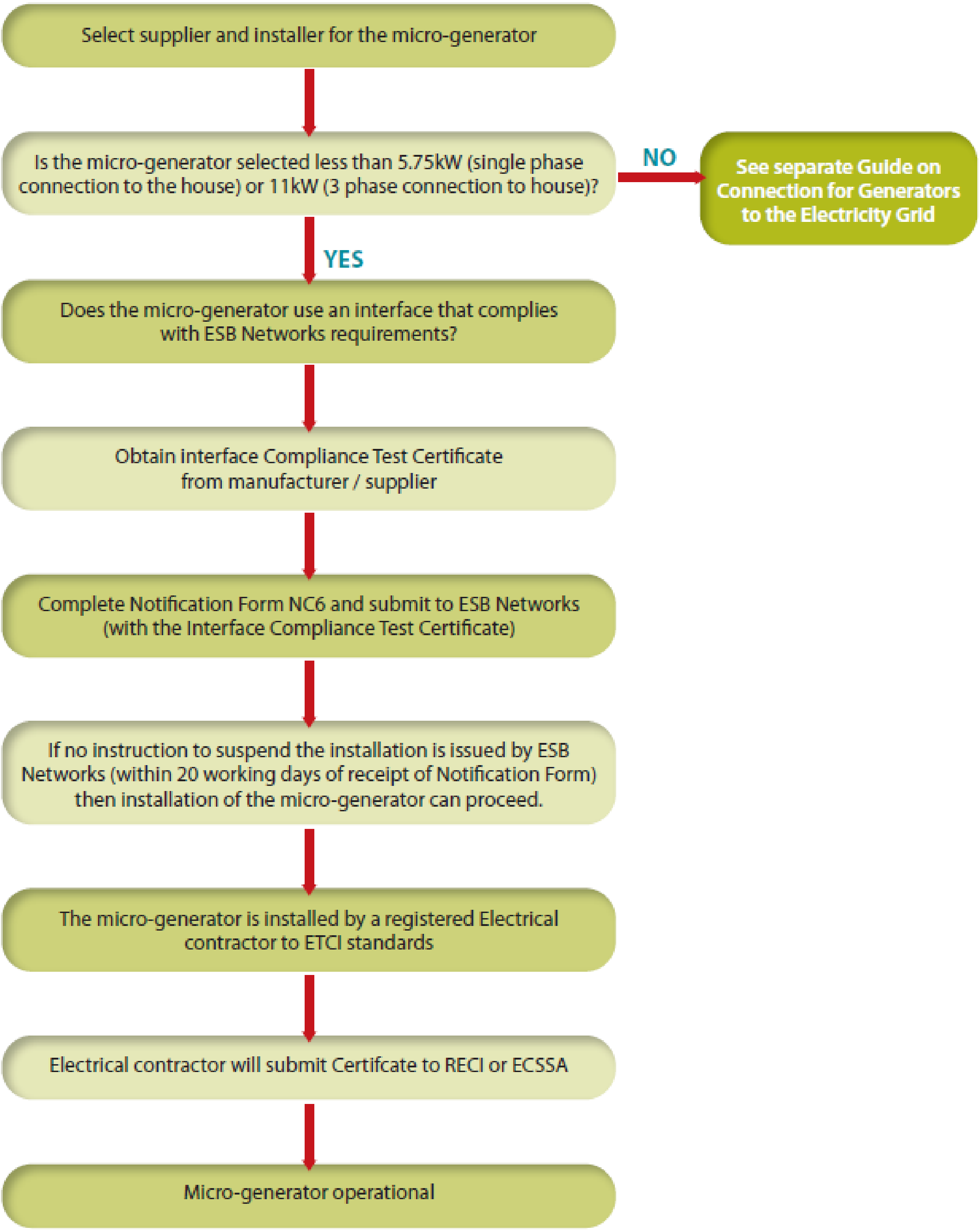


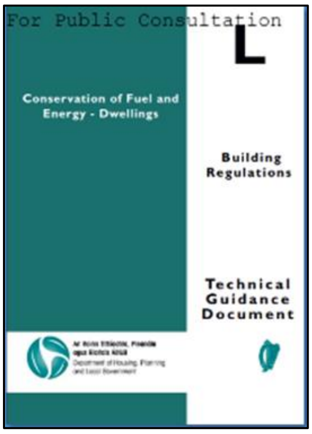

**Figure 5.15 ESB Connection of Micro-generation procedure (www.esb.ie)**

Connection Costs;

There are presently no costs associated with processing an ESB Networks Micro-Generation Notification NC6 form; it is not typical for micro-generation connection to provoke the need for network upgrades. In the unusual event that network upgrades are required, ESB Networks will inform the customer after the ESB Networks Micro-Generation Notification NC6 form is submitted.

## Renewable Energy Solutions and NZEB Compliance

In order to comply with NZEB standards, all new buildings will be required to provide 20% of their energy use from renewable energy sources. This figure may be reduced to 10% where the energy performance of the building is more than 10% better than the reference building as discussed in the Technical Guidance document Part L – conservation of fuel and energy for dwellings.




Guidance is given in Technical Guidance document Part L – conservation of fuel and energy for dwellings on the minimum level of renewable technologies to be provided to show compliance with Regulation L3(b). Renewable Energy Ratio (RER) is the ratio of the primary energy from renewable energy sources to total primary energy as defined and calculated in DEAP.

The following represents a very significant level of energy provision from renewable energy technologies in order to satisfy Regulation L5 (b); -

Where the MPEPC of 0.3 and MPCPC of 0.35 is achieved, a RER of 0.20 represents a very significant level of energy provision from renewable energy technologies

In the case of electrically powered heat pumps, DEAP sets the procedure to calculate the renewable energy provision for use in RER. Only energy in excess of 2.5 times the electrical energy directly consumed by the heat pump can be counted towards meeting the minimum level of energy provision from renewable technology. In the case of systems based on biofuels or biomass, appliances must be designed to run on these fuels only, i.e. incapable of providing thermal energy from fossil fuels, to be accepted as renewable technology for the purposes of this Regulation. For example, a boiler which could operate on either oil or a biofuel mixture would not be considered to be a renewable technology. Similarly a boiler capable of utilizing coal or peat, in addition to a biomass fuel would not be considered a renewable technology.

To ensure that works are carried out in a “workmanlike manner”, the design and installation of renewable energy systems to comply with this guidance should be carried out by a person qualified to carry out such work. A suitably qualified installer must have achieved Quality and Qualifications Ireland (QQI) or equivalent certification from an accredited training course in each of the technology areas they wish to work in. Qualified installers may include SEAI registered installers and SOLAS trained plumbers who have completed the renewable technology module, or similar.

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## Smart Appliances

With the shift from conventional power generation to more variable renewable power generation, ways of expanding the responsiveness to fluctuations in the grid supply are becoming a major challenge for electricity supply networks. Along with large-scale energy storage, the possibility of influencing the energy demand at short notice is a key option for dealing with this challenge. In the future, the ideal demand needs to be variable and responsive in order to adapt to the production of electricity from renewable energy sources. Smart electric domestic appliances are considered a viable option for demand response activities in the context of matching the variability of renewable energy supply and the levelling out of demand peaks and filling load valleys. Smart appliances utilize modern computer and communications technology to make functions faster, cheaper and more energy-efficient.

A Smart appliance is defined as an appliance that supports Demand Side Flexibility (DSF):

- It is an appliance that is able to automatically respond to external stimuli e.g. price information, direct control signals, and/or local measurements (mainly voltage and frequency).
- The response is a change of the appliance's electricity consumption pattern. These changes to the consumption pattern are what we call the 'flexibility' of the smart appliance;

The flexibility potential of an appliance is defined by two parameters:

- 'A shifting potential = amount of energy that can be shifted, expressed in [kWh/h].
- Average maximal shifting period = average maximum number of hours [h] that appliance can be shifted (i.e., to consume later/earlier in time than initially planned)'

Smart appliances may include all controllable devices within a home, which consume electricity (or gas), such as heat pumps, immersions, storage heaters, dishwashers, fridges, freezers, washing machines, dryers etc.

***Note:*** *The specific technical smart capabilities do not need to be inherent in the product when it is placed on the market; the activation can be done at a later point in time by the consumer or a service provider.*

Demand side flexibility requires

1. Automated appliances (consumption optimization)
   Smart appliances optimise energy consumption by supporting; automation, control and presentation of energy consumption information. Smart home automation allows behavioural choices to be maintained over time; for example consistently turning down the thermostat when the building is unoccupied, or automatically running the dishwasher on the eco-cycle. Automated controls can also be used to allow consumers to better coordinate their energy consumption with their renewable energy generation capabilities.

2. Demand Response
   Smart appliances allow consumers to remotely (phone apps) or automatically (grid response) operate their appliances at times when there is cheap energy is available (excess of electricity on the grid). Consumers can thus make use of real time variations (reductions) in electricity prices.

## Unit 5.2 Smart Metering

Smart metering is an emerging technology in Ireland (figure 5.16). A smart meter is an advanced modern electricity meter that has many functions including:

- Detailed measurements of how much electricity is imported/exported.
- Information on the time of day that electricity has been imported/exported.
- Connection with the system operator through a communications network – this can include functionality to permit the system operator to remotely switch the electricity supply or to take a remote meter reading.


**Figure 5.16 Smart Meter**

A large scale national Smart Meter Roll out programme will result in smart meters ultimately being installed in all buildings.  The phased rollout will deliver 250,000 new meters by the end of 2020.  From 2021 smart meters will give customers access to more accurate and regular information on their electricity usage and ensure no estimated bills.  Smart meters will support the migration to a carbon free electricity network and will enable smart grids, e-cars, local renewable generation and microgeneration.

Currently, residential electricity meters are manually read by ESB Networks up to four times per year. Smart Meters are able to record your consumption more frequently and automatically send your meter readings to ESB Networks.

- As the meters are read automatically, estimated bills will be a thing of the past.
- You will have access to more information allowing you to manage your electricity usage and make more informed choices.

DRAFT

- By 2021 new products and services will enable homeowners to shift consumption to off peak times of day when electricity is cheaper.
- In the future, functionality within the meter will allow ESB Networks to find faults quicker and manage the safety of your meter more efficiently.
- Smart meters will support the migration towards a carbon-free electricity network and will enable smart grids, e-cars, local renewable generation and microgeneration.

## Unit 5.3 Electric Vehicles

The transition from fossil fuels similarly applies to the transport sector with significant targets set for the increased use of electric vehicles. This electrification of transport will demand the installation of an electric vehicle charging point network.

The network continues to expand and provision of charging points available to the network is spreading. https://www.esb.ie/our-businesses/ecars/charge-point-map

The installation of charging points within residential dwellings must comply with relevant ESB Networks standards and requirements. The present version of "National Rules for Electrical Installations" (ETCI ET:101) and IEC 61851 are the relevant governing standards for EV Charge point installations. Equipment should be installed by a certified electrical contractor and in accordance with the manufacturer's instructions up to and including putting into service. The Domestic Charge Point must be installed in such a manner as to not breach the customers Max Import Capacity (MIC) agreement with ESB Networks.

The type of charge point recommended by ESB e-cars and installed under the SEAI grant scheme are single phase 3.6 kW charge points. This type of charge point circuit should be protected by a RCBO or RCD/MCB with the following characteristics:

- 2 pole
- 25 Amp
- Overcurrent Curve C
- At least 10 kA breaking capacity.
- Minimum requirement of type A earth leakage protection.
- 30mA earth leakage

The cable should be correctly sized to have a capacity larger than the switchgear used to protect the charging circuit. (Recommended 32 A rating), length of cable used and installation method.

Building owners and installers are recommended to review current requirements through consultation standards & terms and conditions of ESB Networks and where relevant (where grant supports may apply) SEAI.

## Summary

- 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.
- Before renewable or low carbon technologies are chosen, it is essential to find out how much energy is currently being consumed and ensure that this level is reduced.
- Installing energy efficient heating systems with a percentage of renewable technologies will reduce energy waste and achieve compliance with Building Regulations.
- Renewable Energy Ratio (RER) is the ratio of the primary energy from renewable energy sources to total primary energy as defined and calculated in DEAP.
- A significant level of energy provision from renewable energy technologies is required to satisfy Regulation TGD Part L (L5 (b))
- In order to achieve the acceptable primary energy consumption rate for NZEB compliance, the Maximum Permitted Energy Performance Coefficient (MPEPC) is 0.30 and the Maximum Permitted Carbon Performance Coefficient (MPCPC) of 0.35. If these are achieved the percentage of renewable energy technologies should provide a RER of 0.20 (or 10%) of the energy provision on site.
- Critically renewable energy which is produced on site through relevant technologies does not contribute to the total building delivered/primary energy.
- For most buildings, it is likely that the most practical option to reduce the use of energy will be installing a combination of PV and heat pumps. This should only be carried out after the insulation levels of the structure is maximised.
- A Heat pump is a device that takes heat from a source at a certain temperature and releases it at a higher temperature. Heat pump efficiency known as Coefficient of Performance (COP) is the ratio of heating delivered to the electrical energy input.
- There are a few important things to be considered when designing the system and sizing the heat pump, in accordance with NSAI recommendations where the system "should be designed and constructed in accordance with the Building Regulations, Irish Standards, the EU Energy Performance of Buildings Directive (EPBD) and the Building Energy Rating scheme (BER)":
- Heat loss calculations in accordance with NSAI SR50-1 should be carried out for all dwellings, either for new, renovated or retrofitted and the heat pump should be sized in accordance with this and in-line with current recommendations from SEAI regarding "Heat Pump Tool for DEAP".
- Combined heat and power (CHP) is the simultaneous generation of both useable heat and electrical power from the same source (gas or biogas). It is important to maximise efficiency by correctly sizing the system and regularly maintaining it.
- Energy storage systems allow the capture of heat or electricity when it is available (for example, electricity from a solar PV system during daylight or from a wind turbine when it's windy, or heat from a log boiler when burning batches of logs), and then save it until it is needed. Heat can be stored in 'thermal stores' and electricity can be stored in electrical battery units
- A Smart appliance is defined as an appliance that supports Demand Side Flexibility (DSF):
- It is an appliance that is able to automatically respond to external stimuli e.g. price information, direct control signals, and/or local measurements (mainly voltage and frequency).
- The response is a change of the appliance's electricity consumption pattern. These changes to the consumption pattern are called the 'flexibility' of the smart appliance;

- The installation of charging points for electric vehicles within residential dwellings must comply with relevant ESB Networks standards and requirements. Equipment should be installed by a certified electrical contractor and in accordance with the manufacturer's instructions up to and including putting into service.
- Building owners and installers should be directed to review current requirements through consultation standards & terms and conditions of ESB Networks and where relevant (where grant supports may apply) SEAI.

## Useful Links

Making sense of renewable energy technologies: Carbon Trust - https://www.carbontrust.com/media/63632/ctg011-renewable-energy-technologies.pdf

A Homeowner's Guide To Solar Thermal For Hot Water: Sustainable Energy Authority of Ireland, SEAI - https://www.seai.ie/resources/publications/Homeowners-Guide-To-Solar-Thermal.pdf

Best Practice Guide Photovoltaics (PV): Sustainable Energy Authority of Ireland, SEAI - https://www.seai.ie/resources/publications/Best_Practice_Guide_for_PV.pdf

Illustrated Guide to Renewable Technologies (BG 1/2008) - https://www.bsria.co.uk/information-membership/bookshop/publication/illustrated-guide-to-renewable-technologies/

Photovoltaics in Buildings: Guide to the installation of PV systems: Department of enterprise DTI - http://www.bre.co.uk/filelibrary/pdf/rpts/Guide_to_the_installation_of_PV_systems_2nd_Edition.pdf

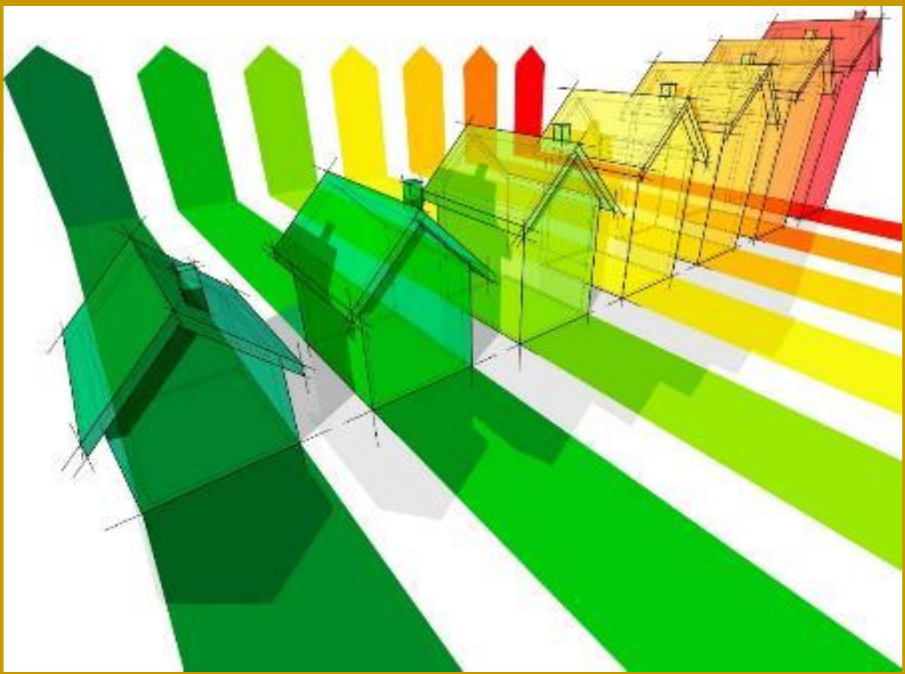
A Guide to energy storage Factsheet (2017) – Energy Saving Trust - Ahttp://www.energysavingtrust.org.uk/sites/default/files/reports/Factsheet_Energy%20storage_version%201.2.pdf

Heating with PV economics of Electric Heating: Sun & Wind Energy 2/2015 - https://www.rennergy.de/fileadmin/user_upload/pdfs/Presseartikel/sun_wind_energy_02_2015.pdf

DEMAND SIDE FLEXIBILITY THROUGH SMART HOMES 2017: Joules Assets Europe and VaasaETT - https://esmig.eu/sites/default/files/dsf_through_smart_homes_18_08_2017.pdf

Smart Domestic Appliances Supporting The System Integration of Renewable: Smart A, Intelligent Energy Europe - Energyhttps://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/e-track_ii_final_brochure.pdf

# Module 6



## COMMUNICATION AND USER INFORMATION

# Module 6: Communication and User Information

In this module we will focus on the importance of communication and collaboration between all trades and craftworkers on and offsite to achieve NZEB building compliance.

In the previous modules we have examined some of the new ways of thinking with regards to the construction of buildings and some of the ways of responding positively to this thinking. This module will bring together all the principles covered and how to most effectively work together onsite to ensure a quality workmanship. It needs to be understood that the role of the craftworker and builder on site have changed greatly over recent years and that they should be responsible for their actions to ensure quality nearly zero energy building is obtained.

**Unit 1. Collaborative Communication**

This section will look at the importance of good clear communication removing any misunderstandings and errors during the entire construction chain. Various types of communication will be outlined to encourage best practice approaches to communication and awareness.

**Unit 2. Systems Thinking**

Combines communication, awareness, working together with the collaboration between all trades and sequencing of works. The systems thinking concept is essential for quality design, energy efficient construction, supervision and NZEB compliance with building regulations.

**Unit 3. User Information**

Clear transfer of appropriate information to the end user to maintain comfort levels and carry out future maintenance of the dwelling.

## Unit 6.1. Collaborative Communication

**Importance of Communication**

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 insulated airtight buildings, reducing thermal bridging and the installation of energy efficient services and renewables. 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.

## Unit 6.2. 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 work - Working together
- Listening and Talking - Good Instructions and knowledge transfer
- 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 make changes appropriately. The approach also considers how each individual affects the outcome of the final build and the NZEB standards that it achieves.


Figure 6.0 Team work

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 NZEB buildings are completed. It is important that all teams make sure that the envelope is insulated, services are energy efficient and ventilation is controlled to achieve quality healthy buildings.

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.

**Good Instructions and knowledge transfer** 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 in achieving quality NZEB 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.

**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.

Taking responsibility of your own actions.

## 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 craft worker is responsible for the quality of the building and responsible for their own actions. The role of the craft worker to comply with NZEB and Building Regulations has changed in the last year and this needs to be understood.

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 craft 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!!

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

Important communications on/offsite:

It is important to establish a coordinated construction strategy and plan between the clients, architects, engineers, site supervisors and main contractors before works starts and preferably before construction details are agreed. Additional meetings are also important to flag any risks and issues periodically to ensure a smooth construction process.

Key details and choice of certified materials should be approved prior to start of works between clients, architects, engineers, site supervisors, main contractors and relevant sub-contractors. Additionally consider BCMS and the important roles of the design, assigned and building certifiers within this process. Certifying and approving products and technologies, best practice detailing and supervising construction works should be of paramount importance.

Although transferring information to all trades on site is generally the role of the site supervisor, it is equally important for the trades to respond and confirm details or installation of materials, back to the site supervisor and architect. More recently, this form of communication is carried through IT or BIM communications via the mobile phone, rather than amending the traditional full scrap hardcopy drawings. This speeds up the process and reaches more people on the construction chain directly, however control of the IT communication needs to be maintained appropriately.

Using relevant toolkits or holding short induction trainings on site in particular for air tightness plan are useful for all construction workers to update their knowledge and be made aware of correct installations of products/materials. These trainings often enable craft workers to understand other trades work as well as assist with CPD.

## Quality Control

Quality Control is essential and generally carried out by a Foreman/ Site Supervisor but success will depend on all trades working together and focussing on a common goal. Controlling the quality of the build involves clear communication and awareness within the workforce, as well as ensuring that works are carried out on time and on budget.

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.

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 site supervisor usually carries out this task but everyone involved needs to understand how the process works.

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 craft workers*** 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 6.1.

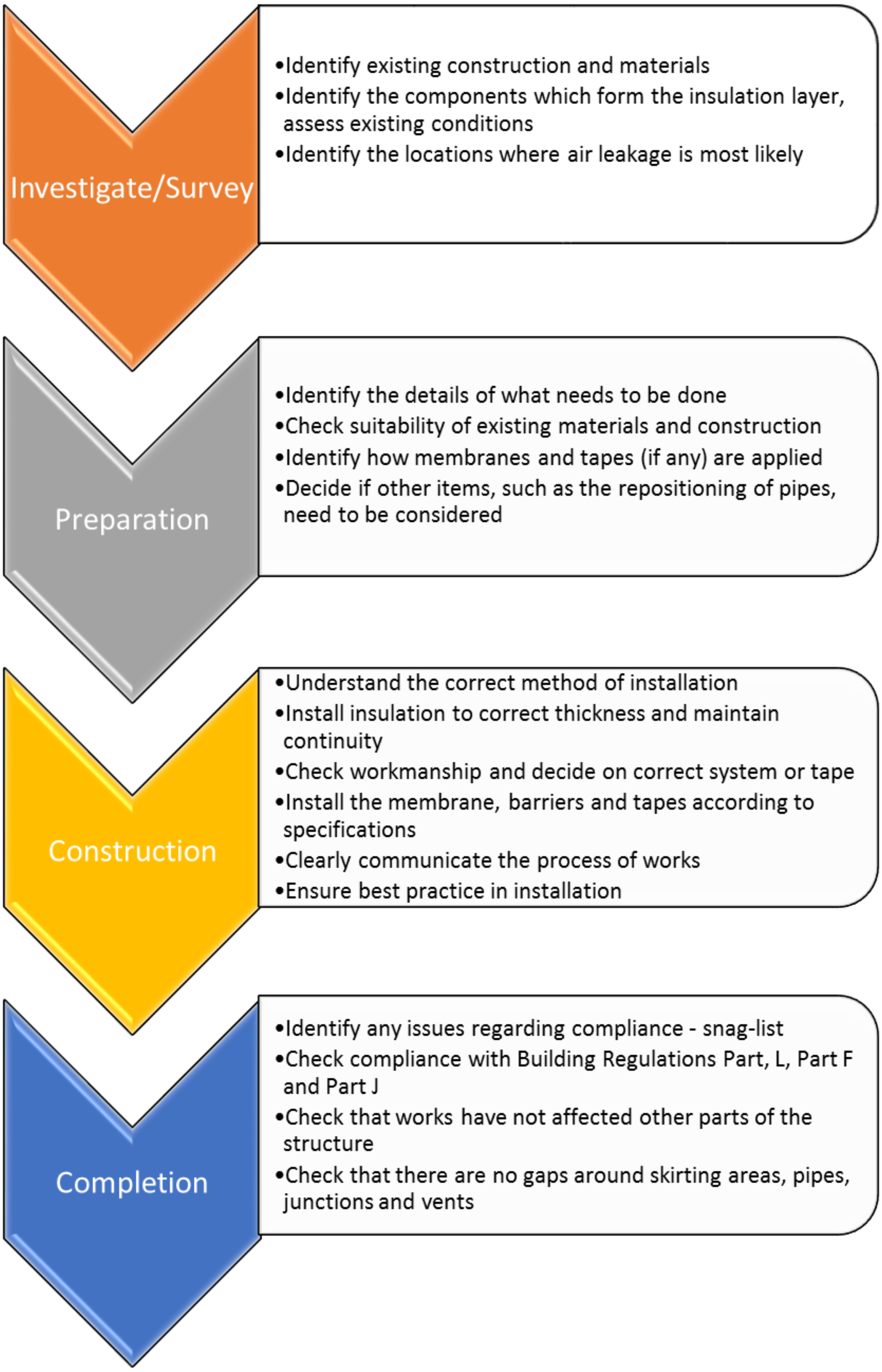



**Figure 6.1 Sequence of Works for External insulation**

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.

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.

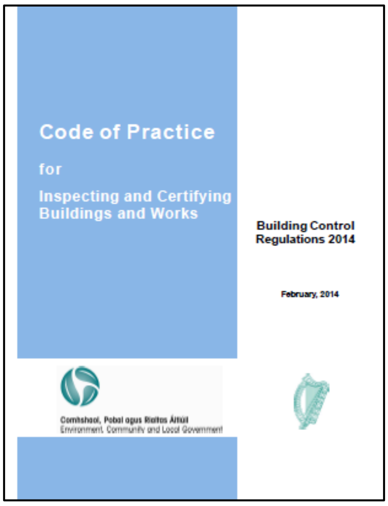
At present it is required to provide the following certificates during construction for buildings, except for single dwellings and domestic extensions:

- 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.

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.

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

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.

## Unit 6.3 User Information

The owner of the building should be provided with sufficient information about the installed system (Space heating, DHW, Ventilation, Emitters, Controls etc), its continuous operation and maintenance requirements so that it can be operated in an efficient and effective manner.

The instruction should be directly related to the system installed in the dwelling without prejudice to the need to comply with health and safety regulations. The instructions should explain the important function of the system to provide adequate comfort levels, how the system is intended to work, why and how the system should be turned off/on or not turned off, how the controls should be used and how and when the system should be cleaned and maintained. The location of the system in the dwelling and the location of filters on the unit should also be identified in the handover documents.

### 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, insulations, air tightness, timber work, lighting, heating appliances and ventilation systems.

<u>User information</u>

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. This can be provided in a number of ways:

1. Building Owners Manual:

Building Owners Manual or the operation and maintenance manual (O&M manual) is generally prepared by the main contractor or site supervisor, however additional information may be required from the specialist contractors, designers (in particular, the services engineer) and suppliers. Providing building owner's manual is a requirement that is generally defined in the preliminaries section of the tender documentation where its contents will be described, although there may be additional requirements regarding mechanical and electrical services in the mechanical and electrical specification.

The owner of the building should be provided with sufficient clear and comprehensive information on any continuing maintenance required to facilitate the effective operation of the heating system or systems in order to protect the health and safety of the building occupants.

A draft version of the document should be provided to the site supervisor/client as part of the handover procedure prior to certifying practical completion. The final document should be available in full form, several months after practical completion, as commissioning information often needs to include summer and winter readings taken in the fully operational building. The preliminaries may require several copies of the building owner's manual and advisable to provide an electronic version.

The building owner's manual should include:

- A description of the main design principles.
- Details of the building's construction (insulation, airtightness products, finishes, cladding, doors and windows, roof construction, and so on).
- As-built drawings and specifications.
- Instructions for its operation and maintenance (including health and safety information and manufacturers' instructions for efficient and proper operation).
- An asset register of heating and fire systems and equipment.
- Commissioning and testing results.
- Guarantees, warranties and certificates.
- Particular requirements for any demolition, decommissioning and disposal.

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.

In addition to a building 'building users guide', it may also be prudent to prepare a non-technical log book with information for users about environmental controls, access, security and safety systems etc.

2. Building Log Book:

Part L of the Building Regulations (conservation of fuel and power) requires that the building owner is issued with information about the building services to help them operate the building properly and efficiently. It is suggested that this is done by issuing a building log book to the building's facilities manager. Building log books are required for new buildings and for existing buildings where the services have changed. Whilst not a requirement of the Building Regulations, it is suggested that existing buildings would also benefit from a building log book.

The building log book is different to, but may draw upon, information in the building owner's manual, sometimes called the operation and maintenance manual (O&M manual), and the health and safety file. Unlike the building owner's manual it should be a concise document (20-50 pages for larger buildings and 5-10 pages for buildings under $200m^2$ (the Carbon Trust's 'Building logbook: users guide' page 8). It should be easy to understand, giving an overview of the way in which the building was originally intended to operate and any changes that have been made.

Building log books can be prepared following the guidance in the Chartered Institution of Building Services Engineers (CIBSE) TM 31 Log Book Toolkit.

Building log books may include:

- A description of key responsibilities.
- A schedule of contacts.
- A description of the overall building, including zoning and occupancy.
- A description of the building's operational strategy.
- A description of the building's services plant, controls and management systems.
- Changes that have been made to the building.
- Health and safety considerations.
- Maintenance requirements.
- Metering and monitoring strategy.
- The data used to calculate the TER (target $CO_2$ emission rates) and BER (building $CO_2$ emission rates), see emissions rates.
- The recommendations report produced along with the construction energy performance certificate.
- Building performance in use investigations and targets.
- References to other documents.

3. Building User's Guide:

In addition to a building owner's manual and building log book, it may also be prudent to prepare a non-technical 'building user's guide' (BUG) with information for users about:

- The principles behind the design of the building and how these affect its operation.
- The building's standard of performance.
- Energy efficiency measures.
- Water-saving measures.
- Means of operating heating, lighting and cooling systems, and the consequences of incorrect operation.
- Access, security and safety systems.
- Methods for reporting problems and obtaining solutions.
- Waste management.

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

The building user's guide should be written as if the user knows nothing about the systems being described. The document needs to be kept up to date to acknowledge changes in the building and should be made easily accessible so that users can refer to it and that new users can learn about the building. Ideally it should be made accessible online.

In Europe, Building Renovation Passports are becoming more popular as a key solution in supporting large scale deep renovation by carrying out cost-effective and streamlined quality deep retrofitting. In fact, voluntary passports are mentioned in the 2018 Recast of the Energy Performance of Buildings Directive (EPBD).

Building Renovation Passports are masterplans for retrofit and include a record of works. They ensure that any renovation works are planned and implemented in a holistic and technically sound manner, hence preventing “lock-ins” and facilitating a step-by-step approach to deep renovation By allowing a new owner to take up where a previous owner left off, it should also reduce transnational cost of retrofit where a property change hands. Extensive research, stakeholder engagement and a small pilot will be carried out in 2019-2020 by IGBC and LIT to assess the viability of the Building Renovation Passports in Ireland. https://www.igbc.ie/policy-and-regulation/renovation-strategies/building-renovation-passports/

## Summary

- Achieving quality NZEB construction 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 Nearly Zero Energy Buildings.
- Remember all product installation, 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.

- Each building should have a user manual and a building manual specifying the products used, materials, services, important contacts, maintenance plan for products, materials and equipment.

## Useful Links

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

The Irish Building Regulations Technical Guidance Documents (TGD's) are available to download at http://www.environ.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-documents

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

TM31 - Building log book toolkit: guidance note: Chartered Institution of Building Services Engineers (CIBSE) - https://www.cibse.org/getmedia/aa39f6d6-9fec-4f96-a936-13db4a9aa54a/TM31-Guidance-Note-DRAFT.pdf.aspx

CIBSE TM31 Building log Book Template: Chartered Institution of Building Services Engineers (CIBSE) - https://www.cibse.org/getmedia/d5b7a5dd-8737-44db-a506-663af85b1f24/TM31-Logbook-Template-DRAFT.pdf.aspx

## Self-Test

1. What are the EU targets for 2030?

2. What is a Building Energy Rating Certificate?

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

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

   1)
   2)

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

   1)
   2)
   3)
   4)

6. Explain why all hot water storage vessels, pipes and ducts associated with the provision of heating and hot water should be fully insulated.

7. Explain why the importance of controlled ventilation increases with decreasing air permeability.

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

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

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

______________________________
______________________________
______________________________

10. Why are heating controls important within a building?

______________________________
______________________________
______________________________

11. List 2 reasons why the sequence of works/construction is important?

1) ______________________________
2) ______________________________
______________________________

12. List 4 items that should be included in the building owner's manual

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

## 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.

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