LEARNER HANDBOOK

NEARLY ZERO ENERGY BUILDING

BRICKLAYER

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Introduction

Welcome to Nearly Zero Energy Building (NZEB) for Bricklayers 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.

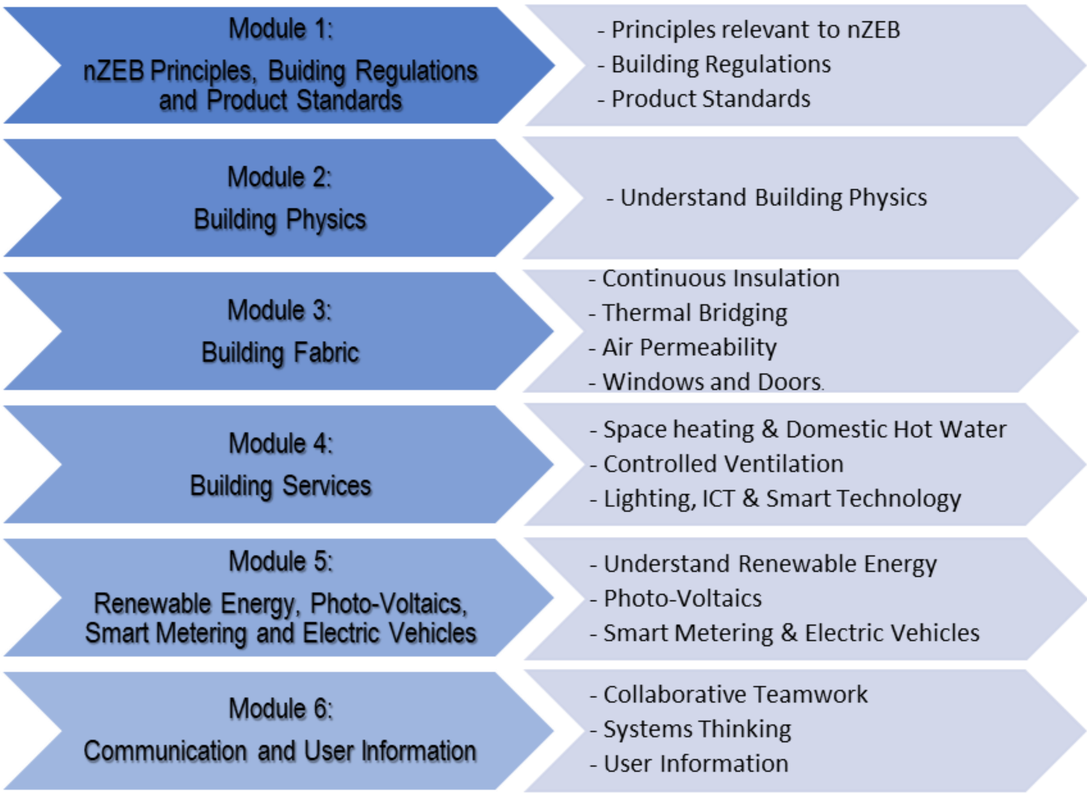


Figure 2: Course structure and layout

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 outline 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.
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.

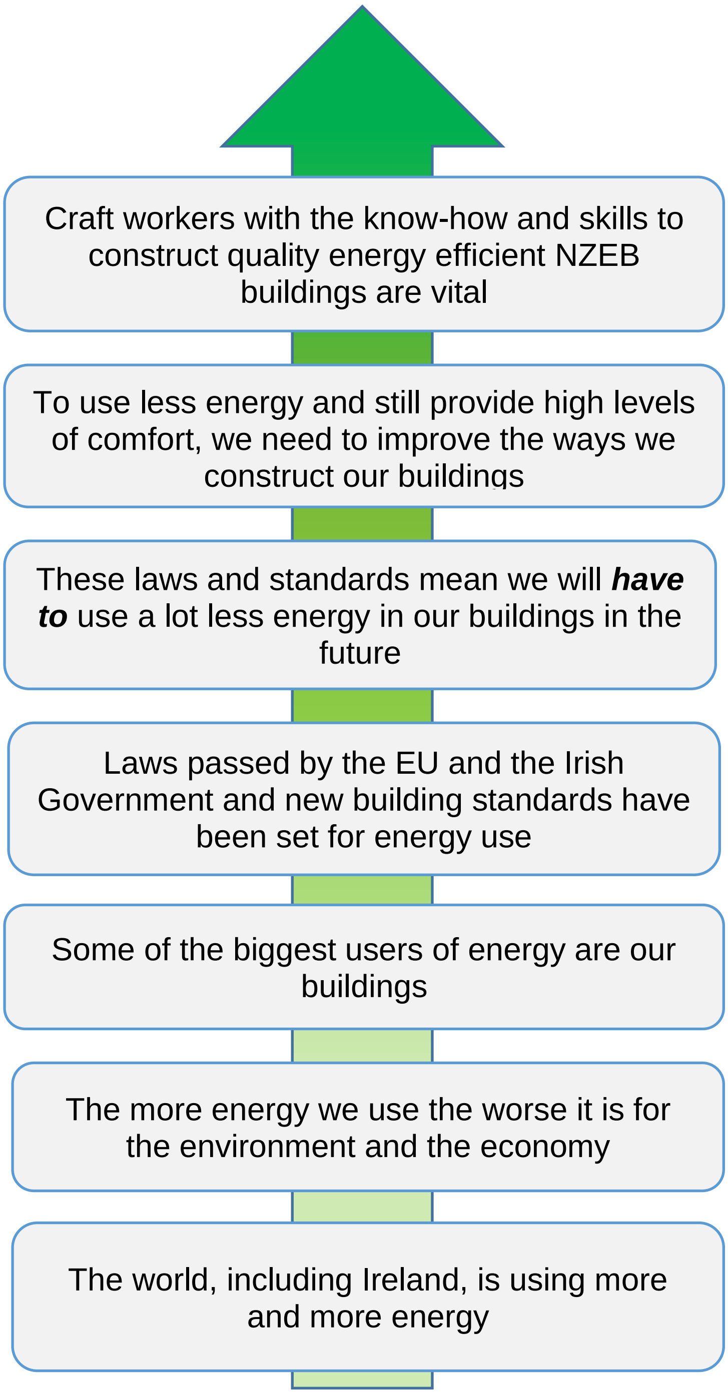


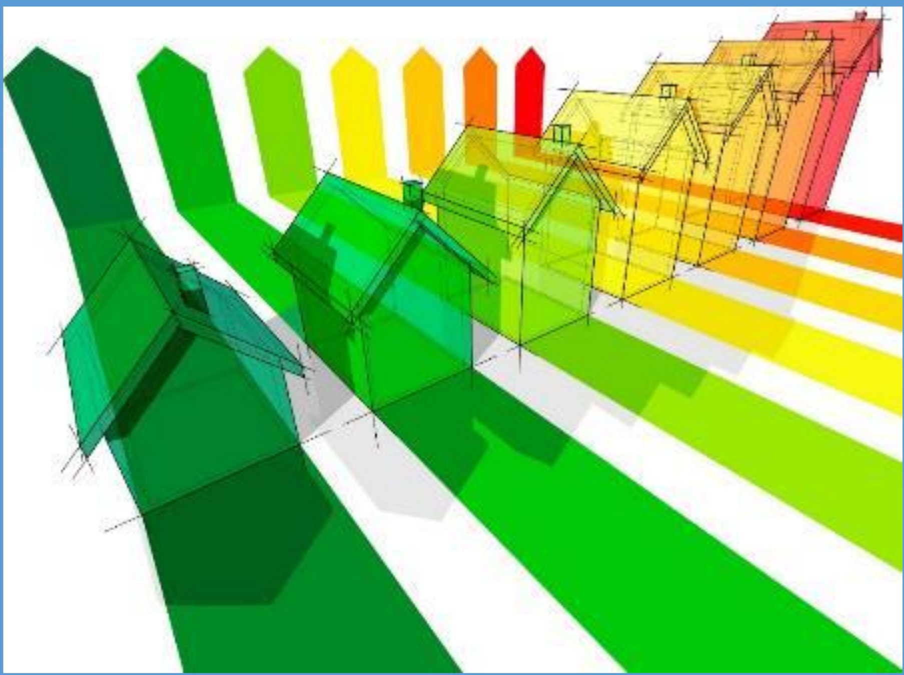
Figure 3: The reasons for the NZEB Course

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.

Module Overview

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.

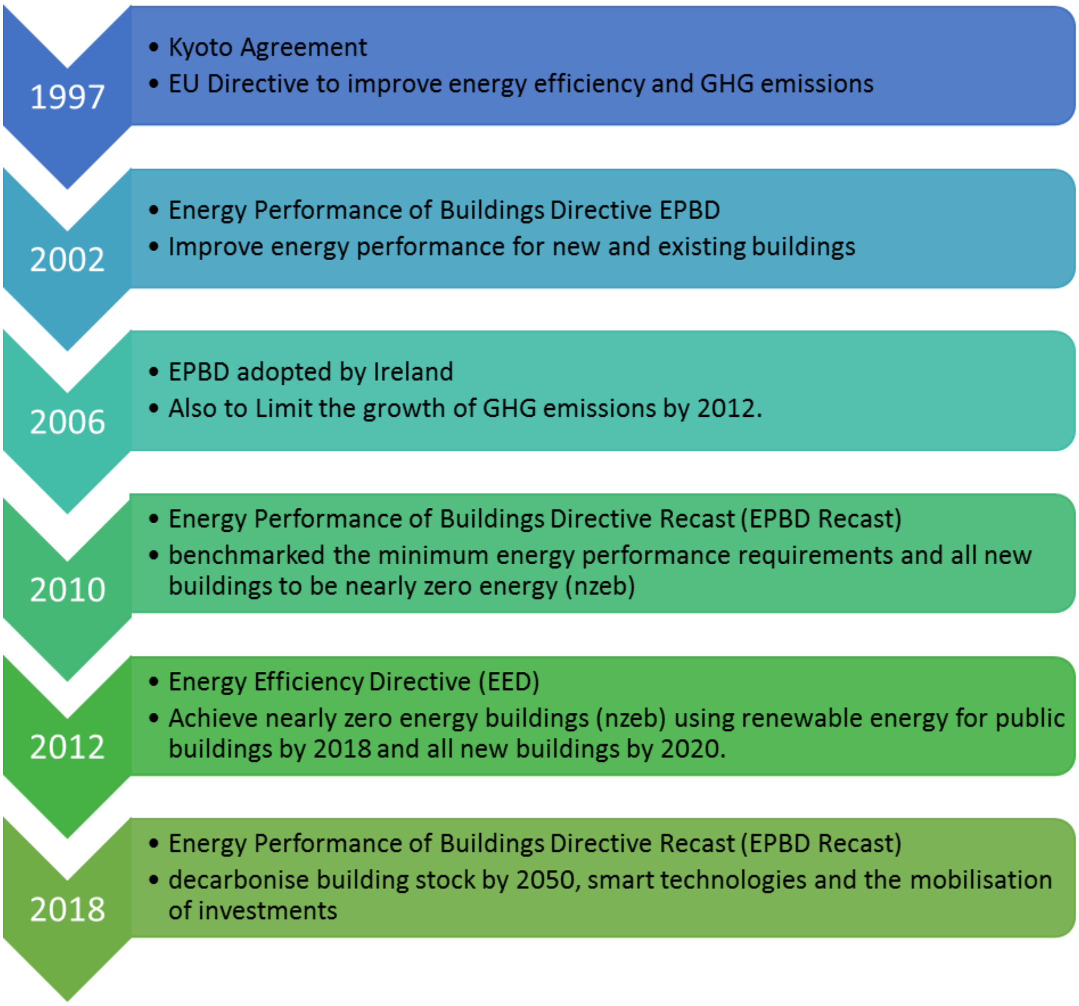


Figure 1.0: Summary of Energy Directives since the Kyoto Agreement

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, EED

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 programs, 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 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.

- 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

[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

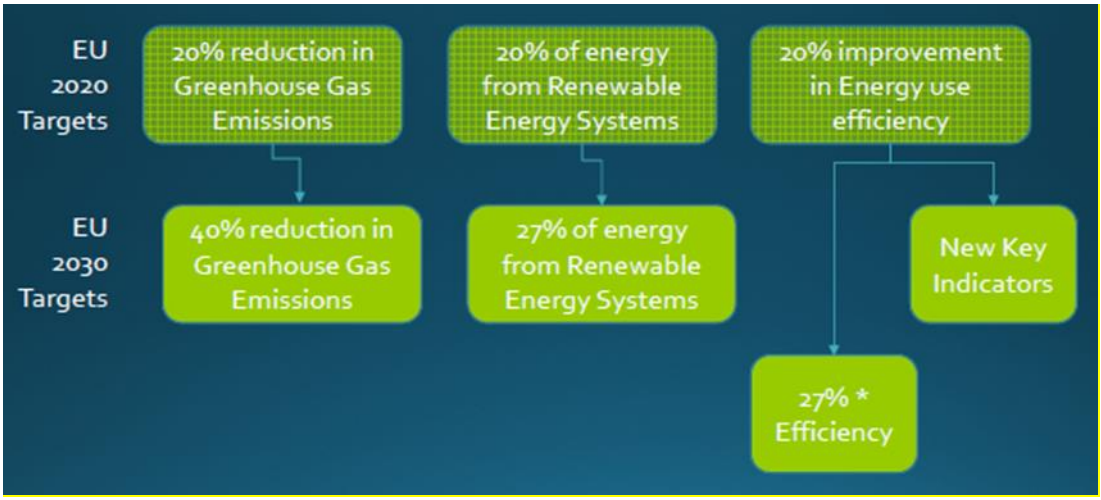


Figure 1.1: Overview of agreed energy and emission targets for EU 2020 and EU 2030

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 details refer to Unit 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 of 40%.

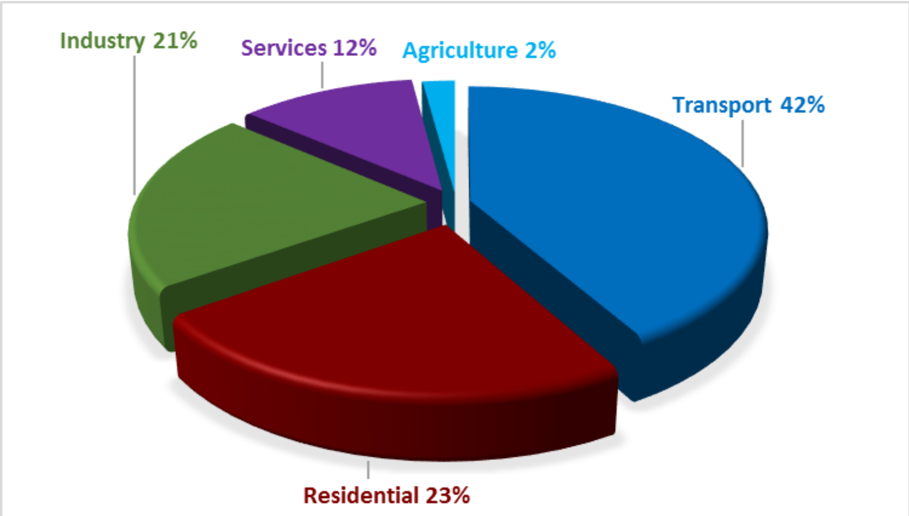


Figure 1.3: Total final energy consumption in Ireland by sector in % of total Mtoe.[4]

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

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.

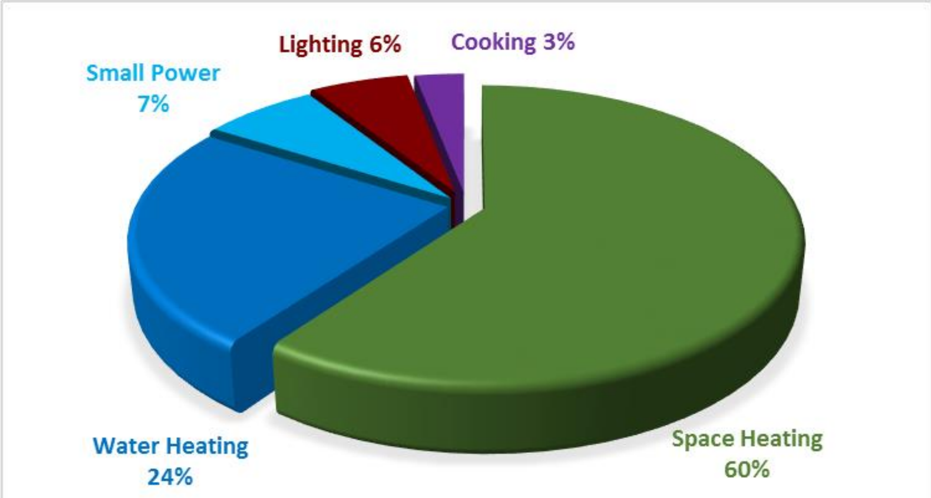


Figure 1.4: Energy Use in the Residential Sector in Ireland[5]

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?

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

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.

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.

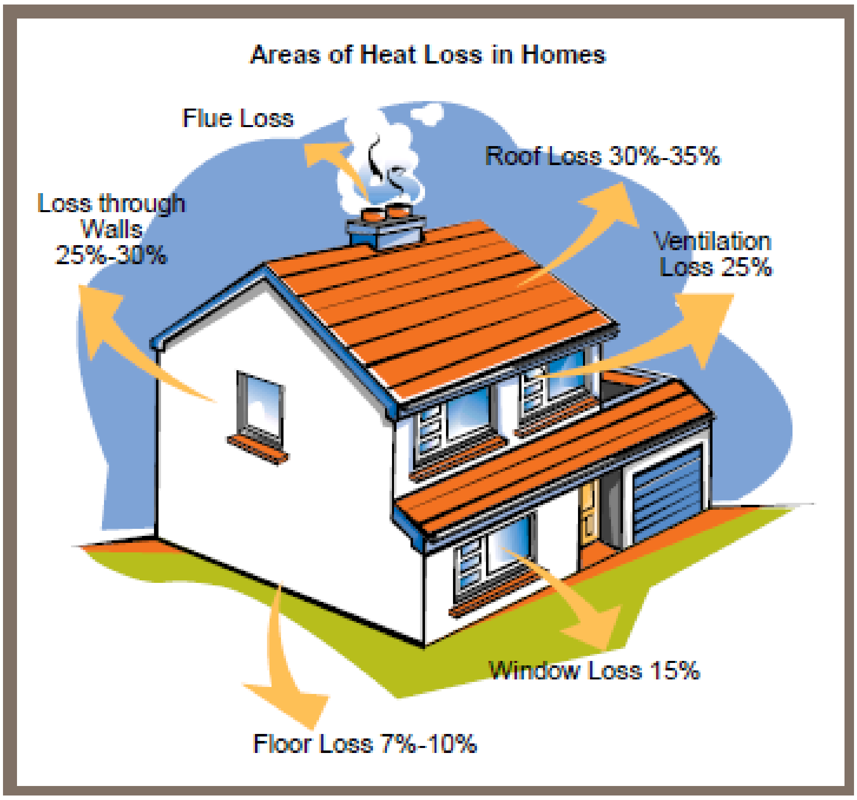


Figure 1.5: Typical proportions of heat loss from dwellings (source: Tipperary Energy Agency)

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 minimum guidance for the construction of buildings towards compliance with regulations. Parts L, F and J will be looked at on this course as these mainly relate to energy efficiency and performance.

Figure 1.20: Technical Guidance Documents (TGDs) for Dwellings

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

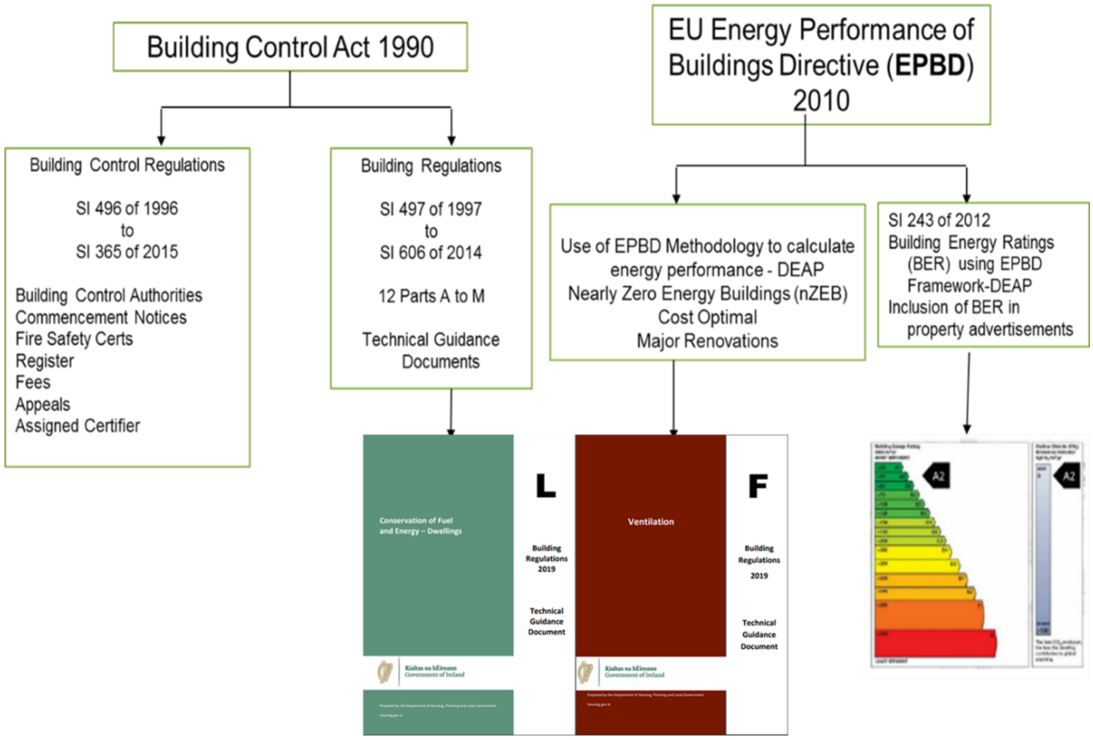


Figure 1.20: Evolution of Building Regulations (Source: Sean Armstrong DHPLG)

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.

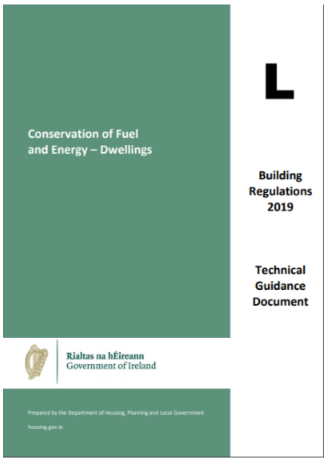
Although compliance with all the TGDs is mandatory, it is important to ensure you are fully versed in **Part L**, Conservation of Fuel and Energy – Dwellings, **Part F**, Ventilation and **Part J**, Heat Producing Appliances. These are guidelines and express the minimum requirements, so as qualified Bricklayers 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 ceases to have effect from ***31st March 2019***, and the new **TGD Part L - Dwellings 2019** comes into force, with some significant changes to the requirements. The 2019 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 **TGD Part F – Ventilation 2019**, 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 (RER) - 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 (PE) 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.

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

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.

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.

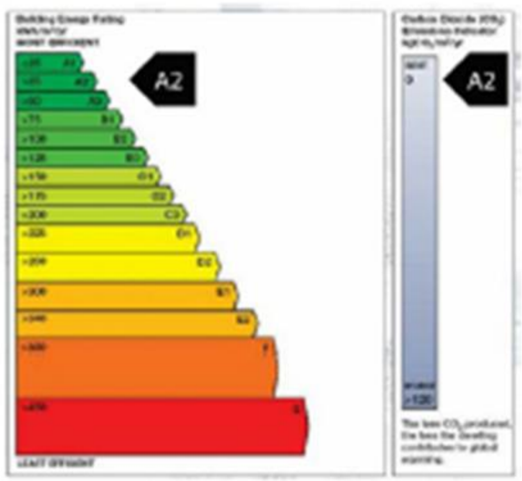


Figure 1.19 Building Energy Rating Categories (source – SEAI)

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.

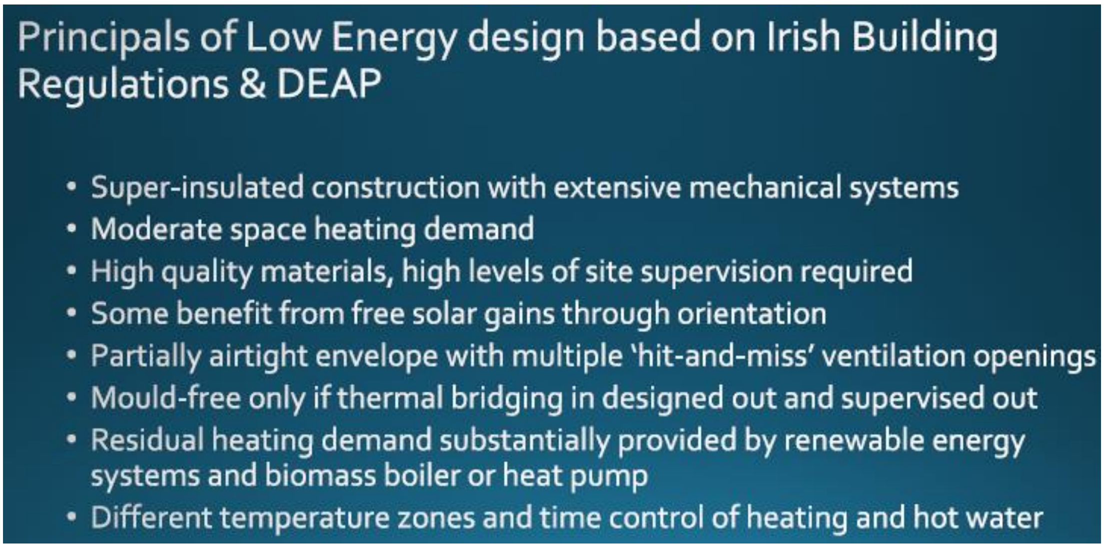
The progression to improved energy performance since 2005 of dwellings is summarised in Table 1.

Year	2005	2008	2100	2019
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

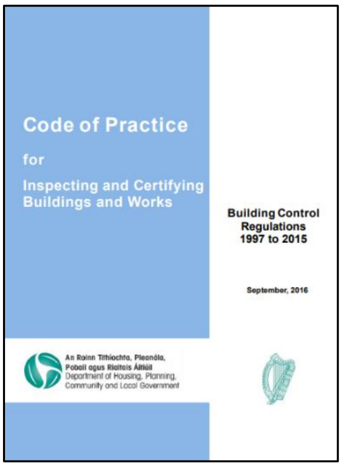
(MPEPC) of 0.302 and not exceed a maximum permitted carbon performance co-efficient (MPCPC) of 0.35.



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.

<u>Building Control - Regulations</u>



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. This document is now updated to Code of Practice for inspecting and certifying buildings and works 2016.

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

The quality of workmanship actually achieved both when constructing masonry and when installing any insulation product, is a very important factor affecting resistance to rain penetration. The workmanship should be in accordance with BS 8000-3. It should also be reminded that quality workmanship involves removing all “mortar snots” to enable the precise installation of cavity insulation, allowing interlocking of all insulation slabs and hence ensuring continuous insulation and therefore reducing heat loss from the building envelope. This will be discussed further in Module 3 of the handbook.

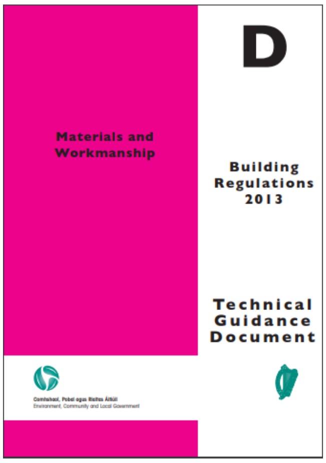
Chases, fixings and holes in masonry may seriously affect the strength of the masonry. As far as is practicable, in order to eliminate unnecessary cutting away and making good, sleeves and chases should be provided during the erection of the masonry. This applies especially to electric ductwork. Reducing the number of holes through the external masonry envelope and breaking the insulation and airtightness layers will also assist with achieving air tightness (air permeability test) and reducing heat loss. This applies especially to plumbing services and ductwork. In external walls, all sleeves and pipes should preferably be laid with a fall towards the outside. Services should not be run within the cavity of cavity walls. The installation of all services should be completed before plastering or other finishing work is begun. This is to ensure continuity of insulation and air tightness to the building envelope and therefore guaranteeing NZEB compliance and the achievement of the requirements for compulsory air tightness testing.

All of those involved in construction have a role to play in achieving these outcomes. The achievement of the necessary 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

There are many product requirements listed within the product standard, Building Regulations Technical Guidance Documents (TGDs) and in Standard Recommendation S.R. 325 (S.R. 325:2013+A2:2018), which together constitute Nationally Defined Parameters (NDPs) for the Recommendations for the design of masonry structures in Ireland to Eurocode 6. Collectively, these parameters must be followed in order to comply with product certification and CPR requirements for the Design, preparation and application of masonry structures in Ireland and the Design, Preparation And Application Of External Rendering And Internal Plastering - Part 2: Internal Plastering I.S. EN 13914-2 : 2016.

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 2019
    - Technical Guidance Documents (TGD) Part F 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)

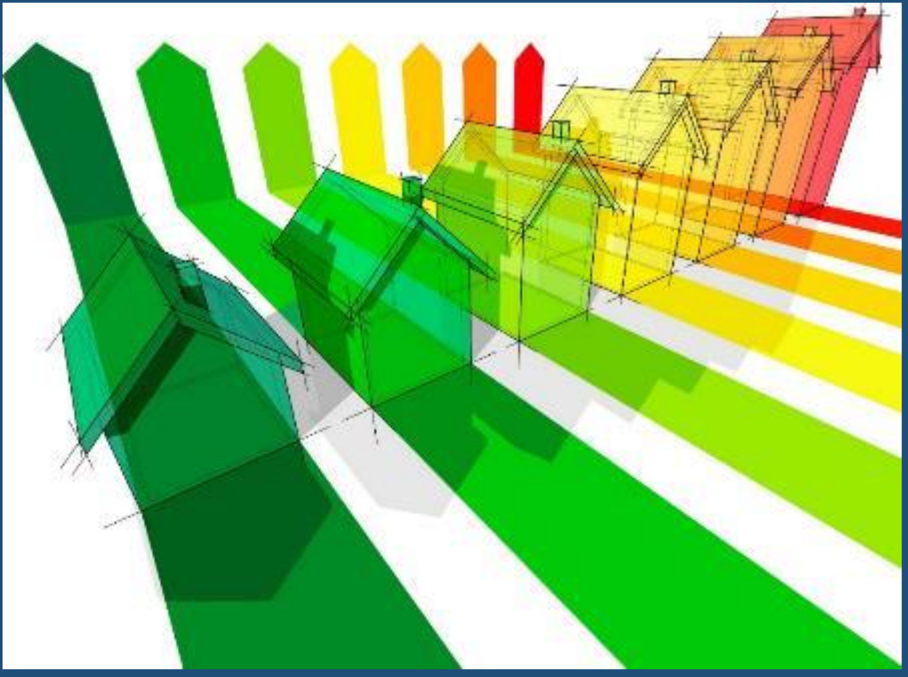
National Standards Authority of Ireland at External Thermal Insulating Composite Systems (ETICS) Installers List (external link)

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

National Standards Authority of Ireland at Recommendations for the Design of Masonry Structures in Ireland to Eurocode 6, S.R. 325:2013+A2:2018,

National Standards Authority of Ireland at Design, Preparation and Application of External Rendering and Internal Plastering - Part 2: Internal Plastering I.S. EN 13914-2: 2016.

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

Unit 2.1 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.

Convection

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

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.

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.

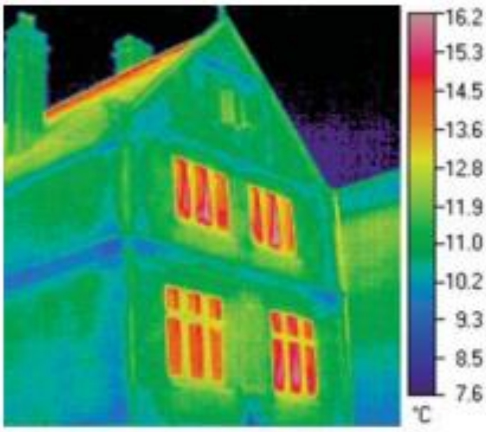


Figure 2.0: Thermographic image showing heat loss through a building envelope (source: SEAI, 2007[7])

Heat transfer through the building envelope

Figure 2.1 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.

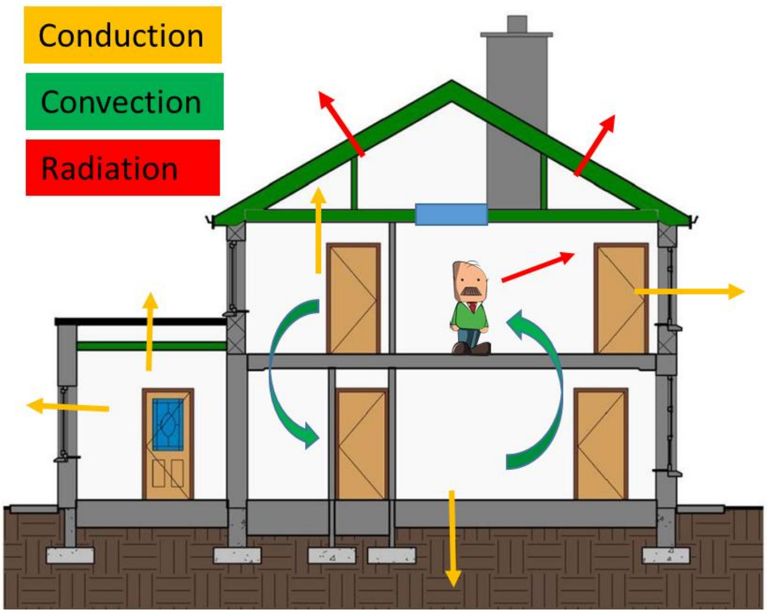


Figure 2.1: Typical heat loss pathways from a house during winter

[7] *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 2.2, 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.

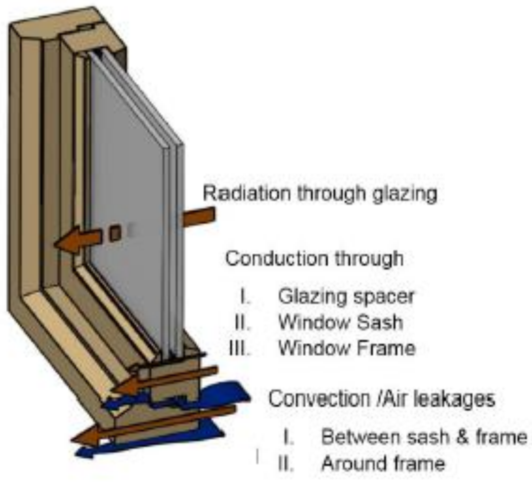


Figure 2.2: Heat loss through a window

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 2.3 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.

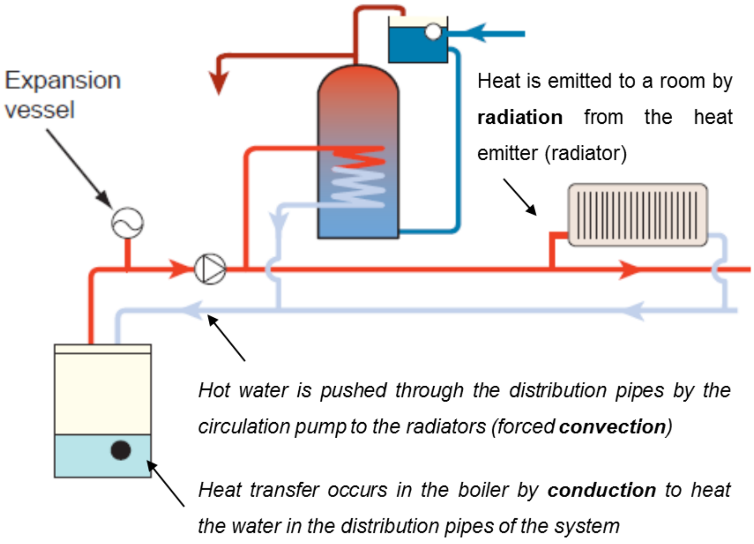


Figure 2.3: Sealed wet central heating system (Source: SEAI)

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 2.4)

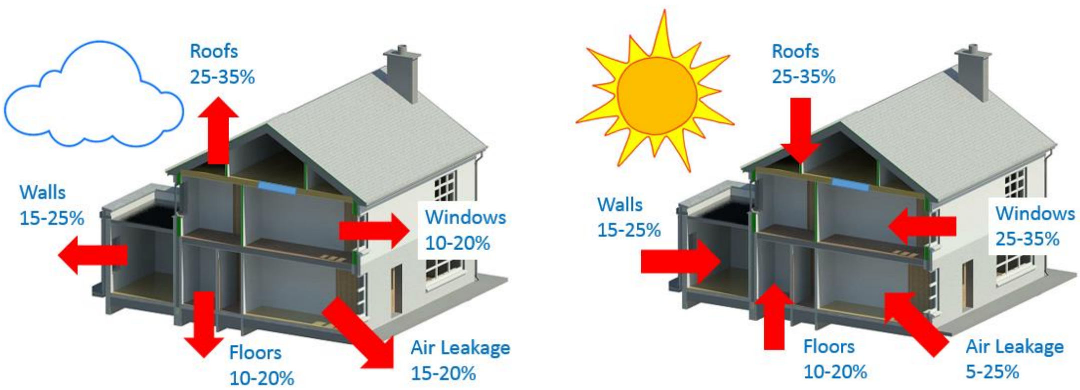


Figure 2.4: Percentage of heat losses in winter time and heat gains in summer time

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 2.5 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.

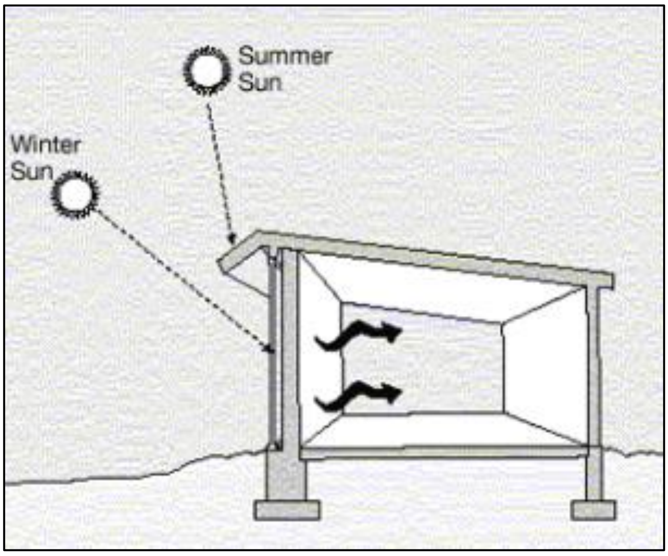


Figure 2.5: External shading to the window preventing overheating of a building.

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 2.6). If there is enough thermal mass it may delay the release until night time, meaning that the building remains warmer during cooler winter nights. During the summer, overhangs or shading can reduce the entry of solar energy and the stored heat is released to the ground. Ventilation can then be used at nigh time to keep internal air temperature down.

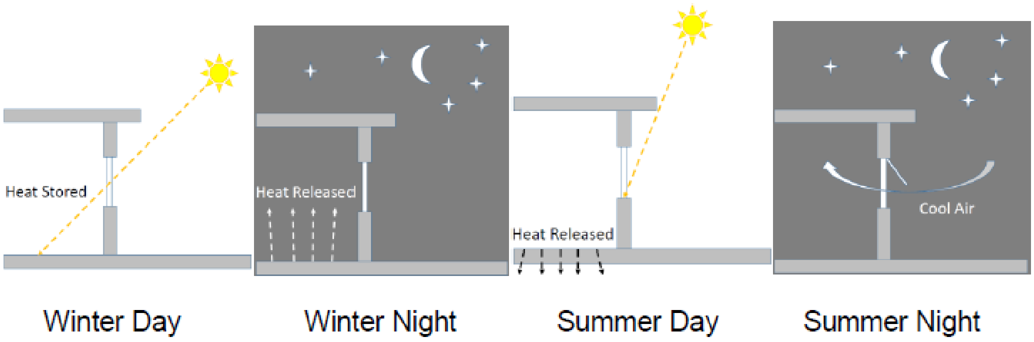


Figure 2.6: Illustration of effect of thermal mass

As Bricklayers, 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 (λ)

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 (R-value)

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).

$$\boldsymbol{U - Value} = \frac{\mathbf{1}}{\textbf{Total R}}$$

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.

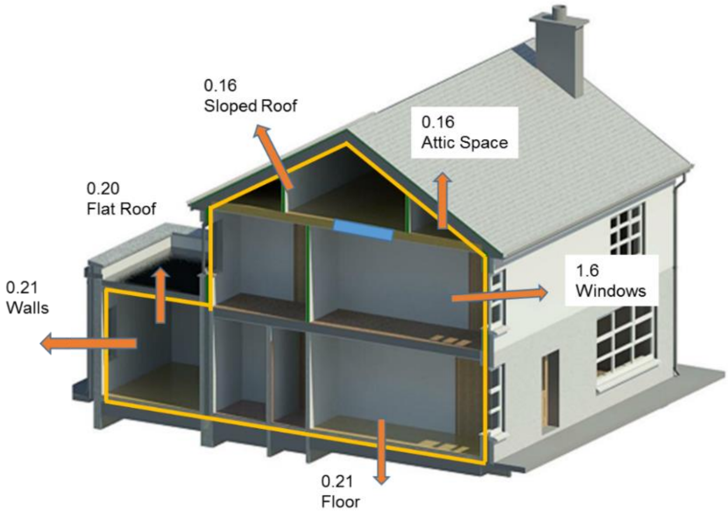


Figure 2.7: Permitted U-values for Dwellings taken from TGD Part L, 2011

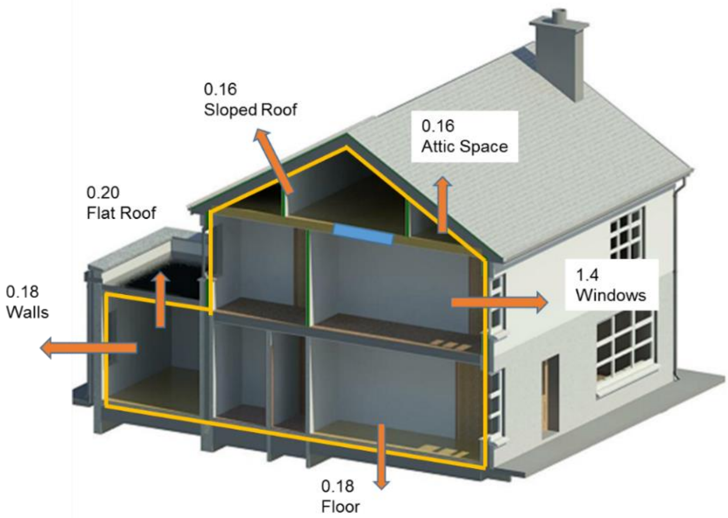


Figure 2.8: Permitted U-values for Dwellings taken from TGD Part L, 2019

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:

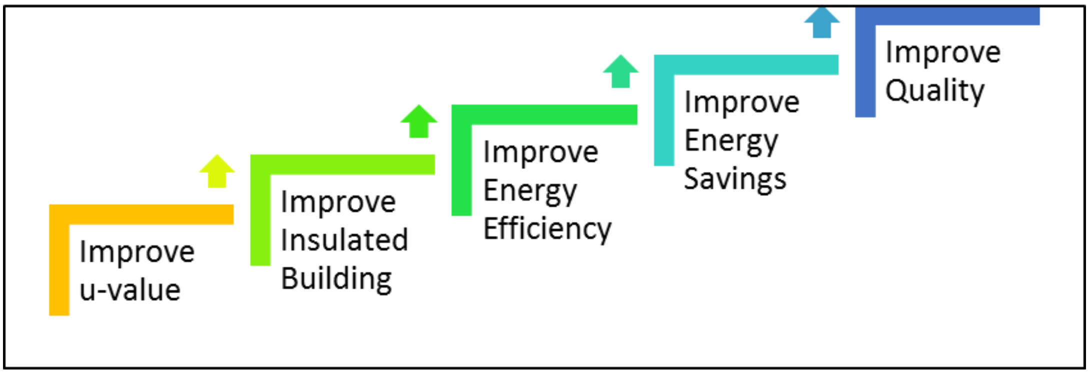


Figure 2.11: Demonstrating the steps to achieving Quality

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 2.9. You will see that the continuous insulation, which, in this case is provided internally, but can equally be installed externally (as with external wall insulation, EWI).

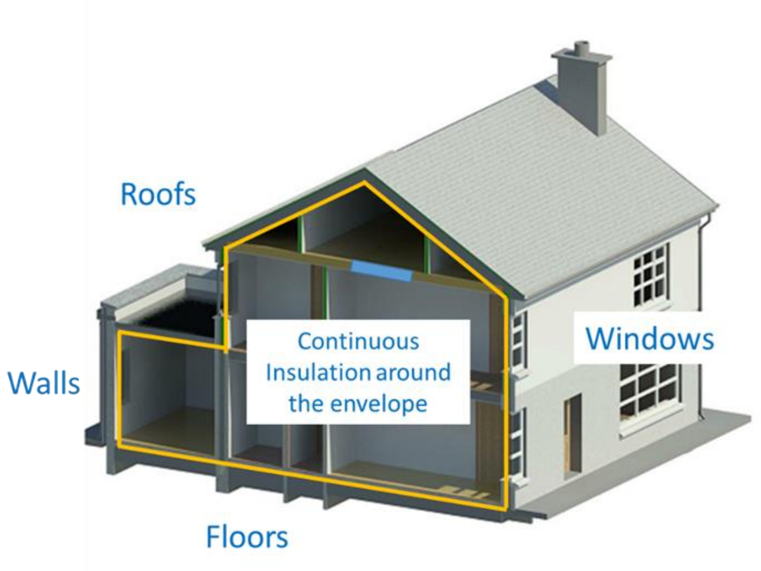


Figure 2.9 Continuous Insulation shown by orange line – controlling heat flows through the envelope

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.

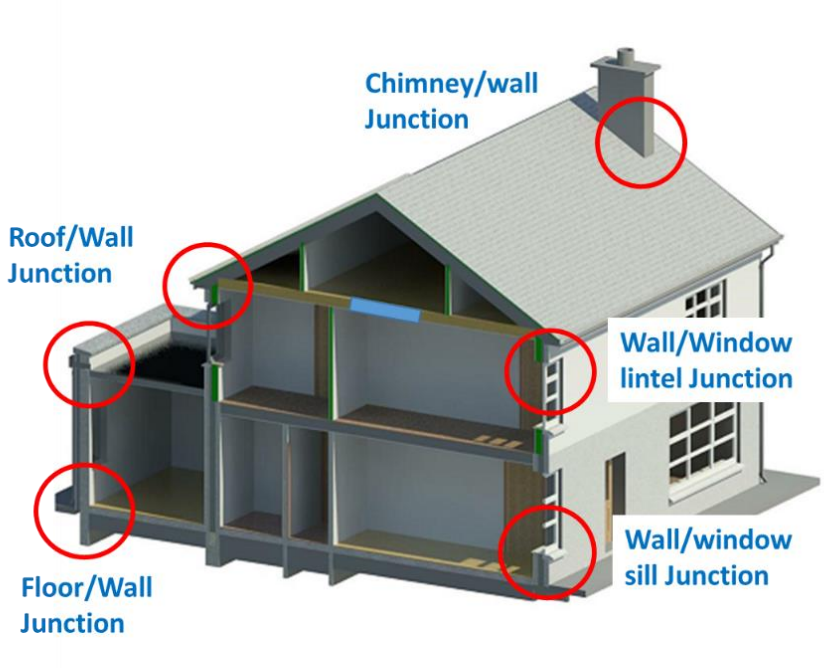


Figure 2.10 Common areas where thermal bridging occurs in a dwelling

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).

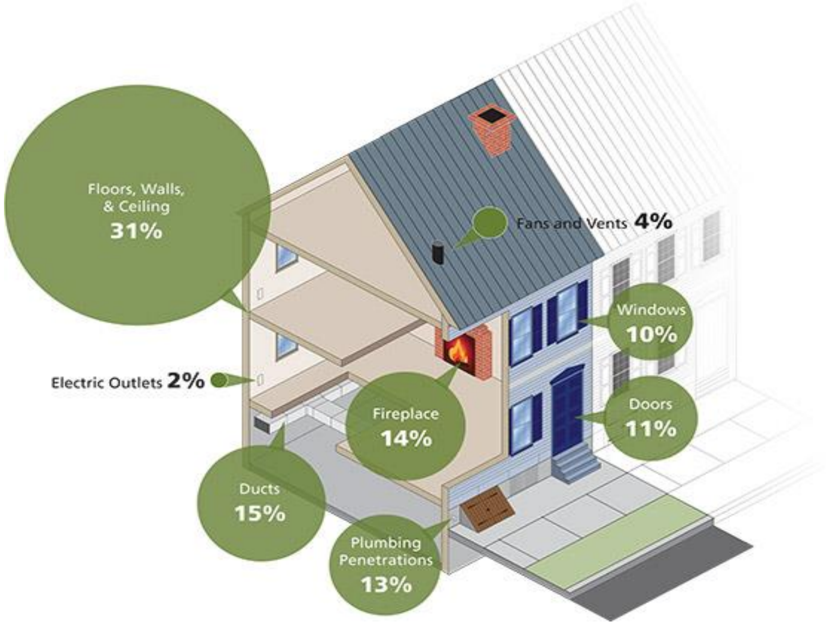
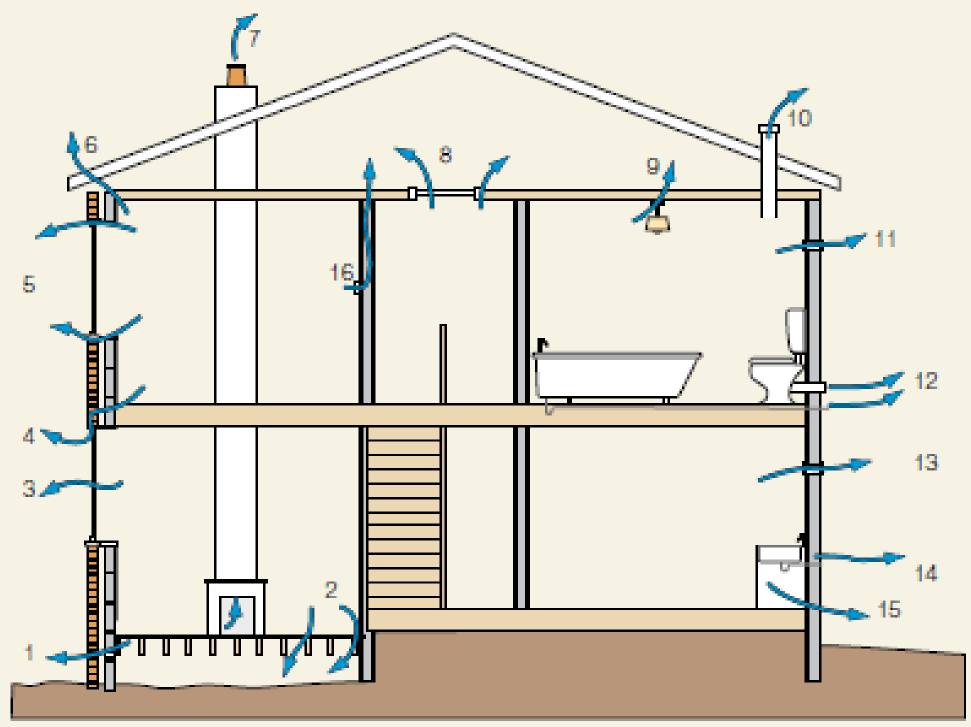


Figure 2.11 Percentage of air leakage through a typical building

Figures 2.11 and 2.12 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 2.12: 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.

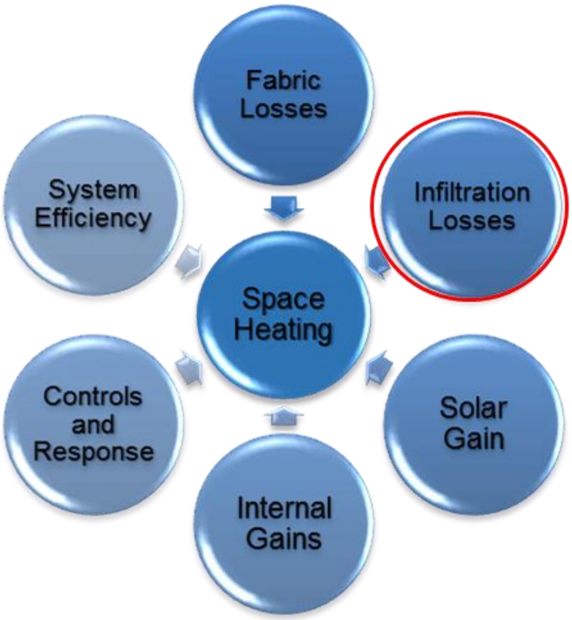


Figure 2.13 Diagram- Infiltration losses affecting energy use for space heating.

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 Bricklayers, 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

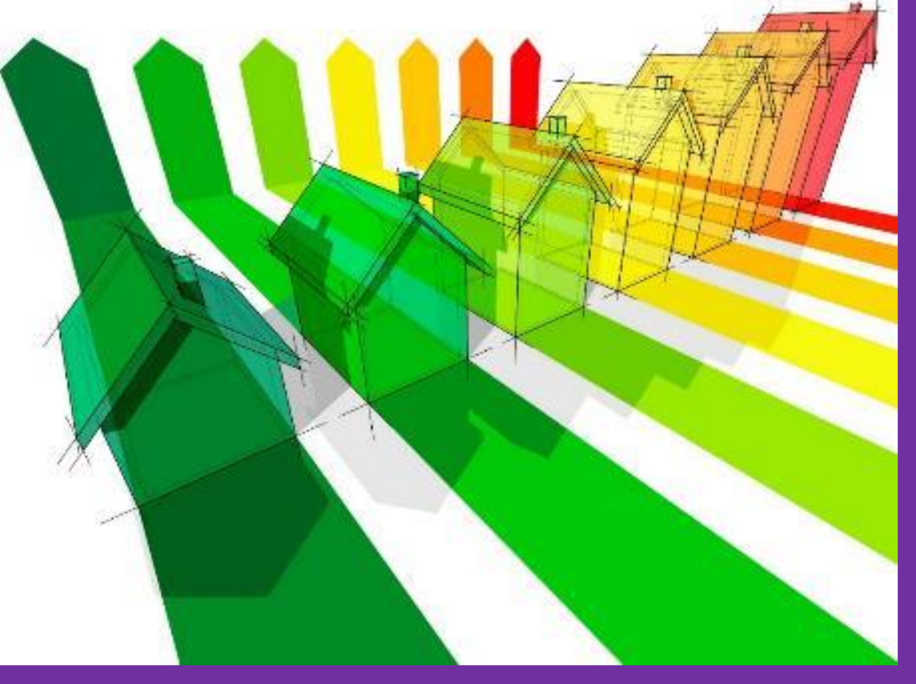
See links below to videos illustrating heat loss principles and calculations:

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

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 one. 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. **If you are 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.**

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).

Figure 3.0: Examples of continuous insulation in the wall and roof

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.

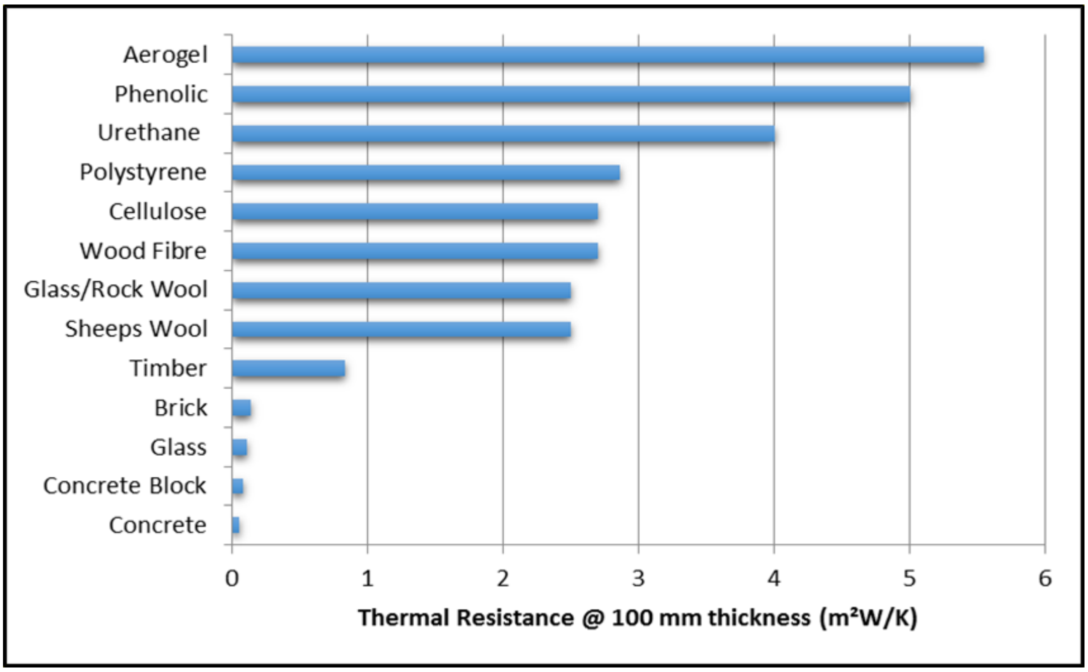


Figure 3.1: Chart comparing the thermal resistance for materials of 100mm thickness

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***".

It is important to consider the properties and characteristics of the material when choosing insulation products and systems. In Figure 3.1, we looked at the different thermal properties of materials. However, other factors to consider are:

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

Condensation:

Surface condensation is caused by warm air meeting a cool surface leading to condensation. You will be familiar with condensation on a mirror in a bathroom after a shower. This also happens when the warm air meets the cold temperatures of the external wall and moisture starts to form on the surface of the wall.

The damp caused by this surface condensation provides an ideal environment for mould growth. Figure 3.2 shows mould growth on the inner surface of an external wall of a building near a window. In this case, the wall is so poorly insulated that the internal surface is cold enough for condensation to occur. There may also be poor ventilation, meaning that moisture is building up in the room.

Figure 3.2: Surface Condensation leading to mould growth

Mould growth caused by surface condensation can be clearly seen in Figure 3.2 and measures should be taken to improve insulation and/or ventilation to the area

Interstitial condensation occurs when water vapour condenses within an element of the building, e.g., within a wall or roof.
This happens when warm damp air from inside the building, makes its way through gaps in the envelope, and turns to water (at dewpoint) when it meets cold temperatures within the material. This can lead to wet insulation that does not perform as well as it should, and can result in rot in the structural fabric.

Remember this type of condensation is rarely seen until structural damage has been done or health issues arise.

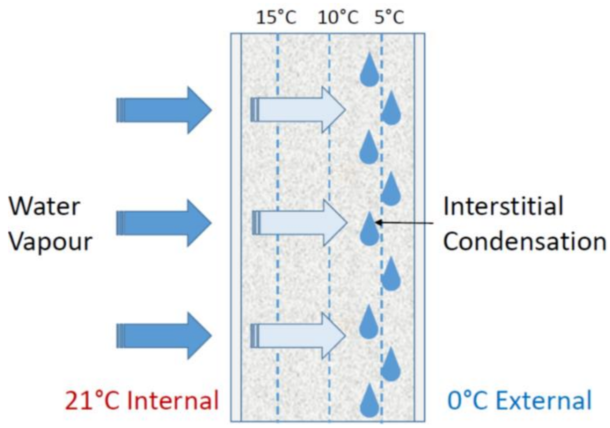


Figure 3.3: Interstitial Condensation leading to internal damage of wall

The diagram in Figure 3.3 shows a section through an external wall and how this sort of condensation can occur. The figure shows warm moist air (at 21ºC) from inside the house moving through the fabric of a wall during cold weather (0°C outside) and meeting cold temperatures, resulting in water vapour turning into moisture. Interstitial calculations, where required, should be carried out to EN standards (I.S. EN ISO 13788 or I.S. EN 15026). Software is available to calculate the transfer of heat, moisture and air through building structures and is used to assess the risk of interstitial condensation.

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

Vapour Resistance/Permeability/Breathability *(μ):*

Moisture build-up is one of the dangers in highly insulated buildings. Vapour Resistance 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 vapour resistivity properties which is also known as Permeability/Breathability ***(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.

This ability to dry out is vital in certain types of construction and in particular solid stone walls.

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

Compatibility with other materials:

A variety of materials commonly used in the construction of buildings are listed in the following Tables 3.0 and 3.1. Take a look at these, and see if any are familiar. Take note of the thermal (W/mk) and permeability (μ-value) properties and where you have seen them fitted within the building envelope.

Building Materials

Material Type	Category	Applications	Conductivity W/mK	μ-value
Metal	Aluminium, Steel	Windows, doors, cladding steel frame, lintels	230 45 45	Extremely low
Concrete	Precast concrete, In-situ concrete	Floors, walls, flat roof	1.13	very low
Concrete blocks	Heavy block, Medium blocks Hollow cavity block	Walls, rising walls	1.33 1.15 1.02	very low
Plasterboard	With foil back	Internal panelling (not for stone walls)	0.16-0.25	very low
Aerated	Cellular, lightweight material from quartzite sand, lime & water.	Wall blocks, walls panels, thermal bridging	0.33	fairly low
Pumiced	Lightweight material from pumice, cement & water	Walls, roof, floors, thermal bridging	0.18	fairly low
Clay blocks	Clay bricks, Aerated clay blocks	Walls, thermal bridging	0.77 0.30	fairly low
Plastic	uPVC,	Windows, rooflights, doors	0.14–0.28	low
Glass	windows	Curtain walls, windows, rooflights, doors	0.96	low
Cement	Cement based tiles, Cement fibre boards Render	Walls, external render, flat & pitched roof, internal render	0.5 0.35 0.18	low high

Timber	Timber, Laminated, Woodchip, Woodfibre, mdf,	Roofs, Walls, floors, external render, windows, doors	0.12-0.14	low - high
Plasterboard	Plasterboard, Mdf,	Internal panelling, to walls and roof.	0.16-0.25	high

Table 3.0: Properties of Common Building Materials

Insulations

Insulation Type	Category	Applications	Conductivity W/mK	μ-value
Sheep's Wool	Blanket/quilt	Loft, rafters, timber floors, timber frame	0.035 - 0.044	1
Glass Wool	Blanket/quilt or loose blown-in	Loft, rafters, timber floors, timber frame	0.032 - 0.044	1
Stone Wool	Blanket/quilt or loose blown-in	Loft, rafters, timber floors, timber frame, EWI	0.035 - 0.044	1
Cellulose	Loose blown-in	Loft, rafters, timber frame	0.035 - 0.040	2
Wood Fibre	Rigid board	Loft, rafters, timber floors, timber frame, EWI, IWI	0.038 - 0.044	5
Polystyrene	Rigid board	Concrete floor, flat roof, EWI	0.025 – 0.035	60 - 150
Urethane	Rigid board or loose blown-in	Concrete floor, rafters, flat roof, EWI, IWI	0.019 - 0.025 0.032 - 0.038	60
Phenolic	Rigid board	Concrete floor, rafters, flat roof, EWI, IWI	0.020	50
Aerogel	Blanket, strip or granules	Loft, walls, rafters, thermal bridging, glazing	0.013 - 0.019	5

Table 3.1: Applications for Common Insulations

The chosen insulating material should not result in creating 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. Some insulating materials are selected because they are waterproof or very vapour tight. This may be a requirement when insulating underground e.g. under a concrete floor slab or below ground level

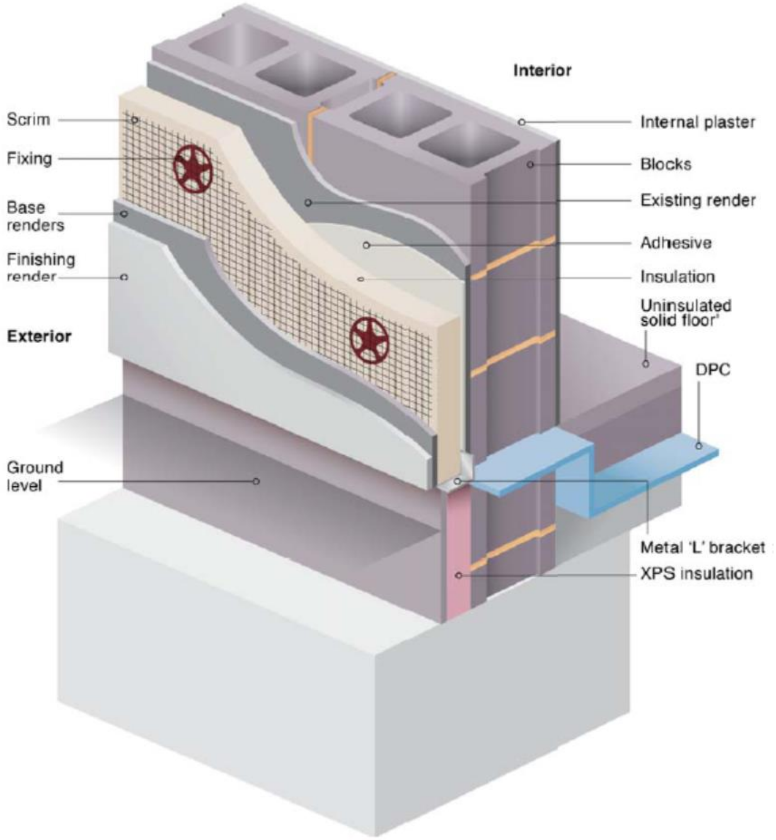


Figure 3.4: External insulation at ground level (Reproduced from S.R. 54:2014 with the permission of NSAI)

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

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.

This is never more important than in retrofitting existing buildings. Choosing the correct insulation systems can be daunting and knowing which one to use is a skill in itself. Common Insulation Systems will be discussed later in this Module taking into account continuous insulation, thermal bridging and air tightness.

Common Insulation Systems

Internal Wall Insulation (IWI)

The IWI system initially in widespread use comprised an insulation layer of glass or wool fibre fitted between timber battens which were fixed at centres to the inner face of the wall. A vapour barrier was placed over the battens and insulation, often a polythene sheet. Gypsum plasterboard was fixed over and finished with either taped joints or with Gypsum wet applied skim coat plaster (see Figure 3.5).

This system often incurred poor performance, particularly significant issues with surface and interstitial condensation. The battens fixed at centres formed repeated thermal bridging and usually there was no insulation returned at the reveals of openings. Continuity of insulation at junctions with adjacent walls, ceilings and floors were also a concern. The polythene used as a vapour barrier was often poorly fitted and, allowing for vapour ingress into the fabric through gaps to condense, resulting in a sweating effect.

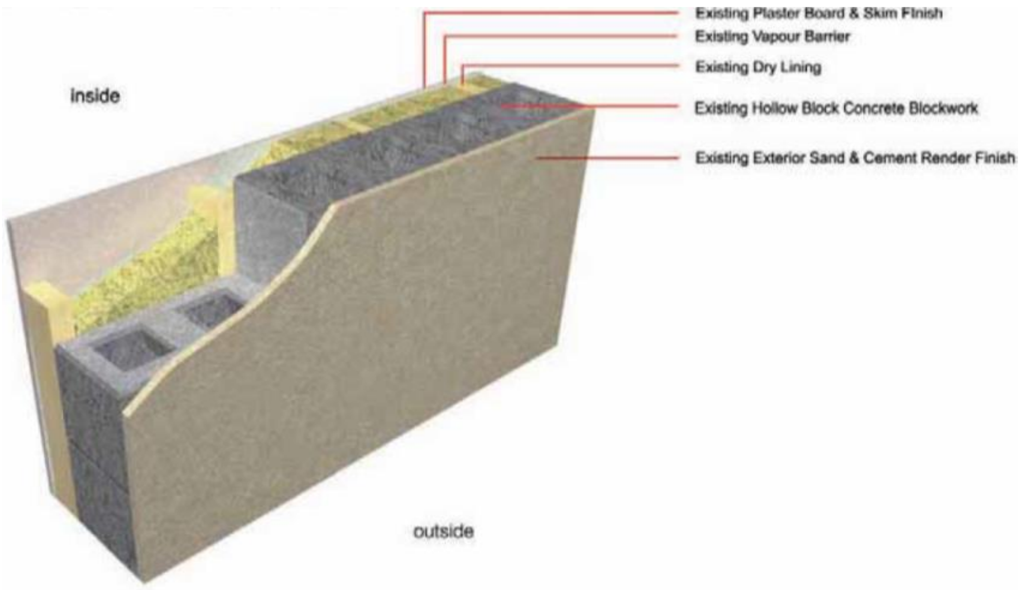


Figure 3.5: Typical dry-lined hollow block external wall construction (Source: SEAI - Passive House Retrofit Guidelines)

In recent times, dry lining has also been applied as an energy efficiency upgrade to various types of solid single leaf walling. Composite boards of rigid slab insulation and gypsum plasterboard have become available for internal insulation, generally incorporating an integrated vapour control layer (see Figure 3.6).

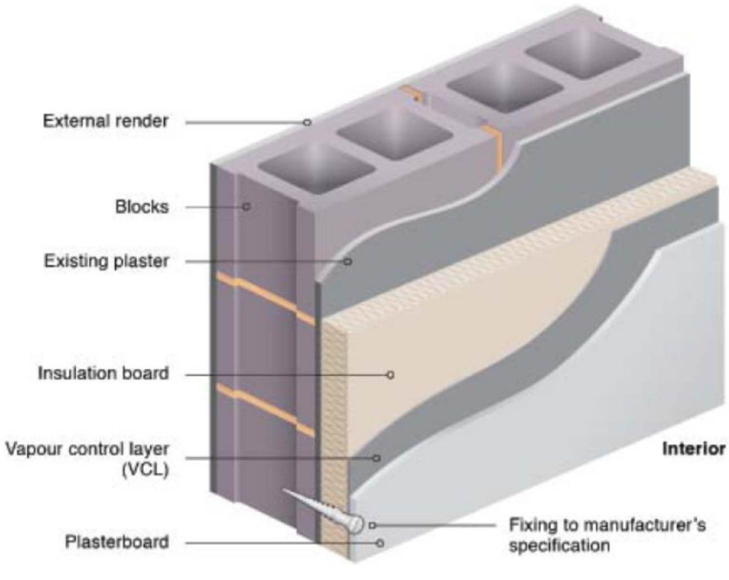


Figure 3.6: Thermal laminated board fixed to internal face of wall (Reproduced from S.R. 54:2014 with the permission of NSAI)

It is important that the vapour control layer be well sealed at wall, floor, ceiling, door and window junctions, around light switches and at all other breaks in the insulation as interstitial condensation (moisture build-up within the fabric) is a real risk when insulating internally. Therefore, it may be argued that this system has a limited suitability in retrofit applications. However, this has not affected the widespread usage and these types of systems have been eligible for grant aid under various energy efficiency upgrade schemes.

As with the majority of energy efficient applications, attention to detail is crucial to ensure correct performance and avoid compromise. Some thermal laminated boards for example, are being supplied by builder's merchants with metal fixings to mechanically attach the boards to the walling. This practice results in multiple thermal bridging pathways through the wall insulation.

Guidance in current building regulations and the recently published Retrofit Code of Practice (NSAI, S. R. 54) emphasise good practice in installation of IWI. The use of additional layers of insulation and detailing at door and window reveals is encouraged to counteract thermal bridging effects. Methods of maintaining integrity of vapour control layers are also outlined, such as provision of service voids (see Figure 3.7)

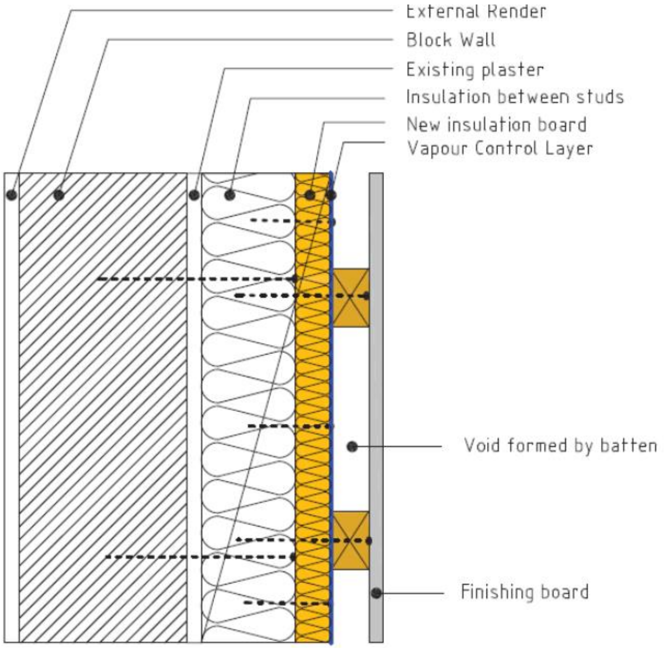


Figure 3.7: IWI with service void formed by timber batten (Reproduced from S.R. 54:2014 with the permission of NSAI)

Typically, these systems are installed by plasterers or carpenters for both new build and in retrofit applications. A fundamental understanding of the principles of thermal bridging, air tight construction, material suitability and interstitial condensation is required to ensure successful results.

External Wall Insulation (EWI)

External wall insulation (EWI) has become widely regarded as best practice for the retrofitting of masonry walls for energy performance. External wall insulation has a number of clear advantages over internal systems as a continuous insulation envelope can be created. This enables the elimination of thermal bridging and significant improvement to the structural air tightness of the building.

By virtue of the fact that the insulation is fitted to the outside of the building, any potential interstitial condensation will be isolated externally to incur little or no adverse effect. Also in its favour, this system of insulation does not impinge on the floor space of a building.

External insulation involves fixing insulation materials such as mineral wool, expanded polystyrene or Polyisocyanurate (PIR) slabs to the outer surface of the wall. This insulation is finished externally with an acrylic or cement-based render to provide weather resistance. A steel or fibreglass mesh (scrim) is embedded in the render to provide strength and impact resistance (see Figure 3.8).

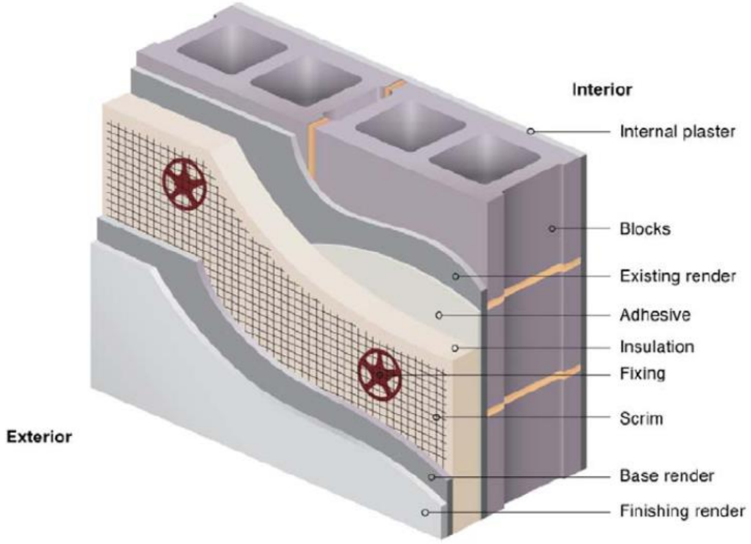


Figure 3.8: Typical External Wall Insulation system using wet render (Reproduced from S.R. 54:2014 with the permission of NSAI)

A thinner layer of insulation is fitted around the window and door reveals to minimise thermal bridging. Existing concrete window sills are cut back and replaced by proprietary sill covers with integrated insulation layers to reduce thermal bridging.

Correct detailing at flashings, plinths and abutments is extremely important to optimise performance. Attention is also needed to fire resistance factors and maintaining function of drains, sewers, gutters and waste pipes. Most significantly, as the system is so effective in reducing air infiltration, adequate controlled ventilation requirements need to be maintained or reinstated according to the needs of the dwelling.

ESB Networks and Bord Gais have also published specific guidance for dealing with service cables, pipes and meter boxes which are affected by the external insulation installation.

For external insulation, the SEAI insist on the use of NSAI Agrément certified products and only list approved contractors that have registered under the NSAI Agrément registered installer scheme as eligible for grant support. NSAI Agrément offer registration to installers of Blown Loft Insulation (see xx later), Full Fill Cavity Wall Insulation (see xx later) and External Insulation. Installers are often from a plastering or bricklaying background (wet trades). Similarly to internal dry-lining, an understanding of air tightness/ventilation and thermal bridging is essential to successful installation.

Cavity Wall Systems

The most commonly adopted cavity wall construction became a 100mm external masonry leaf with a 105mm air cavity partially filled with insulation. An air cavity was maintained on the cold side with a 100mm inner masonry leaf provided. Plastic or metal cavity ties were fitted at regular intervals to provide structural stability and to retain the insulation material against the inner leaf. The insulation is fitted by the block layer as the walling is constructed in courses (Figure 3.9).

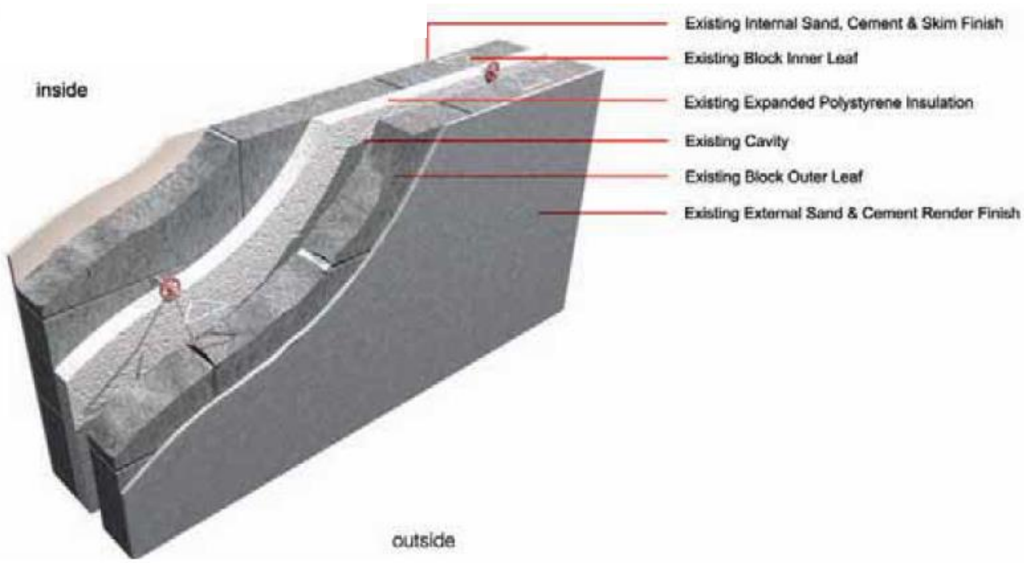


Figure 3.9: Typical Cavity Wall Detail (Source: SEAI, Passive House Retrofit Guidelines)

With amendments to TGD Part L (dwellings) in 2007, 2011 and 2019, the maximum elemental U-value for walls has decreased to **0.18W/m²K**. This has pushed the boundaries of this construction as a cavity up to 150mm to accommodate high performance insulation boards while still retaining a minimum air cavity thickness of 40mm. Alternatively, full fill insulations are on the market and along with specific plastic wall ties are becoming more popular. Proprietary systems for cavity closing around openings have also now widely used to the market to facilitate the achievement of thermal bridging standards set by the Building Regulations and NZEB Compliance.

These performance standards necessitate particular attention to detail in cavity wall construction in order to achieve continuity in the insulation layer. At installation, the insulation material is fitted tight at joints, with particular attention required around openings and junctions. Insulation must also be tight to the inner leaf in order to avoid a phenomenon known as “thermal looping”, where air circulation occurs between the air cavity and gaps on the warm side of the insulation.

Existing cavity walling also lends itself to energy retrofit through ***pumped full-fill cavity insulation*** technology. This system involves drilling a series of holes in the outer leaf of the external wall. This is to accommodate the nozzle of a pump through which insulation is fed into the cavity to fill any voids. NSAI currently approve bonded bead type polystyrene insulation but there are also polyurethane foam alternatives on the market.

Suitability of a cavity wall needs to be determined in advance before using this system to investigate any issues with water ingress or damage in the cavity. At installation, the flow rates of the pumped insulation and centres at which holes are drilled in the external leaf requires careful attention. This is to ensure that the cavity is completely filled. Maintaining designed ventilation is also essential.

This system has certain limitations as the improvement to the insulation layer in the cavity is bound by the existing cavity construction. Existing thermal bridging in the wall at openings and junctions created by closing of the cavity will therefore remain.

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. This is why we should look to achieve continuous insulation, as the risk of thermal bridging is then greatly reduced.

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

Blockwork wall junctions

Careful detailing is required to avoid thermal loss due to thermal bridging and to maintain roof ventilation at the roof-wall junction particularly where the dwelling is also provided with wall insulation. Figure 3.10 and Figure 3.11 show appropriate overlap of roof insulation at the junction with EWI and IWI respectively.

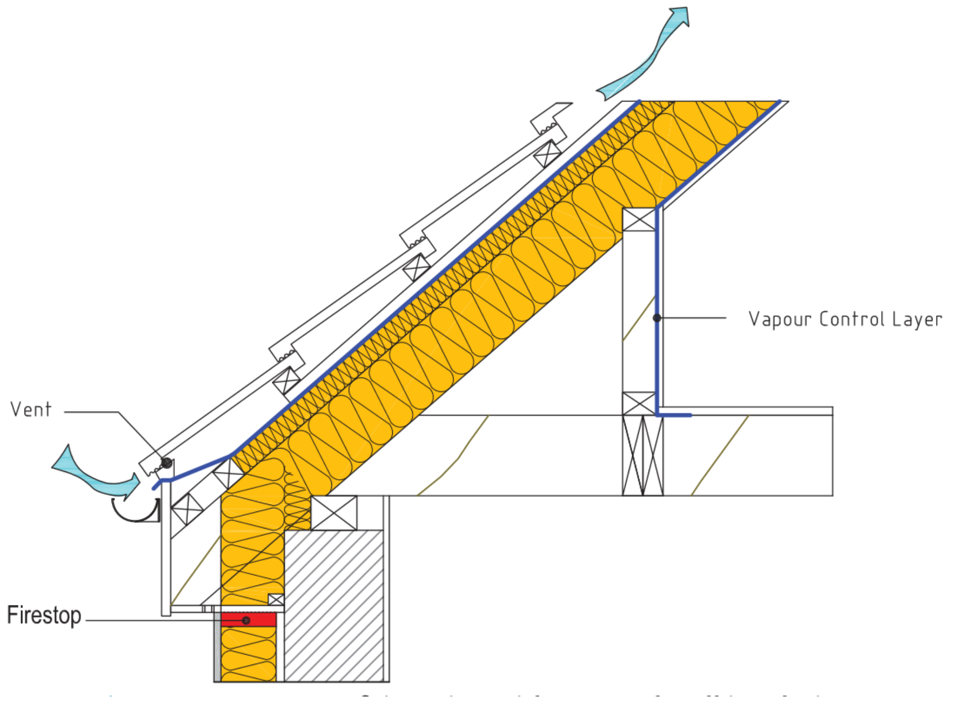


Figure 3.10: Roof and external wall insulation junction (Reproduced from S.R. 54:2014 with the permission of NSAI)

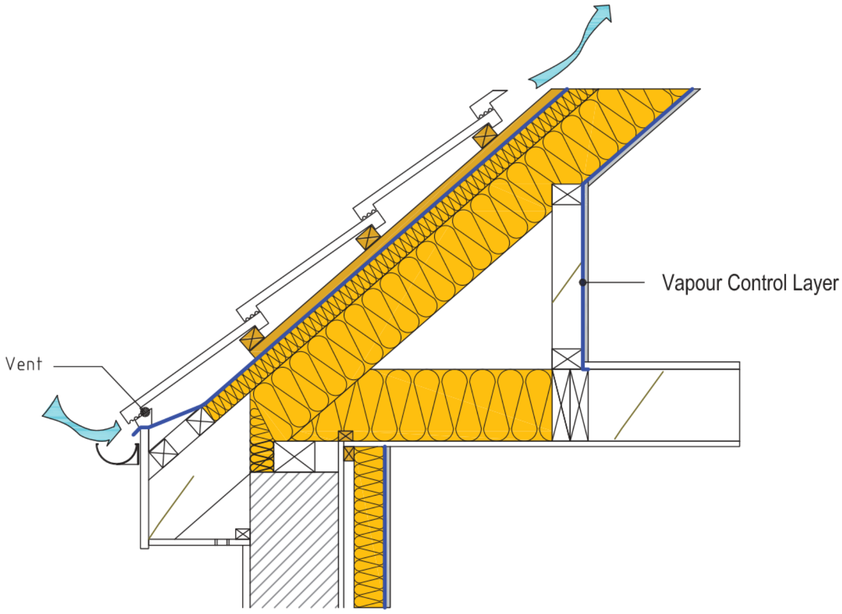


Figure 3.11: Roof and internal wall insulation junction (Reproduced from S.R. 54:2014 with the permission of NSAI)

With the insulation placed above (and possibly between) the rafters, the risk of surface condensation occurring is minimised as all internal surfaces of the roof structure are on the warm side of the insulation. However, it is still necessary to ensure a vapour control layer is provided to reduce the risk of interstitial condensation and to improve the airtightness of the construction.

Consider a layer of mineral wool insulation with low conductive properties fitted within a timber frame construction with medium conductive properties (Figure 3.12), 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.

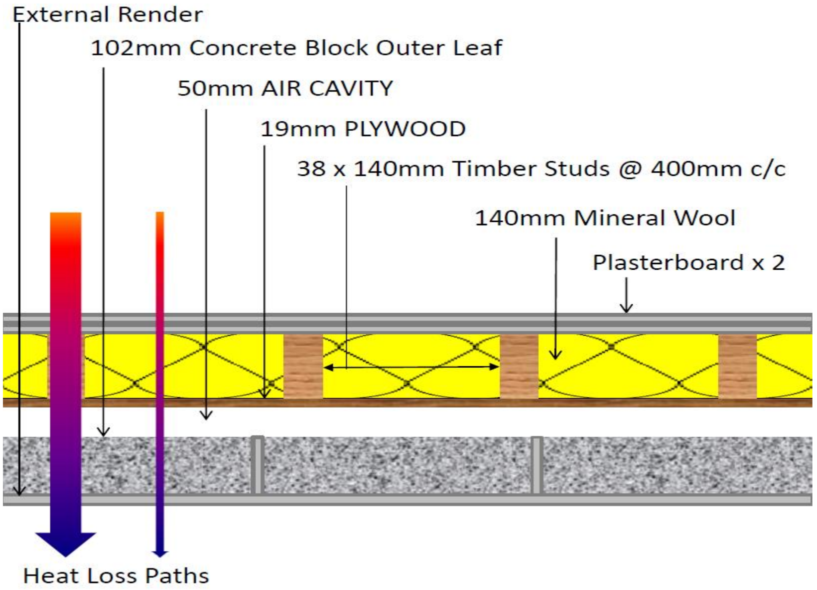


Figure 3.12 Blockwork external wall with internal timber stud construction showing Thermal Bridging

This reduces the effectiveness of the thermal properties 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 floor junction

To minimise the impact of the thermal bridge, improved use of thermal materials along the inside of the wall should be installed (Figure 3.13). Alternatively a service wall may be installed in front of the internal insulation layer to prevent services breaking through the continuous insulation and of course the airtight membrane. This will reduce the impact of heat flow through the wall but the choice and use of appropriate materials should however be considered.

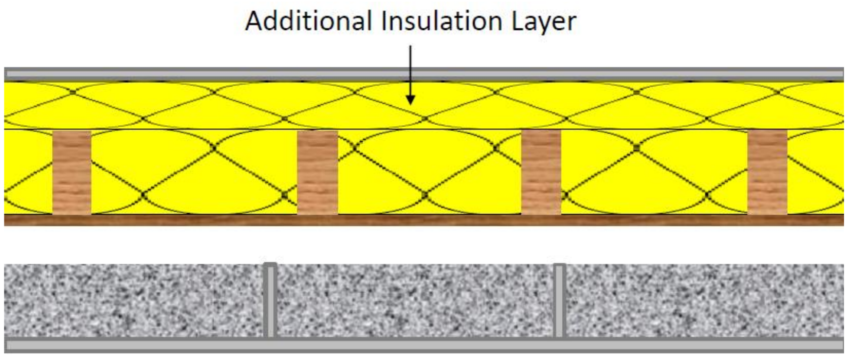


Figure 3.13 Best Practice detailing to minimise thermal bridging

The junction of the cavity wall to the ground floor is also equally important in getting right as extensive thermal bridging can occur if not completed correctly. It is essential to provide additional perimeter insulation from the rising wall (min 20mm thick) to the underside of the external insulation to reduce impact of thermal bridging. This needs to be installed carefully to ensure there are not gaps around the perimeter of the external envelope and also to all internal concrete walls leading to foundations.

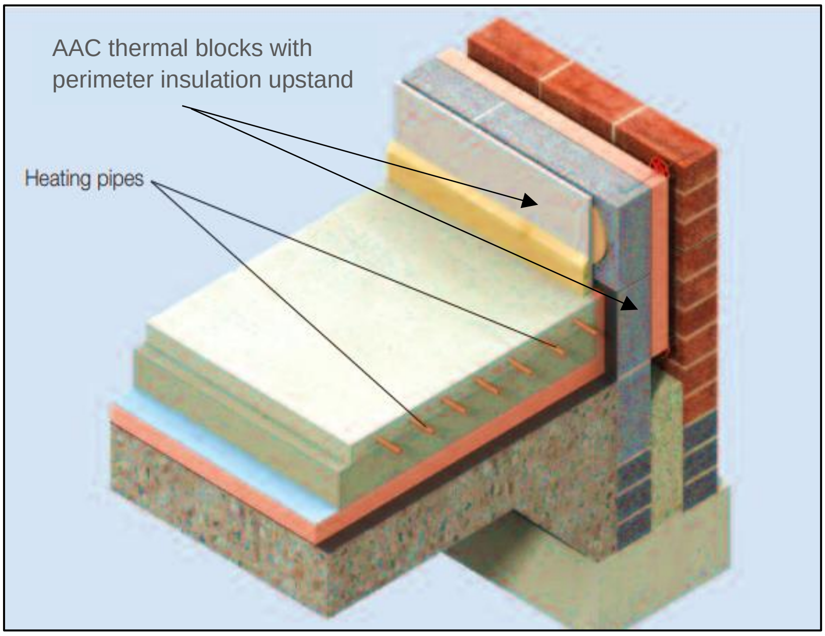


Figure 3.14 Best Practice detailing to minimise thermal bridging

It should be emphasised that the cavity insulation must extend 225mm below the level of the concrete floor. The type of insulation chosen and installed should be fit for purpose and certified to ensure waterproof qualities. The main insulation board under the concrete floor should also be certified and have the compressive strength and waterproof qualities necessary.

The thermal AAC blocks also require certification for the compressive strength and waterproof qualities necessary to prove the product is fit for purpose.

A particular point of weakness of thermal bridging is with the construction of a chimney. Specific details on reducing thermal bridging should be agreed prior to works.

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 3.15 Demonstration model showing additional Insulation Layer and service wall

The proportion of the overall heat loss due to thermal bridging on average for a 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).

Acceptable Construction Details ACDs

ACDs have been developed to provide guidance on how continuous insulation and air-tightness can be maintained at specific locations (weak spots) in the dwelling to minimise heat loss and air leakage.

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

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

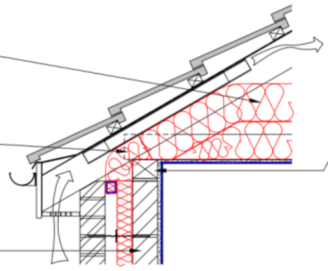
(1) WALLS:- INSULATION IN CAVITY **Eaves - Ventilated Attic** *DETAIL 1.10, 2011*

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 3.00 m^2K/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

Detail is indicative for thermal purposes. Where continuity of insulation is maintained throughout the junction, alternative structural design may be used.



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

AIR BARRIER - OPTIONS

OPTION (TICK ONE)

- ☐ 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** *DETAIL 1.10, 2011*

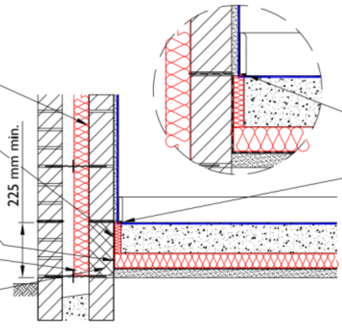
Figure 3.16 ACD at the junction of a cavity blockwork wall and a pitched roof

(1) WALLS:- INSULATION IN CAVITY **Ground Floor - Insulation Below Slab Plus Lightweight Block** *DETAIL 1.02b, 2011*

THERMAL PERFORMANCE

CHECKLIST (TICK ALL)

- ☐ Ensure partial fill insulation is secured firmly against inner leaf of cavity wall
- ☐ Install perimeter insulation with a min. R-value of 1.0 m^2K/W
- ☐ Floor insulation to tightly abut blockwork wall
- ☐ Ensure wall insulation is installed at least 225 mm below top of floor
- ☐ Ensure block with a maximum Thermal Conductivity of .20 W/mK in the direction of heat flow is used and that block is suitable for use in foundations



AIR BARRIER - CONTINUITY

CHECKLIST (TICK ALL)

- ☐ Seal between wall and floor air barrier with a flexible sealant OR seal gap between skirting board and floor with a flexible sealant
- ☐ Seal all penetrations through air barrier using a flexible sealant

Complying with checklist will help achieve design air permeability

GENERAL NOTES

The wall insulation installed below the wall DPC must be fit for purpose with regards to water absorption

Keep cavities clean of mortar snots and other debris during construction

Detail applicable:- Ground-bearing floor; raft foundation; in-situ suspended ground floor slab; pre-cast suspended ground floor; concrete and screed. Insulation below slab

AIR BARRIER - OPTIONS

OPTION (TICK ONE)

- ☐ 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 **Ground Floor - Insulation Below Slab Plus Lightweight Block** *DETAIL 1.02b, 2011*

Figure 3.17 ACD at the junction of a cavity blockwork wall and the ground floor

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 all 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.

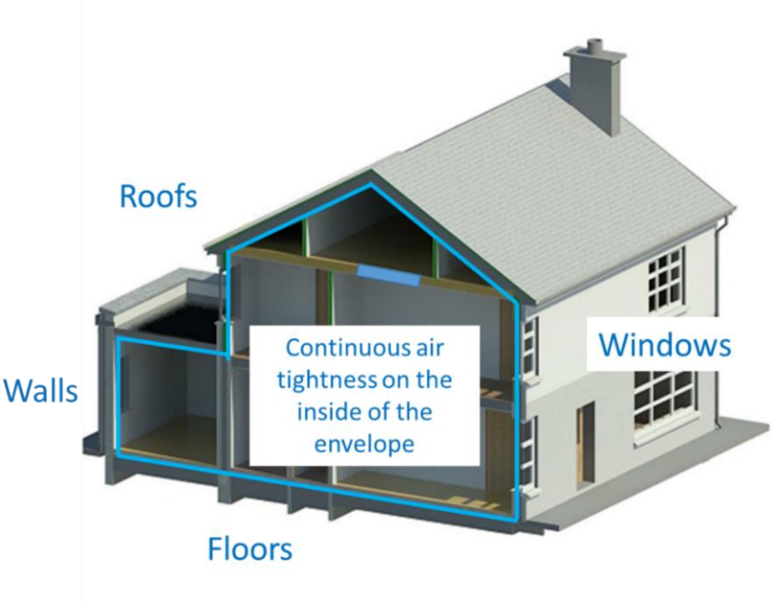


Figure 3.18 Air Tightness barrier in a building envelope

Figure 3.18 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 3.19 shows the position of a wind tight barrier in a building envelope.

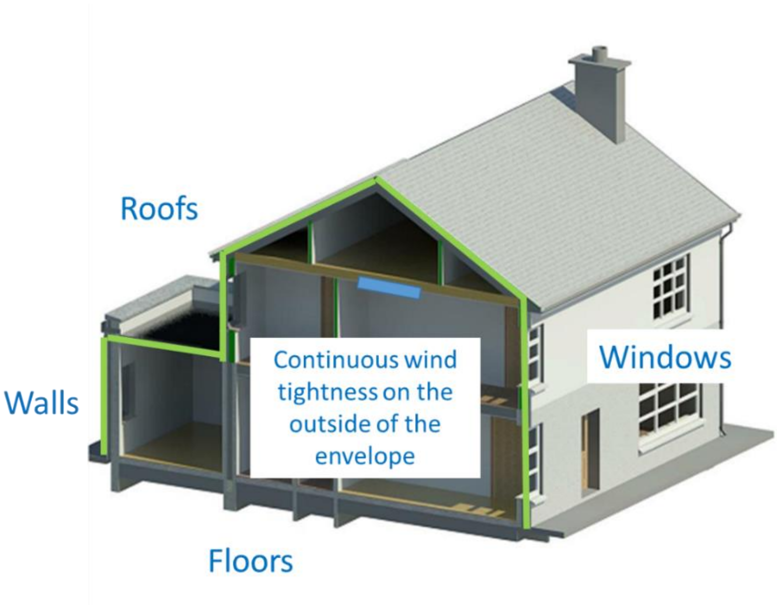


Figure 3.19 Wind Tightness barrier around a building.

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.

Air and Wind-Tightness Strategy

There are 5 important stages to building air-tight/wind-tight:

1. Choose the correct wind/air tightness materials - fit for purpose.
2. Air tightness checklist – quality control
3. Ensure the barriers are continuous – close off all gaps
4. Ensure minimal openings and gaps for services – good preparation
5. Testing process - compliance

Stage 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)	

Not only are there various plasters on the market, there are also a variety of air tight membrane and tapes available for different types of construction and you should be aware of all 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.

Stage 2: All trades must have access to an air-tightness strategy checklist to confirm actions to be and have been completed for which they are responsible, but also to ensure that continuity is achieved between their works and that of other contractors. Air-tightness milestones should also be included in the air-tightness strategy. Knowledge of these dates may permit the site supervisor to schedule thorough envelope pre-test inspections and test dates in advance of the end of the project.

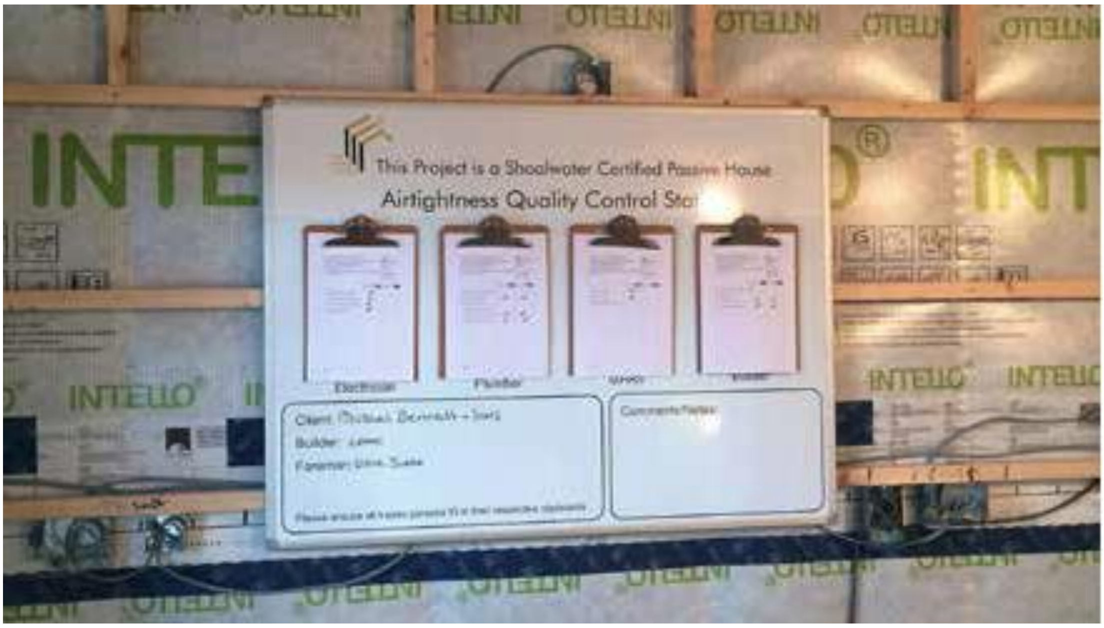


FIG 3.20: Recording air tightness testing at intervals to ensure compliance with NZEB

Stage 3: 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 to detail and agree plan of action at junctions between building elements/junctions and window/door openings.

Stage 4: 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 or electrical cables for example), then steps need to be taken to seal up such gaps and holes to the maximum extent possible.

Stage 5: Testing for air tightness during the construction stage along with good quality control procedures allows problems to be identified and corrected early in the construction process prior to finishing off and final testing. It is prudent to carry out testing 2 or 3 times during the build, 1. Prior to finishing 2. After finishing 3. Final test for inclusion in DEAP and compliance of Building Regulations.

Where the building fails to meet the required airtightness standard, inspections might be undertaken utilising tracer smoke to identify areas of excessive air leakage. Remedial works must then be undertaken to improve the airtightness performance of the fabric. Depending on the design and the formation of the air barrier, this might be difficult and time consuming, ultimately delaying completion.

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 3.20 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 3.20 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 3.21.

Figure 3.21 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 3.22. Other areas of weakness occur at skirting levels so the air tight barrier should be continued and sealed at ground level.

Figure 3.22 Wind tight membrane fitted at floor joist penetrations

Plastering should be completed front top to bottom of the wall making sure all junctions are closed off. Additional appropriate air tightness tapes may be used at junctions alongside plastering. As there are a number of plasters and renders on the market, specific techniques and installations of each of these plasters should be a carried out as per the specifications of the product. The product must have a NSAI

Agrément certified product or equivalent and as a plasterer you must also be NSAI registered to install both external and internal wall insulation systems.

Figure 3.23 Plastering external insulation (Source: SEAI)

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 3.24). 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.

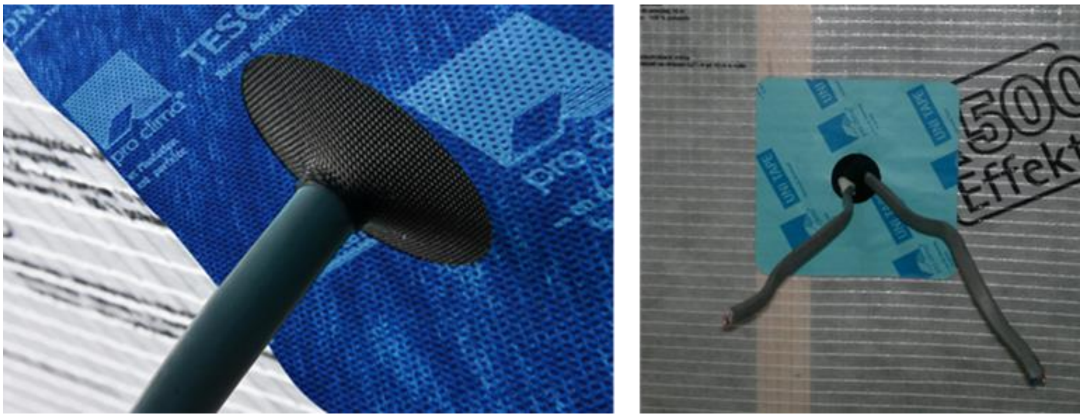


Figure 3.24 Air tightness grommet detailing for pipes and electrical services

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

It is also important to minimise the number of holes or service points in a building to reduce the risk of breaking the continuous insulation and air tightness layers as this can lead to thermal bridging and hence accelerated heat loss.

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 $m^3/hr/m^2$.**

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 lower levels of air permeability are achieved it is important that ventilation is provided.

Figure 3.26 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.

Air permeability can be measured by means of pressure testing of a building prior to completion. The procedure for testing is specified in I.S. EN ISO 9972:2015 Thermal performance of buildings - determination of air permeability of buildings - fan pressurization method. Additional guidance on testing procedure is given in NSAI Agrément Approval Scheme for certified air tightness testers scheme master document to I.S. EN ISO 9972:2015 Thermal performance of buildings - determination of air permeability of buildings - fan pressurization method.

Permeability is calculated by dividing the air leakage rate in m3/hr by the envelope area in m^2. The performance is assessed at 50 Pa pressure difference.

Air pressure testing should be carried out on all dwellings on all development sites including single dwelling developments, as outlined in TGD Part L- Dwelling 2019 paragraphs 1.5.4.3 to 1.5.4.5 to show attainment of backstop value of 5 $m^3/hr/m^2$. The tests should be carried out by a person certified by an independent third party to carry out this work, e.g. Irish National Accreditation Board (INAB), National Standards Authority of Ireland (NSAI) certified or equivalent.

Figure 3.26 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.

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.

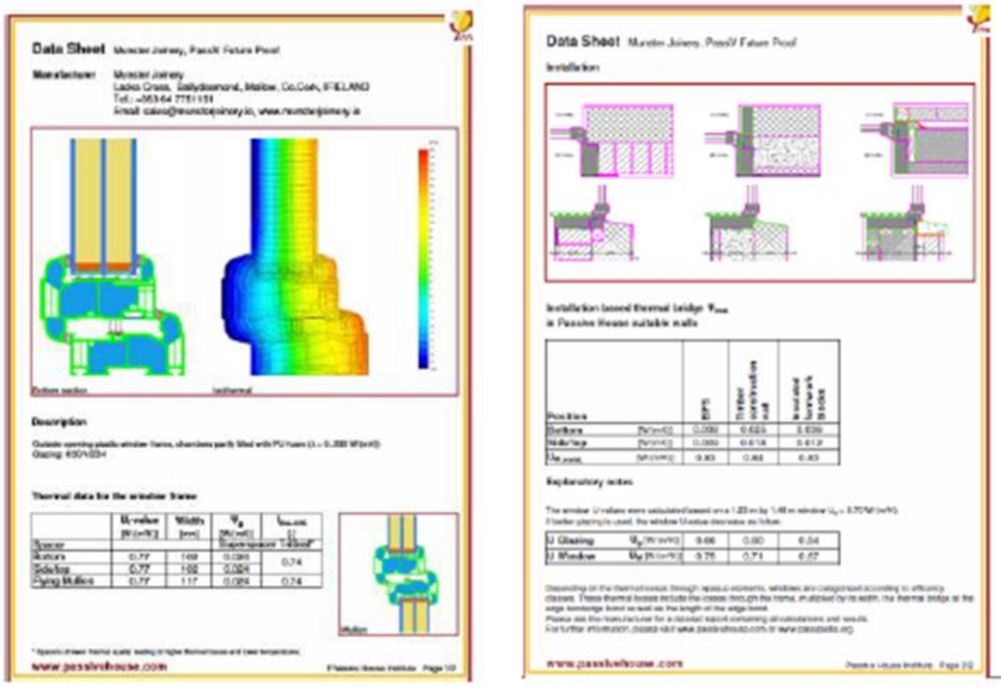


Figure 3.27 Data sheets setting out relevant information on Passive windows

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 common example of thermal bridging is at window reveals.

Traditionally, a blockwork cavity wall was closed at an opening by returning a block. This created a clear thermal bridge of the insulation layer for the full width of the block. To avoid this a strip of insulation or a proprietary cavity closer should be installed between the block and the external leaf.

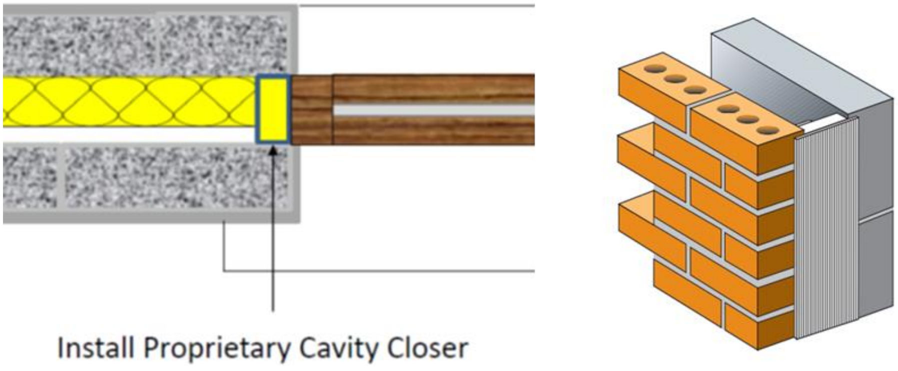


Figure 3.28 Proprietary Cavity Closer installed at Window opening

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, alternatively the full filled cavity insulation can be carried to the edge of the blockwork enabling the window to be tightly placed against this.

For external insulated walls, the external insulation should be carried through to the edge of the wall where the window can be directly fixed to it. Whilst detailing at the junction of the window, it is important to ensure that the window sill does not create a thermal bridge.

A typical case of thermal bridging occurring at the junction of a window sill in a cavity wall as shown in Figure 3.29. 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.

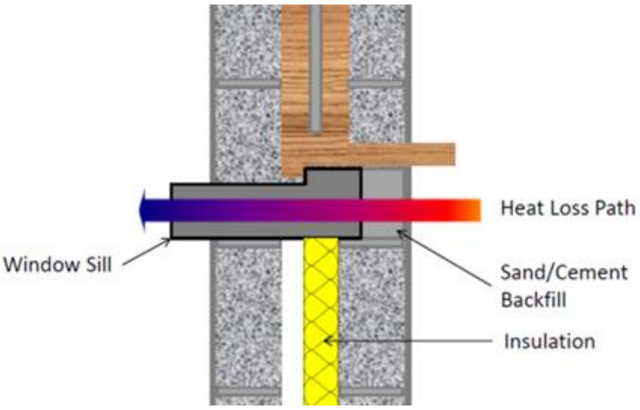


Figure 3.29 Cavity Wall Sill Detail showing Thermal Bridging

It is good practice that concrete sills are backed with insulation, as illustrated in ACDs Figure 3.30.

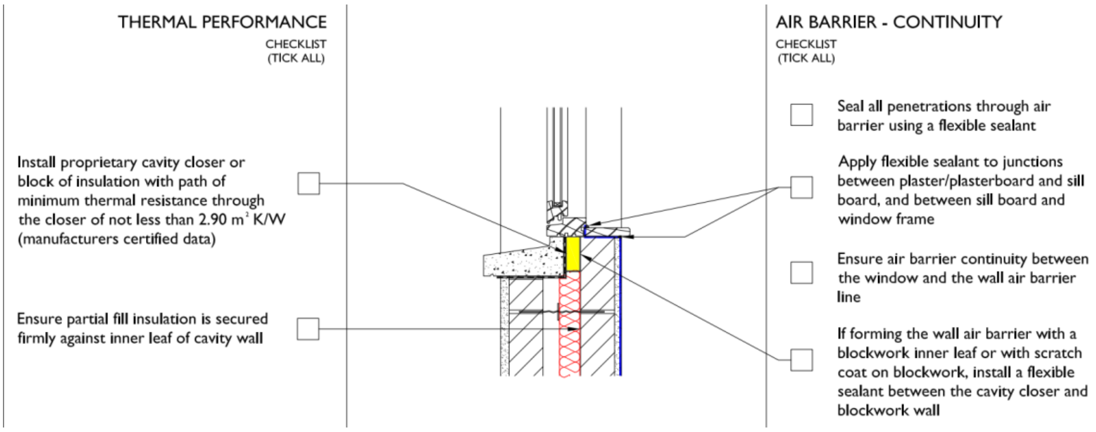


Figure 3.30 Cavity Wall Sill Detail with concrete sill forward of insulation (TGD Part L ACDs)

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. To best practice a propriety insulated window sill could be used eliminating thermal bridging further.

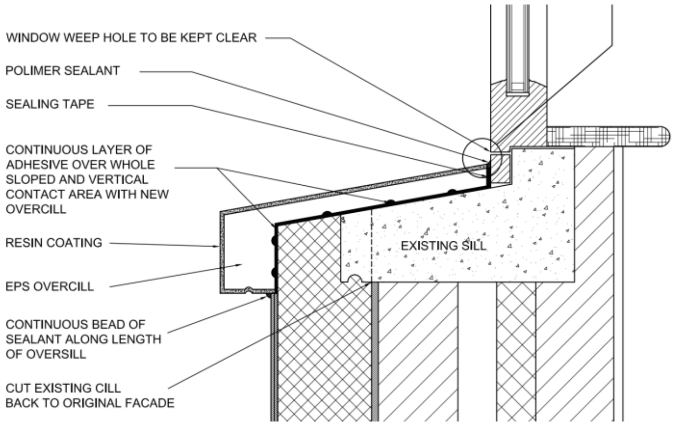


Figure 3.31 Cavity Wall Sill Detail for existing windows (Source: Passive sill)

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 3.32 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 3.33 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).

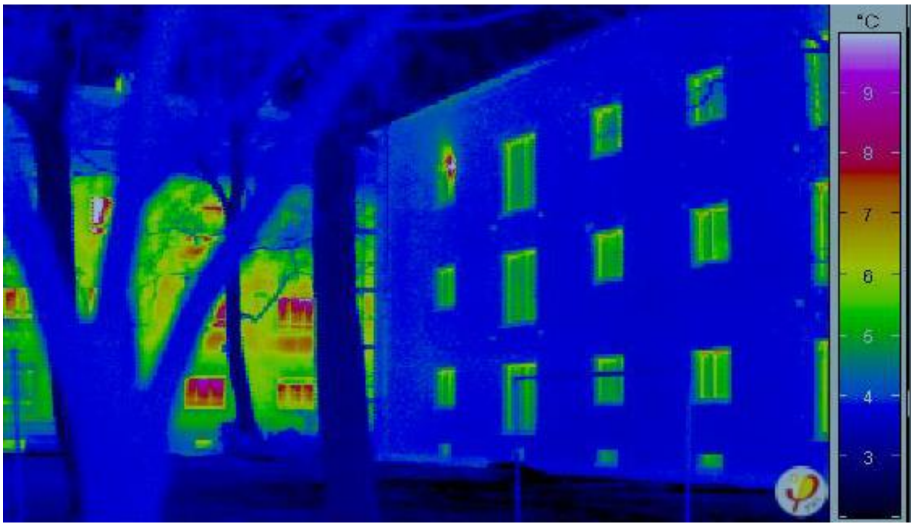


Figure 3.33 Thermal imaging of a well insulated and poorly insulated building in the distance

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

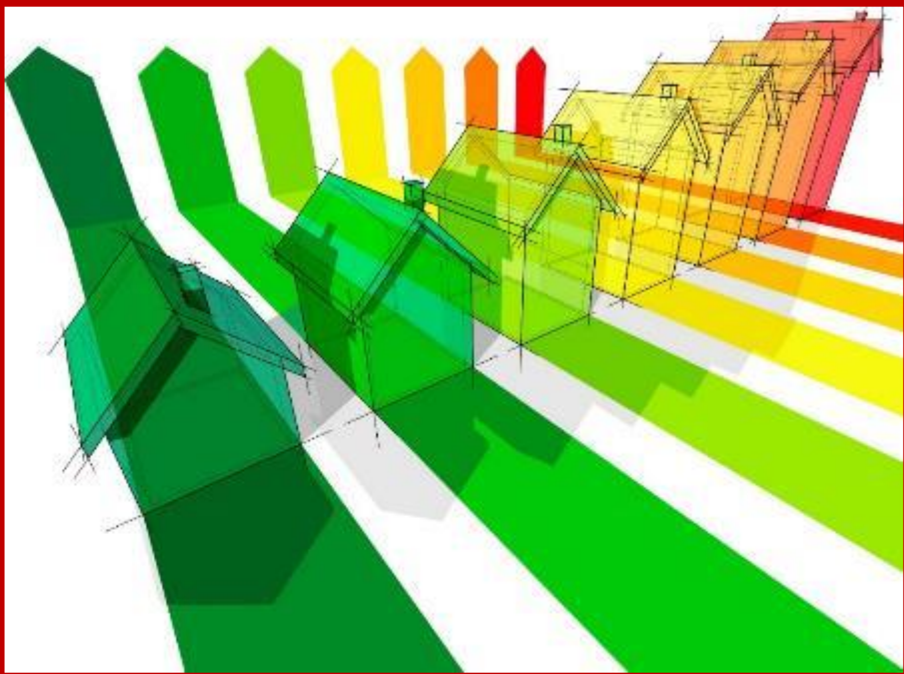
National Standards Authority of Ireland at External Thermal Insulating Composite Systems (ETICS) Installers List (external link)

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

National Standards Authority of Ireland at Recommendations for the Design of Masonry Structures in Ireland to Eurocode 6, S.R. 325:2013+A2:2018,

National Standards Authority of Ireland at Design, Preparation and Application of External Rendering and Internal Plastering - Part 2: Internal Plastering I.S. EN 13914-2: 2016.

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 briefly cover energy efficient heating, ventilation and lighting provision and the importance of choice, sizing, installation and certification 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 briefly explain how these systems improve energy efficiency within buildings.

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

Although as bricklayers you do not play a part in the installation and commissioning of building services, it is important to understand how the other trades work on site and what regulations they also need to comply with. Additionally the work that you carry out will have an impact on their works such as sizing radiators or heat pumps. The quality and workmanship of the insulated envelope may affect the energy efficiency of the systems and comfort of the occupiers.

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 4.0 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 4.0 Typical Design Temperatures for Thermal Comfort

Space Heating System Design & Classification

The design of the heating system and 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:
Centralised Wet systems – these use water (or sometimes steam) to transfer heat from a source (such as a boiler) to a heat 'emitter'.

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).

Electric storage and panel systems – direct resistance electrical heating of space and water is provided using on-peak and off-peak electricity.

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.

Heat appliances/generators:

Heat appliances/generators convert the energy in the fuel to heat energy in the form of hot water and 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

Traditional method where fuel (oil or gas) is burnt 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. 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.

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 and 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 modern approach is to use the heat pump which is becoming more popular and 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 the Ecodesign regulation.

Biomass:

Alternatively, 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):

For larger buildings/clusters Combined Heat and Power (CHP) is getting popular, also known as co-generation, simultaneously generates 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.

As Bricklayers, positioning of the emitters whether radiators, underfloor or convectors should be known in advance. This means collaborating with building services to understand clearly where these heat sources should be located. Ideally these should be located away from external walls to reduce the number of breaks to the airtightness and insulation layers.

Heat Emitters:

1. Radiators

   have limitations: Heat output is mostly convective which can lead to an uneven temperature gradient in the space (See Figure 4.0).

   - 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.

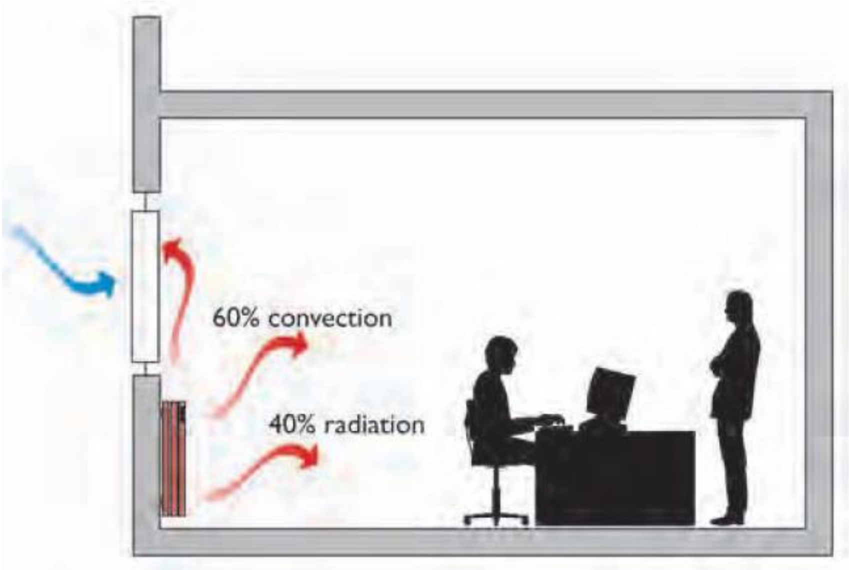


Figure 4.0 How Radiators Heat Space (Source www.bsria.co.uk)

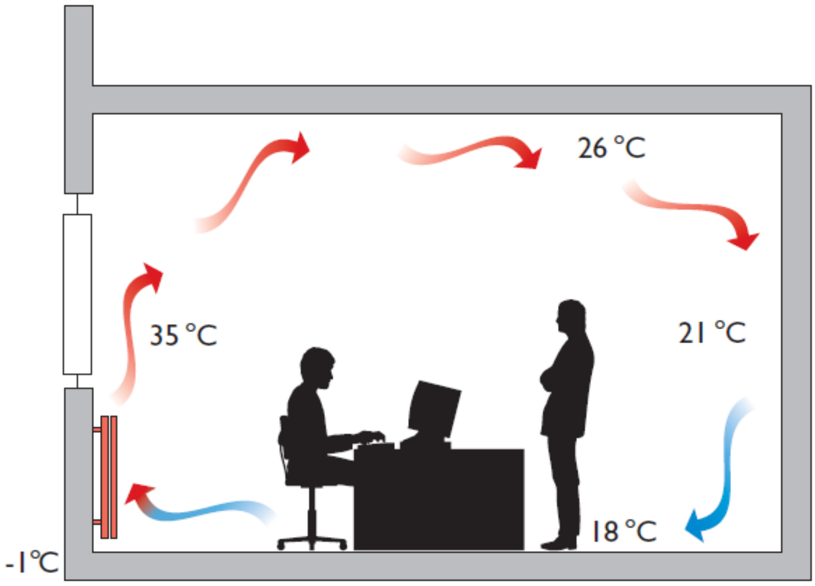


Figure 4.1 Typical temperature variation in a space heated by radiators (Source www.bsria.co.uk)

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 4.1). Some units incorporate a damper to regulate output. Low level convectors are also available (Figure 4.2) 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.

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.

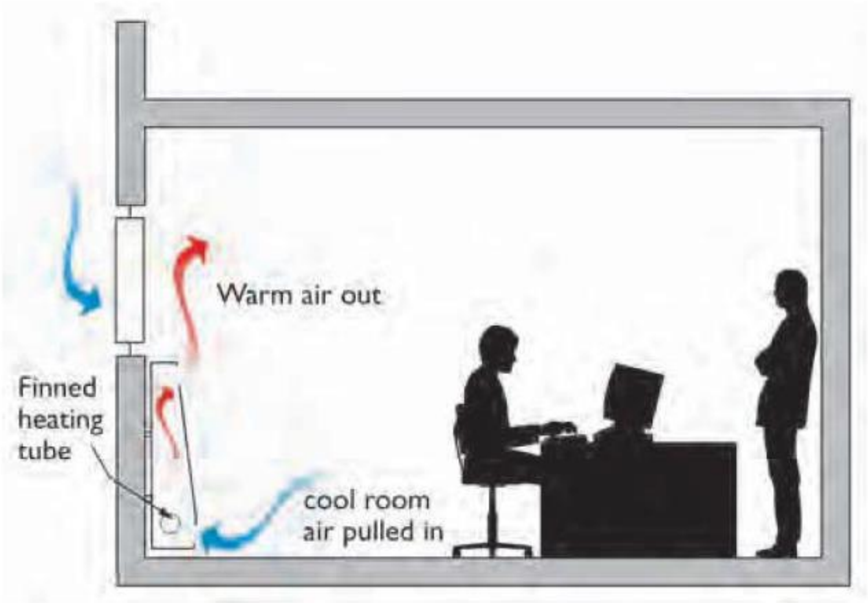


Figure 4.2 How Convectors Heat Space (Source www.bsria.co.uk)

Figure 4.3 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 4.4 & Figure 4.5). 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.

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.

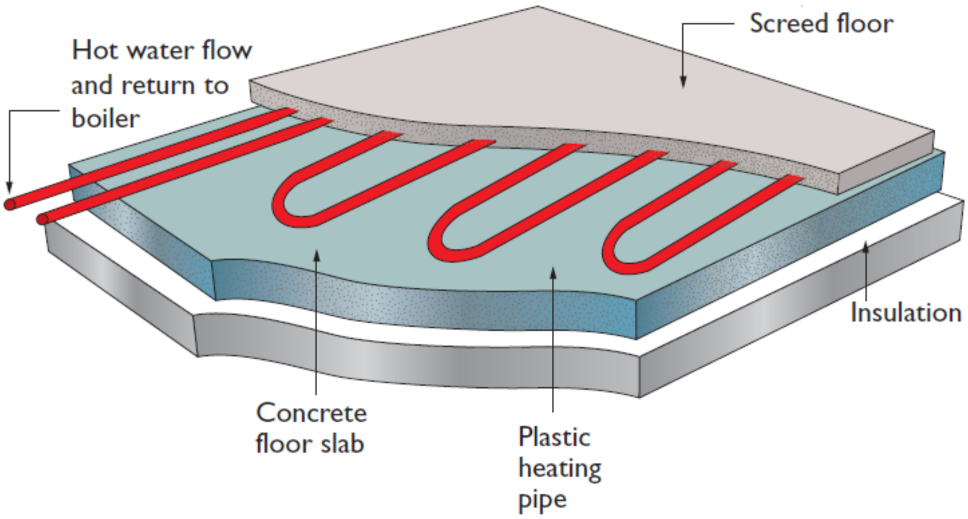


Figure 4.4 Water Based Underfloor Heating (Source www.bsria.co.uk)

Figure 4.5 Electric underfloor heating elements prior to receiving a layer of screed (Source www.bsria.co.uk)

"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.

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. Open vented hot water systems

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.

Indirect Heating of DHW (most common)

In this system 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.

2. Unvented (pressurised)

Unvented hot water systems 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.

The DHW in the unvented system is heated in the same way as the indirect system.

3. Instantaneous hot water heating systems

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 4.6) 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.

Figure 4.6 Example of instantaneous electric water heaters

Storage of hot 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 4.7). 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.

Minimum insulation of hot water storage vessels can be achieved by using a storage vessel with 50mm factory applied insulation as specified in BS 1566, Part 1. Hot piping should also be insulated up to 1m form the hot water storage unit. 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.

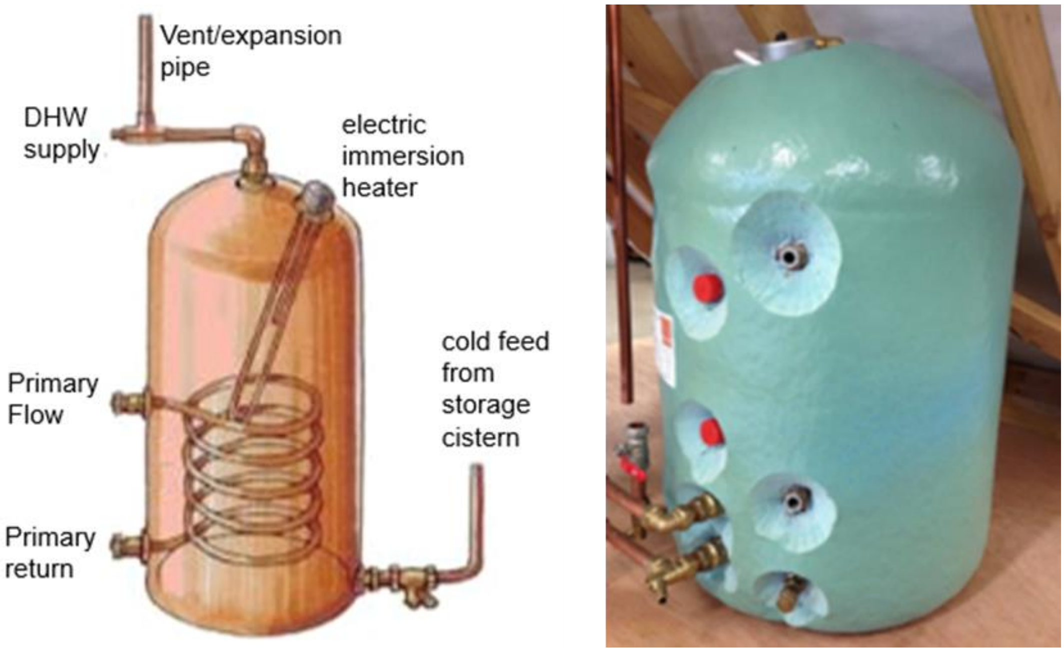


Figure 4.7 Indirect DHW storage cylinder with factory fitted insulation

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.

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 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.

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. Good control not only saves energy, but also maintains a consistently comfortable environment for building occupants, as well as reducing plant maintenance costs.

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.

Individual heating Controls:

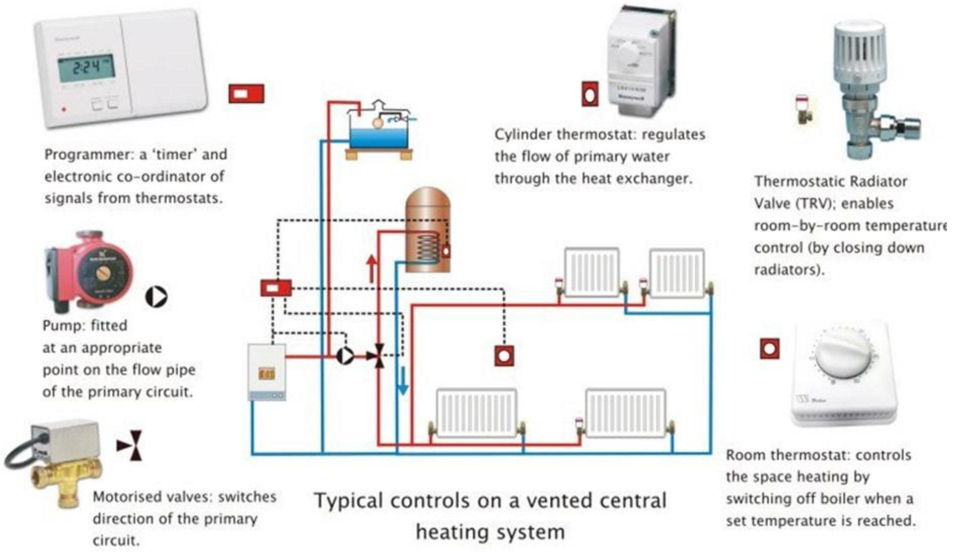


Figure 4.8 Schematic of Typical Central Heating Controls (www.homeenergysaving.ie)

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.

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.

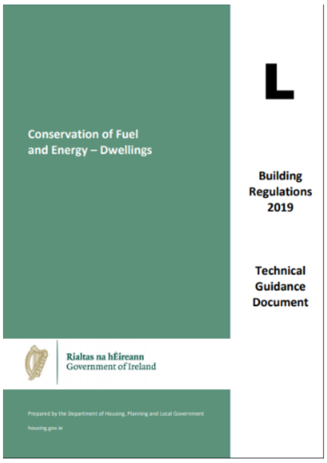
The essence of good heating control is to operate a heating system only when it is required and to the minimum acceptable temperature. There are a variety of controls to help achieve this and the main types affect time, temperature and the operation of the boiler.

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.

Unit 4.2 Controlled Ventilation

Once the building is airtight and highly insulated, appropriate levels of ventilation needs to be provided to ensure a healthy environment for the occupants. **Control** of this ventilation becomes extremely important, whether using mechanical or natural means it is important to keep the unwanted draughts and air infiltration to a minimum.

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 Figure 4.9).

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.

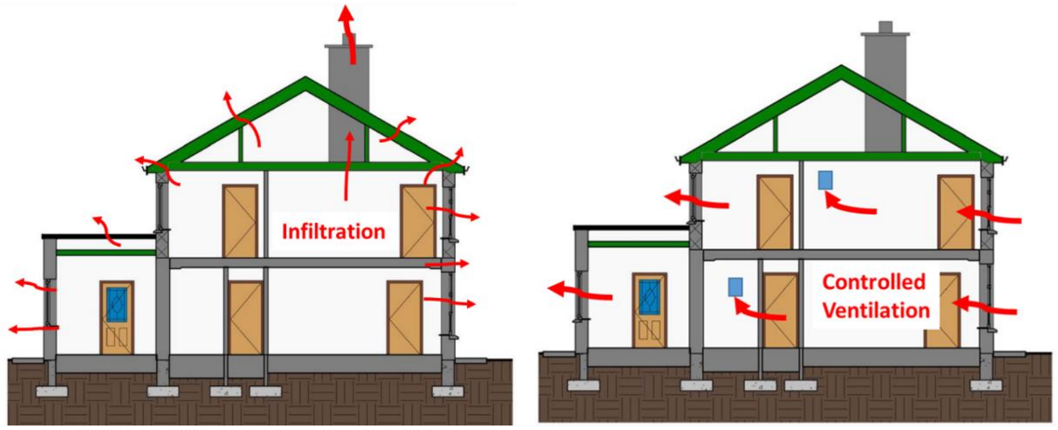


Figure 4.9: Diagram showing flows of uncontrolled air infiltration and controlled natural ventilation

Ventilation and heat loss:

Figure 4.10 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.

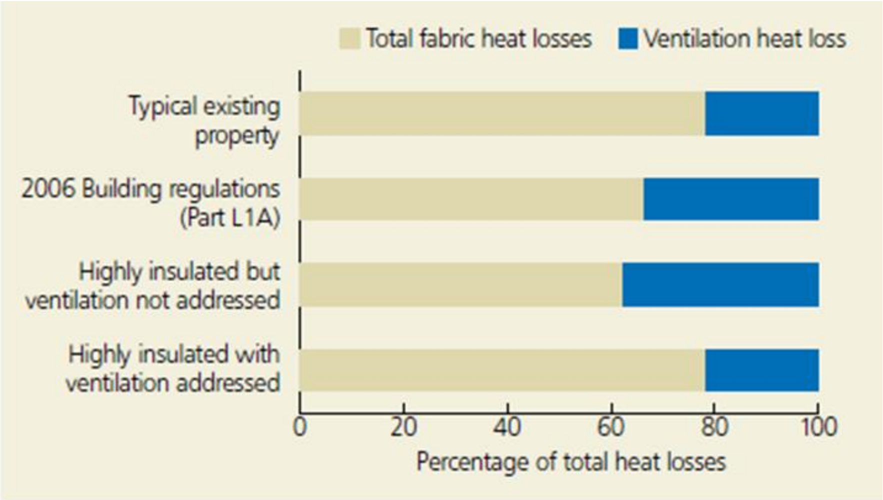


Figure 4.10 Comparison of ventilation and fabric heat losses for a semi-detached house (Source: GPG268)

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.

Problems with Poor Ventilation:

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

Surface Condensation

As discussed in Module 3, 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 4.11 is usually due to heat loss through the windows and the incorrect levels of ventilation.

Figure 4.11 Surface Condensation on windows

Interstitial Condensation

Interstitial condensation has been previously explained in Module 3, 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 4.12).

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 4.12 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 4.13).

Figure 4.13 Diagram showing problems in a building with no ventilation

Indoor Air Quality

Indoor air quality is dependent on the quality of fresh air and how often this is provided by **controlled ventilation**. Ventilation is the process of "changing" or replacing air in any space to provide high indoor air quality (i.e. to control temperature, replenish oxygen, or remove moisture, odours, smoke, heat, dust, airborne bacteria, and carbon dioxide).

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

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 4.14) 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 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.

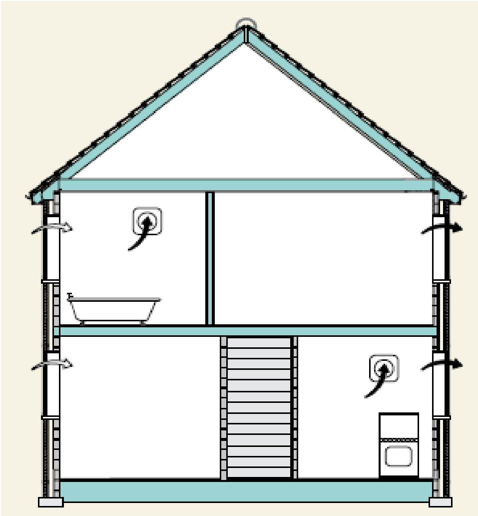
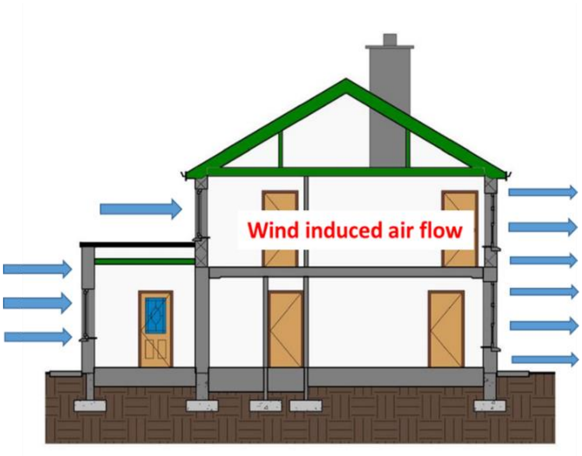


Figure 4.14 Intermittent Mechanical Extract Fans (Source: GPG268)

Natural Ventilation Systems:

Natural Ventilation

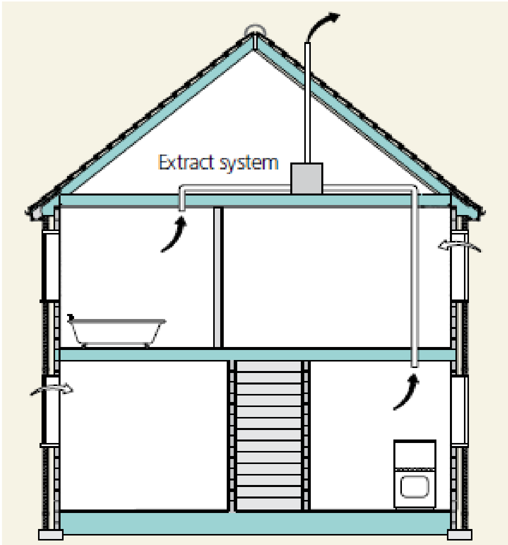


Wind-driven ventilation can be used whenever a building is exposed to the prevailing wind. In order for wind driven ventilation to operate properly, a pressure difference is required and this pressure difference is created by an air stream moving across a building facade. This is known as Cross ventilation (figure 4.15).

Figure 4.15 Diagram showing cross ventilation

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.

Positive Input Ventilation (PIV)

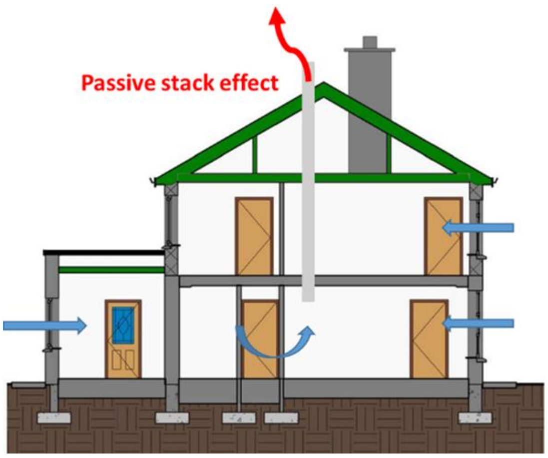


A fan, typically mounted in the roof space, supplies air into the dwelling via central hallway or landing (Figure 4.16). This creates a slight positive pressure in the dwelling. With these systems, excess water vapour is not directly extracted from kitchens or bathrooms, etc. but has to find its way 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 4.16 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.



PSV systems comprise of vents located in 'wet' rooms, connected via 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

Figure 4.17 Diagram of Passive Stack Ventilation

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. Can be manual or sensor automatic using a humidistat sensor

Figure 4.18 Single Room Heat Recovery Ventilator (www.renergise.ie)

Centralised Continuous Mechanical Extract Ventilation Systems (MEV)

A centralised continuous mechanical extract ventilation (MEV) system (Figure 4.19) 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.

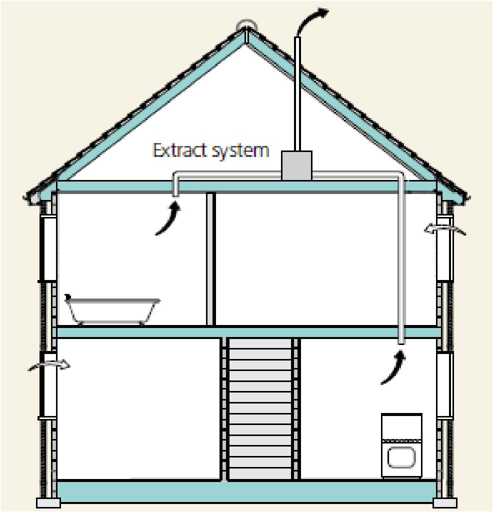
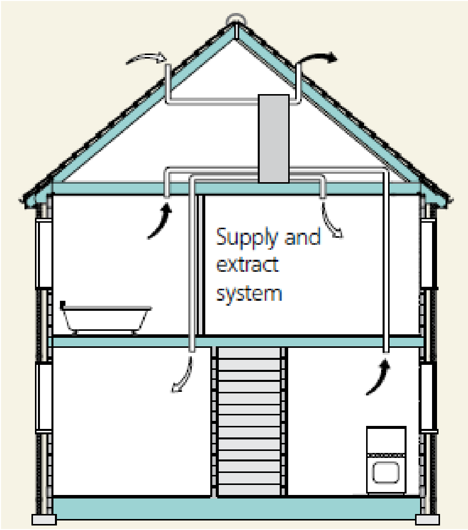


Figure 4.19 Mechanical Extract Ventilation (Source: GPG268)

Whole house Mechanical Ventilation with Heat Recovery (MVHR)



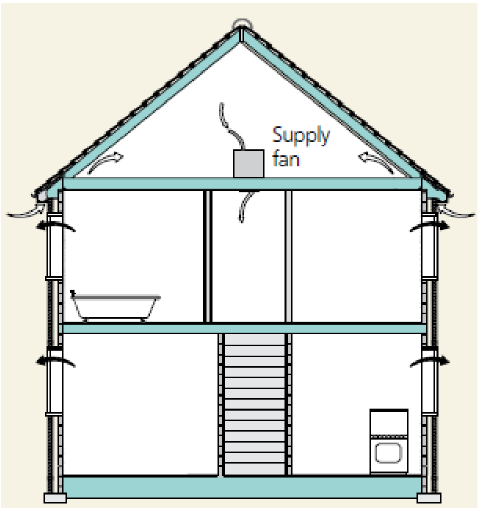
A whole house mechanical ventilation system (Figure 4.20) usually combines supply and extract ventilation in one system. Systems can also incorporate a heat exchanger. Typically, warm, moist air is extracted from 'wet' rooms via a system of ducting and is passed through a heat exchanger before being 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.

Figure 4.20 Whole House Mechanical Ventilation with Heat Recovery (Source: GPG268)

Positive Input Ventilation (PIV)

A fan, typically mounted in the roof space, supplies air into the dwelling via central hallway or landing (Figure 4.21). 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 4.21 Positive Input Ventilation (Source: GPG268)

Building Regulations - Ventilation

For Residential Buildings, the TGD Part F (2009) 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, 30m^3/hr in bathrooms, 20m^3/hr in WCs.

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.

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

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

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 Minimum equivalent area of background ventilator[a] (mm²)	Extract ventilation Extract fan[b] - Minimum intermittent extract rate (l/s)[i]	Purge ventilation 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]

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.

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 (when contemplating heating demand). Within DEAP lighting electricity consumption is based on the proportion of fixed low energy lighting outlets installed, and on the contribution of daylight.

As a Bricklayer it is important to understand that as with other building services, it is important to ensure the number of penetrations through the wall is kept to a minimum. It will be necessary for you to liaise with the electrician and other relevant workers on site and agree a plan if one is not provided. The use of air tightness grommets or taping is essential to maintain air tightness.

<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.

Types of Lighting

1. Incandescent Tungsten Filament Lamps

Light is produced when an electric current is passed through a tungsten filament causing it to glow white-hot. Incandescent tungsten filament lamps 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.

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. Low-voltage lamps are very compact and therefore ideally suitable for directing light precisely, but they do need a transformer.

3. Discharge Lamps - Tubular fluorescent lamps

A low pressure mercury-vapour gas-discharge lamp that uses fluorescence to produce visible light. 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.

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.

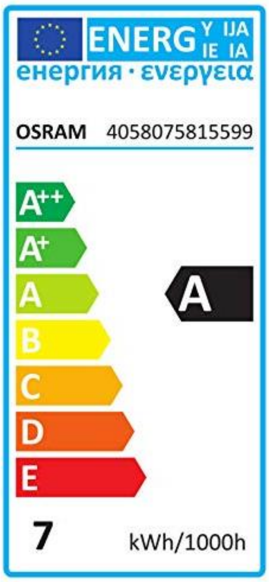
5. Light Emitting Diodes (LEDs)

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.

<u>Energy Labelling of Lamps</u>

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 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 4.22 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.

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 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.

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.



Figure 4.23: Some typical motion sensors (Source: 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.

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 4.24 Light Sensor (Source: www.zumtobel.com)

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

Heating

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

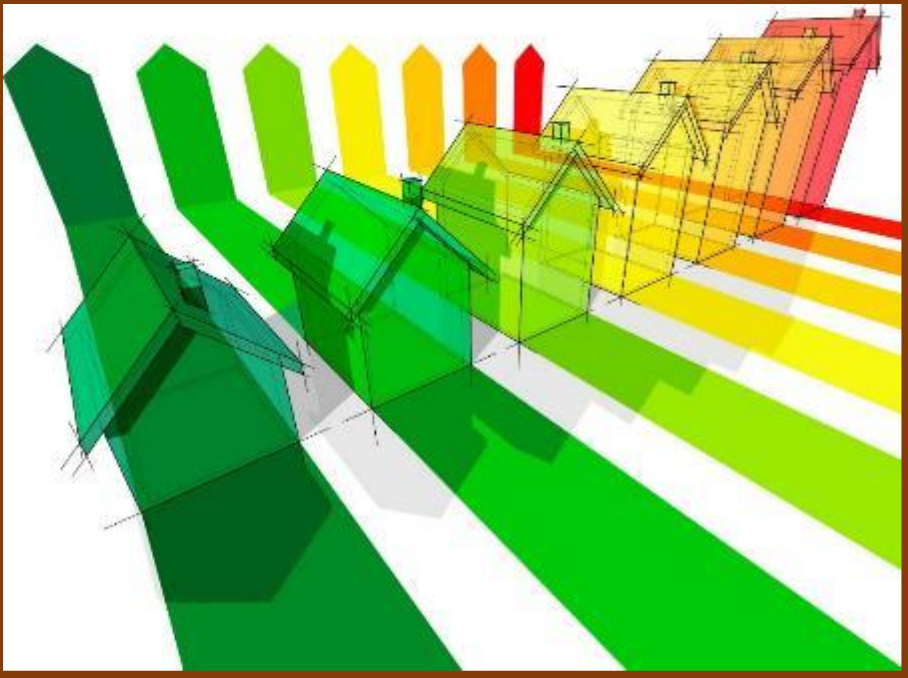
Department of Housing Planning and Local Government; The Irish Building Regulations Technical Guidance Document (2017) Part B Fire Safety Dwelling Houses Volume 2: https://www.iaosb.com/technical_guidance_document_b-_fire_safety_-_volume_2_dwelling_houses-1.pdf

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

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, 2019). 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 provide you with relevant definitions in use.

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 CO2 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.

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

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

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.

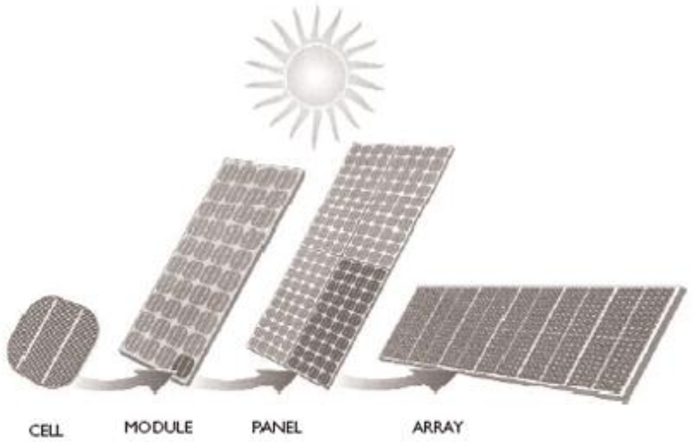


Figure 5.0 Build-up of Cell-Module-Panel-Array (source: www.seai.ie)

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 5.1 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 5.0 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 45º 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.

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".

Heat pump systems can be categorised depending on where the heat is sourced. 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. There are three main GSHP types

- Brine to Water –
- Water to Water –
- DX (direct exchange) or Direct Evaporation Specific requirements need to be met for the installation of the ground source collectors.

Air-Source Heat Pumps:

Air-source heat pumps (ASHPs) are becoming more popular and efficient, and 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 (Fgure 5.1) 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.

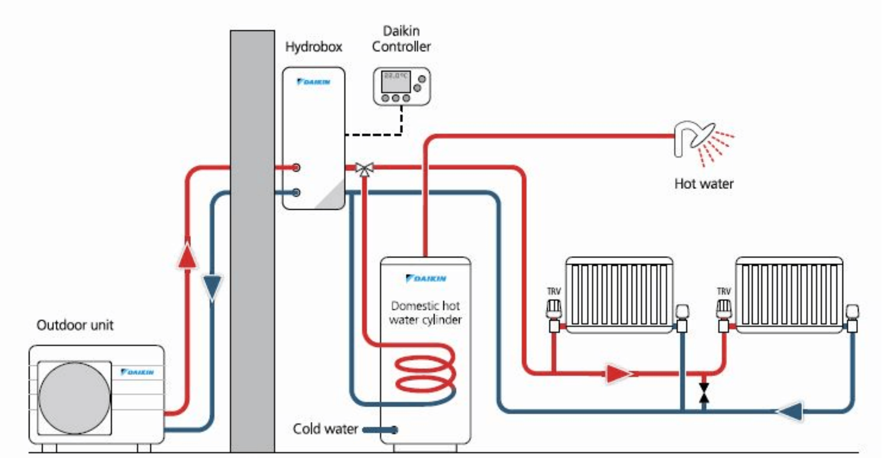


Figure 5.1 Air to Water Heat Pump System (Source: Daikin)

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.

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 5.2). Tube-based systems are about 20% more expensive, but can give up to 10% higher heating output.

1. Flat Plate

2. Evacuated Tube

Figure 5.2 Solar Thermal Collectors (Source: www.seai.ie)

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.

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 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.

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 5.3).

Figure 5.3 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.

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.

Energy Storage Systems

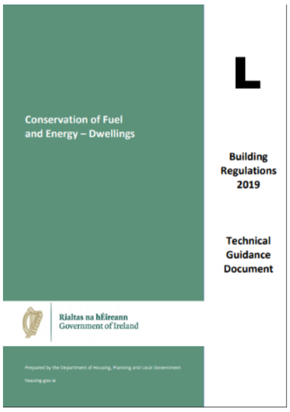
Energy storage systems allow you to capture heat or electricity when it is available (for example, electricity from a solar PV system during daylight or from a wind turbine when it's windy, or heat from a log boiler when burning batches of logs), and then save it until a time when it can be useful to 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.

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

Unit 5.2 Smart Metering

Smart metering is an emerging technology in Ireland (Figure 5.4). 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 5.4 Smart Meter

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.
- 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. 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):

- 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

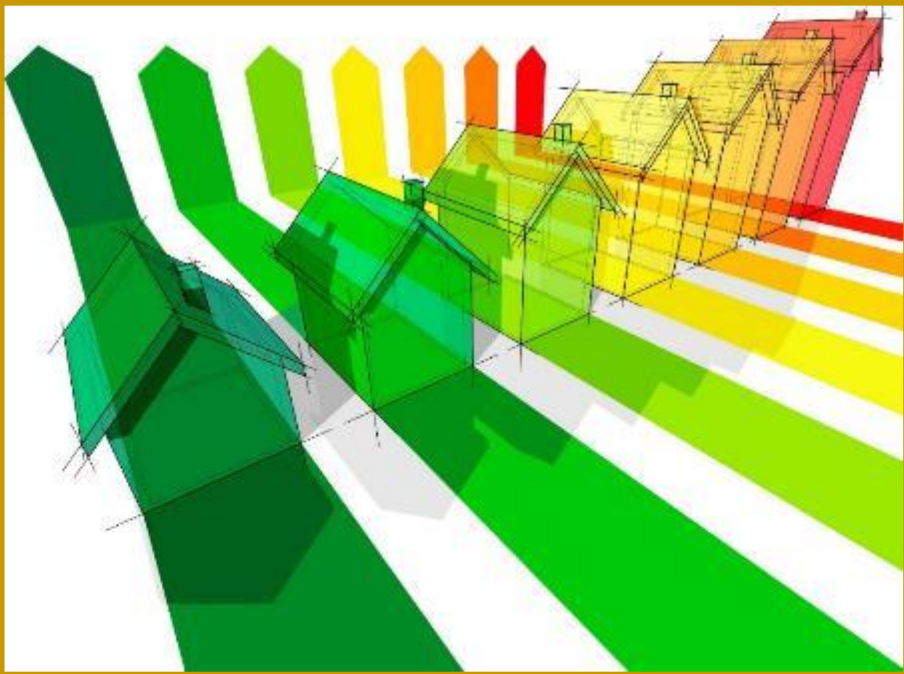
Illustrated Guide to Renewable Technologies (BG 1/2008) - https://www.bsria.co.uk/information-membership/bookshop/publication/illustrated-guide-to-renewable-technologies/

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

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

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 is 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 you 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.

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.

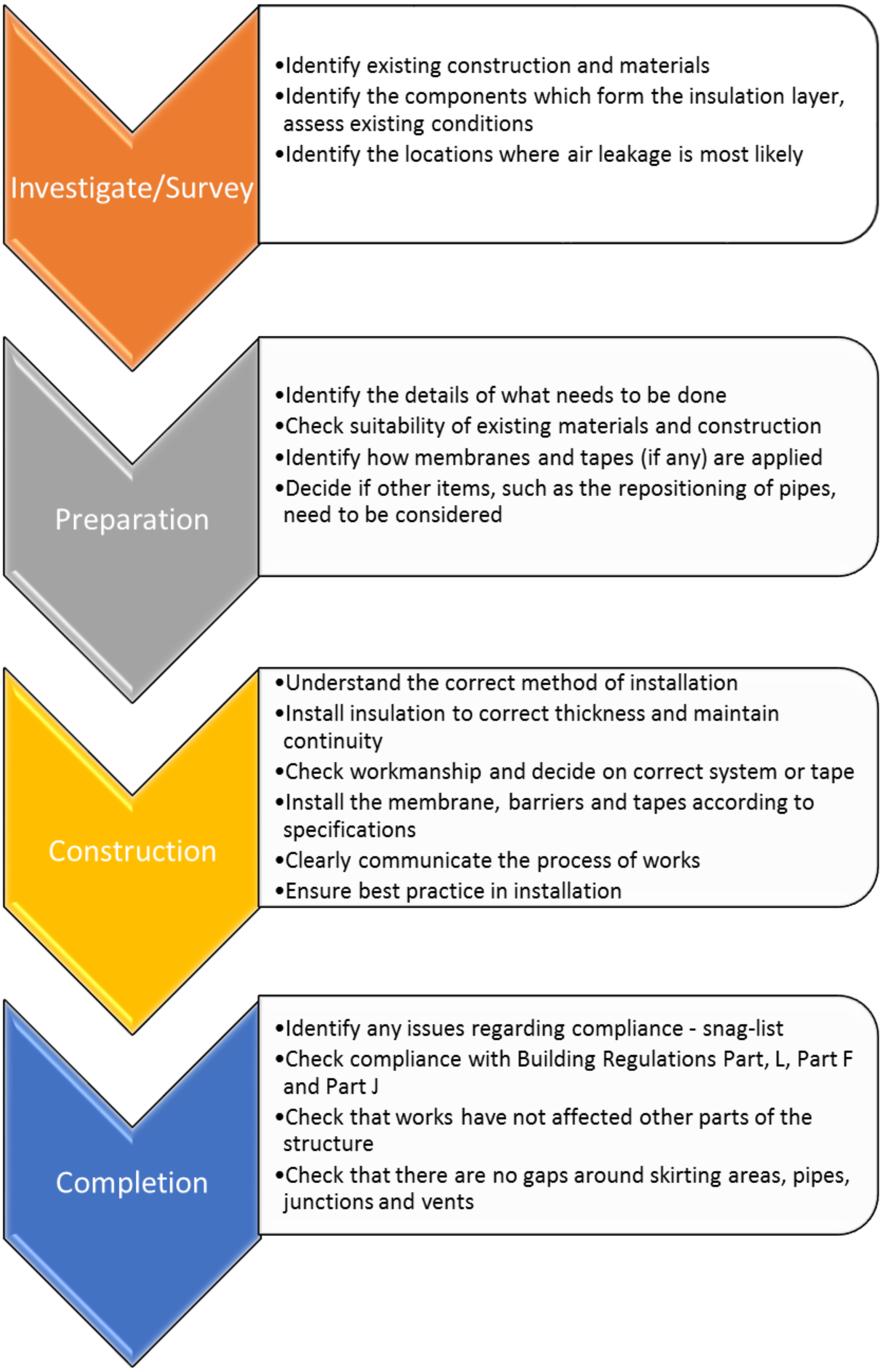


Figure 6.1 Sequence of Works for External insulation

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. Take action.

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.

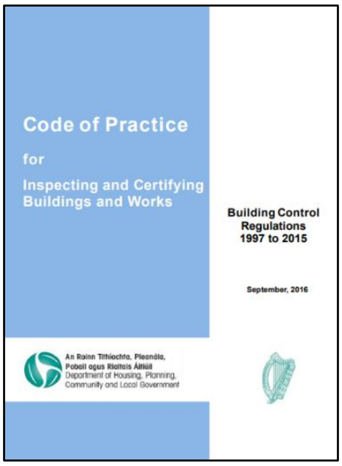
At present it is required to provide the following certificates during construction for buildings, except for single dwellings and domestic extensions:

- 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 2016: 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

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!!

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.

User information

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 may include:

- A description of key responsibilities.
- A schedule of contacts.
- A description of the overall building, including zoning and occupancy.
- A description of air tightness strategy and list of membranes used
- A description of the building's operational strategy.
- A description of the building's services plant, controls and management systems.
- Changes 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

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.

NOTES: