MODULE 6

ENERGY AND WATER USAGE

NEES PROJECT

Natural
Energy Efficient
Sustainable

Vocational Training Modules

Training for Sustainable Building

Vocational Training Modules for the Natural Energy Efficiency and Sustainability (NEES) Project

University of Ulster

Umeå University

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

GCU
Glasgow Caledonian University

Arctic Technology Centre

Teo Páirtnéracht Forbatha Chiarraí Theas
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Northern Periphery Programme 2007–2013
Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

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Where can I get more information on NEES?

If you wish to find out more about the NEES Project, please check our comprehensive Web Site, contact your NEES regional rerpesentative or the NEES Project Manager at the address below.

José Ospina
Project Manager
NEES Project
Cork Centre for Architectural Education
9/10 Copley Street
Cork,
Ireland

Tel. (+353) 28 21890
Mobile (+353) 86 8224429
E-Mail jose.ospina@neesonline.org

www.neesonline.org

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Natural - Energy Efficient - Sustainable

Module 6 Energy and Water Usage

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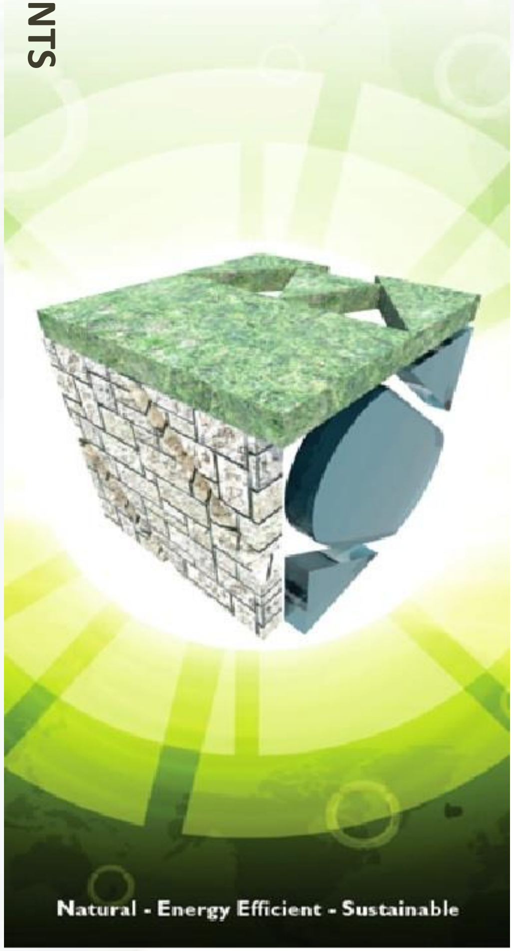


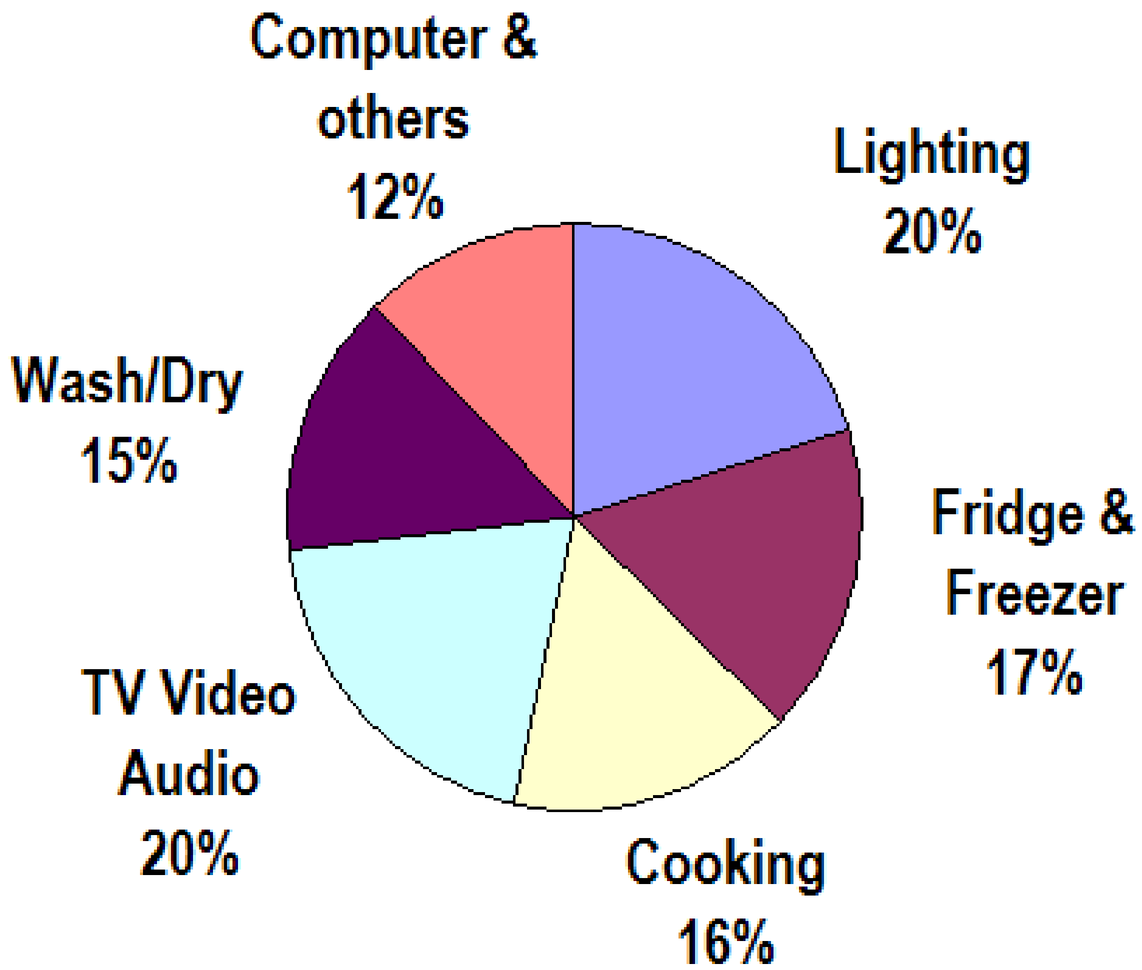
6.0 Introduction

- The NEES project focuses on promoting Natural **products and materials** that are demonstrably sustainable and have a minimum impact on the environment.

- The first four vocational training modules examine how these products and materials can be incorporated into building design.
- Module 5 explores the various certification and accreditation systems that are available for such products.

- This module provides some background information on energy and water usage issues and concepts that underpin the material covered in modules 1 to 4 (energy measurements, U-values, heat loss etc)

UK Domestic Electricity Use



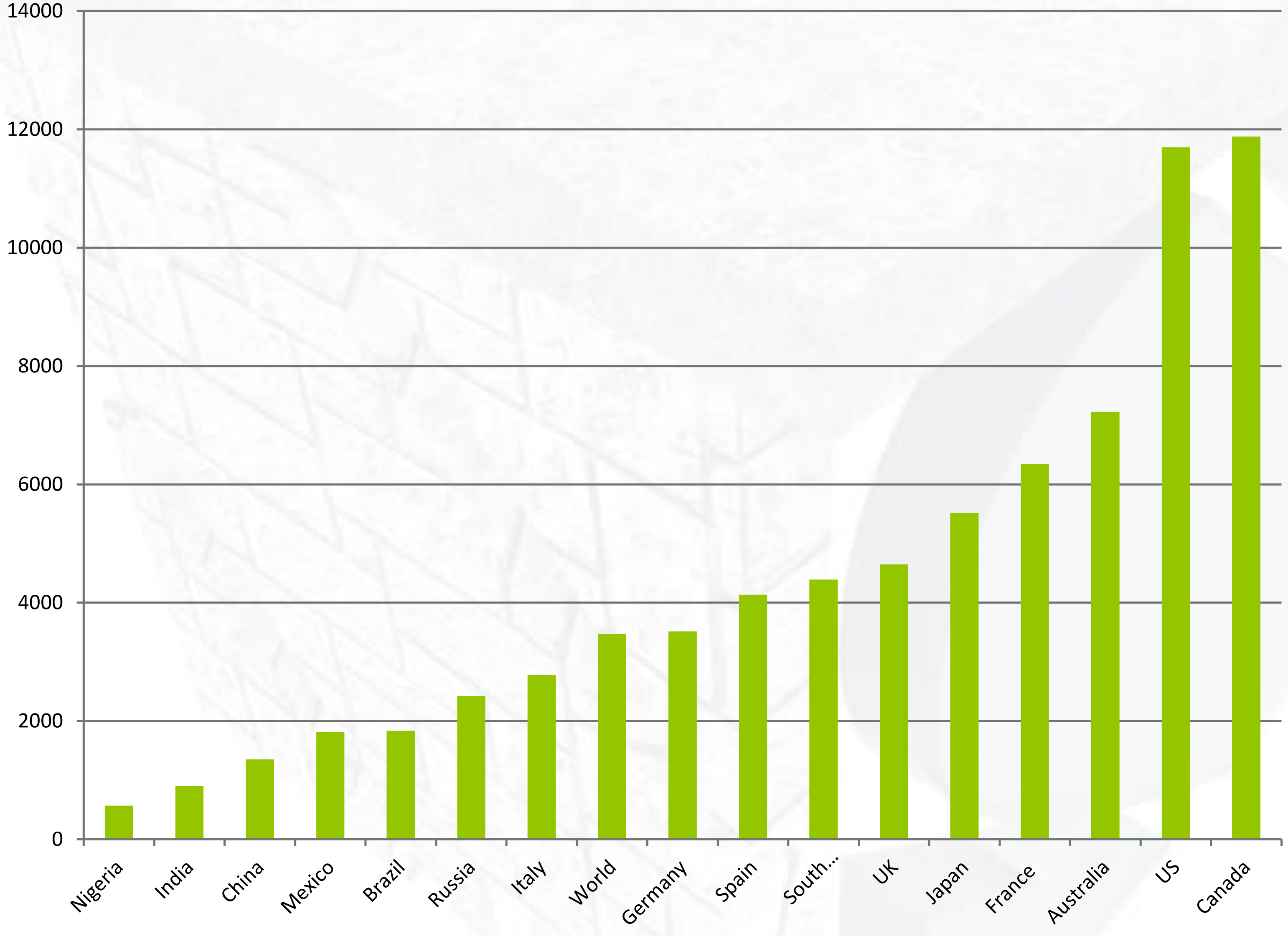
6.1 Energy Usage and definitions

- **Domestic Energy Usage**

- Statistics will vary by Country and are influenced by local climate and demographics.

ITEM	% of TOTAL
Heating	30-50
Hot water	10-20
Lighting	10-15
Wash/dry	10-15
Cooking	5 - 10
Electronics/ Computing	5 -10
Refrigeration	5 - 10

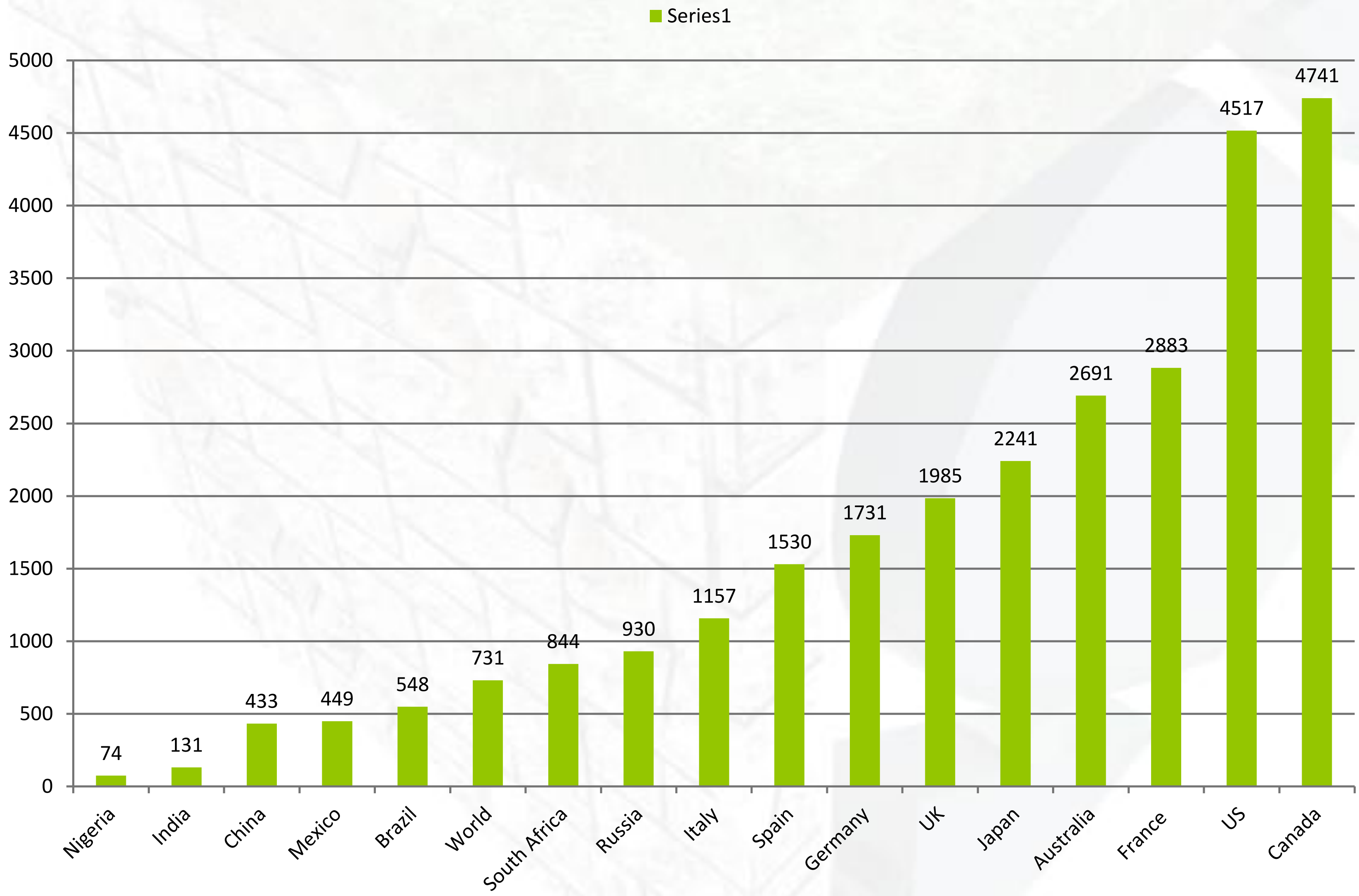
Household electricity consumption (kWh/year) 2010 Data



(source Enerdata via World Energy Council)

RESIDENTIAL ELECTRICITY USE PER CAPITA (KWH/YEAR)

2010 DATA (SOURCE ENERDATA VIA WORLD ENERGY COUNCIL)



6.1 Introduction and definitions

- As buildings becomes better insulated they require less energy for space heating.

- With increasing use of electrical and electronic equipment, the proportion of total energy used by equipment in domestic buildings is increasing.

- Ensuring that the equipment used is turned off when not in use and is highly energy efficient is the only way to reduce electrical energy consumption.

Energy measurement

- Energy is measured in Joules
- Power is the rate at which energy is used or the rate at which work is done.
- Unit of power is the watt (W)
- A watt is defined as a joule per second

ENERGY MEASUREMENT

- Energy usage (and power) are often measured in **kiloWatt hours (kW/hrs)**

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

- 1000 watts of power applied for one hour is one kW/hr

- Eg one bar of a one Kw Electric heater for one hour, or,

a 2kW kettle for 30 mins and so on.

ENERGY MEASUREMENT

- By converting energy usage or power to a single unit, it is possible to compare different fuel sources .

- There are many different units used to measure energy and power (both SI and Imperial)
  - Joules, Calories, Watts, therms, BTUs (British thermal Units), horsepower, TOE (ton of oil equivalent)and Quads (Quadrillion BTUs)

ENERGY MEASUREMENT

- The units used will depend on the system (SI or Metric) and the purpose. The purpose will determine the magnitude, which will in turn determine the most appropriate unit.

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

- Measuring domestic energy usage is normally done in kWhrs whereas national energy usage is often measured in terawatt hours or TOE.

Energy measurement

- 1 **tonne of oil equivalent** *(0.001 ktoe)*

1 TOE= 107 kilocalories

= 396.83 therms

= 41.868 Gigajoules (GJ)

= 11,630 Kilowatt hours (kWh)

= (0.01163 Gigawatt hours (GWh) or

= 0.00001163 Terawatt hours (TWh))

ENERGY MEASUREMENT

- **Thousand tonnes of oil equivalent (ktoe)** – this is a common unit of measurement which enables different fuels to be compared and aggregated.

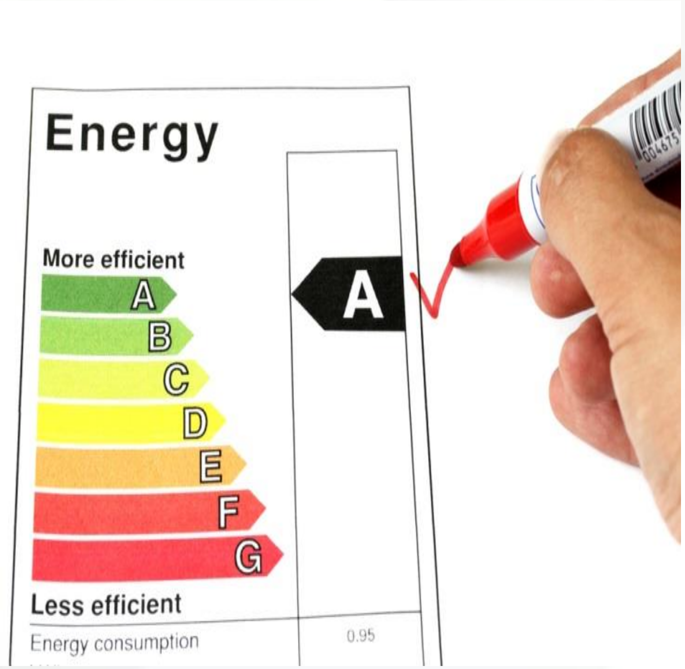
- **Gigawatt hours (GWh)** – the kilowatt hour (equivalent to 0.000001 GWh) is a unit of electrical energy equal to 1,000 watt hours, or 3.6 megajoules.

ENERGY RATINGS

- A Building energy rating is a measure of the amount of **primary energy** used by a building. It is normally measured in kWhrs/sq.m/yr

- The lower the value the “better” the house performs in terms of energy usage

- Lower value means less energy usage and lower carbon emmisions.



PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

PRIMARY ENERGY

- Primary energy is the total energy contained in natrural reserves of primary fuels such as oil, gas or coal.
- The primary energy of fuel is measured in the raw state before any energy is used in conversion or distribution.
- A Primary Energy source is one that can release its energy directly upon combustion.
- When a fossil fuel is burned, heat and light energy are released.
- The main use for Primary Energy sources are to heat water and use the steam to turn turbines to generate electricity. This is generally done in power stations.

PRIMARY ENERGY

- When primary energy source (such as a fossil fuel) undergoes combustion it releases its primary energy and water and Carbon dioxide are created.

- $H_xC_yO_z \rightarrow\rightarrow H_2O + CO_2$ + energy ↑
  - FUEL (organic) WATER CARBON DIOXIDE ENERGY RELEASED

- The amount of CO_2 released is the carbon dioxide emission factor (normally expressed as $gCO_2/kWhr$)

PRIMARY ENERGY

- During combustion the amount of energy released and CO2 produced varies with the Fuel type.

- Depending on the fuel, other chemicals can also be released during the combustion process e.g SOx (Suphur Oxides) and NOx (Ntrogen Oxides) as well as Tar.

- Natural Gas is a relatively pure fuel and as a result is considered a clean burn fuel with relatively low CO2 emmissions and low SOx and Nox

- BUT It is still a NON RENEWABLE fossil fuel!

Total Primary Energy Requirement (TPER)

- Total primary energy requirement or TPER is a measure of all of the energy consumed by an organisation and accounts for the energy that is consumed and/or lost beyond the boundary of the organisation – in energy transformation, transmission and distribution processes, e.g. electricity generation transmission and distribution.

- - See more at: http://www.seai.ie

Primary Energy

- Typical **Primary Energy** and **CO2 Emmisions** factors

Fuel for Delivered Energy	Primary Energy Conversion Factor	CO_2 Emission Factor
Mains Gas	1.1	0.220
Oil	1.1	0.272
Smokeless Fuel	1.2	0.392
Wood	1.1	0.025
Electricity	2.5	0.558
Peat Briquettes	1.1	0.377

Primary Energy

- The primary energy factor for electricity is much higher than the others because of the additional generation and distribution losses incurred in supplying electricity to the Grid.

- The CO2 factor is also high for the same reason.

- The CO2 emisions factor for electricity is steadily reducing as a result of the increased use of renewable energy for grid power generation. (decarbonisation)

6.2 Building Heat loss

Thermal performance– Principles

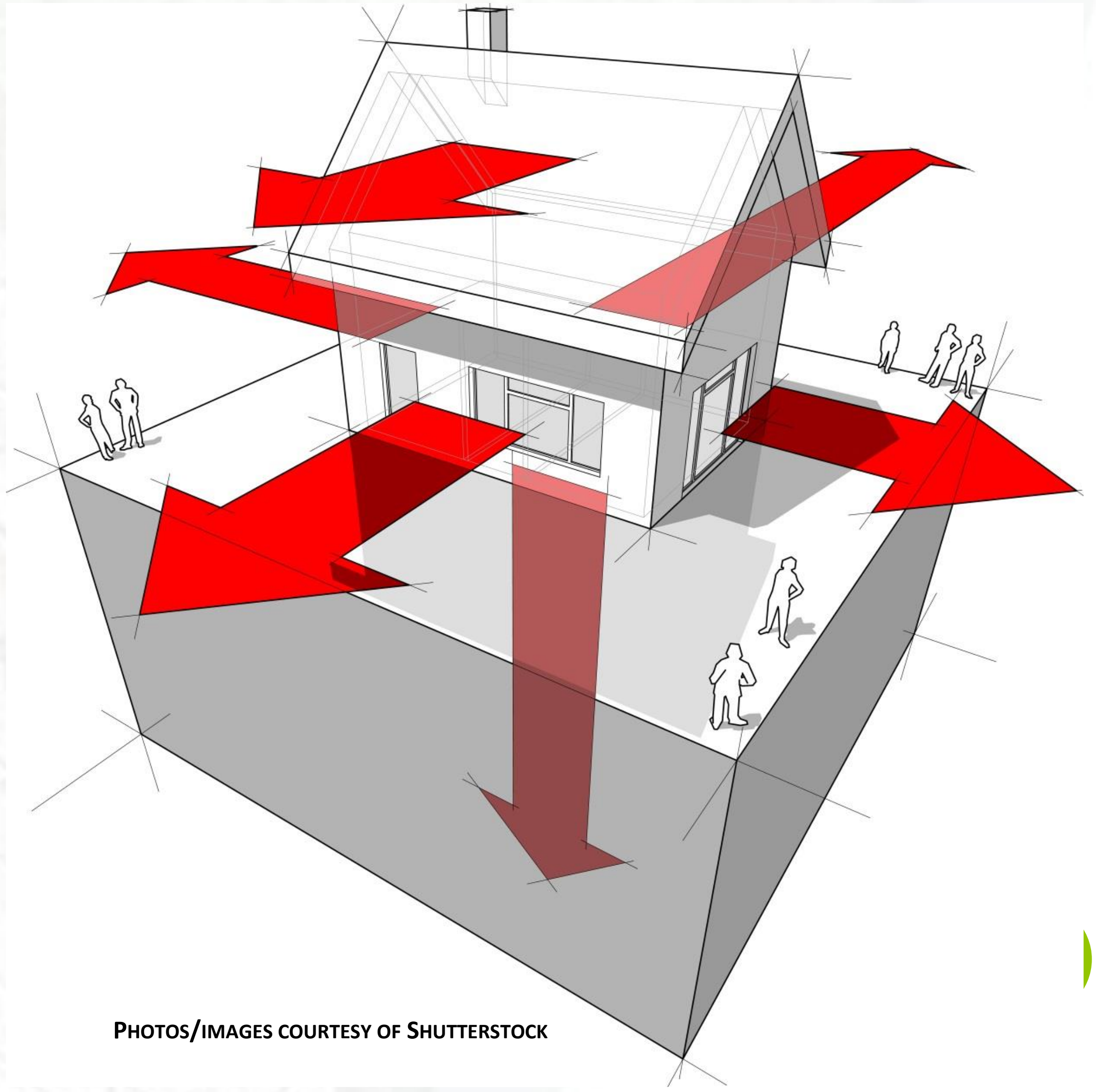
To reduce energy wastage it is important that any energy used or generated in the house is not lost to the outside environment.

*Heat loss from a building can happen in two ways, through the **fabric** and by **ventilation**.*

To have a truly energy efficient building both of these must addressed

6.2 Building Heat loss
Thermal performance– Principles

Fabric losses occur through all parts of the building fabric. Walls, floors, ceiling, roof, windows and doors.



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6.2 Building Heat loss

Thermal performance– Principles

These losses can be conductive, convective and radiative.

In plane elements such as walls and floors the heat loss is measured in terms of a ***U Value***

At junctions and where different materials meet it is measured in terms of ***a Ψ (psi)*** *Value*

Thermal performance– U Values

Thermal transmittance or U values are used to measure the heat loss from plane elements of a building.
The units are **watts** per **square meter kelvin.**

Thus a (single glazed) window with a U value of 5 W/m^2K will lose 5 watts per square meter for each degree difference in temperature between the two sides of the window

THERMAL PERFORMANCE– U VALUES

U Values are a measure of the overall rate of heat transfer, by **all** mechanisms under **standard conditions** through a particular section of construction.

U Values are measured or calculated for various construction build ups.
They are measured under standard conditions and so can change due to wind, rain and sunshine etc.

THERMAL PERFORMANCE– U VALUES

A modern triple glazed window with a U Value of 0.8 W/m^2K will lose 0.8 watts of energy per square meter for each degree difference in temperature between the two sides of the window.

Single glazed window: 5 W/m^2K

Triple glazed window: 0.8 W/m^2K.

Reduction of heat loss by 80%

THERMAL PERFORMANCE– U VALUES

Typical limits of U-value in buildings vary from a maximum of about 5.0 W/m2K for a single-glazed window to a minimum of about 0.15 W/m2K for a modern roof with 300mm of loft insulation – so the window lets about 30 times as much heat pass through 1m2 of it, compared to the roof.

Thermal performance– U Values

The same principle applies to all plane elements floors, walls, roofs and ceilings.

In the last 20 or so years the building regulations have become much more demanding in terms of energy performance and now have stringent minimum requirements for the U Values of all of the fabric elements of a building.

Thermal Resistance R Values

Thermal resistance is a measure of the opposition to heat transfer offered by a particular component in a building element.

Units: m^2K/W

Total Thermal Resistance Rt

The total resistance offered by a component in a building element is made up of two resistances, the **material resistance** and the **surface resistance.**

Thermal Conductivity K values (aka Lambda)

The thermal resistance of a homogenous **material** will depend on the **rate at which the material conducts heat** (thermal conductivity (small K) and its **thickness**.

Thermal conductivity (small **k,** aka a lambda value **λ**)

Is defined as the rate at which heat is conducted through a particular material under specified conditions. It is a property of a material like density or stiffness. Units W/mK

Typical values are 2.0 W/mK for concrete to a minimum of about 0.025 W/mK for polyisocyanurate (PIR) foam insulation. Natural insulants such as sheeps wool and hemp are in the range 0.04-0.06 W/mK

$$R = \frac{\text{thickness (d)}}{\text{thermal conductivity (k)}} \qquad \frac{m}{W/mK} \quad \text{or} \quad m^2K/W$$

Thermal Resistance

The **surface resistance** of a material will be influenced by the direction of heat flow (vertical or horizontal), climatic effects (sheltered or exposed) and surface properties (matt or shiny etc).

The thermal resistance of a surface depends on the conduction convection and radiation at that surface.

CIBSE and BRE publish standard resistances for common building materials.

U VALUES

U = 1/R

For a single component

R = d/k ➔ U = k/d

Example a brickwork outer leaf 100mm thick with a thermal conductivity of 0.84 W/mK.

U = 0.75/0.1 = 7.5 Wm^2/K

BUT

Need to take account of the other materials in the wall **AND** the surface resistances of both sides of the wall.

U Values

U = 1/Rt

Rt = Sum of all resistances

So the all of the releavant resistances must be calculated and summated before you can calculate the U Value.

The following example illustrates this

Notes

The outer, inner and cavity resistances are standard published values for horizontal surfaces (CIBSE, BRE or the Building regulations)

To Calculate a U Value

Component	Thickness l mm	Thermal conductivity k W/mK	Thermal resistance r = l / k m2K/W
Outer surface	-	-	0.04
Outer leaf of brickwork	100	0.75	0.13
Cavity	-	-	0.18
Inner leaf of blockwork	100	0.55	0.18
Plaster	15	0.50	0.03
Inner surface	-	-	0.13
Total, R			0.70
U-value = 1/R (in W/m2K)			1.44

Thermal performance– Ψ Values

As a result of the requirements for lower U Values, the thermal performance of buildings has improved vastly.
So much so, that now the fabric heat loss that occurs at junctions, corners and around doors and windows is becoming a much more significant issue. These losses, which were largely ignored previously are now bcomming important.

These losses are measured in terms of a Ψ value

THERMAL PERFORMANCE– Ψ VALUES

Ψ values are measured in watts per meter kelvin W/mK and are measured linearly ie the length of the junction.

Ψ values are often used when describing “cold bridging” or “thermal bridging”

Good construction techniques ensure that there are no thermal bridges present. This in effect means very low Ψ values.

THERMAL PERFORMANCE– Ψ VALUES

The Ψ Value is often equated with the thermal bridging factor used in energy rating software such SAP in the UK or DEAP in Ireland.
The thermal bridging factor is a summation of all of the Ψ Values in a building (taking account of the length of each junction). It accounts for the heat loss through junctions and window surrounds etc

In Ireland the default thermal bridging factor (known as the Y value) used to be 0.15 W/mK (Irish Building Regulations TGD Part L 2008)

THERMAL PERFORMANCE– Ψ VALUES

The current default using the Part L 2011 is 0.11 W/mK .

If a building is constructed using the approved construction details (ACDs) as recommended by the department of the environment the default Y value can be reduced to 0.08 W/mK

This is a very significant reduction and can have a significant influence on a buildings energy rating.

THERMAL PERFORMANCE– Ψ VALUES

One problem with using these defaults in software such as DEAP (Dwelling Energy Assessment Procedure, the software used in Ireland to calculate Building Energy Ratings (BERs) for certification) is that there is little account taken of the actual geometry of the building.

Recent research suggests that using the default Y Values can give quite inaccurate results.

THERMAL PERFORMANCE– Ψ VALUES

One way to mitigate against this is to calculate the Y value, using actual Ψ Values from the project.

In Ireland the Sustainable Energy Authority of Ireland (SEAI) have developed a simple excel spreadsheet that can be used to calculate Y values for use with energy rating software such as DEAP.

See link for details http://www.seai.ie/Your_Building/BER/BER_FAQ/FAQ_DEAP/Building_Elements/Thermal_bridging_Application_Instructions.pdf

THERMAL PERFORMANCE– Ψ VALUES

One of the problems associated with Ψ values is that they are difficult to calculate.

In order to calculate a Ψ value for a particular junction or build up, the exact geometry and thermal properties of the build up must be known. The Ψ value is then calculated using specialist software such as Therm.

This can be a time consuming and expensive process.

THERMAL PERFORMANCE– Ψ VALUES

Many people use details for which they already have a Ψ value. There are a number of sources for such details e.g. In Ireland the ACDs are used.

The **Energy Saving Trust** have developed a series of Enhanced Construction Details (ECDs) which have been thermally assessed and their Ψ-values have been determined.

See http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/New-build/Factsheet-the-use-of-ECDs-in-SAP2009

THERMAL PERFORMANCE– Ψ VALUES

Ψ Values are now considered to be important because the plane element heat loss has been reduced very significantly, due to the improved building regulation requirements.

One European building standard requires that compliant buildings be constructed without thermal bridges, or as they term it “Thermal Bridge free construction”. Practically this is taken to mean a Ψ value of less than 0.01 W/m^2K

THERMAL PERFORMANCE– Ψ VALUES

To achieve a Ψ value of less than 0.01 W/m^2K in all construction elements is a challenging task from both a design perspective and from a build-ability point of view.

The only way that this can be achieved in reality, is by calculating the Ψ value for each junction as designed and ensuring that it is constructed on site exactly as designed.

THERMAL PERFORMANCE– VENTILATION LOSSES

The other way that heat escapes from a building is through ventilation or air infiltration.

To counter this buildings need to be constructed in an airtight manner. However, adequate ventilation in a building is essential and a trade off between air-tightness and ventilation must be achieved.

THERMAL PERFORMANCE– TOTAL LOSSES

To demonstrate the relative importance of each loss (fabric versus ventilation) in relation to each other we will use a simple example.

A single storey flat-roof building with an area of 100 square meters, floor to ceiling height of 2.5 metres.

THERMAL PERFORMANCE– TOTAL LOSSES

Design data

Floor area 100 m²
Ceiling area 100m²
Wall area 85 m²
Windows/Doors 15 m²
Linear junctions 120 m

Internal temperature 21 °C
External temperature -2 °C
Ground temperature 8°C

These data are used purely for the purposes of this example to illustrate the relative contributions of fabric to ventilation heat loss.

FABRIC INSULATION – U-VALUES

Table 1: Maximum elemental U-value (W/m2K)		
Column 1 **Fabric Elements**	Column 2 **Average elemental U-value**	Column 3 **Max. Elemental U-values**
Pitched roof insulated at ceiling	**0.16**	**0.3**
Pitched roof insulated on slope	**0.16**	
Flat roof	**0.20**	
Walls	**0.21**	**0.6**
Ground Floors*	**0.21**	**0.6**
Other exposed floors	**0.21**	
Floors with under floor heating	**0.15**	
External doors, windows & rooflights (ope area = 25% of floor area)	**1.60**	**3.0**

Source Irish Building Regulations Part L 2011

THERMAL PERFORMANCE– HEAT LOSSES

Heat loss through roof/ceiling

$Q = U \text{ X Area X } \Delta t$

Heat loss quantity =
U value x area x temperature difference

In terms of units

$W = W/m^2K \text{ x } m^2 \text{ x } K$

THERMAL PERFORMANCE– VENTILATION LOSSES

Heat loss through;

Roof	Q	=	0.2 x 100 x 23	= 460 W
Wall		=	0.21 x 85 x 23	= 410.5 W
Floor		=	0.21 x 100 x 13	= 273 W
Windows/Doors		=	1.60 x 15 x 23	= 552 W
Plane element Fabric loss				1695.5 W
Linear losses		=	0.11 x 120 x 23	= 303.6 W
Total fabric losses				**1999.1 W**

THERMAL PERFORMANCE– FABRIC LOSSES

Ventilation heat loss given by

$$Q = \frac{Cv\ N\ V\ \Delta t}{3600}$$

Where:

Cv	Specific heat capacity of air
N	Number of air changes
V	Volume
Δt	Temperature difference

Simplifies down to **$Q = 0.33\ N\ V\ \Delta t$**

THERMAL PERFORMANCE– FABRIC LOSSES

Ventilation heat loss given by

Q = **$Q = 0.33\ N\ V\ \Delta t$**

N Number of air changes say 2

V Volume 250 m^3

Δt Temperature difference

Q = 0.33 x 2 x 250 x 23 = **3833 W**

Thermal performance– Heat Losses

Fabric loss	**1999.1 W**
Ventilation loss	**3833 W**

Airtightness is critical !

6.3 Low Energy lighting

- Lighting is one of the main energy users in the built environment.
- The use of effective energy efficient lighting is important when trying to keep energy usage and Carbon emmisions to a minimum.
- **Effective** in relation to lighting means that the lighting is suitable for the purpose.

6.3 Low Energy lighting

Make the right choice

Photos/images courtesy of Shutterstock

6.3 Low Energy lighting

- **Luminous flux**
- The amount of light emitted by a lamp, measured in lumen (lm)

- 60w traditional incandescent lamp 700 lm
- 58 w fluorescent lamp 5000lm

- Fluorescent lamps are more energy efficient than Incandescent lamps (better lamp efficacy)

6.3 Low Energy lighting

- **Lamp efficacy**
- Is the ratio between a lamps out put in lumens and the power used in Watts.
- The higher the efficacy the more efficient the lamp.
- 60 W Incandescent lamp 12 lm/W
- 58 W fluorescent lamp 86 lm/W

6.3 Low Energy lighting

- **Colour Temperature (Kelvin)**
- The colour temperature determines whether colours appears warm or cool.
- "Warm" lights have a lower colour temperature than "cool" lights.
- A colour temperature of or below 3300 Kelvin would be considered warm
- A colour temepeture of above 5000K would be considered cool (bluish white)

6.3 Low Energy lighting

- **Colour Rendering** Describes the extent to which surface colours illuminated by a lamp will appear the same as if they were lit by daylight (or a tungsten filament lamp)
- Described using the colour rendering index (R_a)
- Scale goes from 0 to 100
- Most work place interior lights need to be R_a 90
- Compact Fluorescent Lamps R_a 85 (Good colour rendering)
- Sodium lamp (Yellow) Ra 0 (No colour rendreing)

6.3 Low Energy lighting

- **Illuminance**
- The amount of light reaching a surface for example a wall or floor
- Measured in lux (one lumen per square metre)
- Required illuminance in a building is task dependant.
- The required illuminance is normally what is specified for a particular environment, for example
  - Escape routes 1 lux along the centre
  - corridors 100 lux
  - Drawing office 500 lux

6.3 Low Energy lighting

- **Types of lamps**
- Incandescent lamps
  - Standard incandescent and tungsten halogen
- Discharge lamps
  - Fluorescent (tubular and compact)
  - Induction lamps
  - High intensity discharge such as high pressure mercury and sodium lamps and Metal Halides
- Light emitting diodes

6.3 Low Energy lighting

- It is important to ensure that the lamp used provides the correct type of light (suitable colour appearance and colour rendering capacity) and the luminaire (fitting) is appropriate for the task.

- The lamps most commonly used in domestic situations are fluorescent (both tubular and Compact fluorescent) and increasingly now LEDs.

6.3 Low Energy lighting

Photos/images courtesy of Shutterstock

- Light Emitting Diodes (LEDs) provide a very high luminous efficacy and a long lamp life.
- Advances in solid state lighting using LEDs is expected to have a major influence on the future of lighting and is expected to offer significant energy savings

6.4 Renewable Energy Options

Renewable energy is derived from natural processes that are replenished constantly.
In its various forms, it derives directly from the sun, or from heat generated deep within the earth.
Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

From the International Energy agency

6.4 Renewable Energy

"Renewable energy supplied an estimated 19% of global final energy consumption by the end of 2011, the latest year for which data are available.
Of this total, approximately 9.3% came from traditional biomass, which is used primarily for cooking and heating in rural areas developing countries.
Useful heat energy from modern renewable sources accounted for an estimated 4.1% of total final energy use; hydropower made up about 3.7%; and an estimated 1.9% was provided by power from wind, solar, geothermal, and biomass, and by biofuels."

Renewables are a vital part of the global energy mix.

Source, Renewables 2013 GLOBAL STATUS REPORT

6.4 Renewable Energy Options

Photos/images courtesy of Shutterstock

6.4 Renewable Energy

Renewable energy systems (RE) are also referred to as **low** or **zero carbon** energy sources.

Photos/images courtesy of Shutterstock

While the energy produced is from a renewable source there is an embodied energy cost associated with the hardware required to generate the energy.

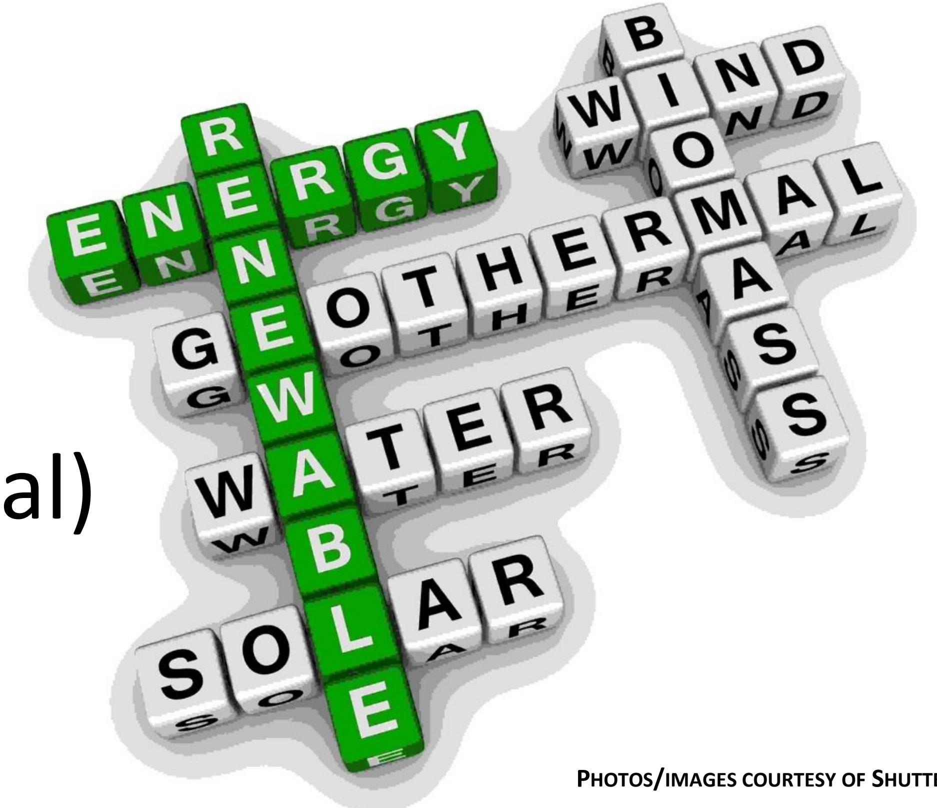
6.4 Renewable Energy systems

It is imperative that RE systems are specified properly and that system performance and project requirements are well matched.

RE systems should be fitted to replace traditional systems whenever possible but only when it makes sense in terms of energy performance.

6.4 Renewable Energy Options

Solar:
Wind:
Biomass:
Heatpumps:
(Geo/Aerothermal)
CHP:
Wave:
Hydro:
Waste Gas:



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6.4 Renewable Energy Options

When choosing to invest in an RE system, it is important to ensure that the system chosen is the best match for the intended purpose.

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This will normally require a detailed consultation with a professional technician or engineer.

6.4 Renewable Energy Options

Some systems are very suitable for smaller domestic projects such solar thermal, biomass, heat-pumps and wind power.

Others are more suitable for larger projects or grid generation such as Hydro, Wave, CHP and large scale wind developments.

6.4 Renewable Energy Options

On many small scale renewable energy systems it is hard to achieve a financial payback in the short to medium term.

However, with a growing uptake by the public and the introduction of legislation that requires and promotes the use of low or zero carbon energy sources, the cost of installing a RE systems is dropping.

Renewable Energy requirements in the Irish Building Regulations 2011

TGD L - **provide low or zero carbon energy sources to contribute to the calculated primary energy requirement as set out in Section 1.2**

- 10 kWh/m2/yr contributing to energy use for domestic hot water heating, space heating or cooling or
- 4 kWh/m2/yr of electrical energy or
- An equivalent combination of these

- E.g. of Renewable Energy Technologies:
  - Solar thermal systems,
  - Solar photovoltaic (PV) systems
  - Biomass / Biofuel systems
  - Heat pumps
  - Wind Turbines
  - Combined Heat & Power

Small Scale and Domestic Options

Solar Panels

- Solar Thermal
- Solar Photovoltaic

Biomass Boilers

- Log
- Chip/pellet

Heat pumps

- Geothermal
- Aerothermal

Wind power

- Generation
- Sell back and storage

Solar Energy Options

- Active
  - Water Heating
  - Space Heating
  - Photovoltaic (PV)
- Passive
  - Space Heating
  - Daylight

Active Solar Options

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Flat Plate   Evacuated Tubes

Solar Panels

In Ireland the erection of solar panels on domestic dwelling was the subject of planning legislation in 2007 with the introduction of certain exemptions.

The total aperture area of any such panel taken together with any other such panel previously placed on or within the said curtilage, shall not exceed 12 square metres or 50% of the total roof area, whichever is the lesser.

The height of a free-standing solar array shall not exceed 2 metres, at its highest point, above ground level.

ETC – Evacuated Tube Collector

- Typical system 4-6m^2
- Costs in region of € 4-8 K
- Supply 40 – 60% of DHW

Solar Irradiation

- Equator = 2000 kWh/m^2 /year
- Europe = 1000 kWh/m^2/year
- Spain = 1500 kWh/m^2/year
- Southern US = 2500 kWh/m^2/year

- Ireland = 4.5 kWh/m^2/day (July)
- Ireland = 0.5 kWh/m^2/day (Jan)
- *(5 kWh = a big bath!)*

SOLAR ENERGY STORAGE

- Buffer tanks can be useful for helping to match the energy available with the demand.
- Work is on going investigating longer term solar thermal storage.
- Long term solar storage using phase change technology is also being investigated

PHOTOVOLTAIC TECHNOLOGY

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Natural-Energy Efficient-Sustainable

PHOTOVOLTAIC TECHNOLOGY

- PV electricity is produced as DC current

- To use in a “normal” domestic setup the power must be converted to AC.

- This requires a device known as an inverter.

- The inverter converts DC current to AC current so that it can be used to power household devices.

PHOTOVOLTAIC TECHNOLOGY

- The nature of electricity usage is that it is sporadic and requirements have peaks and troughs.

- This causes a problem for most off grid supply as it is normally also sporadic in nature and is available intermittently.

PHOTOVOLTAIC TECHNOLOGY

Ways to solve the sporadic nature of supply and demand

•Sell back to grid.

9c/kwhr (tariff dependant)

In Germany there are serious financial incentives to sell power back to the grid and as a result of this Germany is among the global leaders in the use PV technology.

•Storage (in batteries)

Environmental issues

Photovoltaic Technology

In situations where mains power is unavailable PV with an inverter pack and a set of batteries provide a viable alternative source of electric power.

Photos/images courtesy of Shutterstock

Remote area lighting, signage, parking meters

PV often used to trickle charge battery banks that are being used in conjunction with windmills.

Renewable Energy Payback

"The simple **economic payback times** (the time in years taken for the cost savings to offset the initial capital cost) for some swimming pool heating systems and air source heating systems can be under 10 years but, in general, the payback times for photovoltaic and solar thermal systems are long and may be longer than the lifetime of the system. "

Source: CIBSE Knowledge Series Capturing Solar Energy

Renewable Energy systems Payback

The **energy payback time** (the time needed in years for a system to reimburse its energy content) is between 2 and 4 years for solar thermal systems and between 3 and 5 years for photovoltaic systems, depending on location and whether it is roof or façade mounted.

Source: CIBSE Knowledge Series Capturing Solar Energy

RENEWABLE ENERGY PAYBACK

The **carbon payback** (the time needed in years for a system to offset its carbon content by carbon savings) for solar thermal systems is about 2 years and for photovoltaic systems between 4 and 6 years, depending on the technology used.

Source: CIBSE Knowledge Series Capturing Solar Energy

Renewable Energy Payback

The financial estimates do not include potential fuel price increases and any grants or other incentives that could reduce the payback times substantially. The installation of a solar system may also increase the value of a building.

Recent developments in Solar Photovoltaic (PV) technology have produced very significant price reductions in the last three years, making solar PV a financially viable option for small and medium sized public building works.

Heat Pump Systems

Photos/images courtesy of Shutterstock

Geothermal and Aerothermal

DEFINITION OF A HEAT PUMP

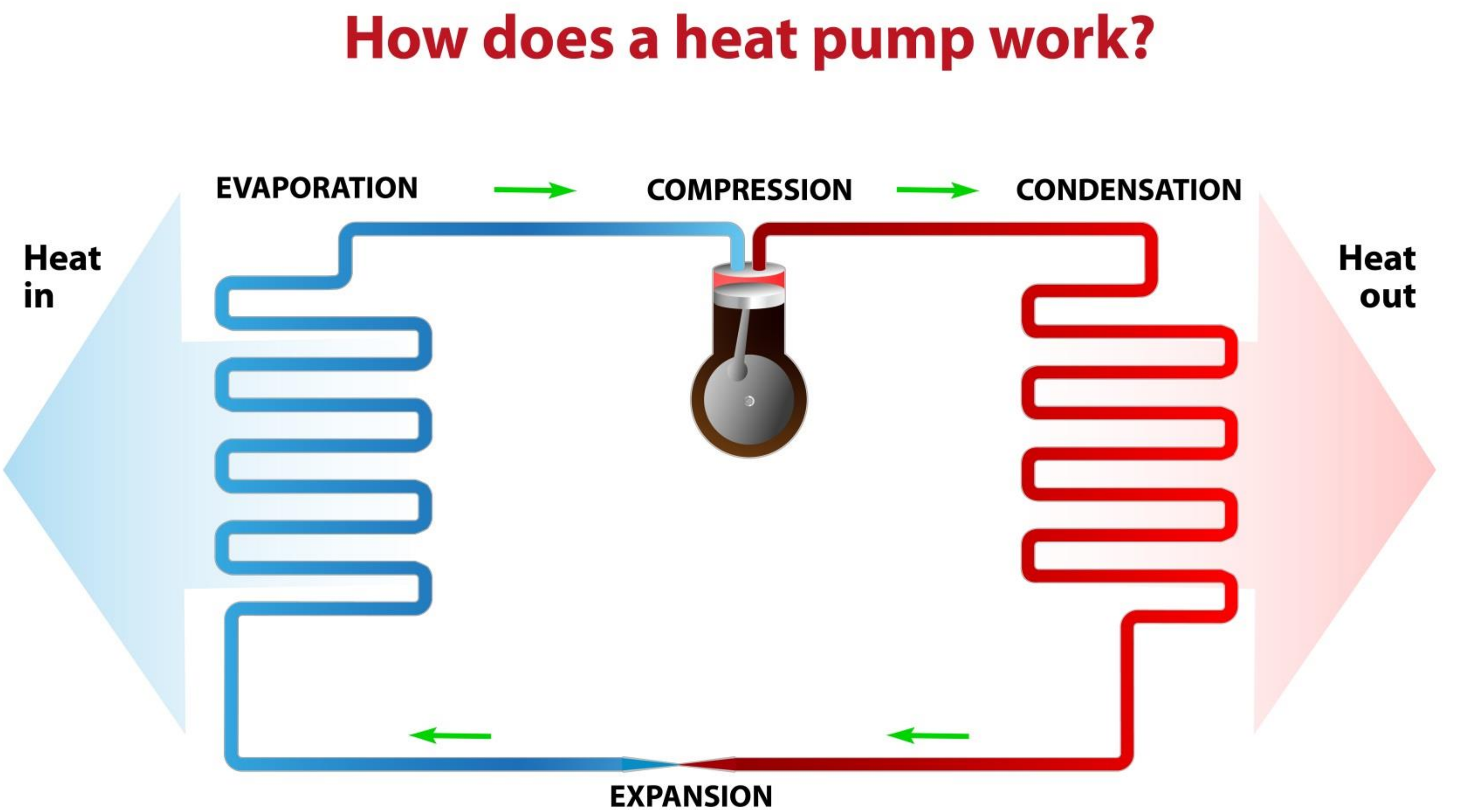
A heat pump is a machine that moves heat from one location to another, from a low temperature outside source to high temperature inside location.

They utilise the “free” thermal energy stored up in the ground

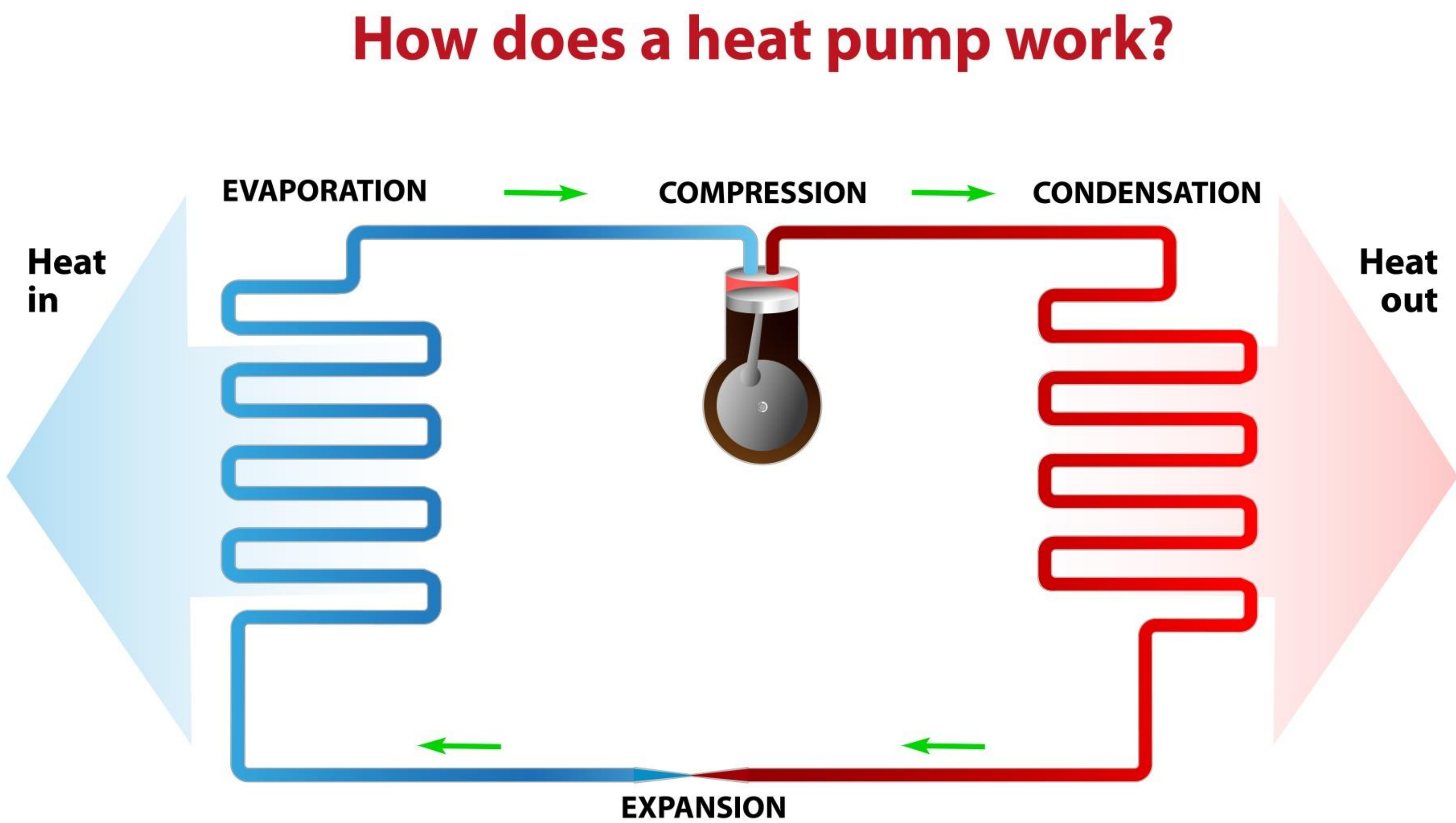
Heat pumps do use energy, this energy is to used extract heat/reject cooling from ground **not** to generate the heating or cooling

HEAT PUMP

A heat pump is used to concentrate heat energy from the ground before distributing it in a building through conventional distribution system



PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK



PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Each kilowatt (kW) of electricity used to operate a GSHP system draws more than 3 kW of renewable energy from the ground

GROUND SOURCE HEAT PUMPS GSHP

The ground absorbs about half of sun's incident energy

The ground dampens temperature variation

Temperature variation decreases with depth.

If a GSHP is sized properly it should perform the same in winter and summer.

Local ground temperatures depend on climate, ground, snow cover, slope and soil properties, etc.

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Air Source Heat pumps

ASHP use the air as a an energy source

Heat is required most on days that are cold.

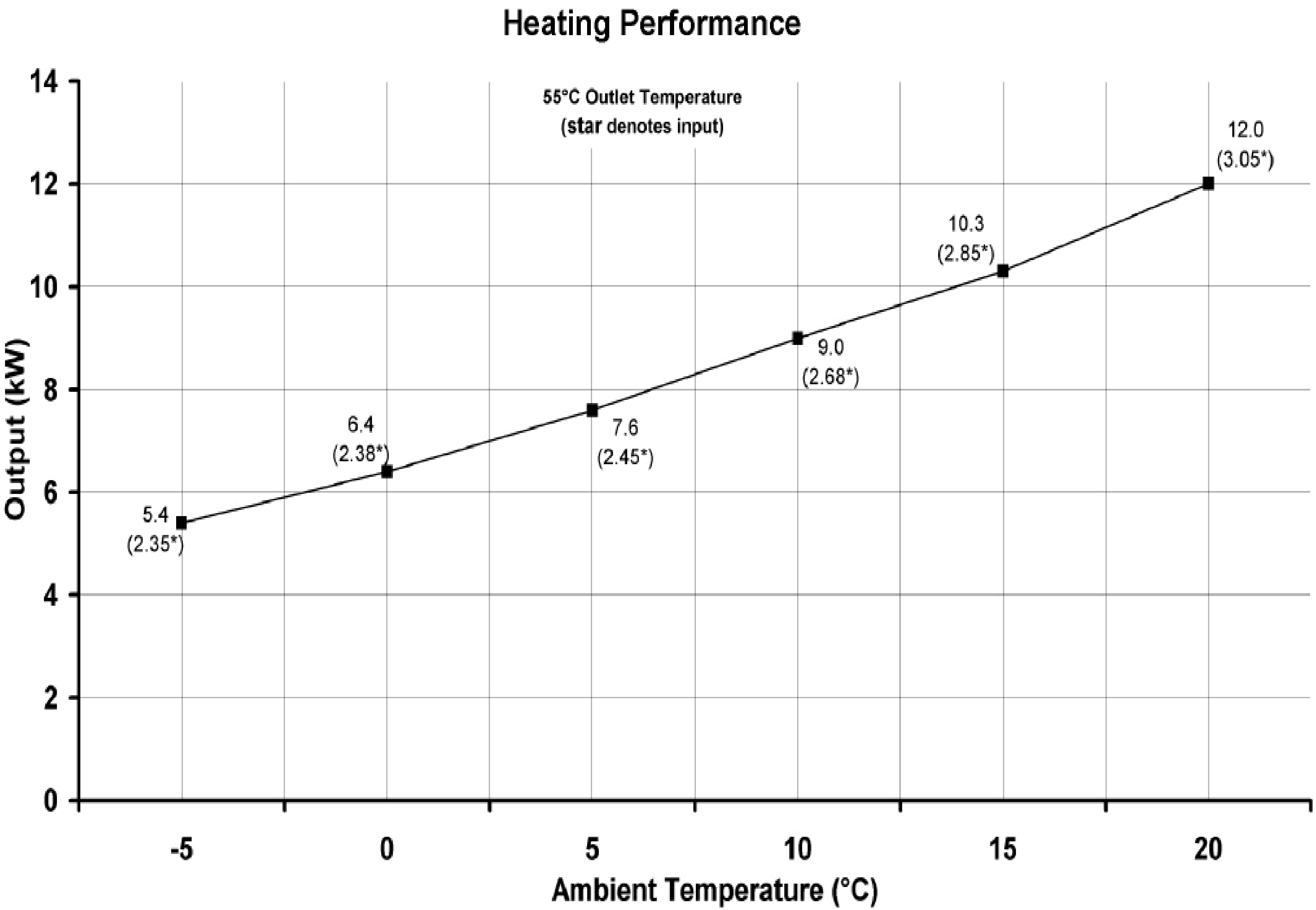
It requires more (electrical) energy to take heat out of colder air.

Thus they are less efficient than GSHP.

External unit

Internal unit

Air Source Heat pumps COP and performance



Heat Pumps for Domestic use

- GSHP have a COP of 3 - 4
- ASHP have COP of 2.5 – 4

- GSHP initial costs are higher, but O&M costs are lower compared to conventional heating systems
- Accurate feasibility cost studies should be undertaken to ensure a GSHP is the best option

Heat Pumps for Domestic use

75 – 80% of the energy from a heat pump is renewable ie heat resource from ground is renewable but **the energy required to extract it is not**.

Improved building insulation will reduce heat loss requiring a smaller heat pump and cut down on the non-renewable energy consumed by heat pump

Heat Pumps for Domestic use

GSHP Coefficient of performance COP 4

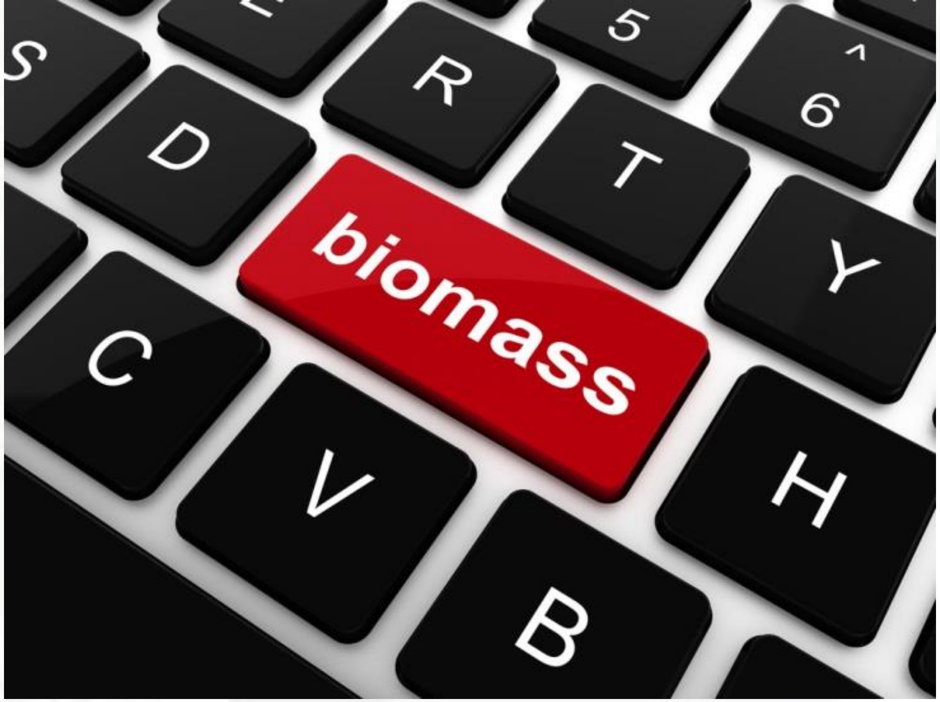
This means that its takes **1** unit electricity for **4** units of heat.

On average electricity generation and distribution system is only 40% efficient

Therefore a heat pump must have a COP of **at least 2.5** to be neutral in terms of carbon emissions if using non renewable electricity.

Benefits in terms of Carbon savings only apply to a to the portion of the COP of above 2.5

Biomass



PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

- A number of biomass boilers are available commercially for large scale energy requirements.
- Domestic biomass boilers generally refer to wood or wood bi-product burning boilers.

- Wood pellet boilers
- Wood chip boilers
- Wood log boilers
- Wood gasification boilers
- Stoves

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Biomass Boilers

Biomass fuels - boiler size and costs

Domestic and light industrial biomass boiler systems tend to be physically larger and more expensive than their fossil fuel equivalents.

There are two reasons for this:

For efficient combustion wood needs to be burned at a high temperature, and this requires a large firebox

Fuel storage and handling is less simple than for gas or oil. The fuel storage and handling system adds significantly to both the complexity and cost of a wood fuel heating system, costing perhaps as much as the boiler itself.

Biomass fuels - boiler size and costs

Various systems and designs exist, and stand alone pellet silos are available commercially.

For many small and medium sized installations, an auger screw feed is used to transfer wood chips or pellets from the store into the boiler

Wood Pellet boilers and stoves

- Use wood pellets that are made from sawdust and glue.
- Very efficient fuel consumption up to 94%
- Clean burning
- Automatic feeder (can use silo)

Gasification Boilers

Burn wood very efficiently up to 95%

Clean burn

Expensive to purchase (compared to a standard stove)

Should be used in conjunction with a buffer tank.

Gasification v. Conv. Wood Boiler

• Forced draft (fan)
• Automatic primary/secondary air valves
• Flue gas monitoring
• Fast hot burn (>1200°C)
• No tar or charcoal build up
• Single fill of wood per day
• Uses approx. 40% less Wood

• Natural draft
• Manual primary/secondary air valves
• No monitoring gases
• Slow cool burn (800°C)
• Tar/charcoal build up
• Must burn when heating is required
• Uses more wood

Wind Turbines

PHOTOS/IMAGES COURTESY OF SHUTTERSTOCK

Wind Turbines

Need to get site assessed

Many different turbine designs available.

Geared models are more expensive.

Health and safety is critical, high wind speeds motor burn out, falling masts, electric shock risks.

Need a registered electrician

Wind Turbines

Turbine systems costs vary depending on a number of factors.

For a given suitable site the choice of turbine and supplier are the key factors which lead to a successful installation and a positive experience.

It is possible to source seemingly inexpensive turbines on the internet from manufacturers in Asia but, without a local support network, if something does fail it could be very difficult to get the system up and running.

If the turbine turns out to be of poor quality or not robust enough to cope with a high wind speed event it may be a wasted investment.

Planning and domestic Wind turbines

Extract from Irish planning laws (Wind turbine exemptions)

1. The turbine shall not be erected on or attached to the house or any building or other structure within its curtilage.
2. The total height of the turbine shall not exceed 13 metres.
3. The rotor diameter shall not exceed 6 metres.
4. The minimum clearance between the lower tip of the rotor and ground level shall not be less than 3 metres.
5. The supporting tower shall be a distance of not less than the total structure height (including the blade of the turbine at the highest point of its arc) plus one metre from any party boundary.

6. Noise levels must not exceed 43db(A) during normal operation, or in excess of 5db(A) above the background noise, whichever is greater, as measured from the nearest neighbouring inhabited dwelling.
7. No more than one turbine shall be erected within the curtilage of a house.
8. No such structure shall be constructed, erected or placed forward of the front wall of a house.
9. All turbine components shall have a matt, non-reflective finish and the blade shall be made of material that does not deflect telecommunication signals.
10. No sign, advertisement or object, not required for the functioning or safety of the turbine shall be attached to or exhibited on the wind turbine.

Photos/images courtesy of Shutterstock

VFM and payback period

Economic payback periods depend on a number of factors including

- What the RE source is replacing
- Heat load of dwelling (size of unit)
- Usage profile of householders (type of domestic heating system)
- Capacity for (pellet) storage
- Amount of land available (geothermal)

6.5 Energy Efficient Appliances

- It is important to ensure that all electrical equipment used is as energy efficient as possible.
- To help ensure this many electrical appliances are now labelled to indicate energy consumption.
- The rating is normally in the range of A to G with A being the most efficient.
- Due to the introduction of a minimum standards directive, different types of product have different ranges of ratings e.g. all refrigeration equipment must be A-C

6.5 Energy Efficient Appliances

- **European Eco Label**

- The Eco Label is available to manufacturers on a voluntary basis and gives a much broader indication of the environmental impact of the appliance throughout its complete lifecycle, so called ‘cradle to grave’, which takes into account manufacture, distribution, use and recyclability.
- It takes into account the content of hazardous substances and any potential harm or degradation to the natural environment.

6.5 Energy Efficient Appliances

- **European Eco Label**

- As much of a products impact is during its manufacture, this can be mitigated by increasing a products durability up to as much as 20 years.

- If the product has been awarded an Eco Label then the EU's flower symbol will be featured on the compulsory Energy Label.

6.6 Water Usage

Water is valuable natural resource.

The vast majority of drinking water (potable water) is mechanically and chemically treated to ensure that it is safe for human consumption.

The degree and amount of treatment required to produce potable quality drinking water will depend on the location.

Consequently the amount of energy used to treat the water will also depend on the location.

6.6 Water Usage

All water treatment requires energy and this will have an associated carbon emission cost.

Well over half of the water delivered to buildings is being used to shower, bathe and do the laundry, while nearly a third is being used to flush the toilet.

A mere 10% of our home water supply is used in the kitchen and as drinking water.

6.6 Water Usage

"Historically, water prices in Europe have rarely reflected the true financial cost of supplying water, nor the economic costs to the environment. This has led to pollution and water scarcity, imposing costs on the environment and society. For example, the general public typically has to pay for the cost of treating drinking water contaminated by agriculture or industry. Putting the right price on water can incentivise more efficient use of water and technological innovation. Effective use of taxes, subsidies, market mechanisms, pricing schemes and other economic instruments can also help balance conflicting demands on water."

Source: http://www.eea.europa.eu/media/newsreleases/europe-needs-to-use-water

6.6 Water Usage

"Inefficient use of water also leads to higher energy use, with extra financial and environmental costs, according to the 'Towards Efficient use of water resources in Europe' report from the European Environment Agency (EEA) .

While the energy needed to pump and treat freshwater into drinking water is typically around 0.6 kWh/m^3, desalination of seawater adds approximately 4 kWh/m^3.

Source: http://www.eea.europa.eu/media/newsreleases/europe-needs-to-use-water

6.6 Water Usage

Reducing unnecessary use of potable water is a key way to reduce emissions associated with water treatment.

Reduce water usage in domestic and commercial buildings.

Reduce unnecessary use of potable where possible

Substitute with “grey water” or rain water

6.6 WATER USAGE

The first step is the **reduction of water usage**.

In organisations this is a management strategy decision.

On a domestic level this can be achieved by simple measures such as ensuring taps are turned off properly, that there are no leaks in a system, metering, using low flow taps and shower heads, low usage appliance and fitting dual flush mechanisms toilets.

See http://eartheasy.com/live_water_saving.htm

6.6 Water Usage

Other options that can be considered are

Grey water recycling

Rainwater harvesting

Both have a place, but both require hardware and additional plumbing and piping. They should only be used when it has been established that they will be beneficial.

6.6 Water Usage

Grey water recycling

Greywater is mainly washwater, that is, all wastewater excepting toilet wastes and food wastes derived from garbage grinders.

There are significant distinctions between greywater and toilet wastewater (called "blackwater").

These distinctions tell us how these wastewaters should be treated /managed and why, in the interests of public health and environmental protection, they should not be mixed together

6.6 Water Usage

Grey water recycling

Grey water can be used for WC flushing and landscape irrigation.

Grey water systems can be installed into new building quite easily.

Grey water systems can also be retro-fitted but it will depend on the geometry of the building and level of destructive work that will need to be done.

6.6 WATER USAGE

Rain Water Harvesting

Harvested rainwater can be substituted for mains water, saving money and contributing to the protection of a key natural resource.

Commercial systems are available for both domestic and commercial situations.

Below are extracts from the Executive Summary of the Environmental agency report on Energy and carbon implications of rainwater harvesting and greywater recycling (Report: SC090018 August 2010)

"This report presents the findings of a study into the energy and carbon implications rainwater harvesting (RWH) and greywater recycling (GWR) systems. The Environment Agency (EA) commissioned the review jointly with the Energy Saving Trust (EST) and National House Building Council (NHBC) Foundation.

This study quantifies:

- Lifetime carbon footprints of RWH and GWR systems, consisting of embodied carbon and the carbon emitted from operational use; and
- The contribution of RWH and GWR systems to reducing carbon emissions associated with mains water demand and foul water volumes."

FINDING 1

"Buildings using harvested rainwater or treated greywater typically increase greenhouse gas emissions compared to using mains water, where total cradle to gate embodied and operational carbon are considered. example over 30 years, where an 'average' 90m2 house has a RWH system with a polyethylene tank, the **total** carbon footprint is approximately 1.25 – 2 tonnes of carbon dioxide equivalent (CO2e).

This is similar to one year of energy-related emissions from a house built to Code for Sustainable Homes Level 3 energy efficiency standards. The footprints of systems applied to commercial buildings vary widely, but over a 30 year lifespan were found to represent around one month's operational energy-related emissions in the hotel, office and schools studied."

Finding 2

"With one exception, the operational energy and carbon intensities of the systems studied were higher than for mains water by around 40 per cent for a typical rainwater application, and over 100 per cent for most greywater applications.

The exception is short retention greywater systems which are around 40 per cent less carbon intensive than mains water supply.

The assumed operational intensities of rainwater and greywater systems are based on the limited measured data and information available to this study."

FINDING 3

"There is scope to improve the efficiency and design of systems to reduce their carbon footprints. Storage tanks account for a large proportion of the embodied carbon footprint of rainwater systems; slightly less so for greywater.

Pumps also make up a large proportion of rainwater and greywater embodied carbon and pumping determines net operational carbon.

Direct feed rainwater systems have a large operational footprint because both rainwater and mains backup are pumped to end uses via the storage tank."

"Innovation in these and other areas could reduce carbon footprints. Manufacturers and suppliers should work quickly to reduce the footprints of their systems, and particularly to reduce the energy intensity of pumps and treatment systems."

Before undertaking the installation of a rainwater harvesting or greywater recycling system, a full assessment of the environmental impacts should be undertaken.

WASTE WATER TREATMENT

The majority of urban and sub-urban buildings are connected to public sewerage schemes and domestic and commercial waste water is treated by local authority water treatment plants.

For those who do not live within service distance of a public scheme, alternative single (or in some cases small group) treatment systems must be used to treat waste water.

WASTE WATER TREATMENT

There are a variety of single treatment unit systems available commercially and many use a series of tanks and pumps to treat the waste water so that it is fit for discharge to the environment.

One potentially low impact option for waste water treatment is the use of constructed Wetlands.

Waste Water Treatment

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http://www.wetlandsystems.ie/index.html