CONSTRUCTION BLUEPRINT

Module 10

# Renewables

Energy Efficiency for Construction

24 partners
12 countries

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# Renewables | Summary

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To equip the learner with the basic knowledge and skills required to understand how Renewable Energy is used and the benefits of these technologies





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# **Renewables** | Objectives

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- Identify examples of the different **types of technology** that qualify as providing renewable energy.
- Outline renewable energy technologies suitable for **space heating and cooling, and water heating**
- Outline and discuss the **minimum level of energy** provision required from renewable energy technologies to comply with National nZEB requirements using case studies
- Understand the principles of **micro generation** and how it can benefit compliance of nZEB buildings
- Discuss and understand the **details** of specific technologies applied eg solar, thermal, geothermal
- Outline the relevance for long and short-term **energy storage** for renewables in buildings



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# Renewables | Content

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# 1. Introduction to Renewables





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## What is Renewable Energy?

"The nearly zero energy required in a building (NZEB) should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby"

## Renewables come from natural sources that are replenished:

- Sources of renewable energy include: solar thermal, solar photovoltaic, wind, bioenergy, hydro, wave, tidal, & geothermal energy.

- Low carbon technologies are not completely renewable as they may still have carbon emissions associated with it, albeit much smaller than fossil fuel burning technologies.
- Heat pump and combined heat and power (CHP) are two low carbon technologies that are used for heating buildings in order to reduce the operational costs and $CO_2$ emissions.
- When coupled to renewable energy sources, heat pumps are completely emissions-free and the energy that heat pumps produce is still classed as 'renewable', even though the pump itself is powered by electricity

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For dwellings, “Renewable Energy” will mostly comprise of:

## Heating

- Biomass and Biofuels
- Heat Pumps (ground, water or air source)
- Solar Thermal

## Power Generation

- Solar Photovoltaic
- Wind (“aerogenerator”)





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# Renewable Energy from Heating Appliances

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- **Energy from renewable non-fossil energy sources**, e.g. solar energy (thermal and photovoltaic), wind, hydropower, geothermal, ambient energy, wave and tidal
- **Biomass and biofuels** are also considered as renewable
- Appliances must be **designed to run on these fuels <u>only</u>**, i.e. incapable of providing thermal energy from fossil fuels
- A boiler capable of utilizing **coal or peat**, in addition to a biomass fuel would not be considered a renewable technology.
- **Small-scale CHP** (combined heat and power) can also be used, providing electricity and heat simultaneously

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TGD Part L 2019: Renewable Energy Ratio

**20% of <u>regulated</u> primary energy demand**

- Regulated energy demand includes heating, cooling, domestic hot water, ventilation and lighting
- It does not include household appliances

# Heat Pumps Contributing Towards Renewable Energy Requirement

| | |
|---|---|
| **Primary energy factor for electricity** | **2.08** |
| **COP (coefficient of performance) for most heat pumps** | **> 3.0** |

- If the COP is higher than primary energy factor, the difference can be counted towards renewable energy contribution
- Many dwellings meeting renewable energy requirement through heat pumps alone (without solar systems)

# Energy Efficiency Labels: Heat Pump

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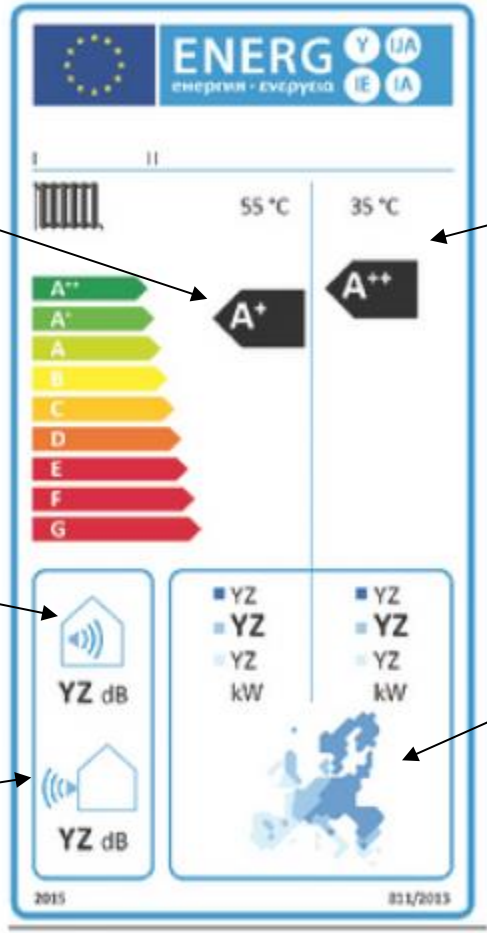
Rating for heating

Noise levels for indoor unit

Noise levels for outdoor unit




Rating for domestic hot water

Power output (heat load) in 3 different climate zones

Image Source: Buildup

# Solar Radiation

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- Solar radiation refers to the amount of ‘free’ solar energy available
- Measured in $kWh/m^2$.year
- Can be used ‘passively’ through windows or ‘actively’ through solar systems (photo-voltaic or solar thermal)
- Be aware of risk of overheating (shading and g-value)!
- Amount of energy will vary with orientation

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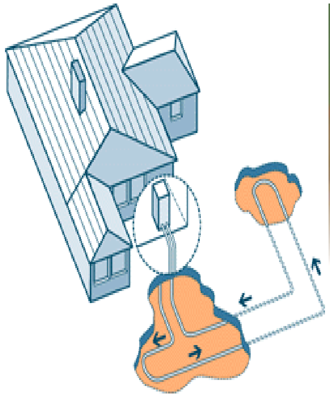
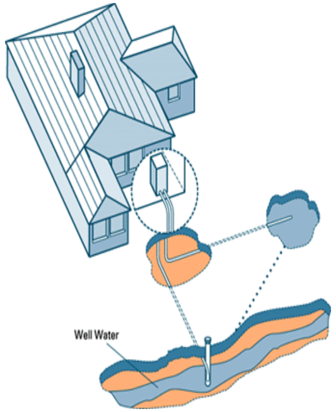
# Heat Pump Types

- **Air-source** (taking heat from the ambient air)
- **Geo-thermal** (taking heat from the ground: horizontal and vertical)
- **Water-Source** (taking heat from water/well)






- Air-source heat pumps are the most popular due to cost of installation – no need for loop in ground or in water.
- The term 'source' is to indicate where heat can be taken from to heat the dwelling



Images source: SEAI Publications

# Heat Pump Types

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**Three types of Air Source Heat Pumps:**

**1. Air-to-Water (Ground Source, GSHP and Water Source, WSHP)**

Extracted energy from outside air is transferred through a heat exchanger to water; can provide full Heating & DHW production

**2. Air-to-Air (Air Source, ASHP)**

Extracted energy from the outside air is being transferred through a heat exchanger to air; these systems can provide full heating only

**3. Exhaust Air (EAHP)**

Extracts heat from the exhaust air of a building and transfers the heat to the supply air, hot water and/or hydronic heating system



source: SEAI Publications

# 2. Renewable Heating and Cooling

# Heat Pumps: Key Concepts

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| Compression | Expansion |
|---|---|
|  |  |
| When you compress a gas, it heats up<br>(feel the heat from a bicycle pump) | When you expand a gas, it cools down<br>(feel the coolness from spraying deodorant) |

Heat pumps compress & expand refrigerants as above to transfer heat from outside to inside.
Refrigerants are often referred to as 'heat transfer fluids'



Image Source: Purchased by MosArt-WWETB (iStock 91813849 + 1156955971)

# Winter Heat Pump Refrigerant Cycle

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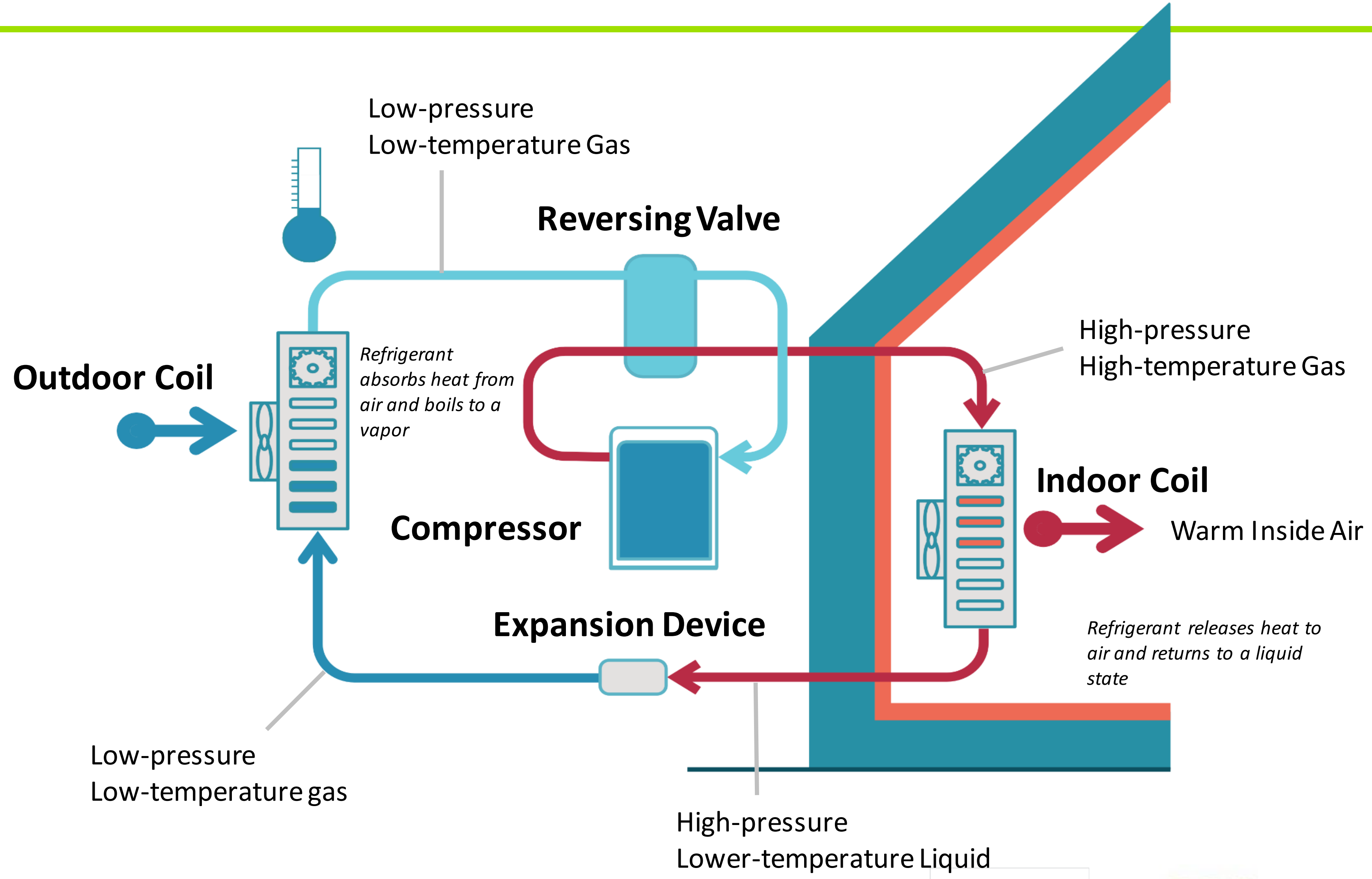


Image Source: MosArt



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# Heat Pump Efficiency

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

**Heating ratios are quoted in two ways:**

- **Coefficient of Performance** (COP) – the ratio of heating delivered to the electrical energy input, based on lab-testing with set indoor and outdoor temperatures
- **Seasonal performance factor** (SPF) - the ratio of heating delivered to the electrical energy input, taking into account outdoor temperature variation throughout the year
- COP generally higher than SPF, but SPF a more realistic measure

# Heat Pump Operating Temperatures

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- The majority of heat pumps have an **operating limit of 50°C – 55°C**. Reducing the output temperature will increase performance
- **Ideal flow temperature = 35°C for UFH systems and 45°C for low temperature radiator systems.**
- Heat pumps are **not suitable for traditionally sized, high temperature wet radiator** distribution systems
- Also **not suited to providing all the DHW** as they cannot raise water to that required (60°C) to avoid risk of Legionella.
- **Most heat pumps use a booster heater/electrical imme**rsion to complete the Anti-legionella/Disinfection cycle.
- A few heat pumps, however, can provide output temperatures of up to 65°C and specially designed two stage compressor heat pumps can provide output temperatures of up to 80°C.



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# Heat Pump Space Heating Controls

**Main Objective:**

Operate the heat distribution system at the lowest temperature that will meet the comfort requirements – this will optimise efficiency of the heat pump.

**Three Control Options:**

1. **Weather Compensation:** most efficient form of control. The output temperature from heat pump is adjusted according to outside air temperature.
2. **Room Thermostat:** thermostat in the house can be used in conjunction with an outside air temperature sensor to influence the curve control function.
3. **Fixed Temperature:** heat pump switched on and off by an in-built return temperature sensor and always operates up to its maximum working temperature. Does not offer optimum savings from the heat pump.

# District Heating and Heat Metering

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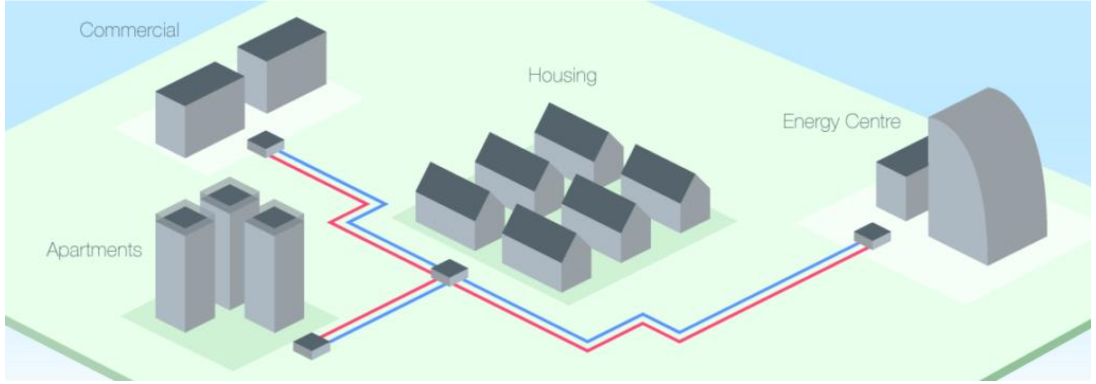
- **District heating systems** deliver heat for both space heating and water heating through a network of insulated underground pipelines.




- **A heat meter** is a device which measures thermal energy delivered to a dwelling, by measuring the flow rate of the heat transfer fluid and the change in its temperature between the flow & return.




Image Source: Top – boilerguide / Bottom - pctflow.com

# Photo Voltaic vs Solar Thermal Systems

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A PV system is used to convert solar radiation (provided by the sun) into electricity.

Solar thermal system, uses the suns energy to heat water.

Image Source: Purchased by MosArt-WWETB (Top iStock-1090440420) (Bottom iStock-1148634888)

# Working Principle Solar Thermal Systems

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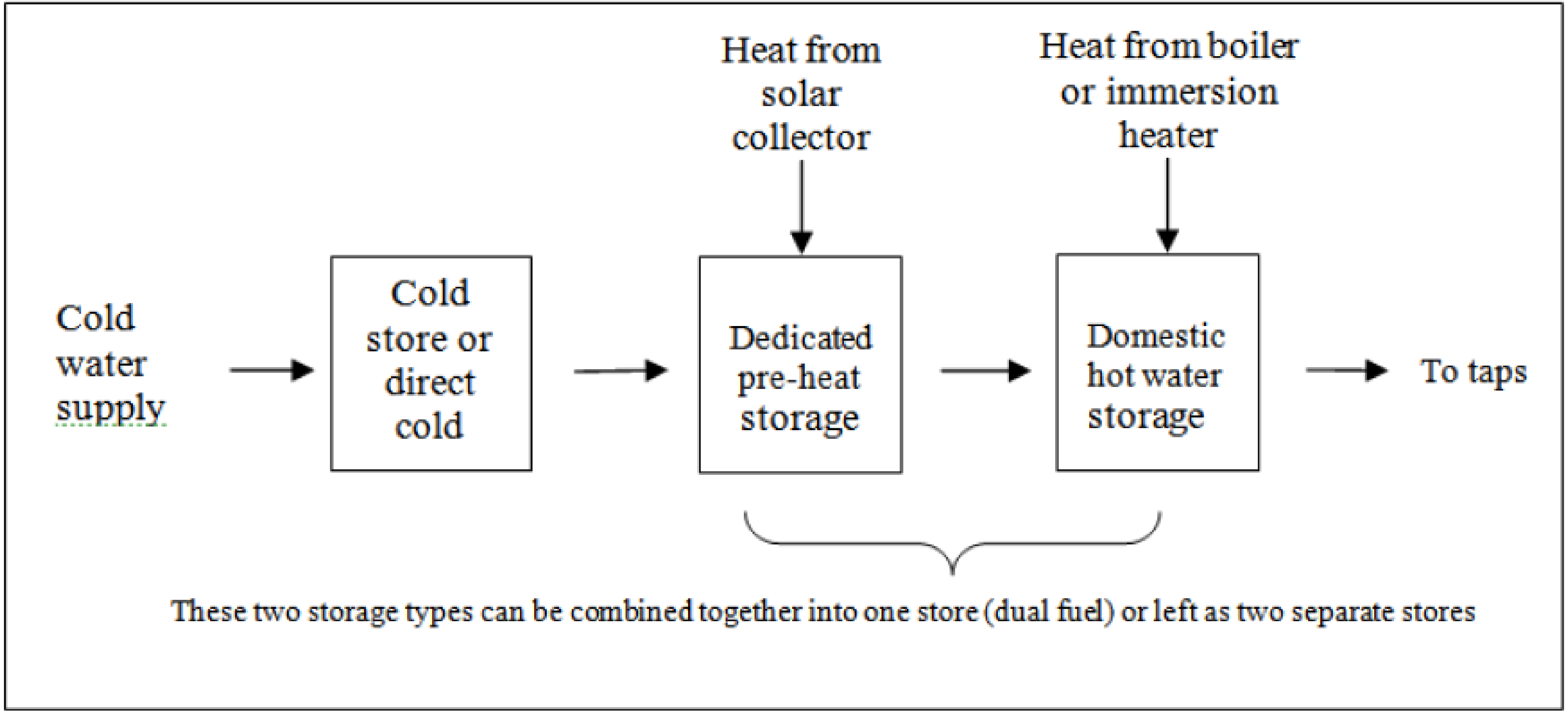


***Figure H1:* Working principle of solar water heating.**

Image Source: SEAI DEAP Manual 4.2.2 July 2020

# Typical Thermal Pre-Heating Arrangements

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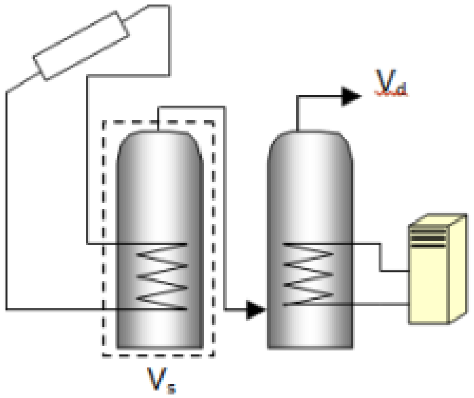
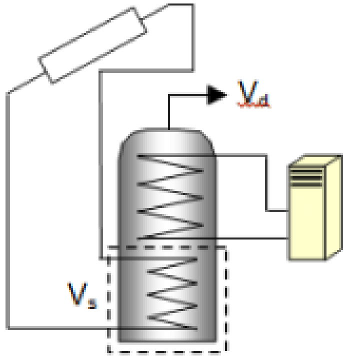
$V_s$ = dedicated solar storage volume

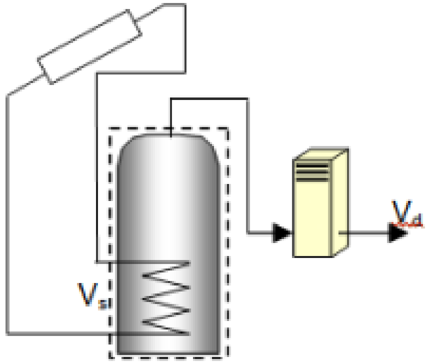
$V_d$ = daily hot water demand



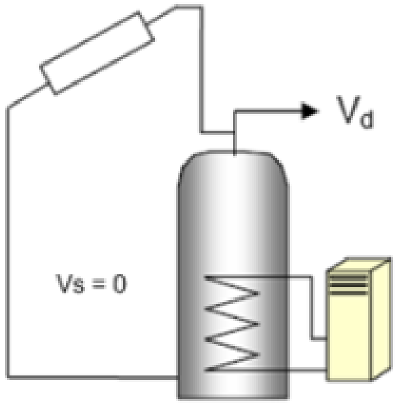

a) With separate solar cylinder




b) With a twin-coil cylinder[1]




c) Combi boiler




d) Direct system



Image Source: SEAI DEAP Manual 4.2.2 July 2020



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There are three main types of solar thermal collector:

1. **Unglazed:** performance is limited by high thermal losses

2. **Glazed flat plate:** a flat plate absorber (which often has a selective coating) is fixed in a frame between a single or double layer of glass and an insulation panel at the back

3. **Evacuated tube:** an absorber with a selective coating enclosed in a sealed glass vacuum tube.

# Factors Influencing Solar Thermal Production

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$$Q_s = S \times Z_{panel} \times A_{ap} \times \eta_0 \times UF \times f(a_1/\eta_0) \times f(V_{eff}/V_d)$$

$Q_s$ = solar input, kWh/year

$S$ = total solar radiation on collector, kWh/m²/year

$Z_{panel}$ = overshading factor for the solar panel

$A_{ap}$ = aperture area of collector, m²

$\eta_0$ = zero-loss collector efficiency

$UF$ = utilisation factor

$a_1$ = linear heat loss coefficient of collector, W/m²K

$f(a_1/\eta_0)$ = collector performance factor = (see H10 below)

$V_{eff}$ = effective solar volume, litres

$V_d$ = daily hot water demand, litres

$f(V_{eff}/V_d)$ = solar storage volume factor = $1.0 + 0.2 \ln(V_{eff}/V_d)$

Image Source: SEAI DEAP Manual 4.2.2 July 2020

# Example - Default Values for Annual Solar radiation

Solar radiation values depend on **orientation and tilt of collector**

***Table H2*: Annual solar radiation, kWh/m²**

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

Image Source: SEAI DEAP Manual 4.2.2 July 2020

# Wind Loading on Roof Mounted Solar Systems

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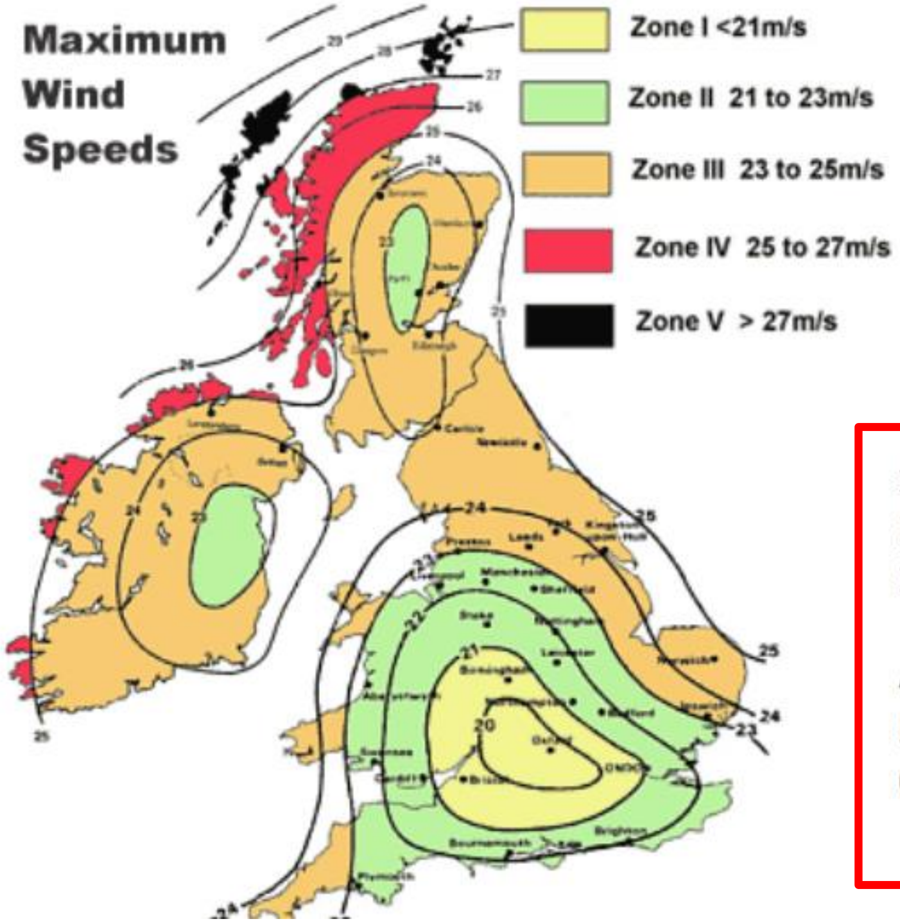


Where more detailed calculations are required, the Eurocode [Note1] for wind loading on building structures and the related UK National Annex should be used. The calculation process has six steps:

1. Determine Site wind speed $V_s$
2. Determine Effective wind speed $V_e$
3. Determine Dynamic pressure $q_s = 0.613\ V_e^2$
4. Determine external surface pressure $p_e$
5. Determine internal surface pressure $p_i$
6. Determine net load on the PV module $P = (p_e - p_i)\ A$

**Factors influencing wind load on solar systems**



Image Source: National Energy Foundation, Ireland

# Options for Roof Mounting Solar Systems

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- **Mechanical fixing:** need to ensure that roof covering penetrations are weather-proofed and airtight (very common with solar thermal)
- **Ballast:** there are no penetrations with this approach - the solar system rests on the roof and is kept in place with weights (increasingly common for solar PV)
- **On-roof:** solar panels mounted on brackets and sitting proud of the roof covering
- **In-roof:** installed similar to a roof window, where the panel is fixed directly to the timber rafters

# Pros and Cons of On-Roof Versus In-Roof Solar Systems

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**On-Roof Advantages**
- Allows for easier future maintenance
- Lots of different systems available
- Typically cheaper

**On-Roof Disadvantages**
- Drilling through tiles or slates – need careful weather-proofing
- Increased wind load risk which may be a problem in some areas

**In-Roof Advantages**
- Aesthetically integrated
- Less exposure to wind buffeting

**On-Roof Disadvantages**
- Solar panels will have to be replaced at end-of-life which could be costly
- Maintenance is more challenging - costly

# 3. Micro generation of electricity and storage

# Photo Voltaic vs Solar Thermal Systems

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PV systems are far more common than solar thermal systems in recent times!

**PV systems have a number of advantages over solar thermal systems:**

- PV panels have no moving parts/fluids.
- They are easier to maintain.
- For every watt saved using solar panels, 2.08 watts of primary energy are saved, which is not the case with all water heating systems.



Image Source: Purchased by MosArt (iStock-1090440420)

# How Does a PV Panel Work?

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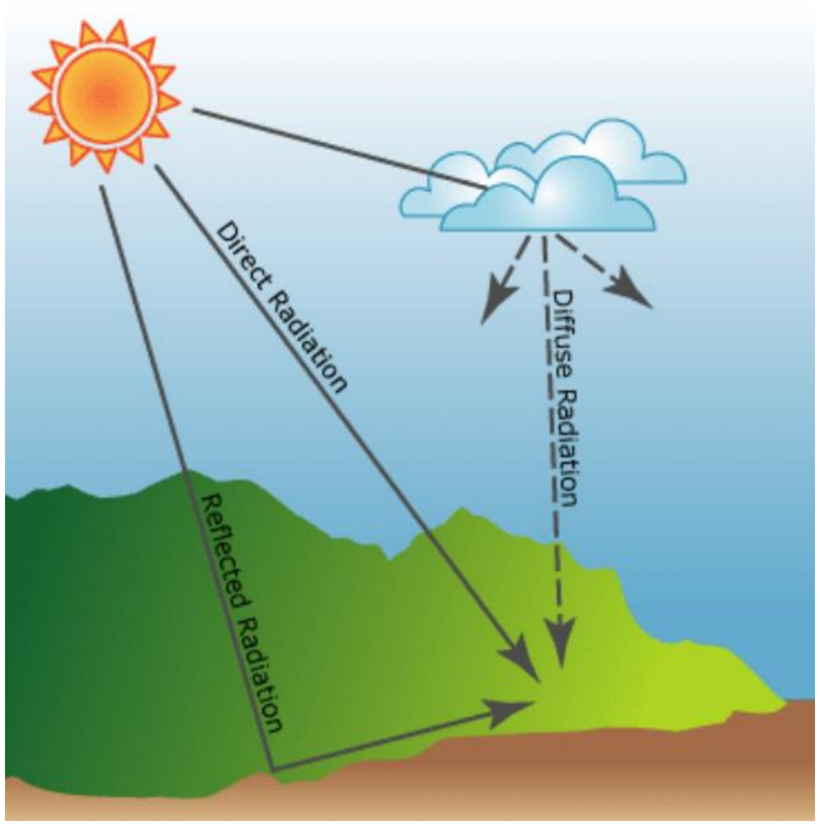
PV panels work using both direct and diffuse radiation




As a result PV panels are effective in most Climates



Image Source: Left – MosArt-WWETB / Right - SEAI

# How Does a PV Panel Work?

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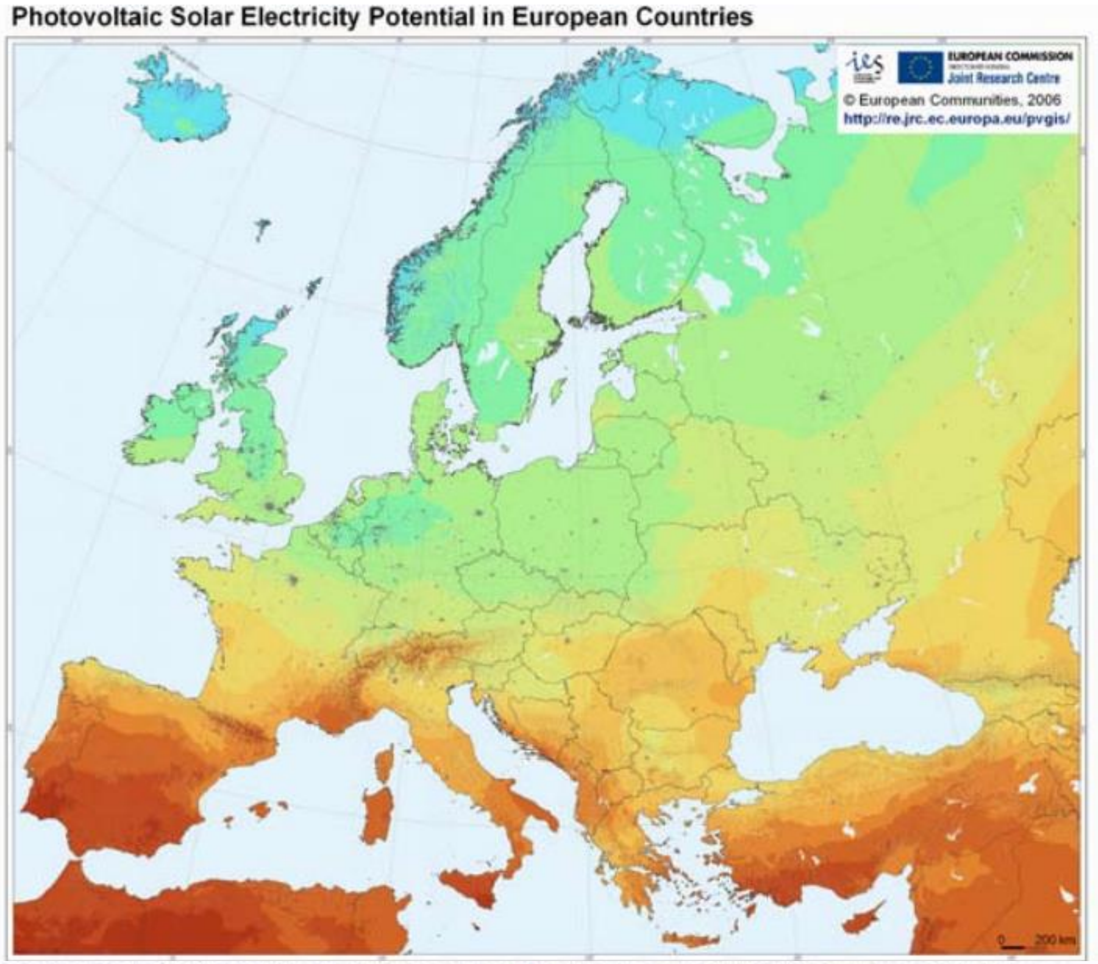


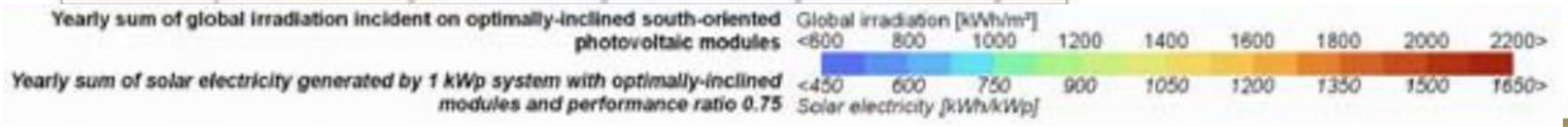


**Irradiation levels:**

~ 900-1100 kWh/m² in North Europe

~ 900-1200 kWh/m² in west Europe

~ 1000-1500 kWh/m² in central Europe

~ 1500-1900 kWh/m² in south-east Europe

~ 1800-2100 kWh/m² in south Europe

That is roughly 15-40 times the energy demand required in an NZEB building!



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# Cells, Modules, Panels and Arrays

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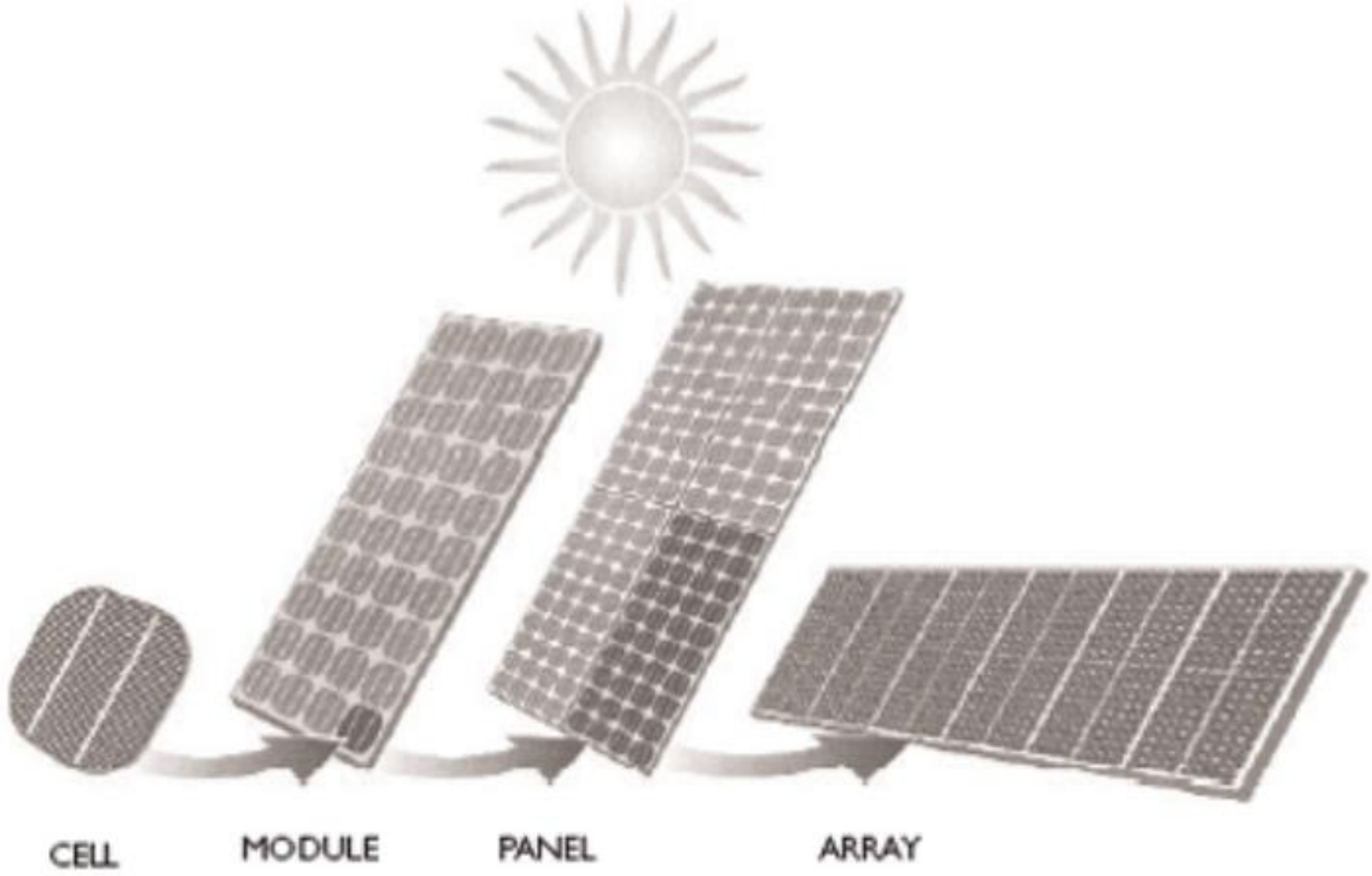


Image Source: SEAI

# How Does a PV Panel Work?

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## The Photovoltaic Effect:

- For the Photovoltaic Effect to occur a positive-negative (p-n) junction must be created. This is done by altering the state of a semi conductive material, usually silicon.
- When photons are absorbed by a PV cell, electrons within the field move towards the surface.
- This current is then harnessed by an external circuit, and can be converted into usable electricity.

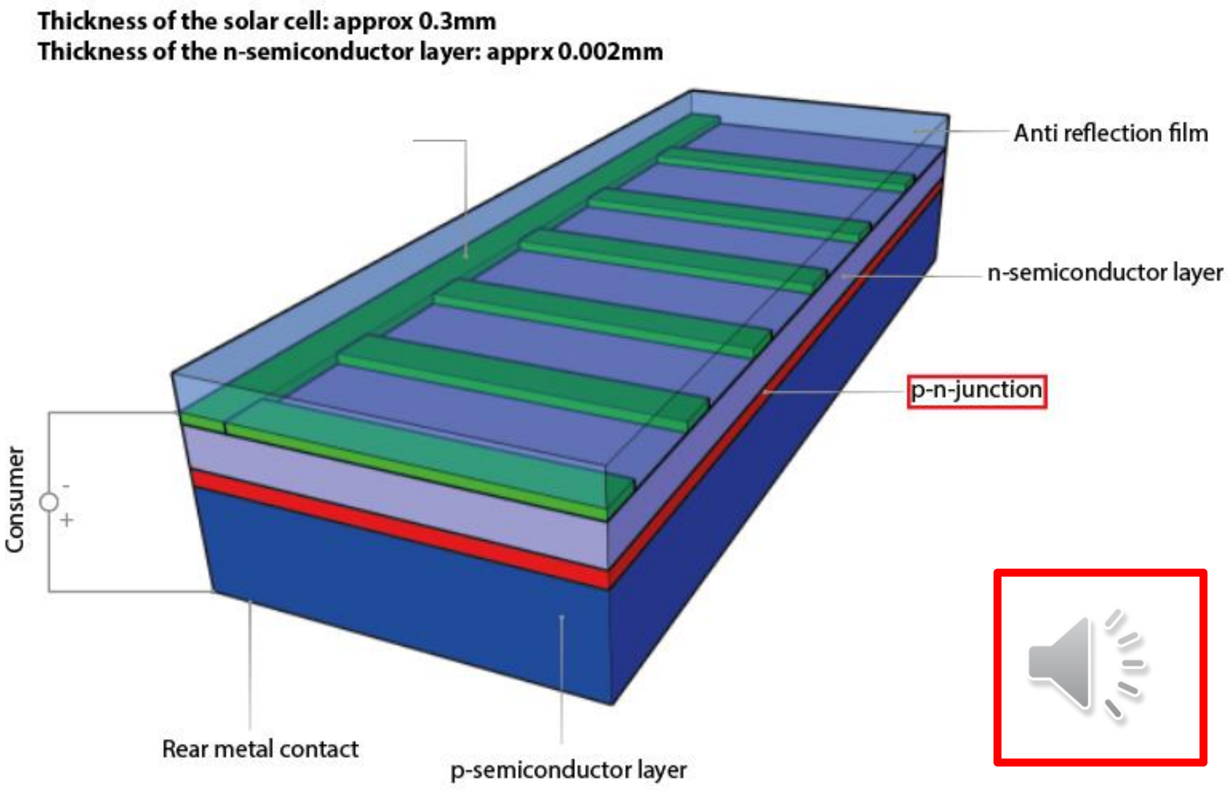


Image Source: MosArt





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# Typical PV Systems in Domestic Dwellings

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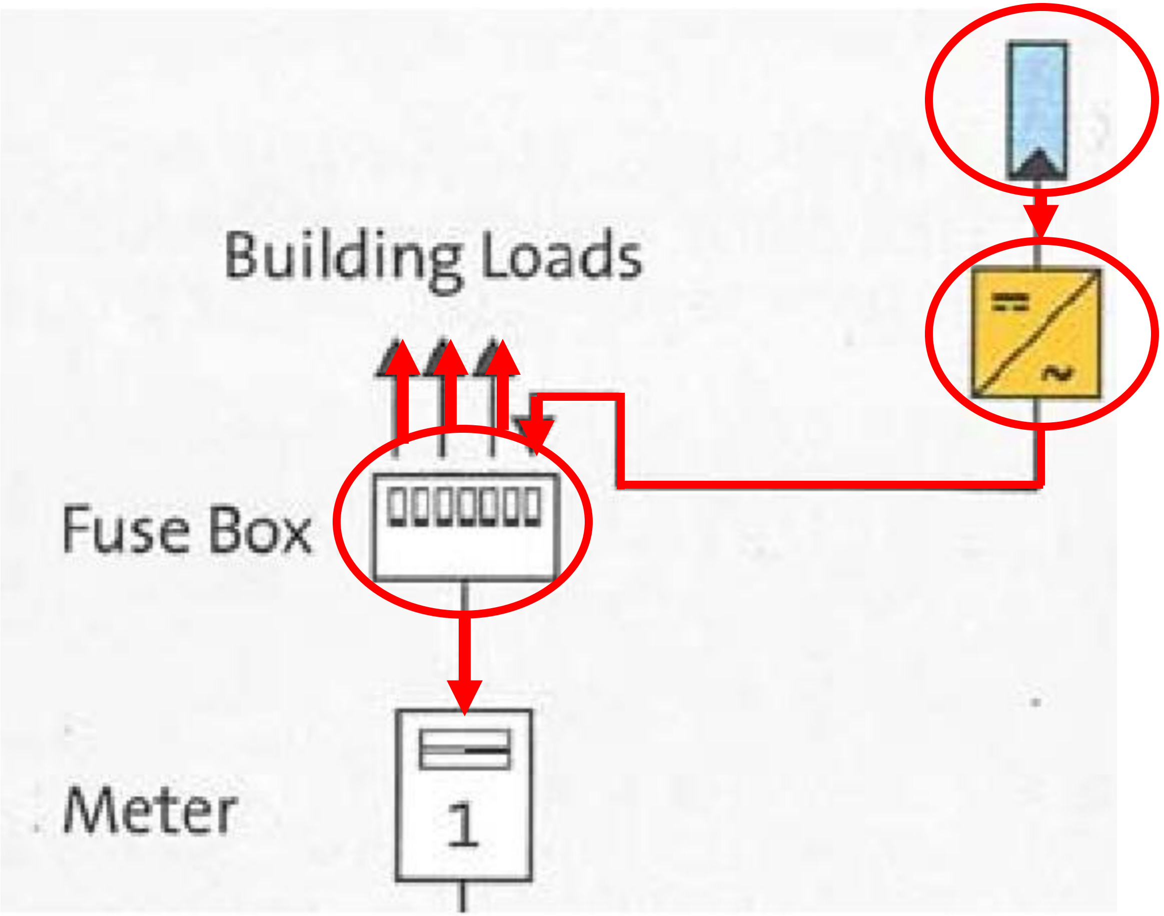


PV Panel

PCU containing Invertor

- Power from the PV panels goes to a Power Conditioning Unit (PCU).
- The invertor is located in the PCU and is responsible for converting DC current to AC current, to make it suitable for use in the building.
- The AC output from the PCU goes to a distribution board.
- Electricity is supplied to the building, or the grid in cases of excess energy production.

Image Source: SEAI





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# Batteries and PV Panels

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- Most PV panels feed into the national grid in times of excess energy production, removing the need for onsite storage of electricity.
- This type of system removes the cost and complexities associated with the purchase and installation of a battery system.
- Paying renewable energy contributors to the grid is under active consideration (2021)
- Smart meters will be necessary for such tariffs to be calculated, recording the amount of electricity being delivered to the house as well as the amount of electricity the building delivers to the grid.

# Typical PV Systems in Domestic Dwellings

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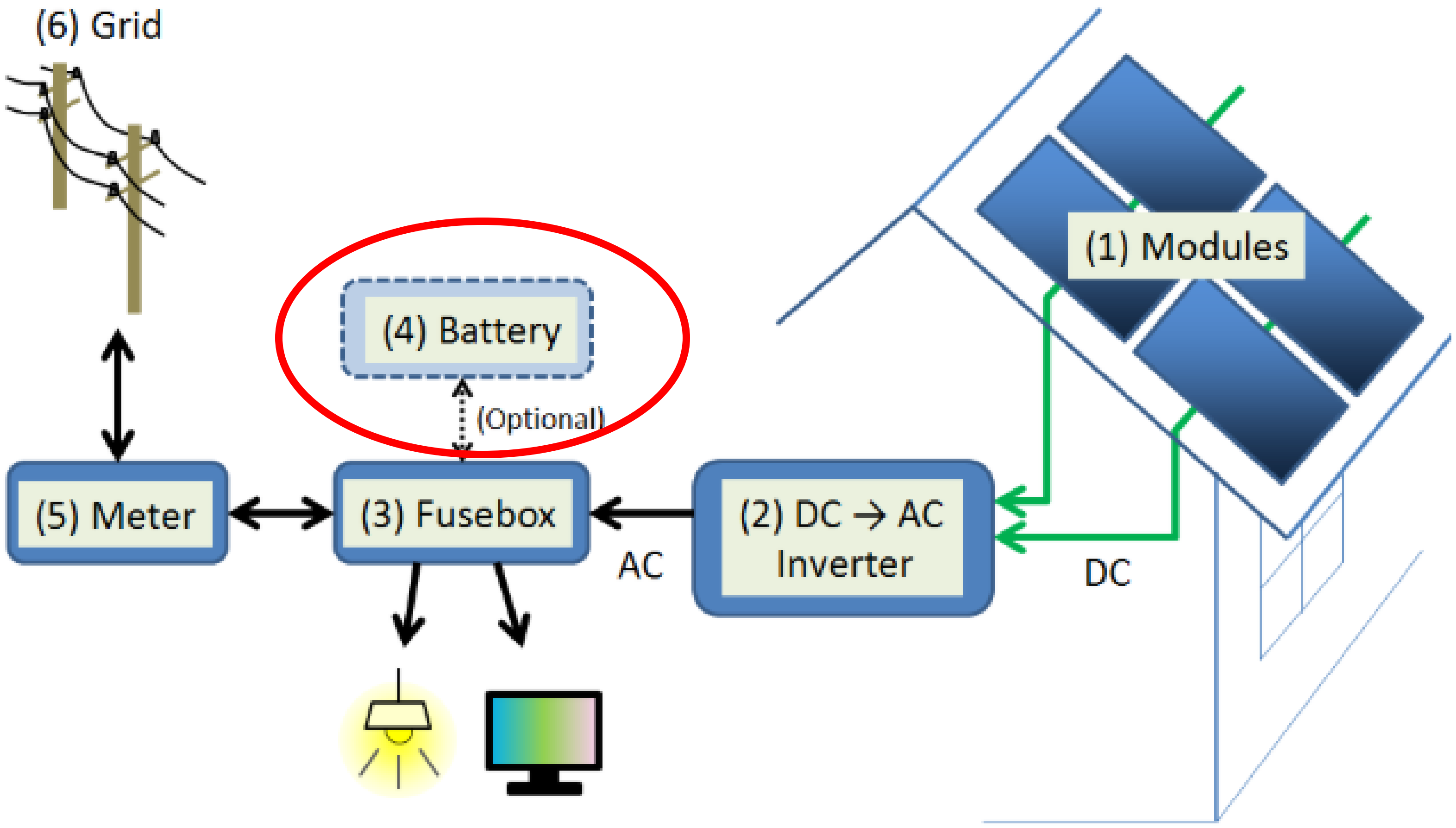


Image Source: SEAI

# Typical PV Systems in Domestic Dwellings

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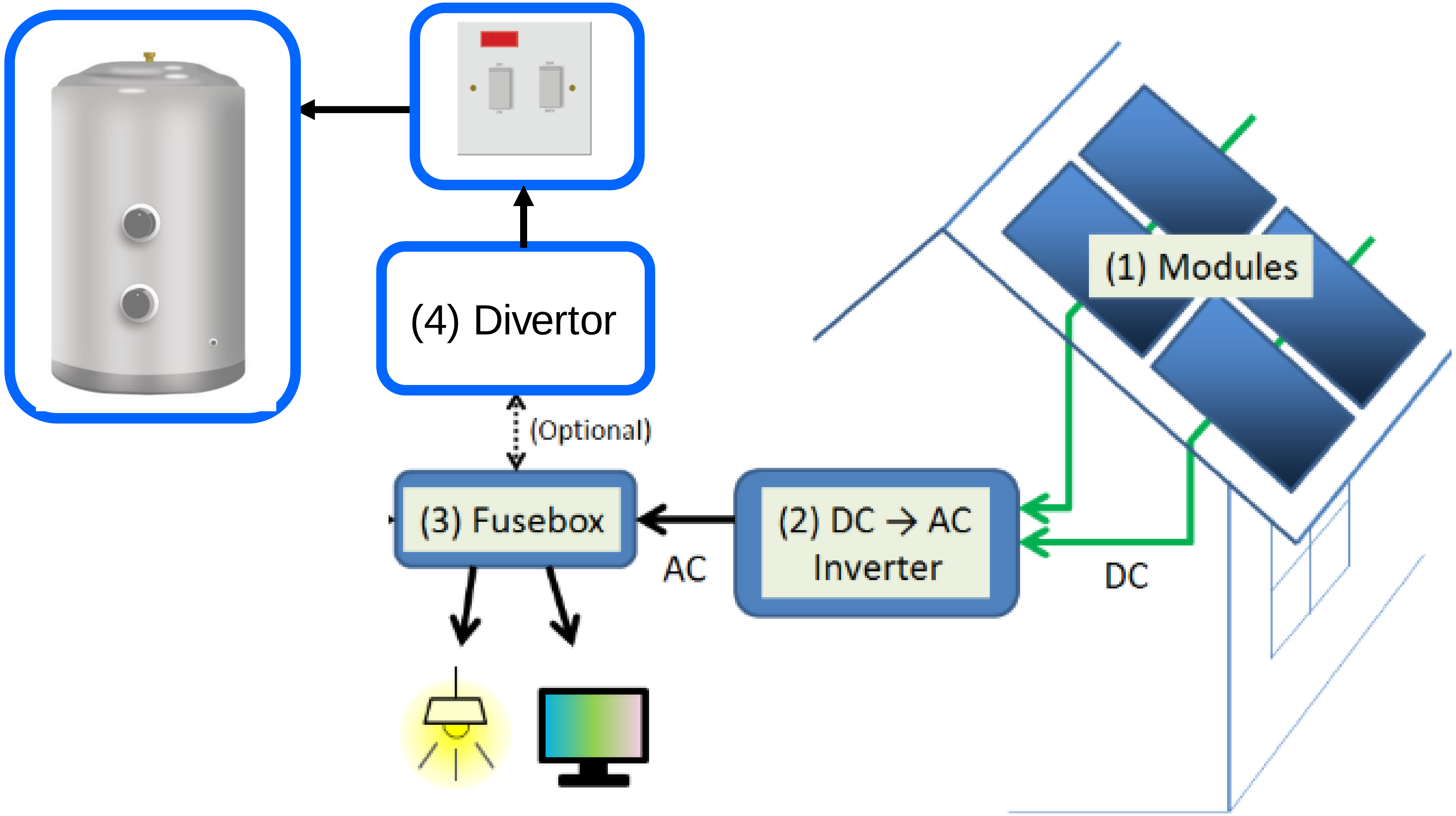


A 'diverter switch' diverts unused electricity to heat your hot water. In this way some of the energy generated is stored as hot water, which you can use later.



Image Source: MosArt

# How Much Energy do PV Systems Produce?

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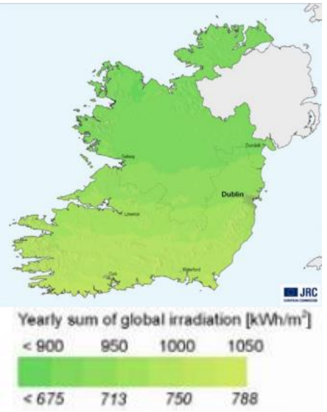
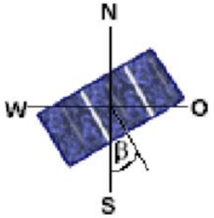
## The output from a PV panel is dependent on a number of factors:

**1. Rotation of the Earth:** The daily variation due to the **rotation of the earth** and the seasonal variations. This issue can result in "winter gap" periods.

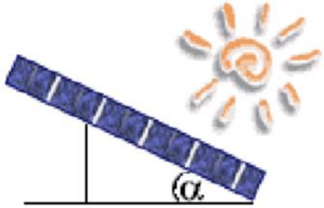
**2. Location:** This determines the amount of global irradiation available




**3. Azimuth**: Orientation in relation to south (N, S, E, W). In Ireland due South is the best orientation




**4. Panel Angle:** The angle of the PV panel will impact its performance. In Ireland 30° is the best panel angle




**5. Shading:** The heavier the shading, the lower the output

| Overshading | % sky blocked by obstacles | Overshading factor |
|---|---|---|
| Heavy | > 80% | 0.50 |
| Significant | 60% - 80% | 0.65 |
| Modest | 20% - 60% | 0.80 |
| None or very little | < 20% | 1.00 |

**6. Ambient Temperature:** In extremely hot temperatures, the cells of a PV panel can be damaged. In extreme cases, PV panels may need to be ventilated.

Due to the mild climate in Ireland, the life expectancy of PV panels can exceed 25 years if properly maintained.



Image Source: SEAI



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# How Much Energy do PV Systems Produce

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## Annual Solar Radiation (kWh/m2 )

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

**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 30°C.**



Data Source: SEAI

# How to Approximate the Output of a PV Array

**Output (kWh) = 0.8 x kW$_p$ x S x Z$_{pv}$**

- 0.8 is the performance ratio, and is used to estimate the installed performance of the panel independently of the orientation and tilt. It accounts for thing such as invertor losses, cable losses, losses due to dust etc.

- KW$_p$ = installed peak power of the chosen panel
- S = annual solar radiation (from table above)
- Z$_{pv}$ = over shading factor (which we mentioned is typically a value of 1 where placed on a roof with no shading)

# How to Approximate the Output of a PV Array: Worked Example

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Output (kWh/year) = $0.8 \times kW_p \times S \times Z_{pv}$

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

$KW_p$ = installed peak power

S = annual solar radiation (from Table above)

$Z_{pv}$ = over shading factor (which we mentioned is typically a value of 1 where placed on a roof with no shading)

**Worked example 1:**

- Take an array of 8 PV panels (approx. 1.3 $m^2$ per panel) each with a peak power of 170 Wp, mounted on a roof with a 45° pitch facing directly south with no overshading.
- The total installed capacity would be: 0.170 kWp x 8 panels = 1.36 kWp
- The annual output would be: 0.8 x 1.36 kWp x 1,072 kWh/$m^2$.year x 1
- = 1,166 kWh/year

# How to Approximate the Output of a PV Array: Worked Example

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$$\text{Output (kWh/year)} = 0.8 \times kW_p \times S \times Z_{pv}$$

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

**Worked example 2:**

- Array of 6 PV panels each with a peak power of 170 Wp, on a roof with 30° pitch facing southeast with no overshading
- The total installed capacity would be: 0.170 x 6 = 1.02 kWp
- The annual output would be: 0.8 x 1.02 kWp x 1,021 kWh/m2.year x 1
- = 833.136 kWh / year





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# Sizing a Solar Panel Array

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In sizing a grid-connected PV array there are a number of key points to keep in mind:

- *On-site use of energy*: the more of the energy that can be used on site the better – this would change if feed in tariffs are provided.
- *Contribution to the overall load:* Sizing is usually on the basis of contribution to overall load for the building rather than to meet a particular load (e.g. lighting).
- *Contribution to the annual load*: Usually, sizing is to deliver an estimated contribution to the total annual load (20% in NZEB).
- *Available area*: The available roof and facade area may restrict the array size.
- *Budget:* Often the available budget is the dominant constraint.

## System Design Requirements:

- The Installer must hold a **valid and current registration**, under the Solar Photovoltaic category, on SEAI's Renewable Installer Register AND a registration on SEAI's Solar PV Installer Register at the time the installation is carried out.

- The system must be designed with a **minimum life cycle of 20 years**.

- It is the installers responsibility to design a system that **ensures the homeowners self-consumption is maximised**, either through appropriate sizing or via a storage system.

- The installer is responsible for ensuring the system does not affect the **weather tightness** of the roof (and in NZEB, **airtightness**).

Image Source: Purchased by MosArt (Adobe Stock 314129690)

# Case Study: Madeira Oaks, Enniscorthy, Ireland

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Image Source: MosArt- Michael Bennett contractors





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# Case Study: Madeira Oaks, Enniscorthy, Ireland

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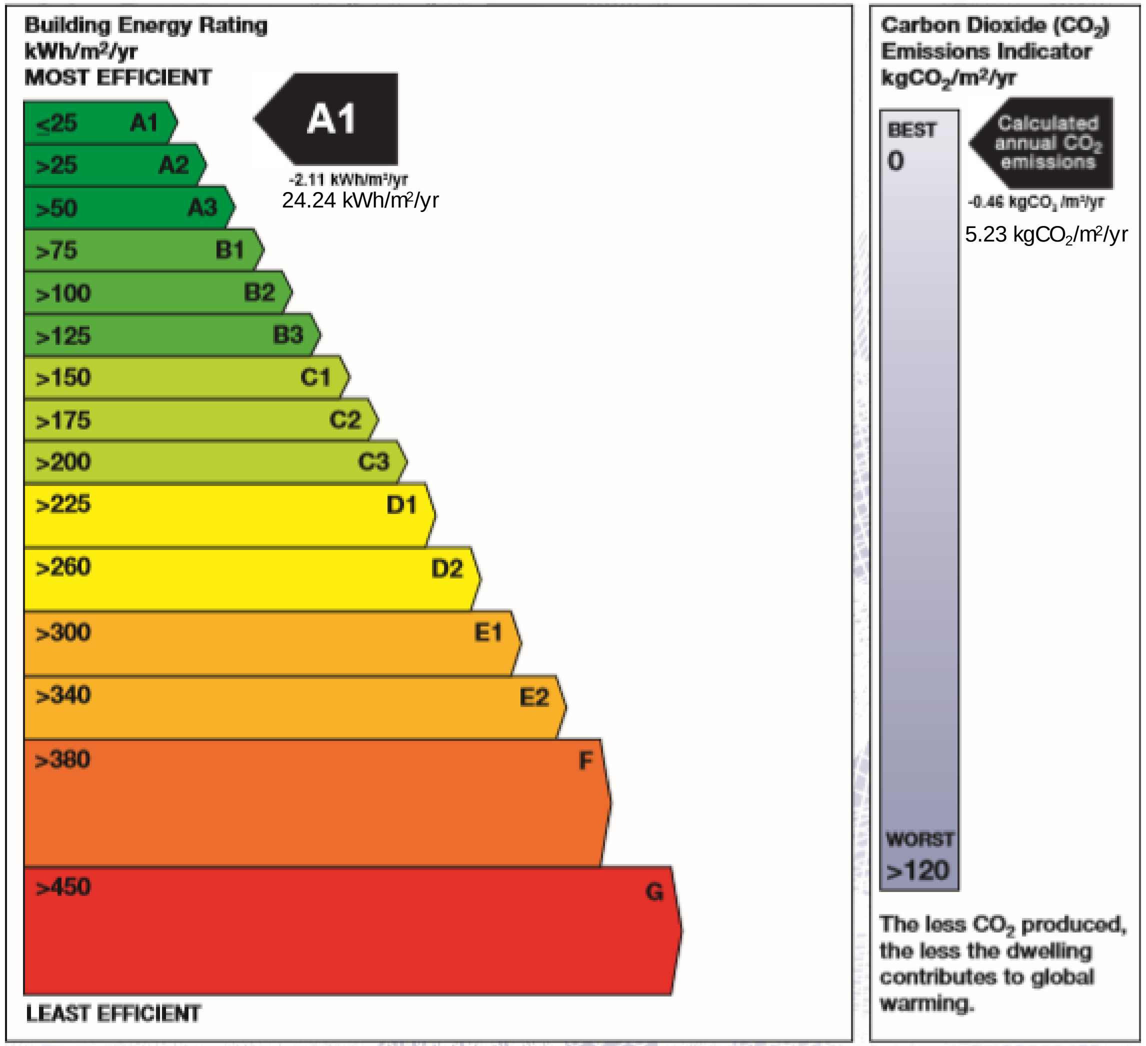


- NZEB and certified Passive House dwellings.
- Built at no extra cost when compared with standard construction methods.
- PV Panels and heat pump used to meet renewable energy production requirements.



Image Source: Domestic Energy Assessment Procedure, DEAP

# Case Study: Madeira Oaks, Enniscorthy, Ireland

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| PART L CONFORMANCE – Renewables (individual heating system) | | |
|---|---|---|
| Type of renewable | Total contribution [kWh/y] | Part L renewable contribution [kWh/m²/y] |
| Solar water heating system | 0.00 | 0.00 |
| Heat pump as main space heating system | 258.05 | 2.51 |
| Heat pump as secondary space heating system | 0.00 | 0.00 |
| Heat pump as main water heating system | 0.00 | 0.00 |
| Wood/Biomass heater as main space heating system | 0.00 | 0.00 |
| Wood/Biomass heater as secondary heating system | 0.00 | 0.00 |
| Wood/Biomass heater as main water heating system | 0.00 | 0.00 |
| Contribution from CHP | 0.00 | 0.00 |
| PV on Roof | 1082.26 | 10.54 |
| | 0.00 | 0.00 |
| | 0.00 | 0.00 |
| Total thermal | 258.05 | 2.51 |
| Total electrical | 1082.26 | 10.54 |
| Total thermal equivalent | 2963.70 | 28.86 |
| Does total thermal equivalent meet part L requirement? | Pass | |



Data Source: Domestic Energy assessment Procedure DEAP Ireland



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# Case Study: Madeira Oaks, Enniscorthy, Ireland

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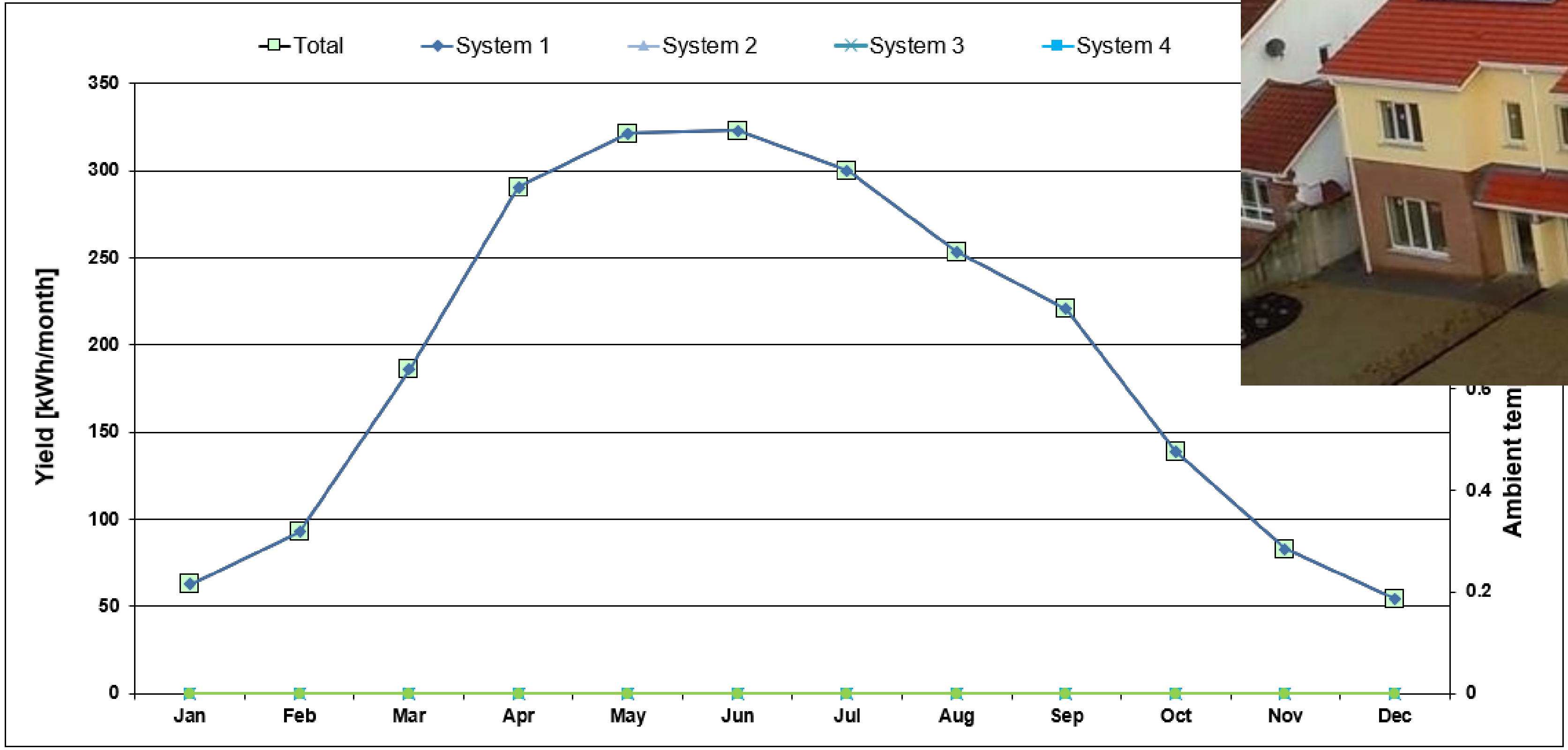


Energy Efficiency for Construction:
Renewables

Image Source: MosArt-Michael Bennett Contractors

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# A Final Note on PV

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- The energy payback period (time required for PV panels to produce the energy required for their production) is 5 to 7 years. This is an excellent life cycle performance.
- In terms of planning in Ireland, PV installed in a domestic setting under 12 sq. m (and represent less than 50% of the total roof area) are exempt from planning.

# Assessment

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QUIZ!

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# Thank You

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BZB Bildungszentren des Baugewerbes e.V.

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ANCE Associazione Nazionale Costruttori Edili

European Federation of Building and Woodworkers (EFBWW)

Šolski Center Kranj

CNC Confederación Nacional de la Construcción

EBC Construction SMEs Europe

FFB Fédération Française du Bâtiment

FIEC European Construction Industry Federation

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