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*Original Article*

# Efficient House Design for the 21st Century in the United Kingdom

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***Abstract*** *- An "Efficient house design" is a design that uses materials and methods which reduce the environmental impact and has low carbon emissions, and does not compromise the health and well-being of today and future generations. Issues like a waste (solid or liquid), energy and water use, etc., are considered while trying to achieve an efficient design. The different techniques and methods suitable for designing efficient housing using sustainable technologies available in the 21st century are discussed. The techniques include utilizing sustainable building materials and discussing their role in reducing carbon emissions and their impact related to embodied energy. Incorporating photovoltaic cells and passive solar heating techniques to make the buildings more energy efficient is also presented. All the methods discussed are those which are suitable for house designing in the UK. Several examples from case studies have been presented to illustrate the use of efficient design techniques, sustainable materials and renewable energy systems. As for the conclusion, an effort has been made to design a Zero Carbon emission house, and the proposed design has been presented along with the report. The report is an effort to offer an alternative to building design, specifically housing design so that implementing the techniques described can help minimize carbon emissions and preserve the natural resources that are exhausting day by day.*

***Keywords*** *- Sustainable construction, Energy conservation, Design engineering, Building construction.*

## 1. Introduction

There has been an increase of almost $1^{o}$ C annually in the World Temperature over the past 100 years (Anderson and Shiers 2002), and it is indeed a shocking revelation. Although a change in world climate is natural and inevitable (Roaf 2003), climate change is happening at an alarming rate, mainly because of large quantities of CO2 emissions into the atmosphere daily. (Anderson and Shiers 2002).

If continued, the current emission rate may cause a significant reduction of flora and fauna and lead to an alarming rise in sea levels by 2080 (Roaf 2003).

Construction of buildings is the reason for at least 46% of the world's total carbon emissions, as per the environment agency report. by evolving means to reduce carbon emissions during construction. Subsequently, this adverse climate change can be significantly controlled.

A healthy environment is necessary for people to have a healthy life, and our environment is greatly influenced by how our houses are built and maintained. The construction materials, decorations and furnishings for houses often contain toxic chemicals and pollutants, thus greatly diminishing the quality of air and water surrounding us (Anderson and Shiers 2002). A glaring example is the large no of asbestos-related deaths and lung cancer Reports in Great Britain in 2009 and 2010, further aggravated by poorly ventilated areas and worsening air quality, making the environment inhabitable. (Health and Safety Executive).

It is scientifically proven that houses built with the help of eco-friendly materials largely minimize the threat of "sick building syndrome" while taking adequate measures to ensure the right amount of ventilation and sunlight entering the building leading to a healthy and habitable environment (Roaf 2003).

The above can be achieved by adopting any of the following elements: an easy approach, correct orientation, energy efficient fittings and appliances, materials with lower Carbon emissions, water efficiency by using low flow fittings and rainwater harvesting, wastewater recycling, use of the right façade etc. (Roaf 2003).

Theoretically, a zero-emission building is an ideal habitat choice, consuming no external energy or water while restricting the emission of any pollutants into the environment. A few simple measures that can be considered to make an existing building more sustainable include generating renewable power, using efficient light and plumbing fittings and better insulation, harvesting rainwater and recycling wastewater, solid waste etc.

The main objective of my project is to consider important factors of an efficient house from constructability, maintenance, running costs and environmental points of view. Within the permitted time frame, efforts have been made to understand and describe the impact of appropriate selection of building materials, passive techniques, photovoltaic panels, ground source heat pumps, solar water heating and water conservation techniques etc., all of which combine to make an efficient house and minimize the carbon emissions to help conserve the environment as a whole.

As Engineers, we must commit ourselves to championing sustainable design practices for all forms of Housing, especially Affordable and Mass Housing. As developers, we must strive hard to push beyond compliance and create greener buildings to our full capability. As investors, we must demand sustainable assets, thus ensuring a minimized overload of existing natural resources. Moreover, as Customers, we must demand naturally comfortable and green environments thriving in good health and business while ensuring a SAFE future for the planet (Gesler 2006).

## 2. Impact of Building Materials on the Environment

A careful selection of construction materials can help in making a positive impact on the immediate environment and on the entire planet. Green building strategies can be implemented in the building at any time of its lifecycle, from the time of design to the time of its demolition. Green buildings can reduce the environmental and economic impacts and benefit us in the following ways:

**Table 1. Benefits of Green Buildings**

| | |
|---|---|
| Environmental benefits<br>● Enhance and protect biodiversity and ecosystems<br>● Improve air and water quality<br>● Reduce waste streams<br>● Conserve and restore natural resources | Economic benefits<br>● Reduce operating costs<br>● Create, expand, and shape markets for green products and services<br>● Improve occupant productivity<br>● Optimize life-cycle economic performance |
| Social benefits<br>● Enhance occupant comfort and health<br>● Heighten aesthetic qualities<br>● Minimize strain on local infrastructure<br>● Improve overall quality of life | |

Building construction consumes huge quantities of natural and physical resources and greatly impacts the environment. Apart from the physical resources consumed during its life cycle, such as money, building materials etc., they also sometimes end up in biodiversity loss.

A "cradle to grave" analysis of the building must be considered if the impact throughout its lifecycle must be reduced. This included assessing each part involved during its life cycle and looking into its various environmental impacts. This may be considered the first step while building a sustainable and environment-friendly building.
The lifecycle of a building material tends to complete in five steps:

- Mining/extraction/harvesting
- Manufacture
- Construction
- Use
- Demolition

The major environmental impact occurs during the first two steps of the lifecycle of a building material. There may also be small effects of the building material during the last stage, which is the demolition, as it is getting more difficult and expensive to find a renewable method for the disposal or recycling of material. It has been considered that the energy required to produce a building material defines its environmental impact(embodied energy) degree.

### *2.1. Embodied Energy*

It is important to understand the concept of embodied energy, which is the total energy consumed by a building material during its lifecycle. It can also be summed as the amount of carbon a building material releases during its entire lifecycle.

"Cradle to Gate" has become a common classification of building materials, specifying the amount of energy used from the start of its manufacture to the point it goes out the factory gate.

### *2.2. Ways to reduce the Impact the Construction Materials*

EU LoRe-LCA project -' Low Resource consumption buildings and constructions by use of LCA in design and decision making" is a European-based study which revolves around finding the environmental impact of building materials by utilizing a method known as LCA (life cycle assessment). The LCA method was used to compute the environmental impact of producing 1kg of different building materials, which were then compared to more environment-friendly materials that could be used for the same purpose.

There were three main outcomes which were taken into consideration:

- The main energy that is required relates to a phase of a product production, use and disposal.
- The environmental impact relating to the amount of $CO_2$-Equivalents.
- The water requirement of the products during their entire lifecycle.

The tests gave a variety of results, and the conclusions and suggestions have been tabulated below:

**Table 3. Result of the LCA method of producing 1kg of building materials**

| | |
|---|---|
| 1. | The results suggest that making roof tiles out of concrete is better than using ceramic or fibre cement roof materials. Although ceramic tiles are better than fibre cement roof tiles in that they save 60 per cent more primary energy, concrete tiles are better again in that they save 42 per cent primary energy compared with ceramic roof tiles. In addition, it is preferable to use quarry tiles instead of ceramic tiles in flooring: quarry tiles provide an 86 per cent saving in primary energy and a 66 per cent saving in Emissions. |
| 2. | For bricks, local clays and renewable constituents, such as straw, had lower Environmental impacts compared with conventional bricks. |
| 3. | Replacing synthetic insulation materials, such as rigid polyurethane foam and EPS (expanded polystyrene), with natural insulation materials, such as cork, wood fibre and sheep's wool, also reduces environmental impact. For example, the production of polyurethane places high demands on primary energy and water consumption, whilst sheep's wool emits 98 per cent less CO2 if the wool is incinerated at end-of-life. |
| 4. | The energy-intensive manufacture of clinker (the main component of cement) is a Major Contributor to the environmental impact of cement products used in buildings. |
| 5. | Construction materials, such as steel, aluminium, copper, glass and PVC, should be reused and recycled where possible to reduce the primary production of these materials. For example, producing secondary steel (e.g. using scrap steel) reduces emissions by 74 per cent compared with producing the same amount of primary steel. |
| 6. | Companies should be encouraged to construct buildings that can be disassembled rather than demolished at the end of life to make separating materials for reuse and recycling easier. For example, bolts can be used instead of adhesives to fix joints between materials. |
| 7. | Upgrading technologies (e.g. in kilns) and techniques (capturing and reusing heat) and using local resources where possible can also reduce environmental impacts. |
| 8. | In addition, eco-innovation should be promoted by identifying environmentally friendly products with eco-labels. |

### *2.3. Embodied Energy in a Typical Building*

(Cole and Kernan 1996) The embodied energy in a building depends on the type and quantity of different materials utilized in its construction; thus, it varies in different buildings. The initial embodied energy is associated with the materials used during the construction phase and their respective manufacturing sources; therefore, the embodied energy for different materials greatly differs when manufactured in different countries.

Research carried out by Cole and Kernan (2006) using a modelled three-storey office building of area 4620 $m^2$ with underground parking. Three different systems of construction were used to carry out the research. The results for the wood, concrete and steel construction systems were averaged to find the total initial embodied energy.

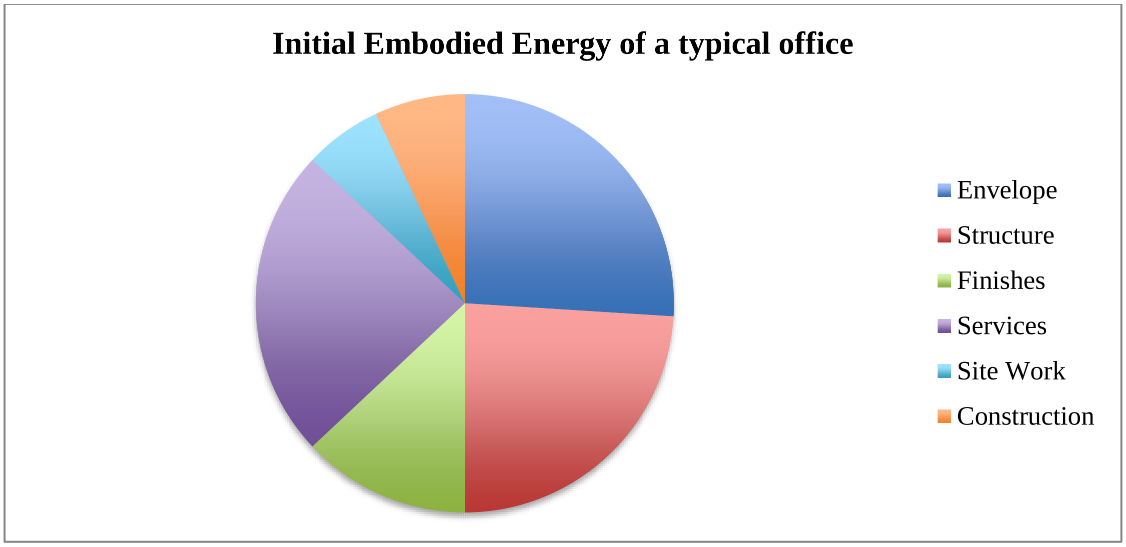



**Fig. 1 Initial Embodied Energy of a typical office, figure reproduced from Cole and Kernan (1996)**

13% of the embodied energy is given by the finishes initially but is responsible for the highest increase in the embodied energy that recurs at a certain time in the whole lifespan of a building. The embodied energies do not differ largely between the two building systems. For example, if compared, concrete and wood greatly differ in the environmental impacts related to different materials (Canadian Wood Council, 1997). It is to be noted that site work accounts for only 6 % of the embodied energy, whereas the services account for 24% initially. However, these might have a large influence on the recurring embodied energy.

Many other interesting observations can be made from Cole and Kernan" s research regarding the relationships of recurring embodied energy. The graph below shows the recurring embodied energy over a period of 100 years.

After 25 years, there seems to be a 57% increase in initial embodied energy. This increase can largely be attributed to the envelope, finishes and services. The recurring embodied energy is calculated to increase by an exponential increase of 144% 50 years after the initial embodied energy is measured. A further increase to 325 % from the initial embodied energy is noted after 100 years. This relationship is a direct result of what is referred to as differential durability, where the service lives of the various materials, components, and systems comprising the building differ dramatically (Cole and Kernan, 1996).

## 3. Photovoltaic Systems (PV)

The Photovoltaic system comprises a group of solar cells made of semiconductor substances like silicon. Photovoltaics, commonly known as PVs, are among the most popular technologies today, and their use is spread worldwide. PV technology has several advantages: it is one of the lowest-costing options for a number of applications, is environment-friendly/sustainable, and its energy output of a photovoltaic can be varied for different applications ranging from small electronics such as calculators and watches to large-scale power stations. PV Systems have varied utilities: they are used in independent power systems for housing clusters in remote sites where it is difficult to supply electricity from a power grid, in telecommunication sites, water pumping, emergency call boxes etc.

PV technology is sustainable and minimizes energy losses that occur during energy transportation. Applications connected to a power grid aim at providing energy at a sustainable level for reducing the emissions from fossil fuels that are burnt to generate electricity using conventional methods. $CO_2$, $NO_2$, or $SO_2$ levels can also be eventually brought down as no harmful gasses are produced during the use of PV panels (Lasnier and GanAng 1990). Additionally, natural sunlight is abundantly present worldwide and can provide energy to the PV panels at a site anywhere in the world; therefore, PVs are most likely to be the most upcoming power source for the coming generations (Strong and Scheller 1993). Also, PV technology's energy is produced and used at the site. Hence, no energy loss occurred due to transportation, as caused by typical conventional methods, which depend upon energy supply lines.

### *3.1. Advantages and Disadvantages of PV Panels*

This is a sustainable form of producing energy and does so without generating any harmful gasses and therefore helps conserve fossil fuels for the coming generations. These systems work without producing any noise and have a long life span of at least 20-25 years. They can be used for the generation of large-scale energy and, at the same time, can be used for providing energy to operate calculators and watches. PVs are very cost-effective for remote sites where it is difficult to put power supply lines from a power grid. The reliability is very high compared to investors or diesel generators. The market for this product is spread worldwide; hence it is competitive in both quality and price. PVs provide benefits that go further than electricity. They can provide passive solar heating and cooling can be provided in the cases of building integration, and they can also work as noise buffers. Also, They may replace the conventional methods by replacing cladding and giving a new and appealing appearance.

Each Technology has its advantages, but it also comes with disadvantages. Some of the materials required for manufacturing PVs are unsafe and slightly negatively impact the environment. An environmentally safe and acceptable means of disposing of the current systems have not been considered, but the process involves a few toxic materials like cadmium. Human health is subjected to the same threats by the building integration as by any other electrical system. The installation cost is quite high compared to other comparable technologies. The system is exposed to damage that natural factors can cause, and also, there is a possibility of dust and dirt accumulating on it. Also, a minimum tilt of 10 degrees is required to avoid snow and water getting collected on the surface.

## 4. Passive Design

A principal advantage of Solar PV Power is that it aids the structure in taking advantage of the climate when there is abundant sunshine and protects the building from the climate when the sunshine might not be present (Rosenlund, 2000, p.8). This technique utilizes the energy given off by the ambient sources to regulate the climate and ventilation without using any mechanized form of cooling or heating and provides a comfortable living environment. This is affected by various factors like the site's orientation, average sunlight hours, the climate of the area, and the placement of windows and doors.

### *4.1. Passive Techniques*

The passive techniques that can be commonly used in the UK are summarized in a table below with a brief explanation of each.

**Table 6. Explanation of Common Passive Techniques**

| Passive Technique | Use | Explanation of Techniques |
|---|---|---|
| Overcast sky Lighting | Lighting | The windows being higher up on the wall will give higher visibility to the sky vault and, therefore, higher the daylight will be, although the light is considered to be orientation independent as light is dispersed in rays. |
| Clear sky Lighting | Lighting | Used in climates where there is generally a clear sky; windows are placed lower on the wall to allow entry of externally reflected light |
| Thermal storage walls | Heating | Solar rays hit a vertically high thermal mass wall, and re-radiated rays are trapped by glazing. |
| Sunspace/ conservatory | Heating | Glazed area attached to buildings; used as a buffer zone. Solar radiation allows for convection; the adjoining room should have a thermal mass |
| Day direct Ventilation | Cooling | Cooler air is allowed directly into space; the wind that passes over the occupant promotes evaporating cooling. |
| Night direct Ventilation | Cooling | Uses cooler nighttime air to cool down building fabric |
| Wind tower | Cooling | Draws air from the higher, cooler and more reliable winds; can use this technique with thermal mass and nighttime vision |

| | | |
|---|---|---|
| Solar chimney | Heating and cooling | Solar-induced buoyancy, solar gains hear glazed chimney which raises the radiant temperature and propels air upwards. This needs to be well insulated to prevent the conduction of solar radiation into the building |
| Ground Tempered Ventilation | Heating and cooling | Ventilation pipes are placed underground at a depth where the ground is warmer in the winter and cooler in the summer. Needs ducts and fans (some active components) |

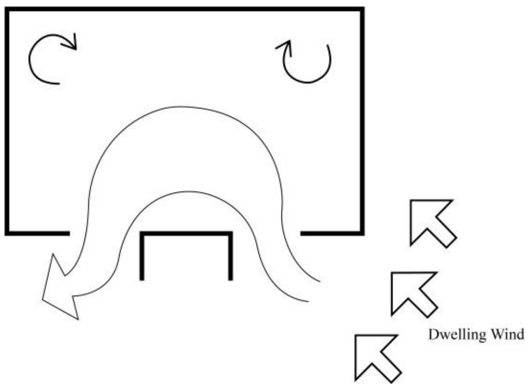



**Fig. 6 Top View of Wing Walls**

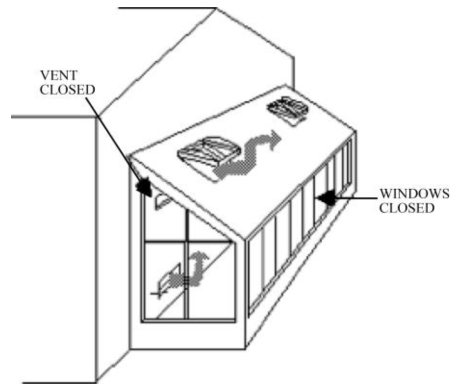



**Fig. 7 Summer Venting Sunroom, Airflow Pattern, figure reproduced from Rosenlund(2008) figure Reproduced from Rosenlund(2008)**

## 5. Solar Hot Water System

A high amount of energy is needed in the heating of domestic water. In many countries, the 2nd largest energy demand is for heating water (CatN 2011). The basic solar water heater operates on the concept of using solar radiation's energy to heat water. The main components of a solar water heating system include a collector panel that is tilted at an angle towards the sun to maximize the solar radiations falling on it fig (13). This heated liquid (water) is then collected into an insulated storage tank that is generally of about 200 litres.

A well-maintained solar water heating system has a lifespan of 20-30 years (Duffie and Beckman, 1980). Most of the solar water heaters produced in the UK are expected to have a minimum lifespan of 30-50 years (Roaf et al. 2007). Most of the good-quality tubes are made of copper. In places where the climate is hotter than normal, i.e. the temperature goes more than 35$^o$c, it is advised that double-glazing glass is used to avoid the excessive heat loss which is caused by the overheating of the absorbing plate. However, double glazing only allows 75% of the radiation to pass through (Duffie and Beckman 1980).

### *5.1. Flat plate v Evacuated Tube*

There is a continuous argument over the performances of flat plate vis the evacuated tube collectors, without either one emerging as clearly and decidedly better. However, it can be said that for a given absorber area, evacuated tubes are more likely to remain efficient over a wide range of ambient temperatures and heating requirements.

Flat plate collectors have greater efficiency in warm climates with abundant sunshine, whereas their energy output declines rapidly in cloudy weather conditions compared to evacuated tubes.

## 6. Ground Source Heat Pump (GSHP)

Ground source heat pumps, also known as geothermal heat pumps, extract heat from the ground during the winter and transfer it to the heating systems installed in the living space. The best way to show how it works is by looking at the functioning of a refrigerator as it takes out the heat from the inside and throws it all out through the elements situated at its back. Similarly, the ground source heat pumps extract the heat from the ground, raise the temperature by compression, and then transfer the heat to the heating systems.

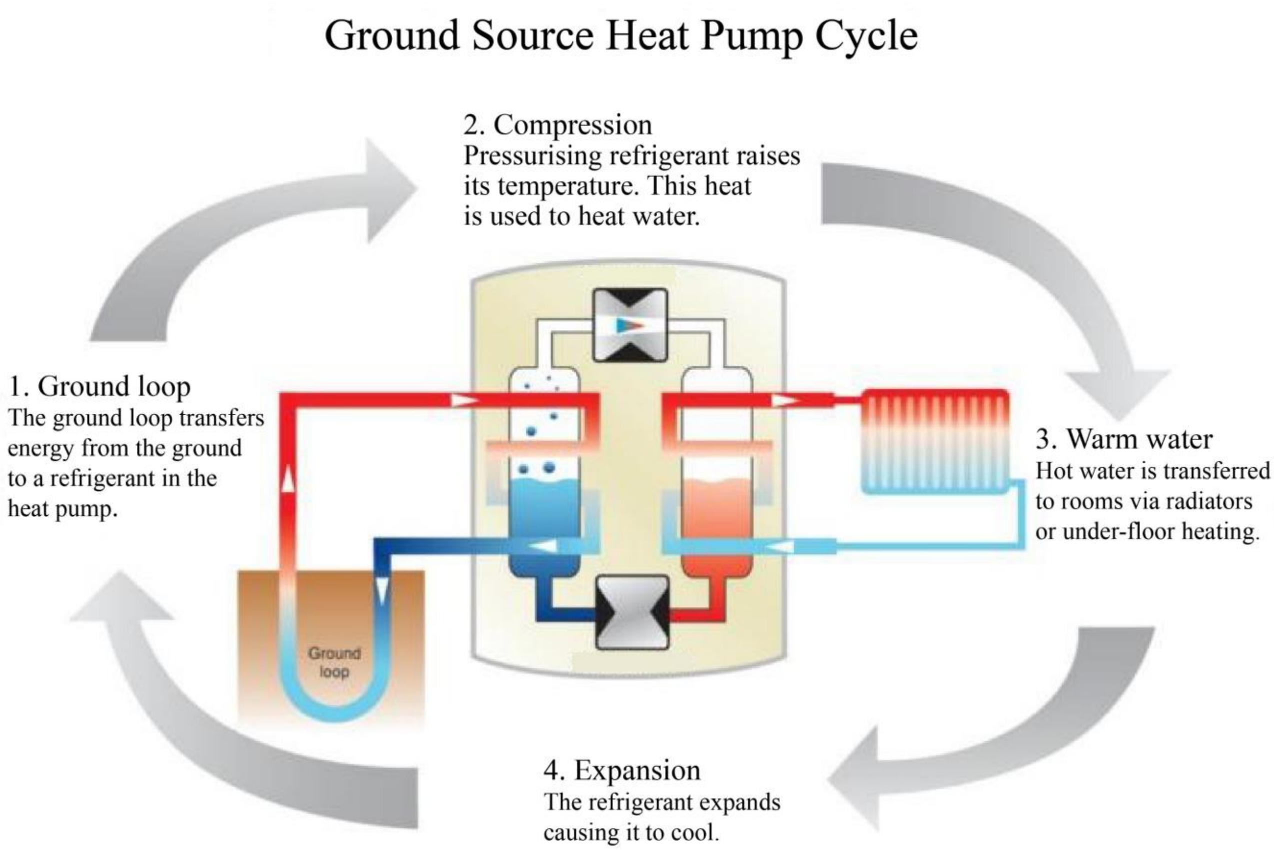



**Fig. 19 Ground Source Heat Pump Cycle, the figure produced by Spirit Solar (2010)**

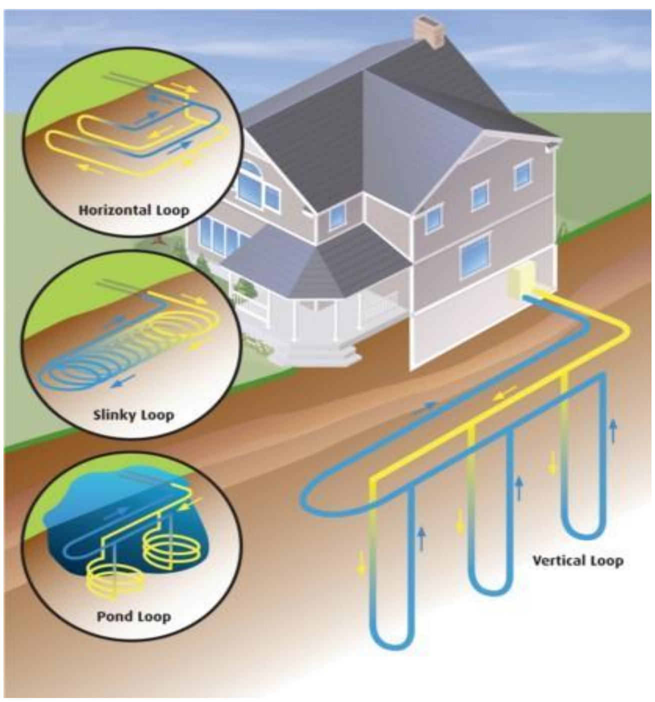



**Fig. 20 horizontal, slinky, vertical loops and pond loops, the figure produced by spirit solar (2010)**

GSHP functions by circulating fluid consisting of water and antifreeze through pipes put in the ground. The UK has a fairly constant temperature just below the earth's surface, which stays the same throughout the year and is about 8-13 $^{o}$ C. The fluid in the pipes has a lower temperature than the ground in which these pipes have been inserted; hence, the fluid gains temperature and gets slightly warm. The temperature of the warm fluid is further increased by compression to about 45-50$^{o}$ and then transferred to the heating system in the living space.

The GSHP can be reversed during the summers, and the ground can be used as a HEAT SINK to provide cool fluid in the systems provided in the building.

### *6.1. Ground Loops*

The diagrams below show four types of ground loops currently available in the market: horizontal loops, slinky loops, vertical loops, and pond loops.

The ground outside the building is dug up, and these loops are buried into it. Depending upon land availability, the loops can be horizontally extended over 100 "s of meters of land. On the contrary, the loops can also be buried deep down to over 100 meters if less land is available.

The ground source system is generally located just outside the building, with flow pipes running between the system and the living space.

The hot liquid flowing through the heat pumps gives two feeds. One line goes to the hot water circuit, and the other line goes into the central heating system that may contain radiators, floor heaters etc. However, the point that needs to be noted is that at a time, only one feed can be operated; that is, the heat pumps cannot give feeds to the hot water and space heating systems simultaneously. A switch is usually present to determine the direction of the flow. A timer can also be set to alternate between the two feeds periodically to get maximum efficiency.

### *6.2. Costs*

A common GSHP system varies largely in cost from £9000-£16000. The running cost of a GSHP depends on the area of the living space to be heated, the hot water system's volume and the building's insulation. Apart from these costs, very little maintenance is needed to run; thus, it is also known as a "fit and forget" system**.**

### *6.3. Savings*

How much a GSHP can save depends upon the previous system that has been installed in a building and the size of the GSHP it is being replaced with. It is advised to use underfloor heating systems as they work best with GSHP since the water temperature is not required to be very high for its functioning.

The heat pumps require electricity for their working and hence would incur an electricity bill, but the savings would depend on the fuel one is replacing it with. The efficiency could be limited because the heat pumps also supply hot water to the household. Solar water heaters should be considered to keep up the heat pumps efficiency in summer.
Zero saving is considered where the cost of using the GSHP may be equal to the previous system that was installed. The average boiler efficiency for different fuel types has been assumed. The heat pumps' efficiency has been taken more than 100 percent as they produce more heat than they consume.

### *6.4. Earnings*

People using ground source heat pumps could also benefit from the *Renewable Heat Incentive (RHI)* scheme after its launch in October 2012 by receiving payments for the heat generated through the scheme. Also, the government has provided with one various incentive for installing a GSHP since August 2011 through the *Renewable Heat Premium Payment scheme*.

## 7. Water Conservation

The current rise in population, climate change, and infrastructure is playing a major role in increasing water demand. Governments worldwide are trying to develop strategies, regulations and techniques that will promote water-efficient products and hence balance the demand and supply for water in the near future.

The drought that occurred in South East England in 2004-2006 and the floods of 2007 have highlighted the pressures brought on by the ongoing climate change. It is predicted that in the near future, the climate of the UK is quite like to change with the temperatures rising, more rainfall during winters, and dry summers; hence, higher water demand is expected. There are chances of extreme downpours, and hence water quality problems may arise.

An average person per day uses 150 liters of water in England and Wales, mainly for washing, cooking, drinking etc. Water usage has increased by about 45% compared to what it used to be 25 years ago. It is predicted to rise by another 18-22% by the year 2020 compared to the year 2009 due to the excessive use of modern appliances such as washing machines and dishwashers (Fangyue 2009).

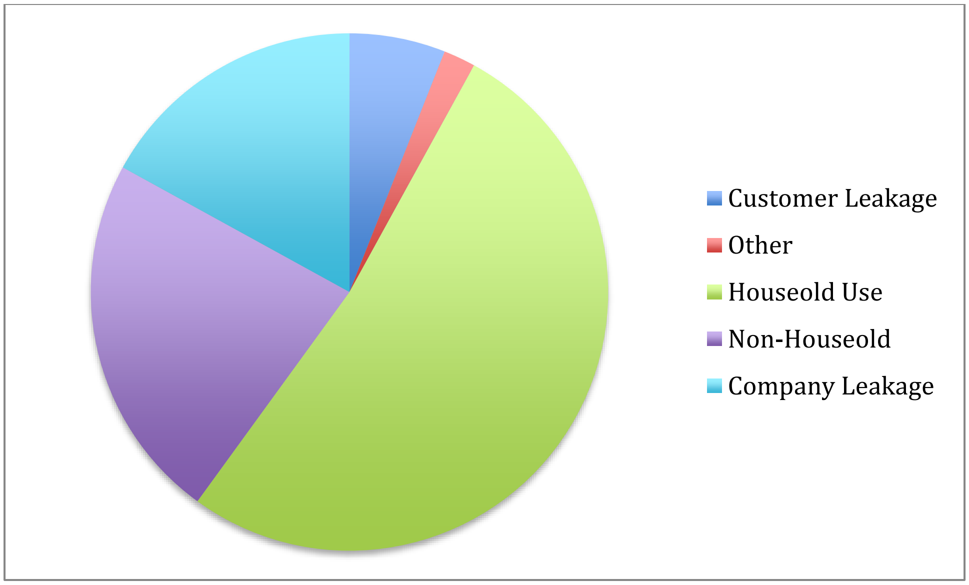



**Fig. 21 Water usage in different sectors, Produced by DEFRA (2010)**

### 7.1 *Water Conservation Techniques*

#### *7.1.1. WCs*

A WC is generally the highest water Consuming unit found in a house. The water drained in a single flush has been reduced to 4.5 litres in 2009 from 13 litres in 1950. This is a significant improvement in order to conserve water.

#### *7.1.2. Dual flush*

Dual flush systems are easily available in the market, are comparatively efficient, and use less than 4.5 liters of water per flush. On average, a single person uses the WC 5 times a day; hence, dual flush systems save around 23,725 liters of water per year compared to the 90's.

**Fig. 23 Flush systems in 1950, produced by BMA (2009)**

The dual flushes work on a two-button system with the option of using either one of them. Generally, the small button activates the flush for a shorter time with a much less volume of water and is usually used to dispose of liquid waste. On the contrary, the larger button is used to dispose of much more sustainable waste.

#### *7.1.3. Taps and Showers*

Taps have the 2nd highest excess consumption after WC" s and can use 5-6 litres of extra water per minute if left on at a full flow. People worldwide often tend to leave their taps on while showering, brushing their teeth, washing vegetables/utensils etc.; if these little things can be avoided, millions of gallons of water can be saved daily.

Taps also tend to waste a lot of water due to leakage and waste 10-15 litres of water every day, which, if avoided, can aid in water conservation. Annually, 4000-5500 litres of water can be prevented from being wasted by changing malfunctioning taps or simply replacing worn-out washers.

Taps allow efficient water usage and are now easily available in the market. These taps have a flow regulator inserted into them, allowing them to work on 25%- 100 % flow, saving 10-15 litres of water per day. The user can lift the leaver to a suitable height without using excess water. When the lever is lifted to the full height, the full flow is in, and the full flow is in function. Another form of the widely used tap is the press tap. When pressed, these taps give out water for a short specific period of time and then automatically switch off.

**Fig. 25 Taps with flow restrictors, Produced from BMA (2009)**

These types of taps are ideal for washrooms, hotels, restaurants, pubs etc. The same facilities are also available in showers, saving much water from being wasted. Replacing a shower with a bath saves about 55% of water. Most of the showers that are in the market these days come with a low water consumption feature. Showers come with automated timers and pause buttons that track the time you spend in the shower and give you the advantage of pausing it while soaping up, allowing minimum wastage.

An average person takes a 10-minute long shower. Modern, efficient showers use at least 9 litres of water. Therefore, a person uses approximately 90 litres of water while showering. If the showering time of an individual is reduced by 3 minutes, then 9370 litres of water can be saved per year.

#### *7.1.4. Grey Water Recycling*

Grey water is an effluent produced from domestic and non-industrial activities such as washing dishes, laundry, bathing, etc. It is neither fresh white water nor heavily polluted black water and is therefore known as Grey Water.

Grey Water can be reused by recycling this water. Recycling involves collecting water from tubs, showers, washing machines, etc., which is then filtered and treated before being reused for the flushing of toilets. In several areas, treated grey water is utilized for irrigation purposes.

Based on available information, about 70% of the water disposal in typical households can be classified as grey water. However, several important aspects must be considered before adopting recycling. One must consult with the local plumbing and regulatory representatives and follow the Building Codes so that the use of grey water is safe and compliant with local regulations. It is important to consider a few additional points before adopting the recycling process: Treating grey water is necessary if it is to be stored. Proper treatment helps avoid any bad odours and prevents further contamination as the contaminants in the water begin to break down.

Chlorine treatment is commonly utilized to kill the bacteria during recycling since it produces a residual effect or free chlorine. Free chlorine remains in the water for a long time and provides treatment longer than point-of-contact type treatments such as UV.

#### *7.1.5. Rainwater Harvesting*

The technique of gathering and storing rainwater for later use is as old as the pre-roman times and can be traced through biblical times. It is spread worldwide across all major continents, whereas in the developed countries, the concept had literally died due to the introduction of well-maintained water supply lines, which guaranteed water supply throughout the year. Now, with the growing water demand, there is a need to grab as many resources as possible, and hence in the UK market, the demand for rainwater harvesting systems has seen a vast growth.

This is a relatively new industry for the UK markets currently, this relatively new industry and it is developing with time. The government needs to work alongside the market so that the benefits of this technique can be brought into society and help the environment as well.

## 8. Implementation of Sustainable Building Techniques

This section will discuss how the people of the United Kingdom in their daily life use the above techniques that have been discussed in the report.

### *8.1. Milton Keynes-Case Study (2010)*

Energy saving trust (UK) invited the people of Milton Keynes to discover the home truths of fighting fuel costs. Terry Siggins, one of the trust's satisfied customers, explained how he had adopted green techniques to cut his electricity bill.

Terry Siggins stated that he had his house insulated during the energy-saving mission. He also had a new double glazing which significantly reduced the heat loss to the air outside and acted as a noise buffer. According to Terry Siggins, installing solar panels on the house's roof was the most beneficial move. He had installed the largest system that could fit on the roof with the largest feed-in tariff, a form of compensation provided by the government for producing electricity and supplying it to the main power grid.

The users who generate their own electricity are currently paid £0.41/kWh of energy produced by the system and £0.3/kWh on electricity that they do not use and that is fed back to the grid. The PV system installed at this site is guaranteed to produce about 3,264 units of electricity per year, avoiding more than 28,000 kgs of $CO_2$ emissions annually. Considering the current electricity prices and approximating that about 50% of the energy produced will be fed into the grid, the PV module is expected to have a total benefit of about £40,000 over its entire lifespan. Therefore this shows that PV not only helps in reducing the environmental impact of the energy being currently produced but, at the same time, is a long-term investment which turns out to be quite profitable for the people who are using it.

### *8.2. Marks and Spencer Sheffield (Green Building Council)*

This project involved the design and building of a new "sustainable learning" M&S store in Sheffield. It integrates all aspects of sustainability – climate change, waste, natural resources, fair partnership, health & well-being and involves customers in the journey. This store was an opportunity to try new things, invest in sustainable innovations – technologies, processes and systems, and, if successful, embed them into the way that M&S does business.

The project set out to exceed planning conditions, which stated that 10% of the store's energy needed to come from renewable or low-carbon energy. A BREEAM excellent rating was also targeted from the outset.

The store was built on a Brownfield site, previously home to a car showroom and garage.

The site included sustainable transport solutions for customers, including:-

- Charging points for electric vehicles
- Screens in the store show real-time updates on the local transportation system.
- FSC-certified material for cycle and trolley sheds.

100% of the heating in the store is provided by expelled heat from its refrigeration units. All powered lighting comes from LEDs, using 25% less energy than conventional lighting. In addition, sun pipes are installed in the premises to light up the area with sunlight as a green approach to save on the extra energy usage of artificial lighting techniques.

There is natural ventilation in the stock room and staff areas rather than air conditioning and glass doors on mobile fridges, with predicted energy savings of 45%.

The water conservation technique of harvesting rainwater is used that will take care of the water needs of the toilets present in the store and, at the same time, provide water to the neighboring flora present. This store will use at least 40% less water than its other peer stores.

98.2% of soil from the site was recycled; the remainder was treated off-site and reused.

A sedum roof and green "living wall" will create wildlife habitats, contribute to the insulation of the store, and, at the same time, act as a filter to air pollution. There are more than 60 types of plant species on or around the building, with a large number of bird boxes.

This is a revolutionary step in the engineering field, which shows the growing concern about the earth among the people of the United Kingdom. This is the right step in the direction of a green future with sustainable development.

## 9. Results and Discussions

### *9.1. Results*

Through the study, it can be preliminarily concluded and recommended that the construction of a sustainable house can be carried out in a traditional manner if the processes are subjected to close attention and scrutiny at every stage of design and construction. One of the main fundamental steps to building an efficient house includes a sustainable choice of resources and engagement with every plausible source of green energy. By abiding by the process previously mentioned, it can be assured that the house is receiving maximum solar energy. Also, housing structures can be supported with passive ventilation systems to lessen the requirement for heating and cooling segments. Above all, the solar energy trapped can also be utilized for generating power and hot water by reducing the use of conventional energy sources.

### *9.2. Discussion and Design Report*

To conclude my research, a sustainable design has been presented that is sustainable and minimizes the environmental impact of the building. The design is suitable for construction in the UK as all the design techniques that have been included are researched for suitability in this country, along with various examples stated in the project report.

Ground source heat pumps and solar hot water systems have been used in the design as they largely cut electricity bills.

For the roof, the use of ceramic roof tiles was first thought of as it saves 60 per cent more primary energy as compared to fibre cement roof tiles. But more research gave away the use of concrete tiles, as they are 42 per cent more efficient in saving primary energy.

Straw, along with FSC-certified timber, was used in different design locations. Straw and being a renewable constituent, has low-embodied energy and insulating properties.

Instead of synthetic insulation materials, such as rigid polyurethane foam and EPS (expanded polystyrene), natural insulation materials, such as cork, wood fibre and sheep's wool, are incorporated within the walls as they reduce environmental impact. Recycled steel and glass have been used to construct the house to reduce the impact.

Photovoltaic is a sustainable form of energy. There are no $CO_2$, $NO_2$, and SO2 emissions while extracting energy from it. Base load array provides sufficient energy for 9 months of the year and is ideal for countries like the UK. They have been adjusted on the roof facing south at an inclination of 30 degrees, which is appropriate for the design.

The principles of a Passive solar design have been used in the house to achieve thermal comfort.

Direct gain systems have been used in the living room by which the windows are ideally put south facing where the glass admits the sun's radiation, which strikes the thermal mass material inside the house, such as masonry walls and floors. 60 – 75% of the solar radiation coming through the window is utilized by this method.

Overcast Sky Lighting is a passive design technique used for this design. By this technique, the windows are aligned higher up on the wall, which gives higher visibility to the sky vault and, therefore, higher the daylight will be, although the light is considered to be orientation independent as light is dispersed in rays which will save on the lighting bill during the day hours.

The windows have been placed in such a manner that they provide cooling in the building during the day and night. Promote Direct day ventilation allows; Cooler air is allowed directly into space; the wind that passes over the occupant promotes evaporating cooling.

A sunroom has also been incorporated within the design, facing south. They work on a combined feature of direct and indirect solar gain systems as the sunlight entering the room is captured, and the thermal mass is retained. Solar radiations fall on sunroom glazing, and then the heat is transferred to the living space by a mass wall through the conduction process or through the process of convection, where the vents permit the flow of air from the sunroom to the living space and back.

15% – 30% of the sun's radiation falling on the glazing is utilized by the isolated gain system for heating purposes. At the same time, it retains the energy in the sunroom (solar greenhouses).

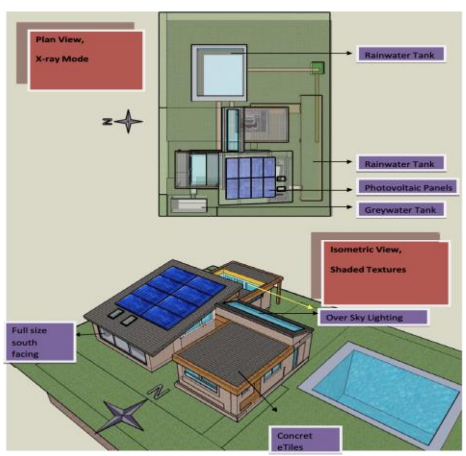
Various methods of water conservation have been adopted in the following design. Dual flushing systems are used in the bathrooms. It has been known that toilet flush consumes almost one-third of the total water usage. Small baths and water-efficient small sieve showers have been installed in the bathrooms to reduce water consumption.

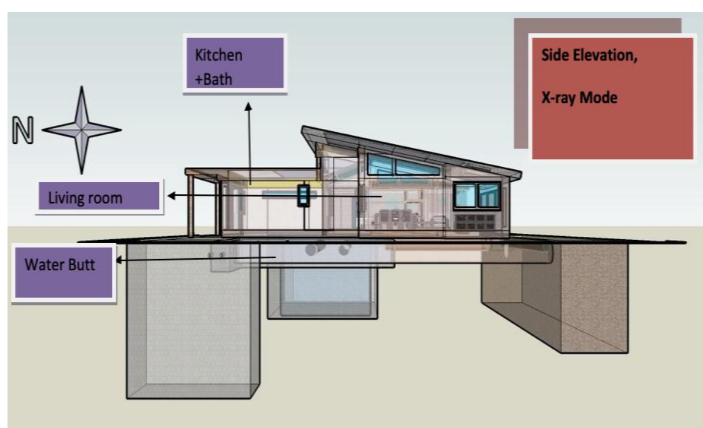
A fairly large tank has been installed for harvesting the rainwater, which leaves an option of recycling the greywater from sinks/baths and can be used for toilet flushing, water gardening, etc., which is done by installing a water butt. Installation of water-efficient dishwashers, washing machines and sink taps helps reduce kitchen water consumption. Ground source heat pumps, also known as geothermal heat pumps, have been installed on the site, which functions by extracting heat from the ground during the winter and transferring it to the heating systems installed in the living space. They have multifunction and also help as water heaters.

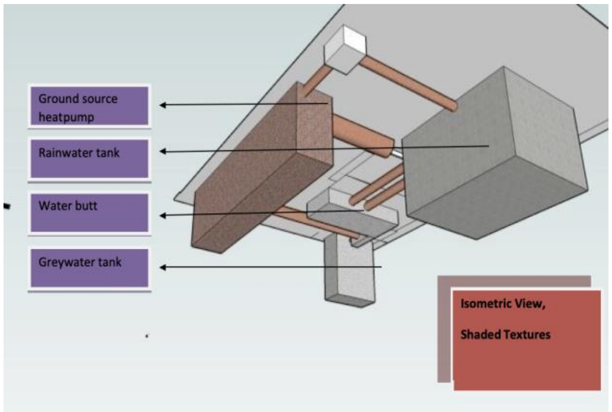
After evaluating all the possible points, project professionals form a suitable checklist and apply it under a rating system. If all the mandatory requirements have been met, the project can be applied for UK LEED certification.

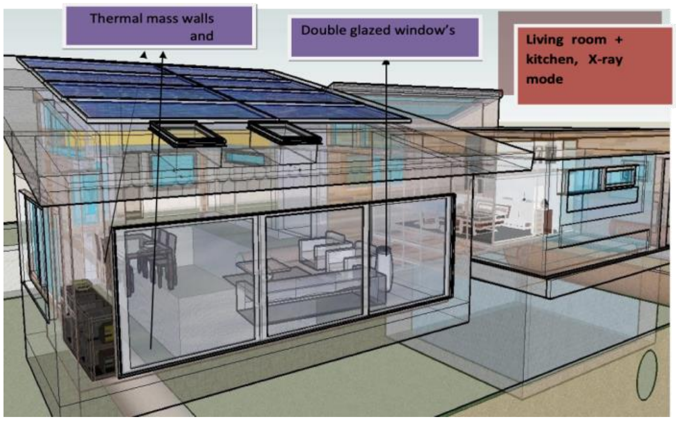
LEED bases its evaluation on a housing building's performance in the following seven key areas: energy efficiency, water efficiency, materials and resources, indoor environmental quality, the overall sustainability of the site, location and linkage, and awareness and education. Of which the last two are specific to residential buildings. Location and linkage focus on the building's location and accessibility to amenities and transport. At the same time, Awareness and Education address the most overlooked aspect: the occupant's awareness of how to operate the house and maximize its green features.

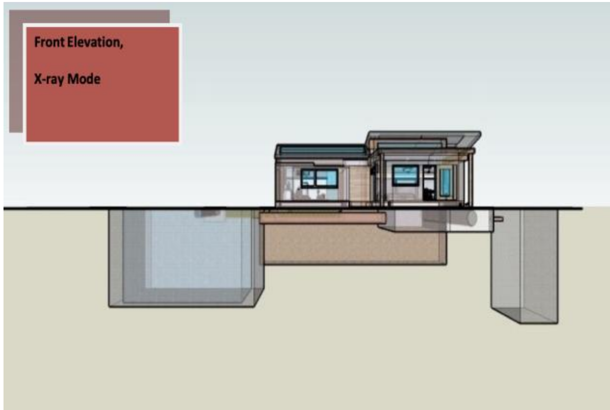
***9.3. Design Illustration (created in Sketchup)***



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