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Research Article

Renewable Energy in Architecture

"Used Techniques to Achieve Green Net Zero Energy Buildings"

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Abstract

There are various negatives to use non-renewable energy resources, it consumes the exhaustible resources, as well as their use produces emissions that affect and pollute the environment and cause major changes in global climate. On the global level, we find the construction field is a key consumer of energy and natural resources, therefore, its participation is essential to achieve the sustainable development. The buildings and constructions are mainly responsible for the gas emissions that cause the global warming. Therefore, the importance of keeping and saving the energy, to keep resources from running out and reduce CO2 emissions which cause the global warming. The research reviews current techniques in addressing energy problems in buildings. The research consists of three parts; Part one reviews the concept of new and renewable energy in general, the second part reviews the concept of new and renewable energy in buildings, and then we end with the third part which reviews successful case studies that have been built in the world, studying and analysing the examples, and studying technologies and methods of reducing energy consumption and production to achieve green net Zero Energy Buildings (ZEB).

The Research Question

The traditional buildings significantly contribute to the global energy consumption and are mainly responsible for the gas emissions that cause the global warming due to the consumption of fossil energy source. Therefore, the trend to use renewable energy, green Architecture, and sustainable buildings is the optimal solution for the problem through greatly reducing the energy consumption rates and reaching other solutions for producing the energy in buildings to meet their needs in a clean manner.

Research Goal

The research aims to shed light on the importance of these emerging concepts and the need to apply these concepts in architectural design because the world is moving quickly towards what is known as green architecture because we see that in the near future there will be no existing building without being environmen tally evaluated by the various environmental assessment systems around the world (LEED, BREEAM, DGNB, ….etc) whether locally or globally.

The expected findings

The expected results are reaching the technologies and methods of reducing the energy consumption and optimizing its production, which may be used to accomplish sustainable buildings meet their needs via renewable energy.

Methodology

The research reviews current techniques in addressing energy problems in building as follows:

Theoretical approach:

First: A review of the current technologies in the world to address energy problems in general and in buildings, through

a quick Briefing of current ideas that exist to address energy problems in buildings and consists of two parts:

Part one: Reviews the concept of new and renewable energy in general.

Part two: Reviews the concept of new and renewable energy in buildings.

Analytical approach:

Second: A review of successful models and cases in the world that have been implemented in the world now and consists of one part:

Part three: Studying and analysing the successful examples that have been built in the world, and studying technologies and methods of reducing energy consumption and production.

Discussion

Green building energy conservation standards

Overview:

a. Energy conservation: The energy conservation process depends on the process of reducing energy consumption, therefore, the design and construction of the building must be executed in a way that reduces energy consumption.

- Energy consumption causes: The buildings need energy for light, heat, air conditioning systems and operating the various appliances at the building to serve its occupants.

There are some design errors at the buildings which increase energy consumption:

- The architects neglect the climatic design.
- Increasing the room circumference.
- Increasing the numbers of walls and holes that face the sun rays in the southern direction.
- Using dark-colored facades and surfaces that absorb heat.
- Using highly conductive glass types to increase the heat convection.
- Depending on fossil energy source (oil, coal, and natural gas) in operating and managing the building.

- Saving energy consumption technologies: To save energy consumption, the buildings must be designed and constructed in a way that reduces the required energy to run the buildings and reduce the energy consumption that necessary to manage and run the building, whether by providing light and appliances that save energy or for the heat process in winter or air conditioning process in summer. The used techniques in saving energy consumption are shading the buildings with sun breakers and using plants to reduce heat convections[1].

The building orientation in the site must be taken in consideration, the proper direction helps to provide appropriate light and heat for building spaces, using the passive design of building (Figure 1).

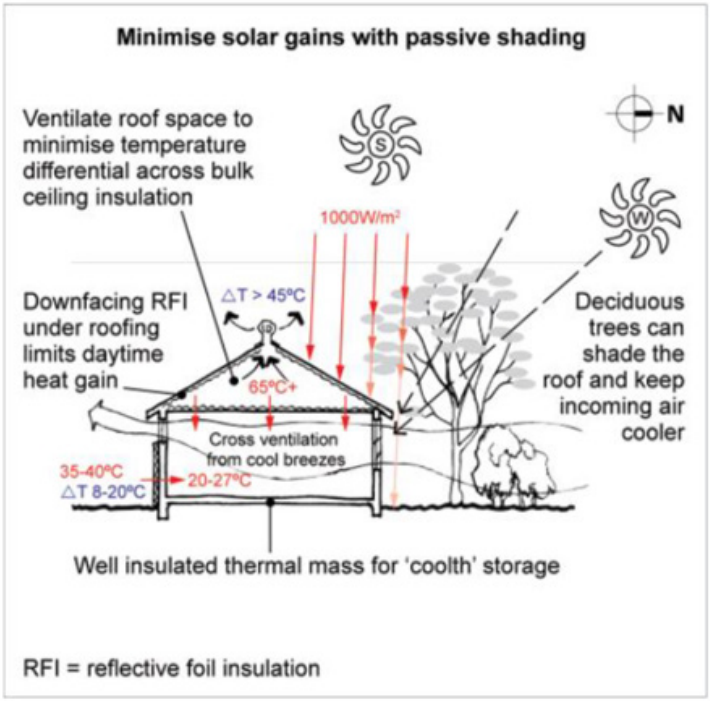

Figure 1: Using the Passive Design to Reduce the Heat Gain Inside the Building.
The Source: Australian government 2019.

[1]Ahmed Faisal – Thermal Insulation System of Buildings to Reduce Energy Consummation (2019).

Renewable Energy

Renewable Energy is the energy that is collected from the resources that found repeatedly in the nature. These resources are sustainable and inexhaustible natural sources that available in the nature, whether in limited or unlimited amounts, and constantly replenished. Most of renewable energy resources are green and didn't cause relatively environmental pollution[1].

Solar energy

Solar Energy is the Energy that comes from the brightness of the sun, it is the most important source of the thermal & light energy that can be converted to electrical energy, and solar energy can be captured "Actively" or "passively" as shown in (Figure 2).

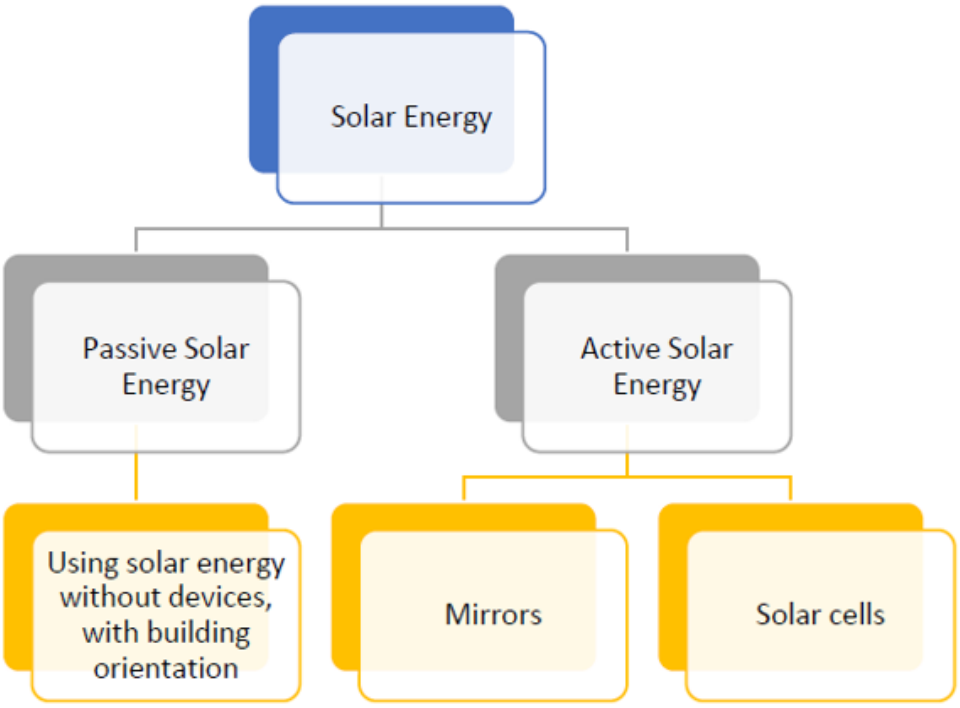

Figure 2: Solar Capture Technologies.
The Source: The Researcher.

[1]Ahmed salah et al - Renewable Energy and its role in achieving sustainable development considering the international experiences of Egypt's case study (2018).

Wind energy

Wind Energy is airpower that transforms kinetic energy into electrical energy. The common technology of wind energy is using the rotor blades which works as engines and moves the Wind turbines.

Hydropower

There are many resources of hydropower; it can be generated from various resources, as shown on (Figure 3), but to use the water as resource of energy, the hydroelectric power plants must be located near of water source such as river, waterfall, or sea.

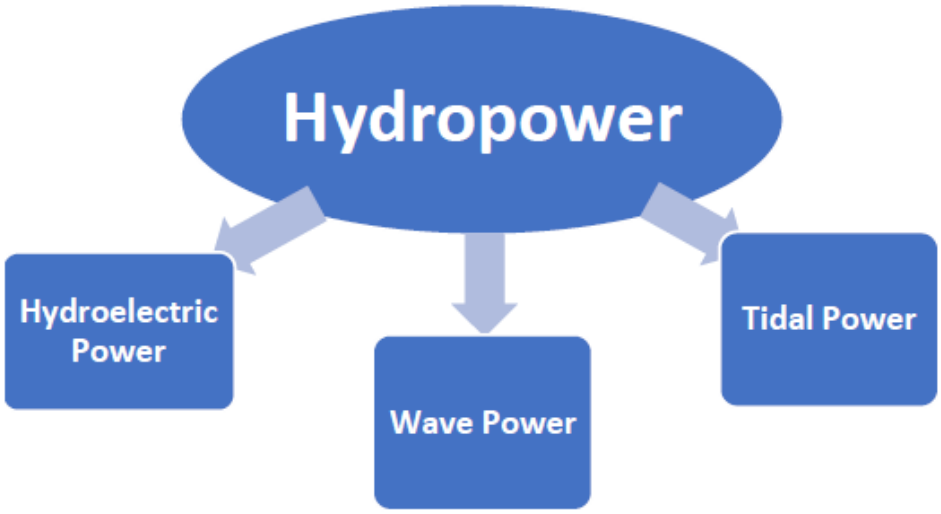

Figure 3: Types for Producing Hydropower.
The Source: The Researcher.

Biomass

Biomass is renewable organic material that comes from plants, animals, and garbage. Biomass contains stored chemical energy from the sun (Figure 4). When biomass is burned, this stored energy is released as heat. Biomass can be burned directly for heat or converted to renewable liquid and gaseous fuels that can be burned[1].

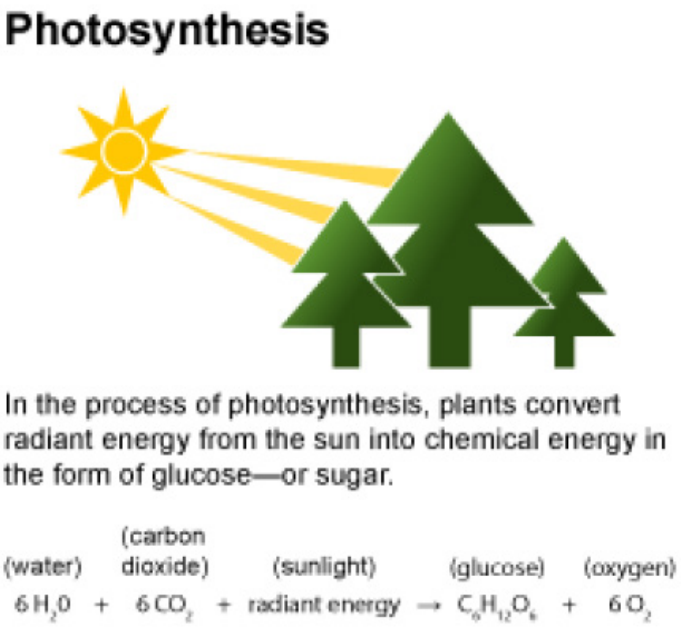

Figure 4: Photosynthesis Process.
The Source: US Energy Information Administration (2019).

[1]US Energy Information Administration, Biomass Explained (2019).

Geothermal energy

The increasing temperature of the earth's interior can be used to generate energy (called Geothermal Energy), which can be used to produce electrical energy, especially the exploitation of high groundwater temperatures.

Renewable Energy in Buildings

Green zero energy buildings (ZEB)

ZEB is any building characterized by zero net energy consumption. It generates its own required energy from renewable energy and does not consume more power from the public network (Figure 5).

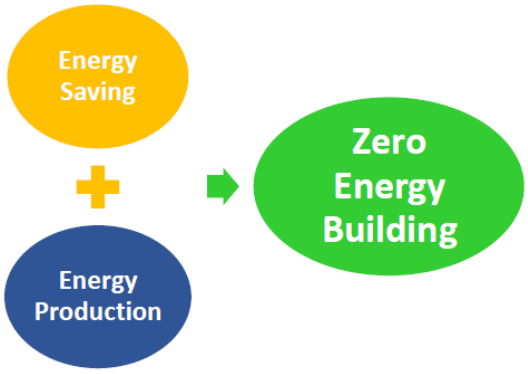

Figure 5: Equation of having ZEB.
The Source: The Researcher.

Saving energy techniques in green buildings

There are many techniques and methods to reduce the energy consumption and requirements in the buildings that are as follows:

Insulation: The first and most important measure on the path to have ZEB involves increasing the insulation for the floors, walls, and ceilings using standard insulation practices to meet the R-values set by the energy modelling[1].

Air sealing: One of the most cost-effective measures involves air sealing the building envelope to eliminate air leaks from the building structure itself and from around windows, doors, and all other building penetrations. The building is usually sealed, and air sealing usually done with using fillers and foams. Air curtains technology is used on doors and entrances that pushes a great amount of air to create pressure differential within the building[2].

Heating and cooling: For efficient building energy management, the building must be adapted to the climate, so it may not need to consume a lot of energy to provide an acceptable temperature inside the building for its occupants. Air Source Heat Pump (ASHP) and Ground Source Heat Pump (GSHP) are effective technologies for heating and cooling in terms of energy consumption. They greatly reduce the used power in heating and cooling process[3].

Lighting: The well-designed ZEB will take advantage of natural light by using properly oriented windows and louvers to direct the light where needed, while blocking heat when not needed. In the case of using artificial light, LED lights greatly reduce the artificial lighting energy consumption and cost while increasing lighting quality. Automatic lighting controls can lower or turn off artificial lighting when natural light is sufficient. Outdoor solar lighting fixtures, which use solar cells, may be used to store energy from the sun during the day, in the time that the lighting is not required, and lighting at night without consuming any electricity.

[1]Emerson, J. How to achieve a zero-energy building (2017).

[2]Emerson, J. How to achieve a zero-energy building (2017).

[3]Emerson, J. How to achieve a zero-energy building (2017).

Windows: The double and triple glazing windows are available with low-emissivity coatings that helps to capture or reject solar heat. Thermally enhanced aluminium window frames reduce conductive heat transfer[1].

Shading Systems: ZEB is usually designed with roof overhangs or movable or fixed awnings, that are carefully calculated, based on the sun angle in winter and summer, to shade the summer sun but allow in the winter sun for solar tempering of the building. This reduces heating and cooling costs and optimizes natural lighting[2].

Appliances: Appliances, such as dish washers, dryers, and stoves, should be selected for the highest energy efficiency at the lowest cost, using those with ENERGY STAR ratings when possible[3].

Phantom load reduction: Electronics and appliances use power when turned off, which represents a significant energy drain. In some electronics, the standby mode accounts for the majority of the device's annual energy consumption. The simplest solutions include developing protocols for unplugging devices when not in use and utilizing smart power strips. Smart technology, that is now available, can automatically kill all phantom loads when devices are not in use[4].

Smart energy management systems: Energy Management Systems can kill all plug loads when occupants leave, adjust each room's temperature using sensors to determine if they are occupied, adjust internal shades or external lights to optimize temperature and lighting, and adjust the level of artificial lighting based on the amount of natural lighting and on the presence of people in the room.

Green building power-generation technologies

There are many ways to generate your own power or necessary heat for the building. The ways of generating the necessary power to the building or sell it back to the grid are as follows:

Solar energy: When you install photovoltaic panels on your roof or in the back yard, you can generate electricity and heat water (Figure 6). Also, you can generate your own electricity or sell it back to the local grid[5].

Figure 6: Using the Photovoltaic Panels at the National Renewable Energy Laboratory in Golden, Colorado.
The Source: Zero Energy Project.

[1]Emerson, J. How to achieve a zero-energy building (2017).

[2]Emerson, J. How to achieve a zero-energy building (2017).

[3]Greener Scotland. Generating your own power (2019).

[4]Greener Scotland. Generating your own power (2019).

[5]Greener Scotland. Generating your own power (2019).

a. Photovoltaic energy: Backing to the techniques of generating energy, we find that the photovoltaic system is occupying less space in the building comparing to all other techniques of generating energy. It optimizes the use of different building roofs as well as may use the building surfaces, walls, or windows as photovoltaic systems[1].

The photovoltaic panels can be used as a car parking shaded area or building awnings; therefore, their use will not be only in generating the power, but also shading as shown on (Figure 7).

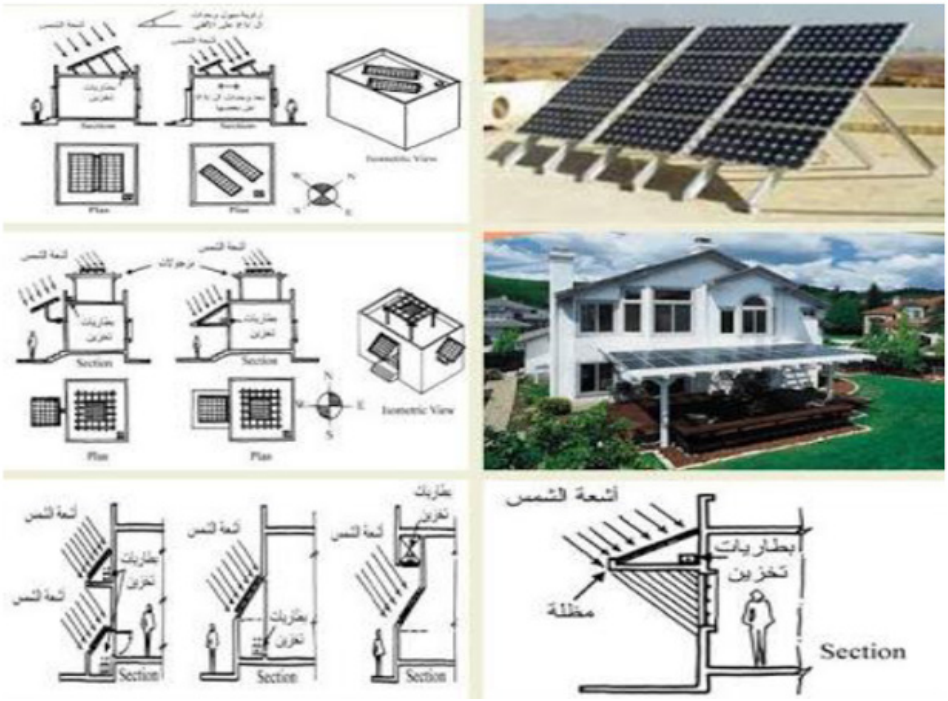

Figure 7: Using photovoltaic Panels in Generating the Power and Shading.
The Source: Ahmed Atef Fagal 2002.

Figure 8: Battery to Collect Excess Solar Energy from Solar Panels.
The Source: Solar Alliance 2019.

[1]Allianz. Six ways to generate energy at home (2010).

b. Solar batteries: In addition to the panels, you will need a battery to store electricity produced during the day and a voltage stabilizer that prevents the battery from being overcharged. If you plan to feed the surplus electricity to the public grid, you will also need an export meter[1].

The way in which solar batteries work is by taking the AC power that's harvested by the solar panels and stores it as DC power to be used later on (Figure 8). The higher the capacity of the battery, the more solar panels it can charge[2].

c. Building integrated photovoltaics: Large multi-story commercial buildings may have a too small roof area for the number of solar panels required to meet the building's energy needs. In such cases, PV panels can be integrated into other building surfaces as shown on (Figure 9). There are even window glazing systems that use photovoltaic technology to generate electricity[3].

Figure 9: Using the Photovoltaic Panels on the façades to meet the building's energy needs.
The Source: Zero Energy Project.

d. Solar water heater: Even in colder climates, the sun can provide up to 60% of a household's annual water heating[4]. Solar thermal units consist of a photovoltaic plate capture the heat from the sun and various pipes, through which the water runs and is warmed up, and a water tank for storing the received hot water. This cylinder tank has an inlet and an outlet; one for cold water and the other for hot water (Figure 10). These heaters can be fixed on roofs, colonies, or the ground[5].

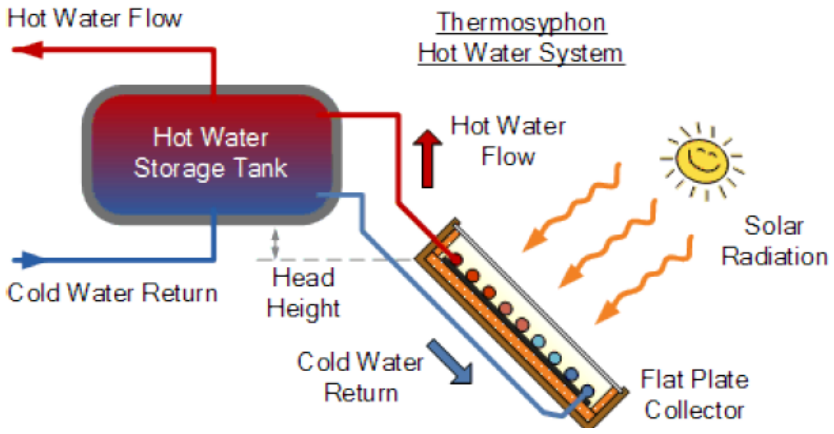

Figure 10: The Way to Make Solar Water Heaters.
The Source: Alternative Energy Tutorials 2019.

[1]Allianz. Six ways to generate energy at home (2010).

[2]Solar Alliance. Solar Rechargeable Batteries: How do they work? (2019).

[3]Emerson, J. How to achieve a zero-energy building (2017).

[4]Allianz. Six ways to generate energy at home (2010).

[5]Energy Saving Trust. Solar Water Heating (2019).

Wind: Generate your own electricity using small-scale wind turbines (Figure 11). A typical system in an exposed site can easily generate more power than your lights and electrical appliances use[1].

Figure 11: Using Small-Scale Wind Turbines around the Building to Generate Electricity.
The Source: Froese, M. 2019.

Geothermal: Energy can be generated from the heat within the earth. Ground source heat pumps (GSHPs) use pipes that are buried in the garden to extract heat from the ground (Figure 12). To use this energy, ground holes must be drilled and provided with long pipes that push cold water in the ground to be warmed and used in heating systems and hot water in the building[2].

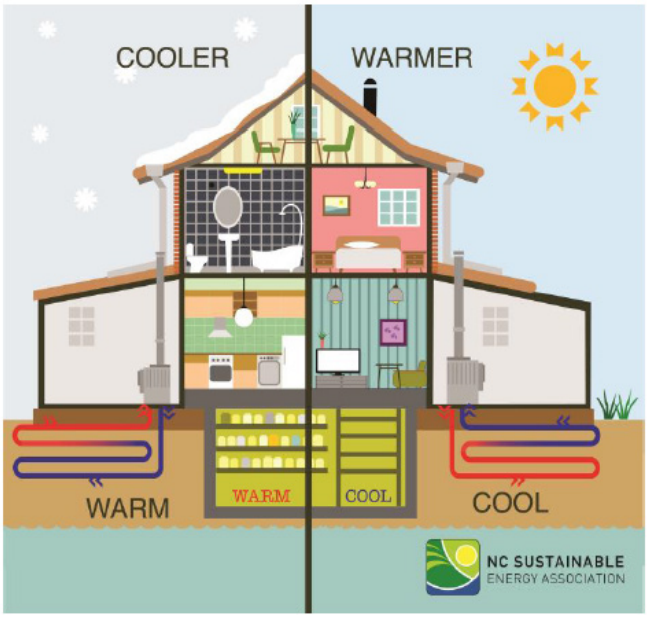

Figure 12: Geothermal Heating and Cooling Systems.
The Source: Energy.gov. 2019.

[1]Greener Scotland. Generating your own power (2019).

[2]Greener Scotland. Generating your own power (2019).

Biomass: Biomass is organic material, often industrial products that can be used for heating. The Biomass systems provide heating in one room or central heating and hot water (Figure 13). Biomass burns cleaner than conventional wood and the stoves operate more efficiently[1].

Figure 13: Traditional Biomass Stove.
The Source: Kelley, J. 2016.

Hydroelectric energy: Hydro technology uses running water to generate electricity, whether it's a small stream or a larger river. Moving water rotates the blades of a hydroelectric turbine, which in turn moves the copper armature inside the electric generator to produce electricity. It can produce enough electricity for lighting and electrical appliances in an average house[2].

Innovative technologies to generate power in the buildings: With Technology development, many Innovative technologies and practices have arisen to generate power in the buildings by using clean and renewable energies, such as;

a. Solar roof tiles: Some companies, such as Tesla, make roof tiles which work as PV panels but in beautiful manner[3].

The tiles collect energy during the daylight hours and then save it in batteries integrated at the building for whenever it may be used (Figure 14).

Figure 14: Solar Roof Tiles.
The Source: Keller H., 2019.

[1]Allianz. Six ways to generate energy at home (2010).

[2]Gilani, N. Different ways to make electricity (2018).

[3]Keller, H. What You Should Know Before Buying Tesla's Solar Roof Tiles (2019).

b. Solar glass block: Renewable energy experts from University of Exeter in UK have created an innovative glass block, which can be incorporated into the fabric of a building and is designed to collect solar energy and convert it to electricity. The blocks, called Solar Squared, are designed to fit seamlessly into either new buildings, or as part of renovations in existing properties. They are similar to existing glass blocks by allowing daylight to resonate around a property to enlighten it by replacing traditional bricks and mortar with transparent glass bricks[1] (Figure 15).

c. Transparent solar panels: Researchers from Michigan State University developed completely transparent solar panels, which can have numerous applications in architecture[2].

They developed a transparent luminescent solar concentrator (TLSC*) which can be placed over window or any transparent surface. It can harvest solar energy without affecting the transmittance of light[3], which can make the most out of the buildings' facades in energy production (Figure 16).

d. Photovoltaic concrete façade: Photovoltaic Concrete Façade captures solar energy to power buildings. The product combines Lafarge Holcim's concrete with a top layer of Heliatek's HeliaFilm, which is a flexible solar film that is just one millimeter thick (Figure 17). It has the potential to double the energy generation that a building can achieve by traditional roof-based photovoltaics, because facades take up a greater surface area.

Figure 15: Solar Glass Block.
The Source: University of Exeter, 2017.

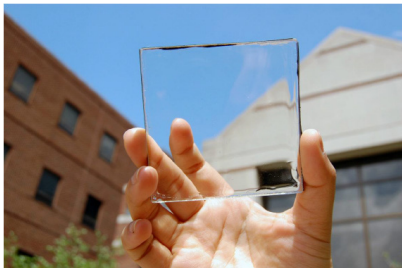

Figure 16: Transparent Solar Panels.
The Source: Cosma, Ana. 2019.

Figure 17: Photovoltaic Concrete Units.
The Source: Ouf, Rima 2018.

[1]University of Exeter. Buildings to generate their own power with innovative glass blocks (2017).

[2]Cosma, Ana.Transparent solar panels will turn windows into Green Energy Collectors (2019).

[3]Cosma, Ana.Transparent solar panels will turn windows into Green Energy Collectors (2019).

*Transparent Luminescent Solar Concentrator.

It has the potential to double the energy generation that a building can achieve by traditional roof-based photovoltaics, because facades take up a greater surface area.

Weighting less than five percent of a traditional solar panel, HeliaFilm is made to be integrated into construction materials by building element manufacturers. Beyond Lafarge Holcim's concrete cladding, it could be used with steel or glass1.

Weighting less than five percent of a traditional solar panel, HeliaFilm is made to be integrated into construction materials by building element manufacturers. Beyond Lafarge Holcim's concrete cladding, it could be used with steel or glass[1].

Analysing Successful Examples (Zero Energy Building) Case Study

San josé environmental innovation centre, california, USA

Building location: The building is located at San Jose, California, in the west of the United States of America. It is bounded on the south and west by Bayshore-Hwy Road, on the east by Chinese Cultural Park, and on the north Greekland as shown in (Figures 18 & 19).

Figure 18: An aerial photo of San José Environmental Innovation Centre location.
The Source: Google Maps.

Figure 19: Environmental Innovation Centre.
The Source: New Buildings Institute 2017.

[1]Ouf, Rima. Photovoltaic concrete facade uses sunlight to generate energy – dezeen (2018).

Reasons of choosing the building for study: The main reason is that the energy use index (EUI) needed by the building equals 55.2 Kw/M^2/year, and the building produces 55 Kw/M^2/year, which means the building can almost generates its energy, therefore, it is considered one of ZEB[1]. This was achieved by some distinctive design additions that save the building's energy consumption and produce its needs. Also, the building has LEED Gold certification (Figure 20).

Building's energy efficiency strategies: The most important sustainable elements and systems that are used in the building and its efficiency to achieve the main target of establishing the building, are as follows (Figure 21):

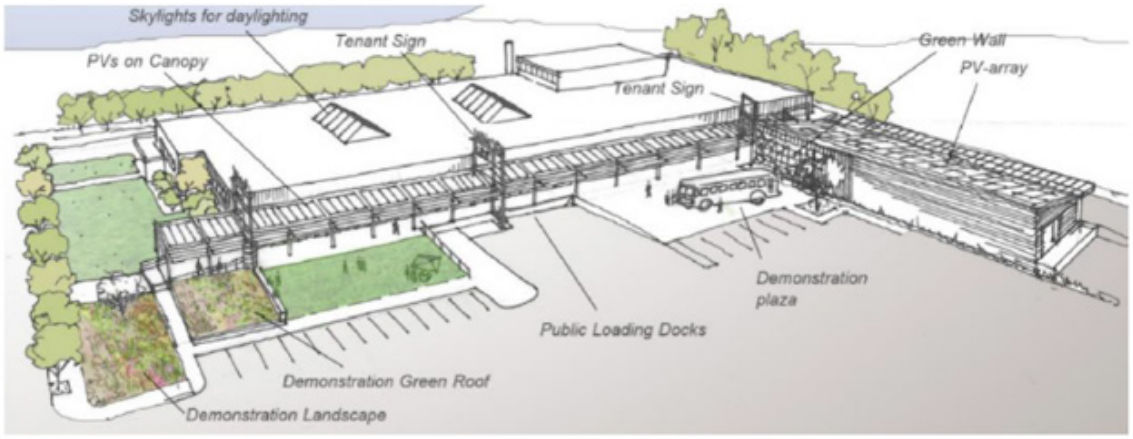

Figure 20: Sketch for Some Innovative Elements and Systems in the building.
The Source: New Buildings Institute 2017.

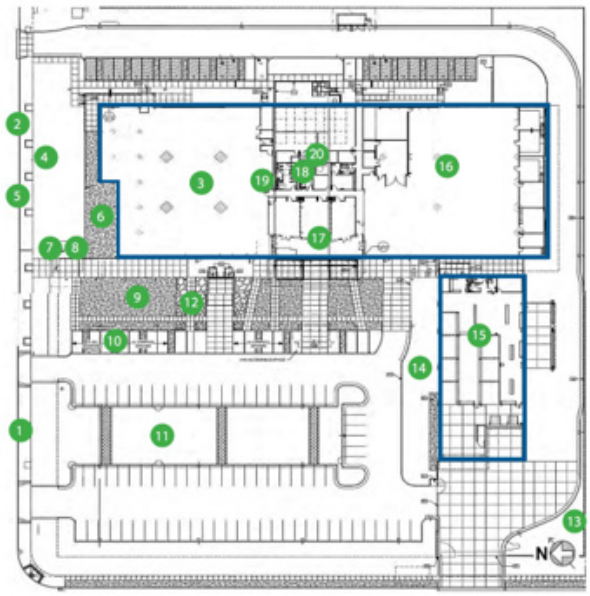

Figure 21: Sustainable elements in the building and its distribution on the plan.
The Source: San Jose Government 2019.

[1]New Buildings institute. EMERGING ZNE BUILDING CASE STUDY: ENVIRONMENTAL INNOVATION CENTER (2017).

a. Lighting: Many technologies and methods that provide the buildings' lights and save the power are used and applied as follows:

- LED lights are used and controlled partly by the occupancy sensors which ensure that lights are off when rooms are not in use.
- Solar tracking skylight and solar light tubes are used to provide natural lighting that reduces the electricity required for artificial lighting[1].

b. Building envelope: The walls were insulated, and operable windows were used to control ventilation. White ceilings, that reflect heat away from the building and reduce the need of air conditioning during the warm weather, were used.

c. Air conditioning systems: System that uses a water-cooled chiller with air handling unit (AHU) and thermal storage was applied. It uses night-time evaporation to pre-chill the water, which is stored in a tank for use the next day to reduce the cooling load on the chillers[2].

d. Wind turbines: There are four wind turbines, as shown in (Figure 22) that could generate power at night on cloudy days to meet with the building energy needs.

e. PV panels: PV on the buildings' roofs and parking canopies generate enough power to fully meet the annual electrical needs of this site.

Figure 22: Wind Turbines and some PV Panels of Environmental Innovation Centre.
The Source: New Buildings Institute 2017.

[1]New Buildings institute. EMERGING ZNE BUILDING CASE STUDY: ENVIRONMENTAL INNOVATION CENTER (2017).

[2]EMERGING ZNE BUILDING CASE STUDY: ENVIRONMENTAL INNOVATION CENTER (2017).

The active classroom, swansea city, UK

Building location: The building is located at Swansea University, Swansea city, in the south of UK. It is bounded on the west by Swansea city, on the north Fabian-way, on the east Ts Haulage Forest, and on the south Swansea Bay shown in (Figures 23 & 24).

Figure 23: An aerial photo of Active Classroom Location.
The Source: Google Maps.

Figure 24: The Active Classroom, Swansea City, UK.
The Source: Clarke, J. 2019.

Reasons of choosing the building for study:

- The main reason to choose this project is that it is the first energy-positive classroom in the UK which generate more than one and a half times the energy it consumes.
- The building combines a range of innovative technologies that will enable it to generate, store and release solar energy in one integrated system.

Building's energy efficiency strategies: The building generates its energy by PV panels which are greatly used. All roofs were covered by PV panels to make the most out of it, as shown in (Figure 25).

Figure 25: Using the PV Panels on Roofs.
The Source: Clarke, J. 2019.

The building uses some distinctive state-of-the-art ideas and technologies such as using curved roof with integrated solar cells which showing the flexible nature of PV panels, as shown in (Figure 26), and photovoltaic glass in the windows that produce electricity.

The Photovoltaic Thermal system was used on the south facing wall, as shown in (Figure 27), that can generate both heat and electricity from the sun in one system. The building uses lithium-ion batteries to store the electricity generated from the sun[1].

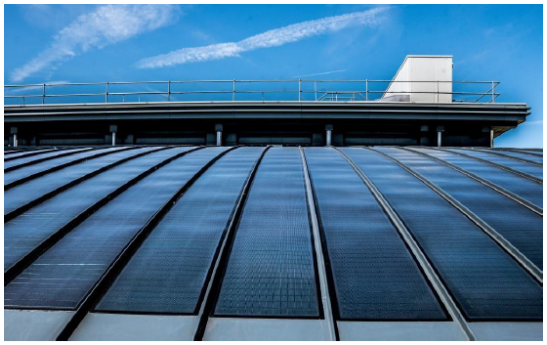

Figure 26: Using the PV Panels on Curved Roofs.
The Source: Swansea University 2018.

Figure 27: A Photovoltaic Thermal system on the south facing wall.
The Source: Clarke, J. 2019

[1]Swansea University - Buildings as power stations-they generate more energy than they consume (2018).

Air source heat pumps are used in heating system and to heat the water. It receives the air warmed by the sun from the photovoltaic wall and raises its temperature by electricity generated by PV panels.

Project location: The project located at American Institute of Architects, Rhinebeck, New York. It is bounded on the west by Lake DR, on the south and east by long pond lake and on the north by woods and gardens as shown by (Figures 28 & 29)

Omega centre for sustainable living, New York, USA

The Source: Clarke, J. 2019.

Figure 28: An aerial photo of Omega Centre for Sustainable Living Location.
The Source: Google Maps.

Figure 29: Omega Centre for Sustainable Living.
The Source: New Buildings Institute 2012.

Reasons of choosing the project for study:

- PV panels generate more energy than the consumed by building annually, which makes Omega Centre positive energy building that may sell the extra energy back to the local grids[1].
- The building is Sustainable and has LEED platinum certification (Figure 30).

Building's energy efficiency strategies: The most important sustainable elements and systems, which used in the project to reduce the power consumption and optimize its production, are as follows:

[1]The American Institute of Architects Omega Centre for Sustainable living (2019).

Figure 30: Sustainable Elements in the Building.
The Source: The American Institute of Architects 2019.

a. Lighting:

- The building depends on natural lighting by orienting it on the east-west direction to make the most out of the daylight.
- big exterior windows, high ceilings, solar tracing skylights to allows more natural light in the building, as shown by (Figure 31).
- The highly efficient artificial lights were used and controlled to be off when rooms are not in use.

b. Heating and cooling systems:

- Cooling with solar energy by the proper building orientation along with using reflective awnings and sun breakers that are powered by solar energy.

Cooling with passive systems by providing high and lower holes to get rid of undesired heat through passive ventilation where the warm air gets out from the high holes and the cold air gets in from the lower holes.

- Heating with passive systems by depending on sun directly to gain the heat.
- Execute double ground heat systems by using ground source heat pump as heating and cooling systems (Figure 32).

c. PV panels: The PV panels were used directly to produce all power required by the building (Figure 33), and it was applied in building's surfaces, canopies and outdoors[1].

Figure 31: Solar Tracing Skylight.
The Source: The American Institute of Architects 2019.

[1]The American Institute of Architects Omega Centre for Sustainable living (2019).

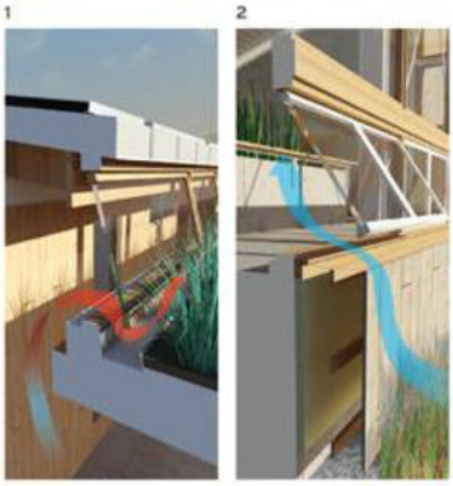

Figure 32: The Cold and Warm Air Movement in the Building by Using the Passive Design.
The Source: The American Institute of Architects 2019.

Figure 33: PV Panels that Used Outdoors to Generate Energy.
The Source: The American Institute of Architects 2019.

Table 1: Comparison between the 3 case studies in terms of using Energy saving methods & Energy Production techniques.

Comparison	Using Energy-Saving Methods						Use of Renewable Resources in Energy Production				
	Using Thermal Insulation Methods	Using Passive Design	Depending on Natural Lighting	Using LED Light	Using Saving Cooling & Heating Systems	Using Sensors	Solar Energy	Wind Energy	Hydropower	Biomass	Geothermal
San José Environmental Innovation Centre	✓		✓	✓	✓	✓	✓	✓			
The Active Classroom	✓				✓		✓				
Omega Centre for Sustainable Living	✓	✓	✓	✓	✓		✓				✓

The Source: The Researcher.

Conclusions & Recommendations

Conclusions

After the Theoretical and analytical study, the following was concluded:

- In the near future, every building will have an environmental assessment certificate from one of the international or local environmental assessment systems. Therefore, the architects' orientation towards green buildings and achieving the principles of sustainability must be evident in order for the designs to be approved by the licensing authorities and to be able to implement the building.

- To have ZEB, the technologies of reducing energy consumption must be taken into account, starting of the design and using the passive systems in design to greatly reduce the energy building requirements, therefore, it is easy to produce the remains of building needs through applying the technologies of renewable energy production that were previously mentioned in the study such as solar, wind, geothermal energies and etc.

- ZEB can produce power more than its needs and sell the energy surplus to the local grid in order to be used by the existing buildings with traditional systems. This case called positive energy building.

- By analyzing the case studies, the examined examples have been shown that the solar energy production systems have been the most effective and commonly used to have Green Zero Energy Buildings as they save the maximum energy with the lowest cost comparing to the other systems based on renewable energies. According to analysis, the small wind turbines that are attached to the building are not producing enough electrical energy comparing to PV panel. So, it is often used as sub solution for night times and cloudy days, and the big reliance will be on the solar energy.

- It is possible to make use of all vertical and horizontal building surfaces and utilize the whole building as a generator using some of the recent and modern technologies by which all the building interfaces (walls and windows and roofs) were covered with PV panels which are producing the energy and being stored in an integrated batteries, so that the whole building will generate energy.

Recommendations

By reviewing the theoretical and analytical study, there are some recommendations as follows:

- Expansion of environmental design courses in architectural colleges and conducting training courses for engineers in the field of environmental design, green architecture and sustainability rules

- Issuing laws and decisions regulating the architectural engineering profession in cooperation with the Syndicate of Engineers, obliging all consulting offices and practitioners of the profession to make an environmental assessment certificate for the project and studies to assess the environmental impact of the projects before licensing their implementation

- The architect must take into account reducing the energy requirements of the building while making the design, whereas the passive design is preferred. The energy requirements of the building and insulation practices must be studied well in order to rationalize the energy consumption of the building.- The architect must use energy simulation programs in order to be aware of the most appropriate technologies and methods to be followed in an attempt to achieve the building better energy efficiency with low budget.

- The architect must take into account the building orientation in order to achieve the optimal use of solar energy in terms of lighting and heat.

- The architect must provide natural lighting as much as possible for all spaces in order to rationalize the consumed energy for artificial lighting.

- The architect must provide the buildings with control systems and sensors attempting to reduce the unnecessary overload of energy.

- The competent authorities must support the construction sectors and landowners to use energy efficient appliances and renewable energy systems by reducing the taxes or licensing costs in case of using these systems.

- The competent authorities must develop legislations for buildings about the energy efficiency in order to meet the design standards in order to raise the energy efficiency of the building and direct the urban development for ZEB.

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Conflict of Interest

No conflict of interest.

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