APPLICATION OF SOLAR POWER FOR BUILDING ENERGY EFFICIENCY; A CASE STUDY OF LAGOS, NIGERIA

PREPARED

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DECLARATION

We hereby declare that this work is the research project titled ‘Application of solar power for energy efficiency, (a case study of Lagos, Nigeria)’ was properly carried out by Onowaro Samuel, Etuk Ubong, Adama Moses in the department of Architecture, Caleb University under the supervision of Arc Saudat Onifade. All information derived from the literature has been duly acknowledged in text and a list reference provided.

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DEDICATION

This project is dedicated to God Almighty, the beginning and the end of all things, who gave wisdom, strength and understanding to do all things, who has been our strength and source

ABSTRACT

In Nigeria, growing urban population; development of the industrial sector as well as the activities of the building construction industry have been associated with increased fuel consumption because of the epileptic power supply from the national grid. The aim of this research is to study the application of solar power for energy efficiency in selected buildings within Lagos, Nigeria. Even though green buildings consume lesser energy; there is limited knowledge and skill in harnessing solar energy for energy efficient buildings in the study area. The specific objectives are to study the development of green building in Nigeria; understand energy efficiency in green buildings; review urban power needs in Nigeria and the dependence on fossil fuel and to identify solar energy strategies in achieving energy efficient buildings in Lagos, Nigeria. It concludes that solar power is a sustainable alternative to generators and therefore concludes that government should invest more in the development of solar technologies.

Key words: Energy efficiency, Generators, Green Building, Solar power.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

A green building is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants as compared to a conventional building. Green building is a concept incorporating a wide spectrum of solution and best practices. It is an outcome of design philosophy which emphasizes on optimum utilization of resources and increases the efficiency of resource utilization. Green building also referred as sustainable building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from sitting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability and comfort.

The field of “green building and technology” encompasses a continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products. The present expectation is that this field will bring innovation and changes in daily life of similar magnitude to the “information technology” explosion over the last two decades. In these early stages, it is impossible to predict what “green technology” may eventually encompass. Regardless, the modern society feels the need for use of pure and renewable natural energies, particularly in building construction industry and considers it very crucial in achieving sustainable development.

Solar energy, given its special properties, such as purity, high safety, very cheap price, and availability is recommended as one of the suitable solutions for this purpose.

Solar power first came into being in 1958 with its use on the Vanguard I satellite. Using solar power cells as a back-up power source, the Vanguard was able to continue transmitting for over a year after its chemical battery ran out of power. Because of this achievement, many American and Soviet satellites began using solar power cells as well. However, due to the high prices of creating these cells, solar power was not widely available until the early 1970s. By Then, however, solar power had become an established source of power for many telecommunications satellites around the world.

Due to the 1973 oil crisis, a rapid rise in solar power production was marked throughout the 1970s and 1980s. This higher demand, along with a decrease in production costs, brought down the costs of solar power cells for home and commercial use. Between 1984 through 1996, growth of solar power cells stayed at a moderate 15 percent per year.

Today, most existing buildings consume and waste energy beyond the allowed limit which is the result of non-observance of the existing laws and professional codes. Most existing buildings in the country one way or another use fossil fuel for heating and cooling in different seasons of the year. Non-insulation of windows, and non-use of two-layer windows and sealants, and building's inappropriate direction etc. have given rise to increase in fossil fuel consumption. Due to this, we experience increase in number of contaminators and air pollution which from economic point of view causes governments to incur heavy expenses.

1.2 STATEMENT PROBLEM

There is limited information and public awareness on the socio-economic and ecological benefits of green buildings. The 21st century global environment challenges are very serious impacting almost every area of life. In Nigeria, there is an estimated deficit of 17 million housing units. Power supply is insufficient, and the electricity supply for about 60 million Nigerians relies on private generators, causing noise, pollution, and high expenditures for mainly imported fuel. Studies suggest that green buildings through its energy efficient strategies can significantly contribute to the attainment of the united nations goal on reducing C02 emission by 2030 (Zalina and Soebarto, 2013). Even though green buildings use a lesser amount compared with usual buildings, energy efficiency is still hard to achieve (Howe 2010), due to limited knowledge and skill in building design and construction practice.

1.3 AIM OF THE STUDY

The main aim of this research is to study the application of solar power in attainment of Green Buildings.

1.4 OBJECTIVES OF STUDY

1. To understand the need for building energy efficiency in Nigeria
2. To study the power needs in buildings
3. To review the various solar power sources available
4. To study ways of adopting solar power in buildings.

1.5 RESEARCH QUESTIONS

In the light of the research objectives, here are the following research questions:

1. Why is building energy efficiency important in Nigerian?
2. What are the power needs in buildings?
3. What are the solar technologies available?
4. How can solar power be adopted in buildings?

1.6 SCOPE OF THE STUDY

The scope of study is limited to the application of solar power in achieving energy efficiency; an important criterion in green buildings in Lagos,

CHAPTER 2

LITERATURE REVIEW

2.1 THE BUILDING INDUSTRY AND ENVIRONMENTAL PROBLEMS

The first UN Conference on the Human Environment (UNCHE) took place in 1972 and it brought environmental issues into international agenda. In 1987 the Brundtland Commission Report defined sustainability as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". The Rio Earth Summit in 1992 identified the requirements of achieving sustainable development. Further world summits including Johannesburg in 2002 and Bali in December 2007 have tried to arrive at agreements to safeguard the environment and to formulate polices for sustainable planning and development. The summits have identified the building industry as a major contributor to environmental problems. The industry consumes 40% of the materials entering the global economy, and is responsible for almost half of the global greenhouse gases. Buildings account for 30 - 40% of the worldwide energy use. Sustainable buildings are prerequisite to the creation of sustainable communities in which people will be happy to live; their needs and aspirations are met without damaging their environment or causing problems for other communities or future generations. The International Union of Architects (UIA) declared the theme of the 2007 World Day of Architecture as "Transmitting Zero Co2 Emission Architecture". The UIA intended to demonstrate architects' ability to drastically reduce carbon dioxide emissions through ecological design, construction, and maintenance of buildings and cities.

2.2 THEORY OF ENERGY EFFICIENCY

Energy efficiency simply means using less energy to perform the same task – that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. While renewable energy technologies also help accomplish these objectives, improving energy efficiency is the cheapest – and often the most immediate – way to reduce the use of fossil fuels. There are enormous opportunities for efficiency improvements in every sector of the economy, whether it is buildings, transportation, industry, or energy generation.

Building designers are looking to optimize building efficiency and then incorporate renewable energy technologies, leading to the creation of zero-energy buildings. Changes in existing buildings can also be made to reduce energy usage and costs. These may include small steps, such as choosing LED light bulbs and energy efficient appliances, or larger efforts such as upgrading insulation and weatherization.

Energy efficiency is a phenomenal term which is technology focused; but imbibes a behavioral essence in practice NEB 2009. Davidson and Henderson present energy efficiency as an indicator of the economic value obtained from the consumption of fuel, which when applied to housing, is best assessed in terms of the cost of energy needed to produce a given output or level of service such as a standard of heating. On this premise, they went further to define an energy-efficient house as one which when compared with houses of similar size, costs less to heat, to light, and to operate its essential services.

It is pertinent to understand that more than one third of the world's energy is used in buildings; and a majority of that energy is particularly used in houses and apartments. One can therefore help humanity and save a lot of money by building a super-efficient house which uses only 10–30% as much energy as a house of similar size that is built to contemporary standards.

The potential benefits of energy efficient designs are immense. Of principal importance are the Europe-wide energy benefits following uptake of the climate-sensitive design. In northern Europe, passive solar gain and daylighting reduce the need for heating and lighting energy. In the United Kingdom, studies on passive solar housing have indicated a significant energy save of about 5% from improved site layout. Curiously, enormous energy could be saved by the application of sound concepts of sustainability in new buildings; and applying retrofit options to existing ones with an accompanied reduction in environmental pollution.

2.3 ISSUES ON EFFORTS TOWARDS ENERCY EFFICIENCY IN NIGERIA.

Energy systems designed to be efficient, decentralized, and diversified are what national security demands, the public wants, and the market is ready to supply. This can be achieved in the Nigerian households through collective efforts of the government and housing stakeholders in addressing the identified study issues. In Nigeria, there is an estimated deficit of 17 million housing units. Power supply is insufficient, and the electricity supply for about 60 million Nigerians relies on private generators, causing noise, pollution, and high expenditures for mainly imported fuel. Altogether, current challenges clearly demonstrate the need for effective energy efficiency policies targeting also the building sector. The Nigerian Energy Support Program began in 2013, among others, with the objective being to support the Nigerian Government in developing the Nigerian Building Energy Efficiency Code (BEEC). The code development is based in particular on two main results of stakeholder involvement activities providing the basis for BEEC development: The Nigerian Building Energy Efficiency Guideline (BEEG), and a case study carried out in collaboration with a Nigerian developer. Activities were carried out as part of the Nigerian Energy Support Program (NESP), a five-year working program (2013–2018), implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in collaboration with the Federal Ministry of Power Works and Housing (FMPWH), and funded by the German Government and the European Union.

The BEEG is described, aiming at creating awareness for the need for energy efficiency among stakeholders, and a common understanding on the challenges and possible solutions. Discussions with stakeholders in preparation of the BEEG as well as the development of the BEEG made it clear that climate adaptive design is the key to reducing electricity consumption for cooling in a cost-efficient way. In order to learn more about the gap between current design practice and climate adaptive design, a demonstration project was started together with a Nigerian developer, aiming at improving standard designs with various energy efficiency measures including renewable energy systems. Both activities, the BEEG development and the case study analysis, helped to shape the requirements for developing the Nigerian BEEC. The actual code as approved and launched by the Federal Minister of Power, Works and Housing on 29 August 20.

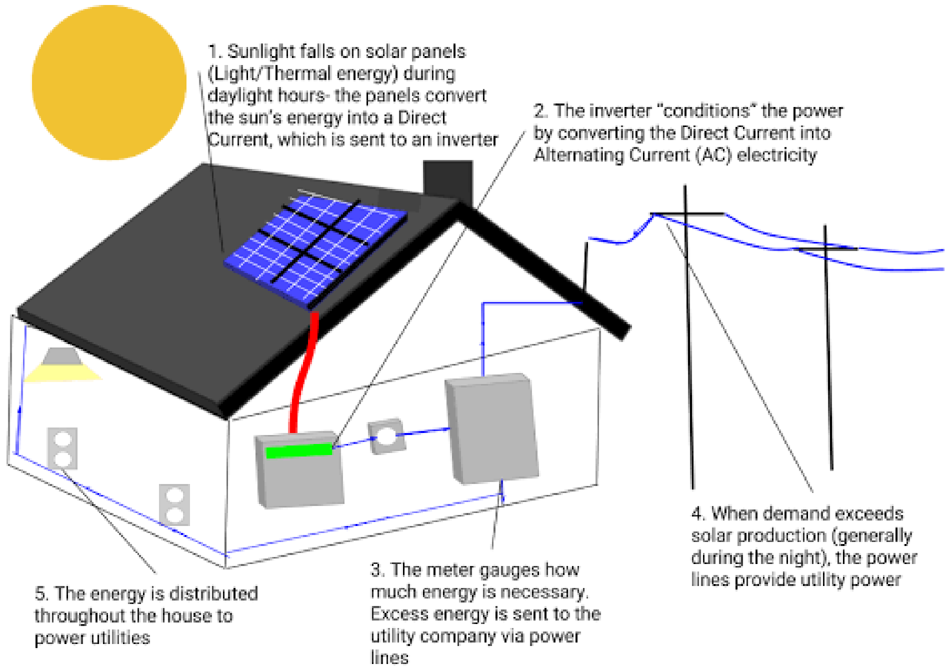


FIG 2.0 Energy distribution.

2.4 ENERGY CONSERVATION STRATEGIES IN BUILDINGS

There are four broad ways to reduce the energy consumption of building which ultimately results in mitigating emissions of CO2 emissions through energy conservation. These aspects are described as follows:

1. Comfort passive building design and its orientation for harnessing solar energy.
2. Low embodied energy materials for building construction.
3. Energy efficient domestic appliance to conserve the building operational energy.
4. Building integrated renewable energy technologies.

2.4.1 PASSIVE BUILDING DESIGN

The most sustainable energy technique is to conserve energy as much as possible. Passive solar building design can aid energy conservation efforts because building design is directly related to energy use. Buildings with passive solar building designs naturally use the sun's energy for free of charge heating, cooling and daylighting. This reduces the need to consume energy from other sources and provides a comfortable environment inside. The principles of passive solar design are compatible with diverse architectural styles and can be renovated with existing building for net zero energy use.

2.4.2 PASSIVE SOLAR DESIGN PRINCIPLES

Passive solar design integrates a combination of building features to reduce or even eliminate the need for mechanical cooling and heating and daytime artificial lighting. Designers and builders pay particular attention to the sun to minimize heating and cooling needs. The design does not need to be complex, but it should involve knowledge of solar geometry, window technology, and local climate. Given the proper building site, virtually any type of architecture can integrate passive solar design.

The basic natural processes that are used in passive solar energy are the thermal energy flows associated with radiation, conduction, and natural convection. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. Additionally, the heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a home. Passive solar energy means that mechanical means are not employed to utilize solar energy. There are some rules of thumb which must be considered for effective solar energy utilization through passive solar systems. The building energy management can be achieved smartly using the nearly zero energy building concept.

2.4.3 PASSIVE SOLAR HEATING

The goal of all passive solar heating systems was to capture the sun's heat within the building's elements and release that heat during periods when the sun is not shining. At the same time that the building's elements (or materials) are absorbing heat for later use, solar heat is available for keeping the space comfortable (not overheated). Two primary elements of passive solar heating required are as follows:

i. South facing glass for northern region and vice versa.
ii. Thermal mass to absorb, store, and distribute heat.

There are three approaches to passive solar heating systems– direct gain, indirect gain, and isolated gain.

I) DIRECT GAIN – In this system, the actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes directly and indirectly thermal mass materials in the house such as masonry floors and walls as shown in Fig. 2.1. The direct gain system will utilize 60–75% of the sun's energy striking the windows. In a direct gain system, the thermal mass floors and walls are functional parts of the house. The thermal mass absorbs solar radiations during daytime and radiates the heat energy during nighttime into the living space as shown in Fig. 2.1.

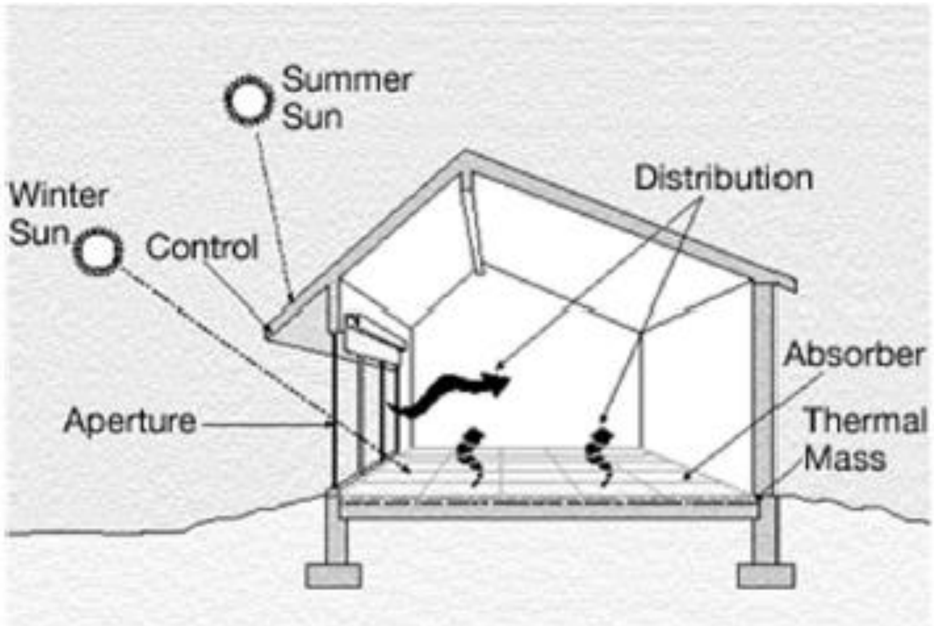


Figure 2.1 *Direct gain: thermal mass absorbs heat in day through window and radiates in night.*

II) INDIRECT GAIN – In an indirect gain of solar passive heating system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilize 30–45% of the sun's energy striking the glass adjoining the thermal

mass. There are three types of indirect gain systems

i. Thermal storage wall systems (or Trombe wall).
ii. Water wall.
iii. Roof pond systems.

In indirect gain solar passive heating system, Trombe wall absorbs and stores heat during the day. Excess heat is carried out by passage air between wall and glass through thermosiphon principle into the interior space as shown in

Fig. 2.2 At night Trombe wall vents are closed and the storage wall radiates heat into the interior space as shown in Fig. 2.2 In water wall indirect solar passive heating system, the wall is composed of water stored in the transparent/opaque containers. During daytime water absorbs solar heat and radiates heat during night. The five basic elements of passive solar design are shown in Fig. 2.2

An indirect gain solar passive design that provides both heating and cooling is the thermal pond approach, which uses water encased in ultraviolet ray inhibiting plastic beds underlined with a dark color, that are placed on a roof. Hence, this system is known as roof pond solar passive heating/cooling system. In warm and temperate climates with low precipitation, the flat roof structure serves directly as a ceiling for the living spaces below (Fig. 4) thereby facilitating heating and cooling for the spaces below. In colder climates, where heating is more desirable, attic ponds under pitched roof glazing are effective. Winter heating occurs when sunlight heats the water, which then radiates energy into the living space as well as absorbs heat within the water thermal mass for nighttime distribution (see Fig. 2.2)

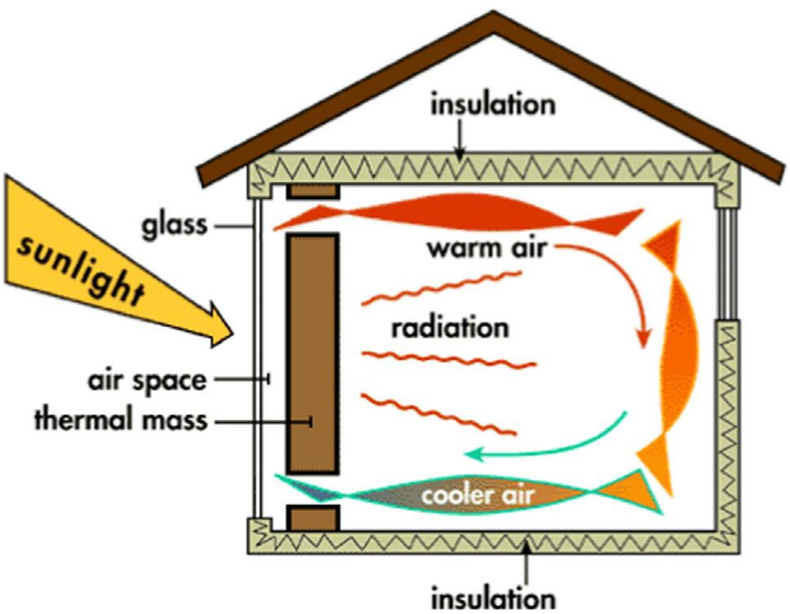


Figure 2.2 *Trombe wall with air circulation open during day and closed in night.*

During nighttime in winter months, movable insulation is covered over the roof pond and hence it radiates heat in the interior living space as shown in Fig. 4. During daytime in summer months, the movable insulation is covered over the

roof pond so that solar heat gain is minimized and water absorbs heat from the room to provide the cooling effect inside the living space. While during nighttime in summer months, the movable insulation is removed and the water radiates heat outside the room by absorbing the heat from the interior living space [*p*]. One of the major advantages of this approach is that it allows all rooms to have their own radiant energy source with little concern about the orientation of the structure or optimal building form [*p*].

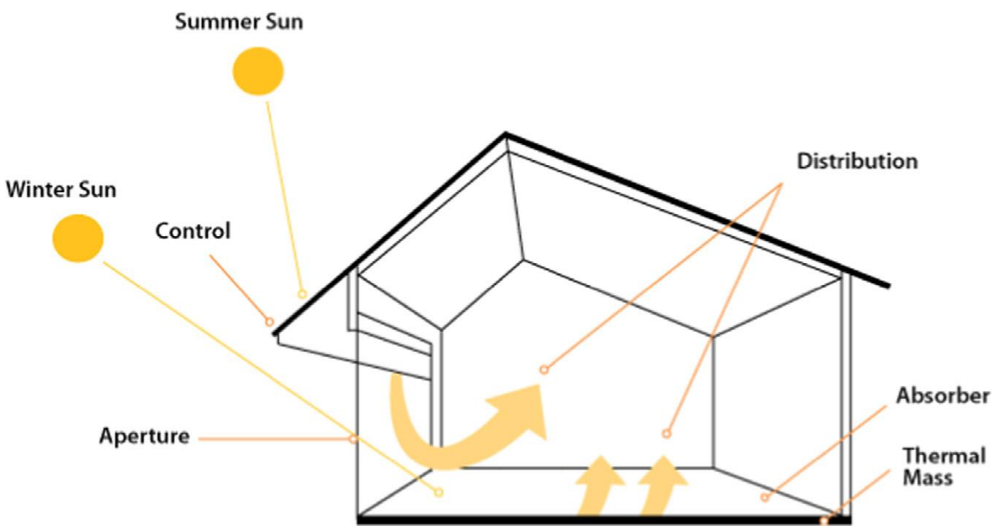


Figure 2.3 *Passive solar design: control using overhang, location of aperture, thermal mass design and distribution of gain.*

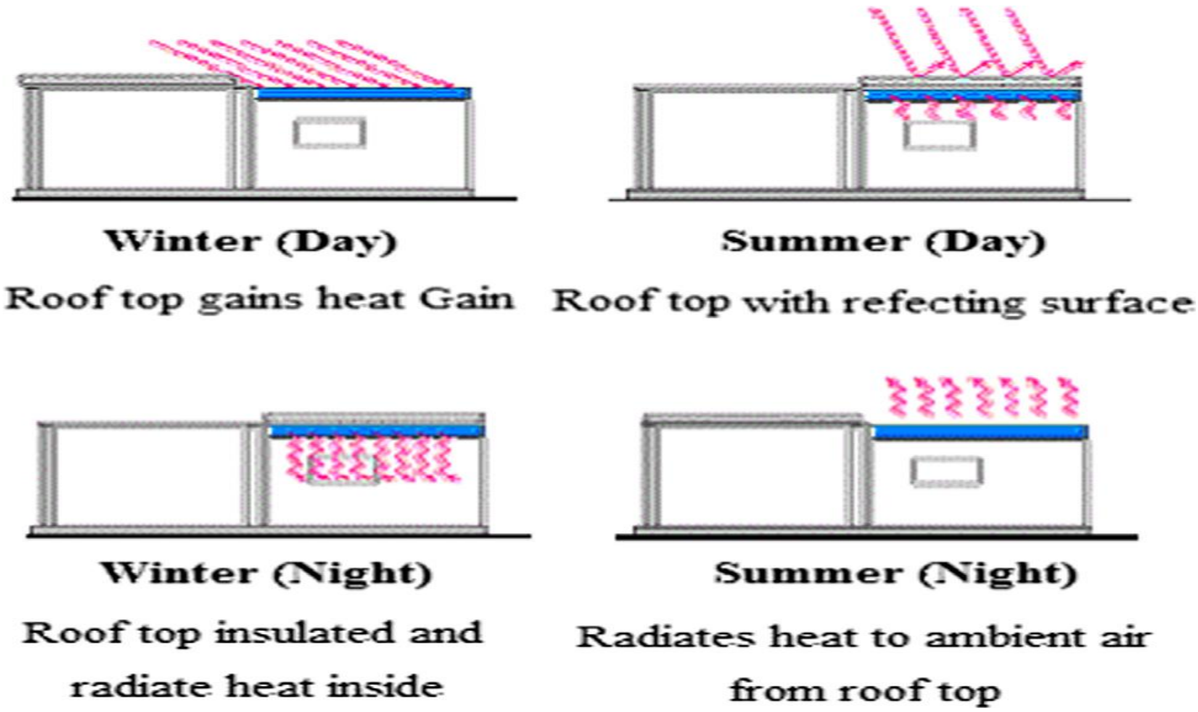


Figure 2.4 *Roof pond stores heat daytime and radiates in nighttime for winter and reverse in summer*

III) ISOLATED GAIN – An isolated passive solar heat gain system has its integral parts separated from the main living area of a house. Isolated gain involves utilizing solar energy to passively move heat from or to the living space using a fluid, such as water or air by natural convection or forced convection. Examples are sunroom and convective loop through flat plate air collector to a storage system in the house as shown in Fig. 2.5. The ability to isolate the system from the primary living areas is the point of distinction for this type of system. The isolated gain system will utilize 15–30% of the sunlight striking the glazing toward heating the adjoining living areas. Solar energy is also retained in the sunroom itself.

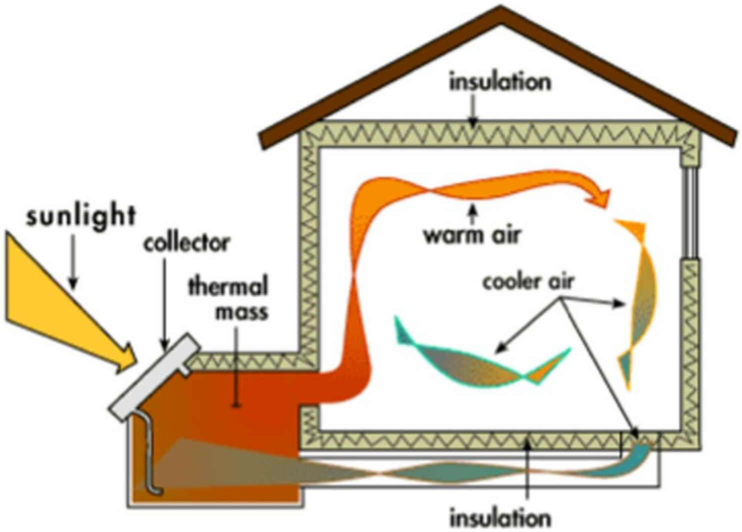


Figure 2. 5 *Isolated heat gain system through integrated solar collector for isolated heat gain.*

2.5 SOLAR THERMAL TECHNOLOGY

Solar thermal is mainly used to supply domestic hot water, heating and refrigeration. In designing the integration of solar hot water system and residential buildings, not only need to consider the layout of solar hot water system, but need to further improve the form of the system itself. Traditional solar hot water system with vacuum tube cannot meet the needs of the ever-changing layout and style of the residential buildings, beyond that, it have other deficiencies, such as the installation is very difficult, easy to destroy the waterproof layer of the roof, have security risks if the lightning protection and drought exclusion device not in place, vacuum tube belongs to quick-wear part and the maintenance ratio is high, water pipes are exposed to the outdoor cause large heat loss, etc. In short, the traditional solar hot water system with vacuum tube cannot meet the need of integration of solar energy and building either in quality or in performance. Now, the flat plate solar collector system is gradually replacing the solar hot water system with vacuum tube, for it has higher adaptability, and the installation of it can better achieve the perfect combination with the construction. Solar collector system mainly operate on the split double-cycle under pressure, the hot water tank can be located in the basement, attic, staircase, balcony and other hidden parts, and not occupy the indoor space, avoiding the load-bearing of roofs, balconies and exterior walls; water tank can use single tank, double tank and even a multi-tank, so as to achieve a larger holding tank capacity, when the tank capacity is increased, the installation area is correspondingly increased to meet the hot water needs; hot water is not just use for bath, but also used for heating and supplying domestic water, the water quality should keep clean to meet the drinking water standards.

Fig 2.6. Ways of solar collector combined with residential buildings.

(a) combined with the roof (b) combined with the balcony (c) combined with the exterior wall

Integrating solar collector with the roofs, balcony rails of the south façade, bay windows and walls, can make the appearance of residential buildings be overall unified, and have rich hierarchies (Figure 2.7). When installed on the sloping roof, the solar collector can be embedded in the roof like a sunroof or flat out on the roof, integrating with the construction to increase the building beauty.

When installed on the flat roof, the flat-plate solar collector can act as roof covering or insulation layer, not only conforms to the residential modeling requirements, but also avoids the repeated investment and reduce the cost. In addition, the flat-plate solar collector can be combined with balconies, bay windows, outside walls of residential buildings, to maximize the use of solar energy and provide new ways and means to the residential façade design, and achieve the aim of multi-purpose as well (Figure 2.7).

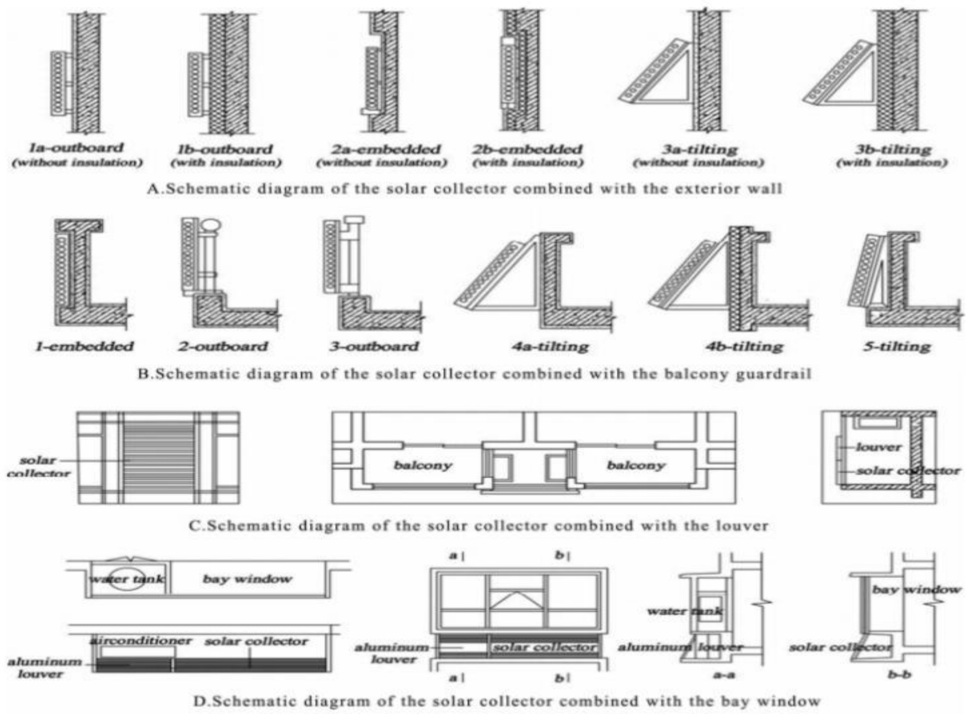


Figure 2. Construction node design of the solar collector combined with the residential building.

fig 2.7 Construction node design of the solar collector with the residential building.

2.6 HOW DOES SOLAR POWER WORK?

Solar power is usable energy generated from the sun in the form of electric or thermal energy. Solar power works by converting light from the sun into electricity. This electricity can then be used in your home or exported to the grid when it’s not needed. This is done by installing Solar

Panels on your roof which generate DC (Direct Current) electricity. This is then fed into a solar inverter which converts the DC electricity from your solar panels into AC (Alternating Current) electricity. Solar power plants use one of two technologies:

Photovoltaic (PV) systems use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power. A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect. The first solar cell was constructed by Charles Fritts in the 1880s(perlin 1999). The array of a photovoltaic power system, or PV system, produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase (Lewis Fraas et al 2010)

Many residential PV systems are connected to the grid wherever available, especially in developed countries with large markets. In these grid-connected PV systems, use of energy storage is optional. In certain applications such as satellites, lighthouses, or in developing countries, batteries or additional power generators are often added as back-ups. Such stand-alone power systems permit operations at night and at other times of limited sunlight.

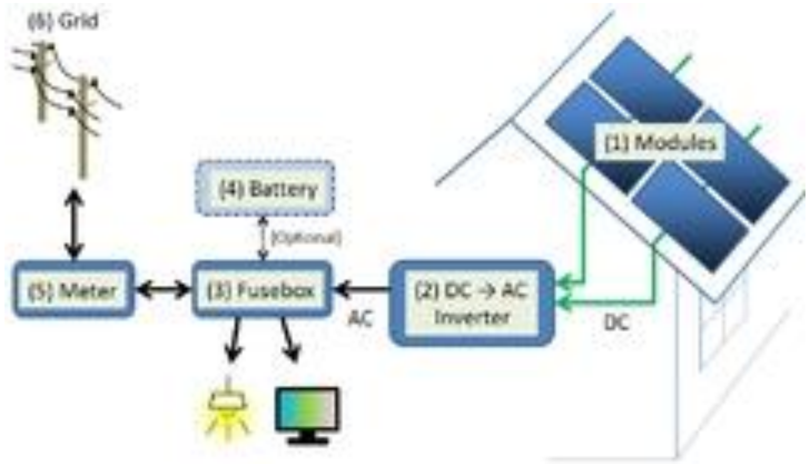


Fig 2.8 an inverter modulus

Concentrated solar power (CSP, also known as "concentrated solar thermal") plants use solar thermal energy to make steam, that is thereafter converted into electricity by a turbine. Concentrated solar power (CSP), also called "concentrated solar thermal", uses lenses or mirrors and tracking systems to concentrate sunlight, then use the resulting heat to generate electricity from conventional steam-driven turbines.

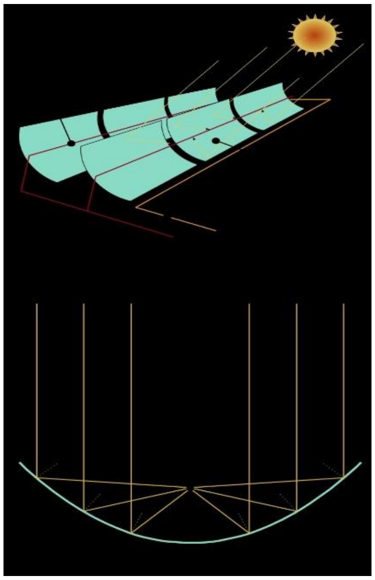


fig 2.9 steam-driven turbines

2.7 ADVANTAGES OF SOLAR ENERGY

1. Renewable Energy Source

Among all the benefits of solar panels, the most important thing is that solar energy is a truly renewable energy source. It can be harnessed in all areas of the world and is available every day. We cannot run out of solar energy, unlike some of the other sources of energy. Solar energy will be accessible as long as we have the sun, therefore sunlight will be available to us for at least 5 billion years when according to scientists the sun is going to die.

2. Reduces Electricity Bills

Since you will be meeting some of your energy needs with the electricity your solar system has generated, your energy bills will drop. How much you save on your bill will be dependent on the size of the solar system and your electricity or heat usage. Moreover, not only will you be saving on the electricity bill, there is also a possibility to receive payments for the surplus energy that you export back to the grid. If you generate more electricity than you use (considering that your solar panel system is connected to the grid).

3. Diverse Applications

Solar energy can be used for diverse purposes. You can generate electricity (photovoltaics) or heat (solar thermal). Solar energy can be used to produce electricity in areas without access to the energy grid, to distil water in regions with limited clean water supplies and to power satellites in space. Solar energy can also be integrated into the materials used for buildings. Not long ago Sharp introduced transparent solar energy windows.

4. Low Maintenance Costs

Solar energy systems generally don’t require a lot of maintenance. You only need to keep them relatively clean, so cleaning them a couple of times per year will do the job. If in doubt, you can always rely on specialized cleaning companies, which offer this service from around £25-£35. Most reliable solar panel manufacturers offer 20-25 years warranty. Also, as there are no moving parts, there is no wear and tear. The inverter is usually the only part that needs to be changed after 5-10 years because it is continuously working to convert solar energy into electricity and heat (solar PV vs. solar thermal). Apart from the inverter, the cables also need maintenance to ensure your solar power system runs at maximum efficiency. So, after covering the initial cost of the solar system, you can expect very little spending on maintenance and repair work.

5. Technology Development

Technology in the solar power industry is constantly advancing and improvements will intensify in the future. Innovations in quantum physics and nanotechnology can potentially increase the effectiveness of solar panels and double, or even triple, the electrical input of the solar power systems.

2.8 DISADVANTAGES OF SOLAR ENERGY

1. Cost

The initial cost of purchasing a solar system is fairly high. This includes paying for solar panels, inverter, batteries, wiring, and for the installation. Nevertheless, solar technologies are constantly developing, so it is safe to assume that prices will go down in the future.

2. **Weather Dependent**

Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops. Solar panels are dependent on sunlight to effectively gather solar energy. Therefore, a few cloudy, rainy days can have a noticeable effect on the energy system. You should also take into account that solar energy cannot be collected during the night. On the other hand, if you also require your water heating solution to work at night or during wintertime, thermodynamic panels are an alternative to consider.

3. **Solar Energy Storage Is Expensive**

Solar energy has to be used right away, or it can be stored in large batteries. These batteries, used in off-the-grid solar systems, can be charged during the day so that the energy is used at night. This is a good solution for using solar energy all day long but it is also quite expensive.

2.8 ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES

2.8.1 ECONOMICS OF PV SYSTEM FOR BUILDINGS

The unit cost of electricity for the typical PV system which can be used for building is summarized in Table 3. Several values of installed cost in dollars per peak watt were considered along with three different values of minimum attractive rates of return (or discount rate (d)).

In all these calculations, it was assumed that (i) the useful life of the PV system is 20 years, (ii) the annual maintenance cost is 2 percent of the total capital cost of the system, (iii) taxes and insurance costs are not to be paid and (iv) capacity utilization is 25% [*v*]. The optimum size and cost for PV system components (such as PV array, battery bank, inverter and solar charge controller) with respect to number of full-sunshine hours on the optimally titled surface corresponding to the location of site in the world map were reported by eminent scientists. The optimal tilt for PV array was reported equal to the latitude of the place. The seasonal variation of this optimum tilt angle for winter and summer months can be considered in the range of latitude ±15o, +15 considered during winter months and -15 during summer months.

Table 3 Unit cost of electricity from photovoltaic technology for building [37].

$/Watt	Unit cost of PV electricity ($/kW h)		
	d = 5%	d = 10%	d = 15%
20	0.92	1.25	1.64
16	0.73	1.00	1.31
12	0.55	0.75	0.98
8	0.37	0.50	0.66
4	0.18	0.25	0.32
2	0.09	0.12	0.16
1	0.04	0.06	0.08

Fig 2.10-unit cost of electricity from photo voltaic technology for building.

2.9 ALTERNATIVE SOURCE OF ENERGY AVAILABLE IN NIGERIA AND THEIR APPLICATION

2.9.1 GENERATORS

An engine-generator is the combination of an electrical generator and an engine (prime mover) mounted together to form a single piece of equipment. This combination is also called an engine-generator set or a gen-set. In many contexts, the engine is taken for granted and the combined unit is simply called a generator. An engine-generator may be a fixed installation, part of a vehicle, or made small enough to be portable.

2.9.2 TYPES OF GENERATORS

There are three main types of generators: portable, inverter and standby. Despite their differences, all of these generators should undergo similar generator maintenance to ensure long-term use.

1. **Portable Generator**

i. A portable generator is powered by gas or diesel fuel and can provide temporary electrical power.

ii. Here are some characteristics to note about these types of generators:

iii. Uses a combustion engine to conduct electricity.

iv. Can plug into electrical appliances or tools via its sockets.

v. Can be wired into a facility's subpanels.

vi. Can be used in remote sites.

vii. Has enough power to run a television, freezer and refrigerator.

viii. The engine should run at 3600 rpm to render the standard 60hz of current.

ix. Use a governor to control the engine's speed.

x. Can power tools and lights.

2. **Inverter Generator**

An inverter generator uses an engine connected to an alternator to produce AC power. It also uses a rectifier unlike other generators to convert the AC power into DC power.

i. Here are some characteristics to note about these types of generators:

ii. Relies on high-tech magnets.

iii. Uses advanced electronic circuitry.

iv. Undergoes three phases to produce electricity.
v. Outputs AC current, convert it to DC current and finally invert it to AC.
vi. Maintains a constant flowing of current to an appliance.
vii. Is more energy-efficient, as the engine speed adjusts itself according to how much power is needed.
viii. Its AC can be set to any voltage and frequency when used with proper equipment.
ix. Tends to be little and lightweight.
x. Can fit into a car, RV or boat.

2.9.3 Standby Generator

A standby generator is an electrical system that operates with an automatic transfer switch that commands it to power a device up during power loss.

Here are some characteristics to note about these types of generators:

i. Operates automatically.
ii. Delivers permanent power protection.
iii. Has two components: a standby generator and an automatic transfer switch.
iv. Can operate on liquid propane or natural gas.
v. Will run on the fuel type already in use in the facility or home.
vi. Uses an internal combustion engine.
vii. Senses the power loss within seconds and boots up electricity so that power loss is felt very briefly.
viii. Executes automatic weekly self-tests to see that it is properly reacting to a power loss.

ix. Is constantly monitoring utility power.

x. Used in safety systems for elevators, standby lighting, medical and life support equipment and fire protection systems.

2.10 APPRAISING A GREEN COMMUNITY; CASE STUDY OF (CALIFONIA- SAN DIEGO)

San Diego is the state's clear solar power leader in terms of both the number of solar rooftops and the amount of solar energy generated by those solar systems (capacity installed), with more than 2,000 solar roofs totaling nearly 20 megawatts installed to date, as seen in the Figures 2.

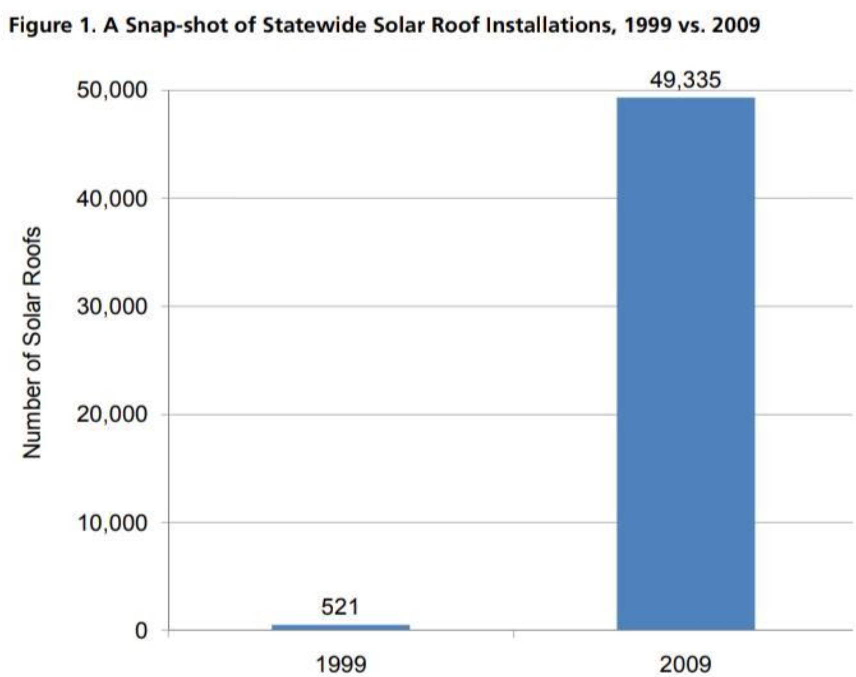


Fig 2.11 a snap shot of a statewide solar roof installation, 1999 vs 2009

It is noteworthy that San Diego is home to the only California solar rebate program administered by a non-profit organization, the California Center for Sustainable Energy, in concert with the local utility San Diego Gas & Electric. Surely, this unique collaborative program structure has contributed to the city's impressive expansion of solar power over the past ten years.

In terms of sheer quantity of solar roof-top systems installed to date, San Diego is followed by San Francisco, Los Angeles, San Jose and Fresno, which have more than one thousand solar roofs each. Bakersfield, Clovis, and Santa Rosa are all home to more than 700 solar roofs and Sacramento and Berkeley are home to more than 600 solar roof installations each.

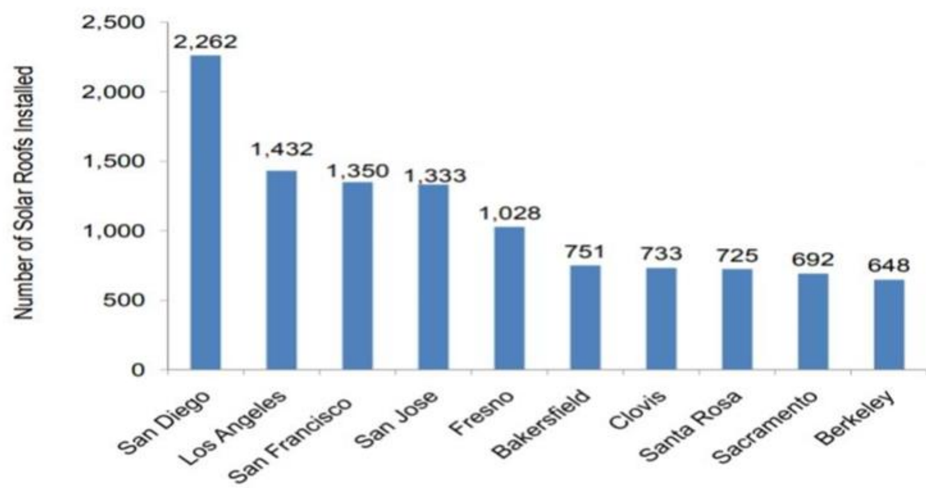


Fig 2.12 top ten solar cities (number of roofs/city)

2.10.1 BENEFITS OF SOLAR POWER IN SAN DIEGO

Solar power makes sense in California. Abundant sunshine provides a free and ample fuel supply. Peak electricity demands coincide with when solar energy systems generate electricity. And a growing concern over air pollution and global warming provide a powerful incentive for consumers and governments alike to embrace solar power as a critical part of California's clean energy future.

Fig 2.13 solar power

What's more, solar power is cleaner and more environmentally sustainable than the energy resources that dominate California's electricity landscape today, namely natural gas, coal, large scale dams and nuclear power. Thanks to the growth in the world-wide market for solar power, it is also becoming more affordable, as discussed in the next chapter.

California's cities and counties have great potential to benefit, both economically and environmentally, from a growing solar power market.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter will explain the method adopted by this research, it also provides the selected mode of analysis and the data collection method.

This study is an attempt to examine the advantages and increase the awareness of the usage of solar power to archive sustainable building in Lagos. This chapter discusses on various materials collected with respect to the topic.

3.2 RESEARCH APPROACH AND DESIGN

A Qualitative approach was followed. Qualitative research method was developed in the social sciences to enable researchers to study social and cultural phenomena: observe feelings, thoughts, behaviors and the belief of the mass society. (G. Ramesh Babu, Research Methodology in Social Sciences (India: Concept Publishing Company,2008),11) Examples of qualitative methods are action research, case study research and grounded theory. Qualitative data sources include observation and participation observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Ibid)

For this research, method of case study was employed.

3.3 CASE STUDY ONE

3.3.1 HERITAGE PLACE, IKOYI, LAGOS

Heritage Place is a world-class development situated in Lagos's commercial and retail area, and just a few minutes' walk from the most important venues in the city. Heritage Place sits in a prime location in Lagos, safely situated at the crossroads of Lugard Avenue and Kingsway Road. It is within easy reach of Lagos's finest amenities and only 45 minutes' drive from the city's international airport, Murtala Muhammed.

3.3.2 HISTORY

The Heritage Place is a 14-story office building in Alfred Rewane Road, Ikoyi, Lagos. The building comprises 14 floors of approximately 15,736sqm of office space and 350 parking bays. It was completed on the 15th of January, 2016 and it currently has a tenancy level of 40%. The sustainable features include a 30-40 % reduction in energy use, a double volume reception, suspended ceilings, raised floors, a cafe and coffee shop, plaza as well as flexible floor plate sizes from 450sqm up to 2,000sqm.

3.3.3 PROJECT DESCRIPTION

This beautiful, meticulously designed building will be a landmark development in Lagos and the first environmentally certified commercial building in the city. Comprising 15,736 sq. m of office space over eight floors, the large floor plates offer great flexibility and efficiency to the modern occupier and are fitted to internationally recognized Grade A standards.

According to the MD (the managing director of the the solar energy company) the solar system adds the wattage rating of each appliance on the building, it doesn't exceed 1920 W on a 20 A circuit and 1440 watts on a 15 A circuit (ignoring appliances on a dedicated circuit).

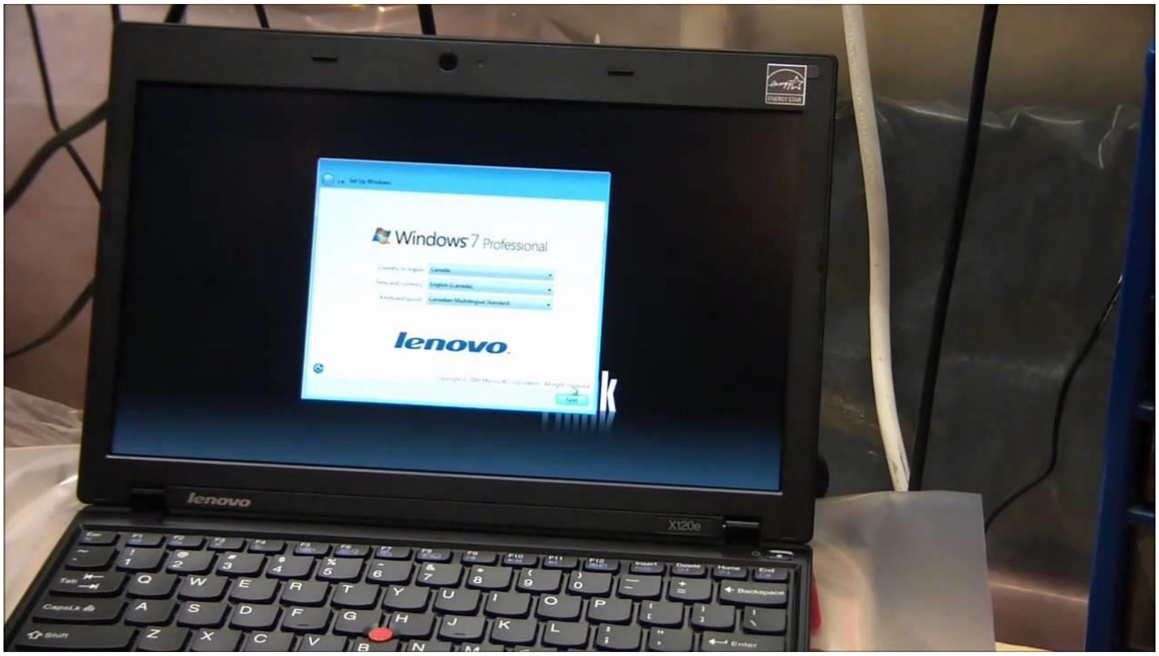
As the first commercial building in Lagos to achieve LEED certification in both design and construction, Heritage Place applies cutting edge technology to fulfil not just today's environmental expectations, but tomorrow's too. There’s an automatic presence detectors and high-efficiency lighting reduce and resupply energy when and where it is needed. The building’s orientation maximizes natural light and ventilation, and minimizes solar exposure, reducing the energy requirements for cooling, heating and air quality systems.

Fig 2: Heritage Place, Ikoyi, Lagos.

3.3.4 APPLIANCES USED IN THE BUILDING.

PERSONAL COMPUTERS:

This an electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program.



DESKTOP COMPUTER

This is the working area of a computer screen regarded as a representation of a notional desktop and containing icons representing items such as files and a wastebasket.

WATER COOLER/ DESPENSER
a dispenser of cooled drinking water, typically used in office workplaces.

COFFEE MAKER
This is a machine or pot for brewing coffee.

AN ELECTRIC TEA KETTLE

An electric tea kettle lets you boil water in an instant and enjoy your choice of beverage whenever you want. There are a variety of options, from stainless steel to glass, so you can pick the one that works for you.

MINI FRIDGE.

A minibar is a small refrigerator, typically an absorption refrigerator, in a hotel room or cruise ship stateroom.

Other appliances include: light bulbs; fans; air conditioners etc.

LIGHT BULBS

a device used to convert electricity into light, consisting of a source of illumination (e.g. an electric filament or one or more LEDs) enclosed within a transparent or translucent shell, typically having a rounded shape and designed to be fitted into a socket in a lamp.

ELECTRIC FANS

An electric fan - a fan run by an electric motor. blower. electric motor - a motor that converts electricity to mechanical work.

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EXTRACTOR FANS

This is a piece of equipment that removes dust, unpleasant smells, etc.

AIR CONDITIONERS.

a system for controlling the humidity, ventilation, and temperature in a building or vehicle, typically to maintain a cool atmosphere in warm conditions.

3.4 CASE STUDY TWO

3.4.1 A 5-BEDROOM RESIDENTIAL BUNGALOW, EJIGBO, LAGOS

HISTORY

This residential building is located at Ejigbo, in Ejigbo Local Council Development Area, LCDA, of Lagos State. The five-bedroom bungalow built has reportedly been off the national grid since 2016. The idea behind such a development was borne out of the need to use alternative means (renewable energy) to tackle the epileptic power supply in the country.

According to Tonade (the managing director of the energy company) the solar system generates 12.6KW of electricity per hour using 63 units of 200W solar modules, three units of 60AMPS MPPT controllers, three units of 3.2KW inverters and 24 units of 200AMPD deep cycle batteries.

Fig 1: completed 5- bedroom bungalow

Source: living spaces

The home is a 5-bedroom bungalow powered by a 12.6KW solar Off-grid system that runs 94 per cent on the power of the sun and six per cent on diesel during cloudy weather. Off-grid means it has been completely disconnected from thermal electricity, and it's been running without a blink since 2016.

APPLIANCES RUNNED IN THE BUILDING

1. **Water heater:** This appliance is a device used for heating up domestic water

2. **Television**

3. Air condition

CHAPTER FOUR

DISCUSSION AND SUMMARY OF FINDINGS

4.0 INTRODUCTION

This chapter deals with the discussion of findings from the study in relation to the purpose of the study which is application of solar power for building efficiency; a case study of Lagos Nigeria.

4.1 DISCUSSION

The initial capital investment for alternative power supply using solar systems is observed to be enormous but on the long run it offers such advantages as quiet operations, environmental friendliness, maintenance free operations and high reduction in cabling for external lighting (Dare-Abel, Oladipo 2010). Onyebuchi estimated the technical potential of solar energy in Nigeria with a 5% device conversion efficiency put at 15.0 × 1014 kJ of useful energy annually. This equates to about 258.62 million barrels of oil equivalent annually, which corresponds to the current national annual fossil fuel production in the country. This will also amount to about 4.2 × 105 GW/h of electricity production annually, which is about 26 times the recent annual electricity production of 16,000 GW/h in the country. In their work, Chineke and Igwiro (2008) show that Nigeria receives abundant solar energy that can be usefully harnessed with an annual average daily solar radiation of about 5.25 kW h/m2/day. This varies between 3.5 kW h/m2/day at the coastal areas and 7 kW h/m2/day at the northern boundary. The average amount of sunshine hours all over the country is estimated to be about 6.5 h. This gives an average annual solar energy intensity of 1,934.5 kW h/m2/year; thus, over the course of a year, an average of

6,372,613 PJ/year (approximately 1,770 TW h/year) of solar energy falls on the entire land area of Nigeria. This is about 120,000times the total annual average electrical energy generated by the Power Holding Company of Nigeria (PHCN). With a 10% conservative conversion efficiency, the available solar energy resource is about 23 times the Energy Commission of Nigeria's (ECN) projection of the total final energy demand for Nigeria in the year 2030 (ECN 2005). To enhance the developmental trend in the country, there is every need to support the existing unreliable energy sector with a sustainable source of power supply through solar energy. In Nigeria, a lot of energy is wasted because households, public and private offices, as well as industries use more energy than is actually necessary to fulfill their needs. One of the reasons is that they use outdated and inefficient equipment and production processes. Unwholesome practices also lead to energy wastage.

In Nigeria, the need for energy is exceeding its supply. In view of these circumstances, primary energy conservation, rationalization, and efficient use are immediate needs.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion

From the energy outlook of Nigeria, it is very clear that the energy demand is very high and is increasing geometrically while the supply remains inadequate, insecure, and irregular and is decreasing with time; the mix has hitherto been dominated by fossil resources which are fast being depleted apart from being environmentally non-friendly. The energy supply mix must thus be diversified through installing an appropriate infrastructure and creating full awareness to promote and develop the abundant renewable energy resources present in the country as well as to enhance the security of supply. The major challenge is an inefficient usage of energy in the country. Though solar is popular in Nigeria. Its use in homes is not spread across all homes due to its affordability. However, solar energy is reliable and has low maintenance costs. They also do not emit greenhouse gases (GHG).

5.1 RECOMMENDATION

In this study, it is established that renewable energy and energy efficiency are two components that should go together to achieve sustainable development in Nigeria. The need to conserve the present energy generated in the country using energy-efficient products and the appropriate practices is essential for sustainable development. Therefore, it is recommended that the country should do the following:

1. Develop policies on energy efficiency and integrate them into the current energy policies. A comprehensive and coherent energy policy is essential in guiding the citizens towards an efficient usage of its energy resources.

2. Promote energy-efficient products and appropriate practices at the side of the end users and energy generation.

3. Create awareness on renewable energy and energy efficiency.

4. Establish an agency to promote the use of energy-efficient products and ensure the appropriate practices.

5. Develop and imbibe energy efficiency technologies (Carry out a resource survey and assessment to determine the total renewable energy potential in the country as well as identify the local conditions and local priorities in various ecological zones).

6. Establish a testing and standards laboratory for renewable energy technologies similar to that in South Africa.

7. Establish a renewable energy funding/financing agency such as India's Indian Renewable Energy Agency.

8. Develop appropriate drivers for the implementation of energy efficiency policies.

9. Clean energy facilities should be embraced in the different sectors of the Nigerian economy.

10. Be plain and blunt sit to the possibilities of the photovoltaic solar power.

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