A Contemporary Study on Solar Energy Applications and Evaluation in Real-Time Environment

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***Abstract*— Solar energy is a primary source of green energy. It supplies an abundance of power in order to meet energy demands for a large scale of applications. The objective of the paper is formulated as follows: (a) the applications of solar energy systems in various domains are reviewed. (b) a case study is conducted to investigate the significance of an optimized solar power plant installed in our research centre. (c) a comparative study has been done to measure the performance of optimized solar panels with the existing traditional Photovoltaic (PV) panels. The outcome of this experimental study demonstrates the efficiency and significance of optimized solar plants, in terms of, energy production over the traditional method. The ground truth energy data collected from both traditional panels and optimized panels are analyzed and the visualization of results illustrate its effectiveness.**

Keywords— Green energy, on-grid/off-grid architecture, Photovoltaic panels, Renewable resource, Solar power system.

I. INTRODUCTION

Solar energy is the most abundant renewable resource. It is a clean and green energy source that supports to achieve energy security of a nation. Earth receives the solar energy in the form of light and heat and it is converted into electricity. The usage of solar energy is increasing in the world wide. China leads the world as the top producer of solar energy with 80%. Denmark, Germany, Austria, Spain, as well as Japan and India, are ranked as next top solar energy producers. India generates 34% of the solar energy used worl dwide, placing it fourth overall and third in Asia.

In India, more than 150 industries use solar technologies to alternate their energy sources. Fig. 1 shows the statistical report of top ten solar producing countries in the world wide [1].

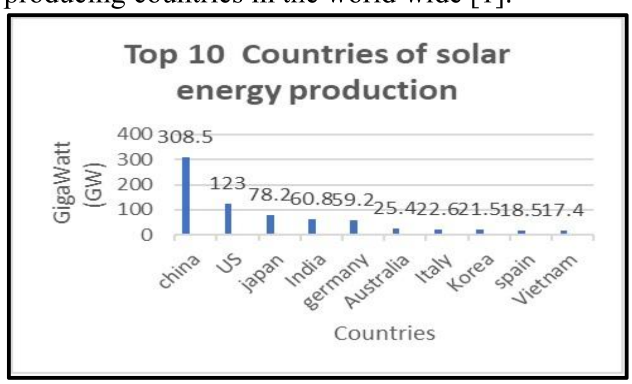
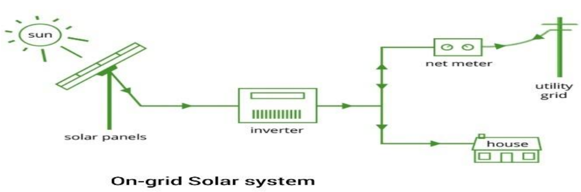
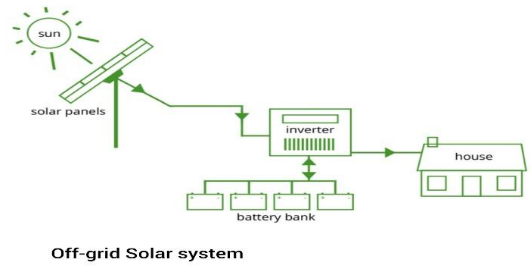


Fig. 1. Solar energy production (GW) of top 10 countries in 2021

Solar energy utilized in various applications such as industrial, commercial, domestic, transports, health services, farming, education and so on. It is useful to reduce CO2 emissions, maintain pollution free environment, and improve sustainability. The development of solar-powered smart cities can help people live better lives, spend less money on energy, and save time. To satisfy the rising energy demands, solar energy utilization is steadily developing. In order to use the power produced each day when there is no sunlight to generate it, solar batteries are employed to store it. The amount of electricity going from solar panels to a battery is controlled by a charge controller. On-grid, off-grid, and hybrid solar systems are the three primary categories of solar power systems. A solar system that is connected to the grid by a utility. It is considered as an alternative promising and consistent energy source to meet the high energy demand. The major components of solar panel system consists of solar panels, solar energy system disconnects, inverters, Solar power meter, solar batteries and charge controllers. Solar panels generate Direct Current (DC) power from the sun. Solar power system disconnects are the electrical switch that complete or interrupt a flow of DC electricity. Inverter's convert Direct current (DC) electricity into Alternating Current (AC) electricity. Solar power meter can measure solar power in units. It helps to understand and monitor the performance of solar system. It is used to run the various appliances. Off-grid solar systems are not connected to the utility grid and uses an additional battery system. The energy stored in batteries, then be used during the night or when it is cloudy. A hybrid solar system is grid-tied and includes battery storage. It is used to produce energy during the day, while the batteries store energy for use and later at night when there is no sunlight. Fig. 2 shows the types of solar energy grid architecture[2][3].





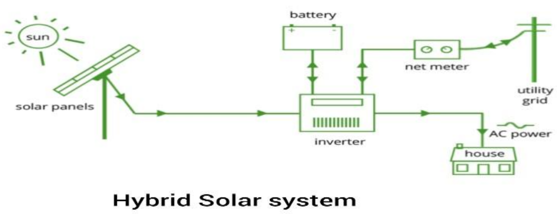


Fig. 2. Types of solar grid architecture

There is a continuous improvement in advancements in the technology used to create solar energy. Solar energy technologies to become increase in the cost competitive with conventional electricity generation technologies over the next decade.

Solar energy systems use the sun's energy to gener ate Power. Solar panel technologies are evolved into three generations depending on the material. It is shown in TABLE I.

Currently, there are three primary types of solar p anels for sale: Thin-film solar panels, monocrystalline solar panels, and polycrystalline solar panels. Wafers that make up a single crystal provide the basis of the mono-crystalline.

Efficiency ratings of monocrystalline solar panels range from 17% to 22%. Polycrystalline solar panels are based on Multiple crystal combined with each other. It is less efficient than mono-crystalline. Polycrystalline panels are within the average, hitting around 15% to 17%. Thin-film solar panels are made from cadmium telluride (CdTe). The thin film is inexpensive and more flexible than crystalline solar cells[4].

The major contribution of the paper is listed as follows.

(a) Literature survey is conducted to analyze the significance of solar energy utilization, technology evolution in making PV panels and its importance in smart city developments, improving the sustainability and well-being of living beings. Advancements in solar energy system were improved rapidly. The improved technologies of solar were harnessed for specific uses inside businesses and homes. The economical progress of a nation is strongly correlated with the availability of sustainable solar energy.

(b) The availability of solar renewable resources increased higher financial rewards that enhance the standard of living and improve livelihood. Electricity requirements for home utilities, the operation of electric cars, as well as cooling and heating needs are all met by solar photovoltaic technology. Performance evaluation of traditional panels and optimized panels are investigated in the real time environment. An optimized solar panel have a number of advantages than traditional for maximize the efficiency and performance. To determine the significance of solar energy and its implications for a real-time analysis of solar panels, a case study was done. In this study, section 2 is a brief discussion of literature review of solar energy technologies, Section 3 describes a comparative analysis of a traditional and optimized panels performance and Section 4 explain the conclusion of this work.

II. LITERATURE REVIEW

The abundant availability of solar energy is widely applied for the sustainable development of society. Various real-world applications of solar energy are industry, commercial, education, medical, governance and so on. The key applications which laid a foundation are shown in Fig. 3. It is useful to improves the livelihood in four different sustainability perspectives namely human, social, economic and environment.

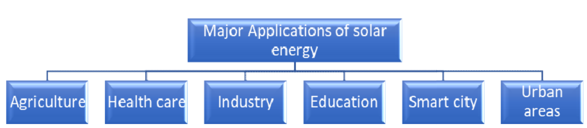


Fig. 3. Major applications of solar energy

A. *Agriculture*

Reda Hassanien Emam Hassanien et al. (2016) investigated and examined the use of PV control systems in greenhouses. Heating, cooling, and lighting systems were used in greenhouse environmental management. Heating systems circulate heat to plants using fans, heaters, and pumps. The generated heat was used to maintain temperature at night to heat greenhouses. Fans are used to circulate air throughout the greenhouse. Heater distributes warm air evenly throughout the greenhouse. Pumps is used to spray water around greenhouse. A cooling system was applied to decrease the accumulated heat energy in greenhouse. It provided conditioning air for a greenhouse. In lightning systems the solar panels provides necessary light through photosynthesis. A solar-powered water pumping system was employed for agriculture and drinking water needs. In order to pull water from an open well, borewell, pond, canal, etc., it operates by converting solar energy into electrical energy. Inexpensive greenhouse applications (cooling, heating, lighting, and irrigation).

The environmental control systems maximize the plant growth and improves plant life by providing a constantly monitored atmosphere. This help the farmers to increase the productivity of crops, reduces electricity bills and great effect on increasing yield [5].

Mohammad vahedi torshizi et al. (2017) investigated different types of solar application systems. In agriculture solar energy was used in solar dryers, a solar home, ventilation and greenhouse. Crops, vegetables, and fruits had their moisture content reduced using solar dryers. In solar drying technology, the air in the atmosphere is heated in a solar collector before flowing through a chamber containing the items. A solar home is outfitted with photovoltaic panels, which are mounted on the roof or walls and use the sun's energy to produce power. Solar batteries connected to PV systems are frequently used in solar-powered homes to store the energy generated by solar panels. In agriculture, ventilation systems were employed to remove heat that had built up inside greenhouses by exchanging the warm air there with the cold air outside. Solar cookers, converts sunlight to heat energy which is used for cooking purposes. Solar water heaters were used to generate hot water for homes. Even in unfavorable weather, the solar-powered greenhouse provides the optimal climate for plant growth. Solar dryers outperform open-air techniques in terms of product quality, grain and fruit and vegetable protection, loss reduction, faster and more uniform drying, and loss reduction. In rural areas solar homes are useful to deliver electricity where electric grids are unavailable. Ventilation systems control temperature and humidity and to remove gases that are harmful to plants. This ensures that ventilation keeps the air fresh and healthy indoor environment. Solar cooker was rich nutrition. The solar water heaters helps to reduce electricity bills. A building used in agriculture to cultivate plants of the highest caliber is the solar greenhouse [6].

Ghulam Hasnain Tariq (2021) spoke on the cutting-edge solar technologies that are currently available to address the energy needs of agricultural machines and irrigation systems. The chemicals were sprayed using a pump known as a solar-operated pesticide sprayer. These machines have direct solar illumination options and rechargeable batteries, making them simple for farmers to handle and carry. Through solar fertilization, dinitrogen is transformed into various nitrogen compounds that serve as plant nutrition. Tractors with solar power were useful for farming. It uses solar-powered electricity to operate. Agriculture items are dried using sun dryers. Solar-powered water pumps would help farmers save countless hours of labor. Grain and fruit are protected by solar dryers, which also reduce losses and dry items more quickly and evenly. Farmers need to perform less physical effort thanks to solar pesticide sprayers. Solar fertilizers will enhance agriculture in rural areas of emerging nations. Farmers can use solar tractors to lessen their reliance on costly fossil fuels. This car is environmentally friendly [7].

Surendra Poonia et al. (2018) looked into how solar energy is used to produce and digest food. In order to meet the energy requirements for processes like solar PV pumping, PV spraying and dusting, drying, winnowing, and cooking, the renewable and environmentally beneficial solar energy was used. A solar-powered sprayer was utilized to apply liquid agricultural pesticides. To control weeds, pests, and insects on greater tracts of agriculture, solar PV dusters spray chemicals. Farmers can clean their threshed materials in the simplest way possible by using solar PV winnowers. It distinguishes between grain and straw. Animal feed cooked in a solar cooker and fed to dairy animals The digestion and nutritional quality of the animal feed is improved by boiling the feed. Crop diseases can be avoided by using a solar PV sprayer and duster. Additionally, it is employed to preserve plants and increase crop output. Farmers can clean their threshed materials in the simplest way possible by using solar PV winnowers. Solar-powered feed cookers for animals maintain the food's nutritious value and enhance farm operations [8].

Farha Rafath et al. (2020) implemented the advanced techniques for smart farming using solar. Solar powered Agricultural robot performs multiple tasks in the agriculture field such as seeding, spraying pesticides, harvesting, grass cutting. Solar cells are integrated into the robot's structure and power is generated through photovoltaic effect. It facilitates the farmers to ease their work. and replaces human labor [9].

B. Healthcare

Hamish Graham et al. (2016) explained about Solar powered medical devices were commonly utilized in health care center Oxygen therapy used to prevent deaths from pneumonia and other illnesses in new born children and adults. Refrigerators were used to store the vaccines, Surgery Suction Machine, Radiant Heater could be connected in the panel, Phototherapy unit for treating Jaundice pressure swing is separate the oxygen and other air. Health care and medical industry used the power is not only need for oxygen therapy its use other basic equipment. It reduces cost Provide safe and effective services in 24 hours [10].

Using a microscope, Badria Ibrahim Eisa Idris et al. (2021) discussed solar power. By cancelling the transformer with its protective circuit, the transformer converts the AC 6 volt lamb into a DC 12 volt lamb, which powers the microscope. The lamb was lighted by the microscope that was powered by the circuit board. Benefits of a solar-powered microscope: One of the cleanest energy sources, easy to use and maintain, and in tune with the environment. Microscope That used up the meagre power. As a result, it was simple to install and secure to use [11].

According to Yashar Haghighi et al. (2017), solar-powered toothbrushes were used in dental clinics. It was an N-type titanium oxide semiconductor. The TiO2 was connected by a copper wire. was charged positively. Dental caries can be prevented in a large therapeutic way by brushing your teeth. H+ ions from the organic acid are evaporating from these toothbrushes. These hybrids lower the emission of greenhouse gases [12].

Hernandez Guzman et al. (2022) solar powered X-ray used photovoltaic panels to charge the UPS lithium-ion batteries. Ultrasound, air Pollution, waste management these applications are used in solar power. Air filtration prevents the transmission of virus and germs Heating, ventilation, and Air-conditioning systems minimize buildings non-renewable energy consumption [13].

Aditya Ramji et al. (2017) PHC health care used solar energy in neonatal care equipment, health care services, radiant warmer and incubators. It prevents illnesses and death. Improves green energy usage, services were delivered without any hindrance or delay. Better access electricity implying neonatal care equipment. It prevents the children to suffer from illness [14].

C. Industry

Jose Pablo Paredes Sanchez et al. (2018) examined how solar energy was used in the mining sector. The mining industry's usage of solar energy was an element of the transition to a low-carbon economy. a cost-effective option for miners who crush, mine, and process materials. Solar energy is becoming a more important source of electricity for mining businesses at outlying locations. Mining firms, which are frequently found in distant places, can increase the dependability of their operations by using this off-grid energy source. Photovoltaic panels, which are incredibly dependable, can also be utilized as a backup power source. Costs are decreased while CO2 emissions are decreased. It reduces environmental risks and improves the resilience of mining sites [15].

Badreddine Boutaghriout et al. (2013) discussed solar heaters used in agroindustry for drying and dehydration process. The uses of solar water heater in agroindustry such as heating, steaming, pasteurization, boiling etc., The heat supplied to a manufacturing process in the form of hot water, air flow, or steam. It helps to reduce the dependence of fossil fuels. and it increases profit/revenues [16].

Fabio Rizzi (2016) analyzed the heat recovery system of a cement plant and solar thermal plant in Morocco. Waste Heat Recovery technology can generate up to 30% of total plant electricity needs by utilizing residual heat in the exhaust gases generated during the cement manufacturing process. The thermal waste energy from the exhaust is converted into electrical power by the solar thermal plant. It improves power reliability, which is especially important in areas with weak electric grids, and it boosts plant competitiveness in the market [17].

Meisam Sadi (2020) discussed, Solar cold storage allows for the efficient use of solar energy for cooling fruits/vegetables and other items. It is used for pre-cooling and storing the perishable items. It preserves them for longer duration. Cold storage protects foods from microbial organisms. Prolonging shelf life of fruits and vegetables. It keep products as long as you need [18].

D. Education

Ramana et al. (2015) discussed solar power use educational institutes and supply Labs and exams in this power used professional colleges like engineering and medicine. They used remote control devices and sensor to automatically control appliance in the classroom. It greatly cutting electricity bills. Batteries are used to save the excess energy to the battery [19].

HakanTerzioglu et al. (2014) explained about serial and parallel solar panel how to obtain the energy and work Solar power directly supply to the computer systems, motors, and water pumps. Minimum maintenance charges Improved lighting provides an opportunity for children to spend more time on their studies [20].

FadhilOleiwi et al. (2021) described about Education institute use solar power and supply in different kinds of applications namely Air conditioner Lamp, fan, water pump server, printer, laptop, mobile charger. Air conditioner reduce the energy demand It use the power directly to the server and it save the current. they use batteries to save the power. It ultimately reduces green house gas emission [21].

Faris Alfaraidy et al. (2017) described Most of the education institute use solar energy in lights, fans, air conditioner and printer. Government bodies offered subsidiary and support to install the solar panels in school. It was abundantly available resources [22].

E. Smart City

Sangeetha DebBarmanet al. (2020) explained A microwave-based wireless power transmission system is a system, that includes a satellite-based Solar Power System (SPS). This system converts solar energy into microwaves and beams them to a receiving antenna on Earth for conversion to regular electricity. Satellite-based solar power systems were advantageous in meeting increasing power demand while lowering CO2 emissions, future generation demand, reliability, efficiency, and sustainability [23].

Syed Ghouse et al. (2022) described, Solar energy was used to develop a smart irrigation System, smart traffic signals, An intelligent road lighting system in smart cities. Smart irrigation System checked the soil moisture level and spray water based on the requirements of plants. Three or more streets or directions are controlled by the smart traffic signal system. It detected traffic at the same traffic signal intersections across all streets. The system concentrates on traffic signal timing, allocating more time to the direction with the most traffic. A smart street light turned on automatically after sunset after sensors detected the presence of sunlight. The smart system aided in improving the quality of life, lowering costs, saving time, and conserving energy. Many problems, such as traffic congestion, will be alleviated by smart traffic signals [24].

Mr.Hayagrish Balaji (2017) discussed, In smart cities, Solar water heaters, solar street lighting, solar pumps, solar concentrators, and solar traffic signals were used to create electricity from solar energy in homes and on rooftops. Solar energy has a significant impact on the implementation of various programs related to the environment and climate change, the potential for industrial growth and job creation, rural population migration to cities, cultural and life styles [25].

Thulasiraman et al. (2019) discussed about the Applications of solar energy in smart cities: In solar vehicles(Solar cars, trams, buses, Impulse) ,solar energy was used to power all the part of a vehicle's population. Solar cookers use direct sunlight energy to heat, cook, or pasteurize beverages and other food materials. People nowadays rely heavily on gadgets such as calculators and watches. Solar vehicles cut down on fuel costs and pollution. Solar cookers aid in the slowing of deforestation and desertification. Solar panel with high efficiency reduces the maintenance costs [26].

Daniele Menniti et al. (2017) analyzed, Solar energy is used in many technologies such as Ice storage air conditioning system , Solar assisted fluidized bed dryer and solar energy compensation system. Ice storage air conditioning system is used to reduces chiller size and shifts compressor energy, condenser fan and pump energies during the electrical demand. Drying materials such as tablets, powders, fertilizers, and plastics are dried using solar assisted fluidized bed dryers. Ground coupled heat pumps use an air heat recovery and solar energy-combined thermal compensation system (GCHP). This system uses ground heat exchanges in different zones to increase borehole spacing or depth. These technologies aid in economic and financial management, allowing consumers to lower their electricity bills and save money. It contributes to environmental protection by lowering greenhouse gas emissions [27].

F. Urban Areas

Matteo Formolli et al.(2022) conducted research, A case study was carried out in order to deploy solar energy in urban and rural environments throughout the Italian territory.

(i) Alessandria (Photovoltaic Village)

PV roof, PV facade, and PV facilities are examples of energy strategies. An urban scale Italian public residential building project was completed successfully. Photovoltaics cover 100% of common area electricity consumption and up to 70% in apartments.

(ii)Bolzano (SINFONIA) Energy strategies include PV roofs, ST roofs, and geothermal. Bolzano was transformed into a smart city through a European project that retrofitted 34,000 m2 of social housing.

(iii) Trento (Le Albere)

PV roof, PV façade, PV shading, Geothermal, CCHP are all energy strategies (Combined Heating and Cooling Plant).

A large brown field is being regenerated and reconnected to the city's fabric. Construction that is integrated Photovoltaic modules provide project identification and enforcement.

(iv) Brescia (District of Violino)

Energy Strategies: PV Roof, DH (Direct Heating). Bioclimatic design principles were used to create a social housing project. Building volumetric composition and orientation are designed to maximize solar exposure.

(v) Bolzano (Casanova District)

PV roof, ST roof, geothermal, and DH-DC energy strategies (Direct Heating -Direct Cooling).Mobility and social aspects must be considered. Solar and wind were used to design the shape, orientation, and reciprocal buildings.

(vi) Montecelli d'Ongina (Agrovoltaico)

Energy strategies: PV trackers on two axes.

Land can be used twice by combining energy and food production at different layers. The photovoltaic system was designed in a secure landscape to reduce its environmental impact. The main takeaway from this case study is that solar energy is the starting point for design process to achieve a higher level of integration. Another advantage of this analysis of solar energy potential is the ability to optimize urban morphology and building design to maximize solar strategies [28].

Ummah et al. (2021) discussed a roof top solar power plant electricity has become relevant with electricity needs in urban areas such as on Office buildings, houses, malls, hotels, apartments, or flats, Residential areas, Industrial areas such as factories, other places such as, recreational park, museums, schools, universities, hospitals, airports, bus or train stations, libraries. It is pollution free and environmentally friendly and economical. It reduces carbon emission [29].

Babon Pavlovic et al. (2019) analyzed, In the real world ArcGIS geoprocessing tool was implemented to compute complex calculation and mapping. Area Solar Radiation is an ArcGIS tool (ASR). It is possible to calculate the maximum solar radiation energy for a defined area and time interval using the ASR tool and the appropriate input data. It provides a quick estimate of the solar energy potential in a given area. Solar radiation was regarded as a good starting point for further technical and economic analyses of the cost effectiveness of generating electricity or heating [30].

Malgorzata Pietras-Szewczyk (2019) explained, For mapping solar energy resources in urban areas, an open source Geographical Information System (GIS) software application was used. The primary goal of this project is to calculate actual solar radiation in urban areas. To obtain accurate solar radiation maps, it is best to use meteorological data that describes the reduction in solar radiation caused by cloud cover. It was used to compute the daily total of actual solar radiation. It helps to reduce the cost of energy production, enforces energy safety, and promotes the use of renewable energy. In the future, it will be more feasible and will reduce reliance on conventional energy resources [31].

Yang Lv et al. (2014) illustrate A method for 3D modelling tree crowns and quantifying the effect of tree shadows on solar irradiance received by buildings in urban areas. In solar energy potential mapping at an urban neighborhood scale, the Poisson surface reconstruction algorithm was used to derive tree crowns and assess the shadow effect. The solar radiation energy received by a building was calculated using the shadow of a tree. This method could aid designers in determining the suitability of PV installations. The tree crown model can be used to forecast the effect of shading loss in the coming years. Increase the efficiency with which solar radiation is converted into other forms of energy [32].

Solar energy is an excellent source of energy for agricultural farms. Various solar energy absorbing devices and systems have been developed, with agricultural applications. There is a continuous improvement in advancements in the technology used to create solar energy so as more cost effective. Solar energy is used in medical and health care and dental industries. Some medical devices operated by using solar such as in oxygen therapy, microscope, air conditioner, x-ray machine, Surgery Suction Machine, pressure swing machine, water supply and many applications. Solar power is used in health care to generate an electric supply that is used in microscope circuits. Today the higher quality medical equipments are using solar energy. The present work analyses the case of supplying solar thermal energy to an industrial dairy process, mining industries, cement industry and agroindustry. Industries have begun to implement technological developments in solar energy with the goal of reducing the amount of electrical energy absorbed from the grid.. Solar energy reduces carbon footprints and fossil fuel consumption thus saves our planet. Solar energy cuts energy costs and increase productivity in the industries. Solar power used in many application in education such as conventional schools, base case school building, design of solar PV plant economic evaluation of PV system, play back period. In education System used solar power in Air conditioner, lab, library, systems, motors and many appliances. It can be reduce environment pollution. Solar energy plays an important role in the establishment of smart city. Solar energy is used to smart irrigation systems, smart traffic signals, smart street light ,solar vehicles, solar cooker, PV roofs, etc. Several technologies, such as solar-powered ice storage air conditioning systems, solar-assisted fluidized bed dryers, air heat recovery, and solar energy-combined thermal compensation systems, were used in smart cities. The intelligent system will help to improve the quality of life, lower costs, and save time and energy. Solar energy applications in various fields are reviewed. To assess the potential for solar power use in urban areas. Solar energy is a reliable and environmentally friendly source of electricity. Rooftop solar power plant utilization has increased by up to 70% in urban areas. At the moment, many buildings and homes in urban areas have roof-top solar panels installed as an electricity generator. Many developing tools and technologies for integrating solar systems in buildings are being developed in urban areas, such as the Area Solar Radiation (ASR) tool, which provides a quick estimation of solar energy potential for a specific space, Geographical Information System (GIS) Technology for calculating solar radiation, and 3D model tree crowns for checking the suitability in PV installations.

III. CASE STUDY

An optimized solar plant is installed at our institute. It is shown in Fig. 4. A case study is conducted on a solar plant to evaluate the performance of optimized 14 solar trees to measure their efficiency and it is further compared with the already deployed conventional solar plants which is portrayed in Fig. 5. A string consisting of 20 solar panels deployed in administrative block and 14 solar panels installed in CMLI have been considered for analysis. In optimized solar panel each panel produces 220kWh of electricity. Optimizers attached to back of each solar panel to maximize the efficiency of production. This solar system use solar inverters to convert DC power to AC power. The generated AC electricity from the solar inverter is fed straight to the main grid which is used to power various appliances such as fans, computers, lights. From the observational study, it is found that the capacity of 14 solar panels is equivalent to 20 conventional panels. The dataset collected from the two sites is presented in TABLE II on the appendix page. The comparative analysis of solar energy production with respect to time is shown in Fig. 9 and corresponds to temperature is portrayed in Fig. 10. On that day, temperatures are frequently change based on climate change. It is partly cloudy from night time to daytime (12 AM to 2 PM) and mostly cloudy from daytime to night time (2 PM to 12 AM). In the time slab of 1-2 PM noon, it is noted that the performance of traditional panels is slightly worse. Optimized PVs produce better results even though temperature has been reduced. Henceforth, it is analyzed that even though optimized panels have less capacity and less number of panels it has high efficiency than traditional panels.

Fig. 4. A view of optimized solar power plant

Fig. 5. Aerial view of the solar array traditional installed solar panel

The Solar visualization is available as a web portal as well as a mobile app. The web portal provides perfect overview of all photovoltaic systems and displays data clearly in dashboard. A solar monitoring mobile app estimates information of energy consumption as well as generation. With the help of these two applications, we can track the energy yields by the solar panel. These two applications become more user friendly. The energy monitoring using dashboard and mobile app is given in Fig. 6 through Fig. 8.

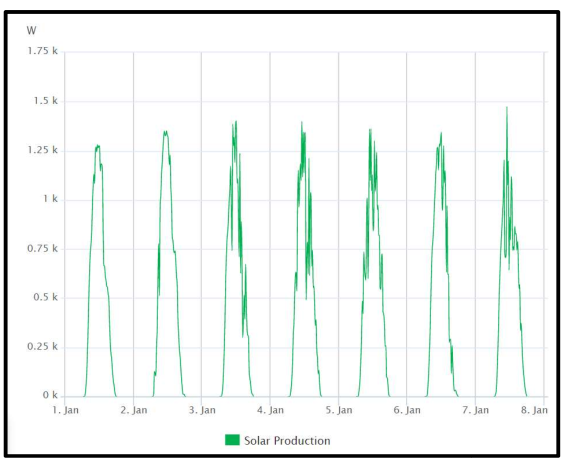


Fig. 6. Solar power production monitoring using web portal

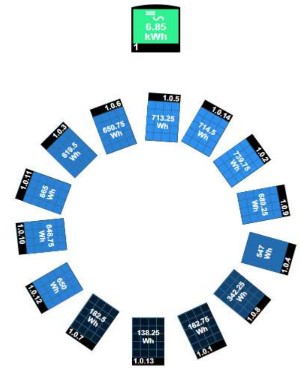
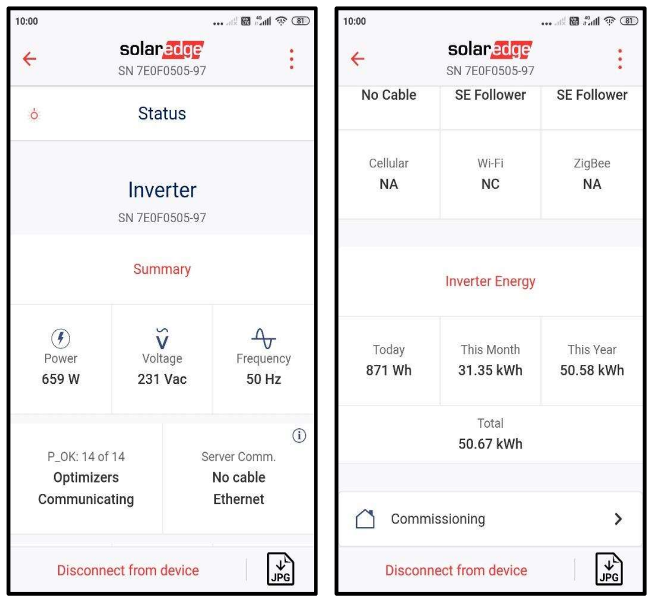


Fig. 7. Panel wise energy production monitoring



(a)Visualizing the power production

(b) Report generation

Fig. 8. Mobile application for monitoring solar energy production

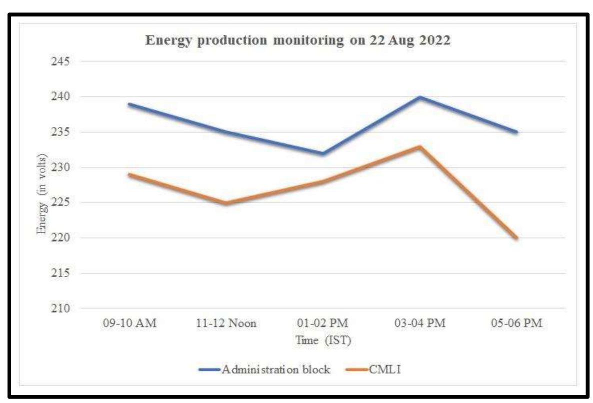


Fig. 9. Comparative analysis of energy production monitoring corresponds to the time

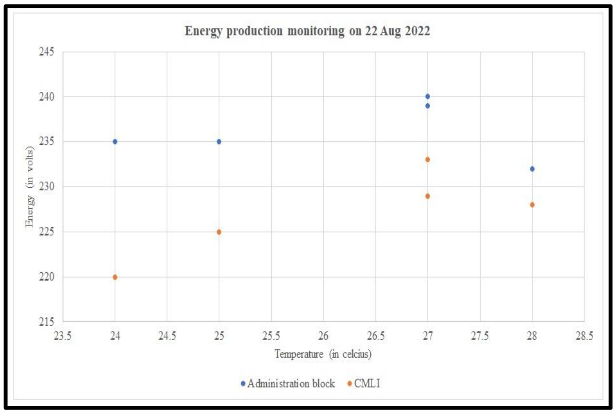


Fig. 10. Comparative analysis of energy production monitoring corresponds to the temperature

IV. CONCLUSION

In this paper, literature review on solar technologies applications in various domains namely agriculture, health care, education, industry, smart cities, residential areas are discussed. A case study is conducted to evaluate the effectiveness of optimized panels over traditional approach. It is analyzed that Optimized PVs produce better results than traditional panels. This study illustrates the tremendous technological improvements in the applications of solar energy in diverse domains. It is greatly improves sustainability, clean energy, reduce cost and it is considered as a predominantly needful resource in the development of smart cities and eco-friendly environment to meet the energy demands in the world.

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REFERENCES

[1] https://en.wikipedia.org/wiki/Solar power in India

[2] https://www.renogy.com/blog/what-are-the-main-components-of-a solar-power-system/

[3] https://www.solarsquare.in/blog/solar-system-types-and-benefits/

[4] https://www.solarreviews.com/blog/pros-and-cons-of-monocrystalline-vs-polycrystalline-solar-panels

[5] Reda Hassanien Emam Hassanien, Ming Li, Wei Dong Lin,"Advanced applications of solar energy in agricultural greenhouses", Renewable and Sustainable Energy Reviews,54(2016)989–1001.

[6] Mohammad Vahedi Torshizi , Atefeh Hosseini Mighani,"The Application of Solar Energy in Agricultural Systems", Journal of Renewable Energy and Sustainable Development (RESD) Volume 3 Issue 2, June 2017 -ISSN 2356-8569 http://dx.doi.org/10.21622/RESD.2017.03.2.234

[7] Ghulam Hasnain Tariq, Muhammad Ashraf, Umar Sohaib Hasnain,"Solar Technology in Agriculture",DOI: http://dx.doi.org/10.5772/intechopen.98266,(2021)

[8] Surendra Poonia, Dilip Jain, P. Santra, A.K. Singh,"Use of solar energy in agricultural production and processing", Indian Farming 68(09): 104–107, (2018)

[9] Farha Rafath, Sohel Rana, Syeda Zaara Ahmed, Juveria, Raaheka Begum, Nishad Sultana, "Obstacle Detecting Mutifunctional AGRIBOT Driven By Solar power" in-IEEE conference, ISBN:978-1-7281-5518-0,(2020)

[10] Hamish Graham,Charlotte Duke,David Peel (Et.al). Solar power used oxygen theraphy, Tuberculosis and Lung Disease: Hamish Graham May 2016 DOI: 10.5588/ijtld.16.0210.

[11] Badria Ibrahim Eisa Idris, Ahmed Mohamed, Ayah Salah,Osman Abdalrahman Almahdi Alamin, Fatehia Garma and Alnazier Osman (Et.al).Application of solar energy in medical instruments (Microscope) :Badria Ibrahim DOI: http://dx.doi.org/10.5772/intechopen.97177

[12] Yashar Haghighi Bardineh, Fatemeh Mohamadian, Mohammad Hossein Ahmadi and Nazila Akbarianrad.Publication 18 August 2018,Yashar Haghighi Bardineh DOI:10.1093/ijlct/cty040.

[13] Hernandez-Guzman,Vizcarrondo-Ortega.A,Bosman.L.B.McNealey.A. Solar energy implementation for Health Care facilities in developing and undevelopingcountires. Hernandez-Guzman 2022 DOI:https://doi.org/10.3390/en15228602

[14] Aditya Ramji,SasmitaPatnaik,SunilMani,and Hem H.Dholakia .powering primary Healthcare through Solar in India.Aditya Ramji july 2017

[15] José Pablo Paredes Sánchez,Solar Energy Applications in Mining: A Case Study,https://doi.org/10.1007/978-3-319-54199-0_15,2018 .

[16] BadreddineBoutaghriout, Amina Bouakaz, Chaiibane Hamouda, Hacene Smadi,AliMalek,"Investigation on the use of solar thermal energy in theagro food industry in Algeria",2013

[17] Fabio Rizzi, Clotilde Rossi di Schio,"Hybrid ORC Waste Heat Recovery System and Solar Thermal Plant in Ait Baha, Morocco ", (2016), DOI 10.1109/TIA.2016.2614955, IEEE Transactions on Industry Applications

[18] MeisamSadi, Ahmad Arabkoohsar,"A 5TR Solar FPC-Cold storage for Year-Round Waste Prevention of food Products in Off-grid Areas",8th International Conference on smart Energy Grid Engineering,2020

[19] P.V.Ramana, Sudheer Prem Kumar.Volume 1, Issue 4, July-2015, ISSN(Online) 2395-566X .Solar energy used in domestic, Transportation, Agriculture and Industrial Field P.V.Ramana published on 08 December 2016 DOI:10.13140/RG.2.2.12177.02402

[20] HakanTerzioglu,MuratSelek,FaithalpaslanKazan:Murat Selek on 09 September 2015 for this publication at: https://www.researchgate.net/publication/280877329 The Designing of an Educational Solar Panel That Can Be Controlled in Different WaysDOI:10.1109/ICISCE.2015.217

[21] Fadhil M.Olewi,AhmedF.Atwan stats, this publication at: https://www.researchgate.net/publication/311857621Connecting Education and Research: Introducing RRI in Solar Energy Non-formal Educational Activities DOI: 10.1088/1742-6596/1879/3/032070 Fadhil M.Oleiwi on published on 31 August 2021

[22] FarisA.Alfaraidy,Hassan A. Sulieman-2017:http://dx.doi.org/10.14500/aro.10461. The Economics of Using Solar Energy: School Buildings in Saudi Arabia as a case study.

[23] Sangeetha DabBarman, Shruthi Gupta, Om Prakash Das, ”A Review: Space Based solar power in development of smart city”, International conference on recent trends in Artificial intelligence, IoT, Smart cities& Applications(2020).

[24] Syed Ghouse, ”A smart city development based on renewable energy sources”,Volume:04/Issue:06/June-2022, ah Research Journal of Modernization in Engineering Technology and science,www.irjmets.com.

[25] Hayagrish Balaji, ”The journey in making ‘smart cities’ smarter with solar energy”,International journal of new technology and research ISSN:2454-4116,Volume-3,Issue-3,March 2017.

[26] Thulasiraman, Mohamed Habibullah.O.M, ”Solar energy applications in smart cities”,Volume6,2019,Journal of Emerging Technologies and Innovative research,www.jetir.org(ISSN 2349-5162).

[27] Daniele Menniti Angel A. Bayond-Rujula, Alessandro Burgio, Diego A.L.Garcia, and Zbigniew Leonowicz, ”Solar Energy and PV systems in Smart Cities”, Hindawi International Journal of Photoenergy,2017,DOI:https://doi.org/10.1155/2017/3574859.

[28] Formolli, M.; Croce, S.; Vettorato, D.; Paparella, R.; Scognamiglio, A.; Mainini, A.G;Lobaccaro, G. ,”Solar energy in Urban planning: Lesson learned and Recommendations from six Italian Case studies”,Appli.Sci.2022,12,2950.DOI:https://doi.org/10.3390/app12062950

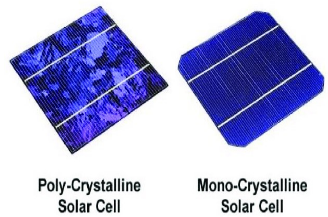
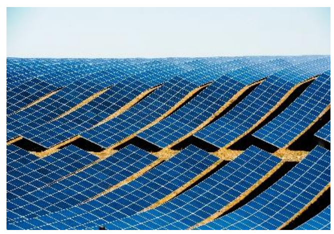
[29] H F Ummah ,R Setiati, Y B V Dadi, M N Ariq and M T Malinda,”Solar energy as natural resource utilization in urban areas: Solar energy efficiency Review” ,IOP Conf. Series: Earth and Environment Science780(2021) 012007,DOI: 10.1088/1755-1315/780/1/012007.

[30] Boban PAVLOVIC, Milica PESIC-GEORGIADIS, ”The application of ArrcGIS for assessing the potential of solar energy in urban area: The case of Vranje”, 12 th international conference on Energy and Climate change, 9-11 October 2019.

[31] Malgorzata Pietras-Szewczyk, “A GIS open source software application for mapping solar energy resources in urban areas”,E3S Web of Confereneces116,00060(2019),DOI://doi.org/10.1051/e3sconf/201911600060.

[32] Yang Lv, Xianferg Zhang, Yu Liu ,”3D modelling of tree crowns and ats application in solar energy potential mapping for urban neighbourhoods”,2014 IEEE, DOI : 978-1-4799-5775-0/$31.00.

TABLE I. GENERATION OF SOLAR PV PANEL

S.No.	Type	Image	Generation	Functionality
1.	Monocrystalline (Mono c-Si) Polycrystalline (Poly c-Si)		First Generation	Silicon crystal is involved in this technology.
2.	Thin Film Solarcells(TFSCs)		Second Generation	Solar cells made by one or more thin layers, or thin film of photovoltaic material on a substrate such as glass, plastic or metal.
3.	hybrid polymer and perovskite SCs.		Third Generation	Solar cells are based on semiconducting organic material such as polymer.

APPENDIX

TABLE II. AN OBSERVATIONAL STUDY OF SOLAR ENERGY PRODUCTION

S.No.	Date	Day	Time slab	Actual time	Temperature (in °C)	Solar energy (in Volts)	
						Administration block	CMLI
1.	22-08-2022	Monday	9-10 AM	9:57	27	239	229
				9:45			
			11-12 Noon	11:16	25	235	225
				11:10			
			1-2 PM	1:51	28	232	228
				2:06			
			3-4 PM	3:41	27	240	233
				3:32			
			5-6 PM	5:45	24	235	220
				5:59			
2.	23-08-2022	Tuesday	9-10 AM	9:30	24	233	231
				9:20			
			11-12 Noon	11:33	28	232	229
				12:06			
			1-2 PM	2:02	29	241	237
				1:52			
			3-4 PM	3:25	25	238	228
			5-6 PM	5:48	27	234	230
3.	24-08-2022	Wednesday	9-10 AM	9:58	25	234	232
				9:51			
			11-12 Noon	12:14	27	238	230
				11:58			
			1-2 PM	1:58	26	240	236

				2:08			
			3-4 PM	3:40 3:31	27	239	236
			5-6 PM	5:37 5:27	25	237	235
4.	25-08-2022	Thursday	9-10 AM	9:50 9:59	27	229	228
			11-12 Noon	11:35 11:26	28	234	229
			1-2 PM	1:58 1:50	28	241	234
			3-4 PM	3:36 3:29	30	236	235
			5-6 PM	5:35 5:50	26	231	229
5.	26-08-2022	Friday	9-10 AM	9:50 9:45	27	236	229
			11-12 Noon	11:50 11:40	28	232	230
			1-2 PM	2:08 1:54	28	240	235
			3-4 PM	3:30 3:19	30	242	231
			5-6 PM	5:50 5:41	26	237	228
6.	27-08-2022	Saturday	9-10 AM	9:15 9:05	24	238	235
			11-12 Noon	12:22 12:07	25	239	229
			1-2 PM	2:22 1:51	25	237	229
			3-4 PM	3:50 4:17	29	242	238
			5-6 PM	5:45 5:35	29	239	239
7.	28-08-2022	Sunday	9-10 AM	9:59 9:50	24	234	233
			11-12 Noon	11:21 11:10	26	237	229
			1-2 PM	2:05 1:57	29	243	236
			3-4 PM	3:34 3:21	30	228	237
			5-6 PM	5:50 5:59	21	219	210