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Recent Advances in Solar Energy Harvesting by Improving Efficiency and Storage

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ABSTRACT

For confronting the majority of today's mankind needles, this paper considers some under-developed and current methods or techniques for advancing solar (sunlight) energy harvesting. Usually, modern energy or power systems presume continuous accessibility of energy, but the energy of the sun or sunlight isn't available or accessible at night time. So, storage of energy nowadays is an imperative concern. Moreover, the usage of current solar power is not so cheap it causes high production costs. Therefore, there is a need to introduce substantiate solar energy harvesting methods to improve efficiency and reduce costs. Therefore, this research highlighted that storage of solar energy can surely be increased by using flywheels or superconducting magnets, mimic. To uplift the storage of solar energy at night time antennas can be used. Moreover, solar energy efficiency can be surely increased by using gold nano-particles, changing solar panels connects ways.

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1. Introduction

Nowadays, wireless sensor networks (WSNs) accessing much popular and are being extensively used. In the globalized world of IoT (Internet of Things), the WSN system works as a fundamental structure block. However, Wireless Sensor Network (WSN) nodes endure major design restraints that are limited battery energy and they work only for a couple of days. Therefore, in this paper researcher tries to present proficient solutions for solar energy harvesting to limit the major design problems. Energy harvesting is a process in which ambient energy is first captured and then converted into voltage or electricity for autonomous electric devices without the power needed for the battery. Applications of Energy harvesting reach from the motor vehicle to the smart grid.

There are two key technological drivers behind the wireless sensor networks (WSN) that are ''energy harvesting'' and "energy management". Harvesting of energy from ecological power resources, for instance, thermal, solar, mechanical, wind, and many others are initialized from standpoint of power supply to wireless sensor networks (WSN) systems. Whereas power management of wireless sensor networks (WSN's) for instance routing protocol design, MAC protocol design, and the management technology of dynamic power are documented from the standpoint of energy management within wireless sensor networks (WSN).

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The ability to utilize and harness solar energy has significantly increased, since the mid of 20th century. This makes use of renewal sources of energy possible for businesses and homes rather than depending on some traditional power harvesting means. The competence of sunlight energy is that it uses the power of energy from the sun and then, forwards it into prevailing electrical networks. The competence of solar energy results largely because solar energy keeps the gains of renewable power (the sun) distinct from the traditional solutions for energy that utilize fossil fuels.

Generally, solar technologies are characterized as either active or as passive relying on the manner energy is captured, converted, and distributed. Active techniques utilize photovoltaic panels, fans, and pumps to convert energy into meaningful output. Furthermore, passive techniques include the selection of materials with favorable thermal properties, space design that unsurprisingly circulates the air, and referencing the building position to the Sun. Active solar technologies raise energy supply that's why considered "supply side technologies" whereas passive solar technologies decrease alternate resource needs that's why considered "demand side technologies".

Nowadays, solar power is utilized in multiple different ways. Although, currently there are two broad manners by which solar energy is being utilized. The first one is 'photovoltaic conversion' (known as a solar panel). Solar panels are utilized to produce electrical energy straight from the sun. The second one is "thermal solar energy" which uses sunlight to heat the fluids, and power turbines and other machinery kinds. Research about the applications and devices of solar energy proceeds to improve, along with the initialization of more cost-effective methods to incarcerate and store energy for future usage perspective.

2. Calculation of the Solar Energy Costs

Two decades ago, the costs of solar energy harvesting are seven (7) times higher than the other energy sources. Technological Advancement contributes significantly to decreasing the costs but still can't reduce them to a large extent. Hydrocarbon fuel costs are considerably low (without tax benefits, rebates and carbon emissions costs) as compared to solar energy. A 2-Kilowatt sunlight power system charges about € 33,880 and fulfills approximately half of a typical individual household's power needs.

At "€ 33,880", the sunlight power system equates to "€ 6,780" a kilowatt (kW). The "€ 6,780" a kW for sunlight energy isn't very accommodating in comparison to the expenses of electricity generation by other fuels like gas or coal. As coal, gas, and oil are calculated per kWh cost, solar costs must be calculated on the same basis (kW). A sunlight power system includes the 20-30 year lifetime and available sunlight hours. The available hours depend on climate, temperature, unblocked disclosure to sunlight, latitude, tilt panels' ability towards the sunlight, and seasonality. Based on average, around 3.6 Sunlight Peak hours (per day) provide a realistic proxy for calculating the average annual production of energy from the power panels.

One-ton of coal = 6,128 kilowatt hours
One barrel of oil = 1,699 kilowatt hours
One cubic of foot gas = 0,3 kilowatt hours

2.1 Cost of Energy

One-ton of coal (€ 27, 1) = 0,006 per kilowatt hours
One-barrel of oil (€ 52, 7) = 0, 05 per kilowatt hours
One-cubic of foot gas (€ 0,006) = 0, 03 per kilowatt hours

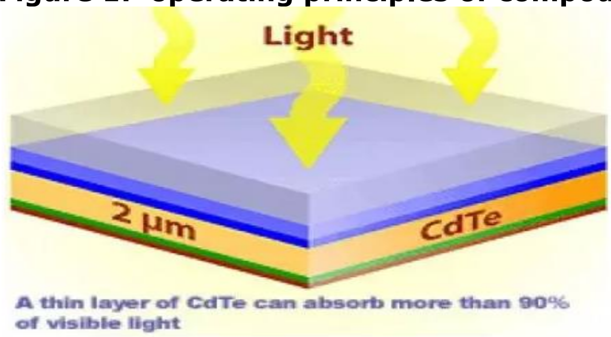
3. Measures to Reduce the Solar Energy Costs of Production

By examining the following scientific measures, solar energy costs can be reduced significantly;

- Usage of cheaper silicon devices
- Use a few layers of semiconductor

- Semiconductors produced from ‘‘compound cadmium telluride’’ are less expensive to create thin-film sunlight cells with the "cadmium telluride" despite using silicon. Indeed, a solar array covers the half cost of today’s solar system.

Figure 1: operating principles of compound cadmium telluride



CdTe in the solar panel field is the cheap cost leader. In CdTe top layer of the panel is known as "p-type" cadmium sulfide while the bottom layer is known as "n-type" cadmium sulfide. These extremely thin layers are connected in vacuum chamber molecules through the molecule on glass. Thus few or little amount of semiconductor (2%) is used. CdTe represents the 2^{nd} most used solar cell material globally. The 1^{st} one is still silicon.

Solar panels are created by cutting big silicon sheets into small wafers. This method wastes silicon. "1366tech" (U.S.) initialized a new technique, making small size silicon wafers directly. This method has not been commercialized.

3.1 Solar Energy Efficiency

Solar energy Efficiency depends on parameters. By calculating the fraction of sunlight power that a solar panel translates into voltage, one can compute solar power efficiency. The majority of solar power panels convert approximately 15 % of sunlight power into electrical energy. New experimental PV panels (like focusing sunlight energy panels) can convert around 40 % of sunlight power into electrical energy. These solar panels employ fluctuating mirror arrays and band gaps and are utilized more for solar power generation at a large-scale. According to the solar modules classification depending on efficiency percentage value, there are five tiers.

Table 1: Efficiency tiers of Solar Modules

Tier	Laymen Terms	Percentile	Eff.
1	Most efficient Tier	80-100%	>= 14.88 %
2	Above Average Tier	60-79%	>=14.3 %
3	Average Efficiency	40-59%	>=13.75 %
4	Below Average Efficiency	20-39%	>=13.13 %
5	Least Efficient Tier	0-19%	<13.13 %

Solar efficiency has three main types.

3.1.1 Module Efficiency:

It shows how well a sunlight module (panel) translates sunlight into utilizable energy. If the sun leaves 100 energy watts onto the panel furthermore the panel emits out 15W, then the panel or module has 15 % efficiency. Its formula is;

$$15\ W / 100\ W = 0.15;\ 0.15 = 15\ \%$$

3.1.2 Density Efficiency (area)

It shows how much utilizable power a panel generates in a specified density. It is Watts’s per-square foot. An increase in Watts will increase the level of voltage acquired from a given area (available space on the rooftop). Usually, 1 square foot provides '14' energy Watts accordingly 15 square feet of panel area provides '210W'.

3.1.3 Cell Efficiency

It is usually calculated in a similar way as panel efficiency though only with a solitary cell.

3.2 Efficiency and Density Comparison of Popular 200w Solar Panels

Best density and high competence 200W solar energy panels are detailed in the following table 2. 200 Watts shows under strict lab conditions, modules produce the same level of output. Different module types are considered with the worst per area efficiency of all modules because it is thin-film, not crystalline.

Table 2: Efficiency and density Comparison of popular 200W solar energy panels

Tier	ID	Manufacturer	Density	Eff.	STC
1	HP-200BA19	Sanyo Electric	14.89	17.24%	200
1	SPR-200-WHT-U	Sun Power	13.55	16.08%	200
1	CS5A-200M	Canadian Solar	13.29	15.66%	200
1	PLUTO200-Ada	Suntech Power	13.28	15.66%	200
1	TSM-200DA01A	Trina Solar	13.12	15.64%	200
2	KC200GT	Kyocera Solar	12.03	14.74%	200
3	SPV 200 SMaU-1	Schuco Solar	11.82	14.21%	200
3	SX3200B	BP Solar	11.52	14.17%	200
4	YL200P-26b	Yingli Solar Industry	11.26	13.65%	200
4	ET-P654200	ET Solar Industry	11.18	13.61%	200
4	ES-200-RL	Evergreen Solar	10.69	13.40%	200
5	ND-200U1	Sharp	9.86	12.27%	200

The efficiency of Solar panels is poor in the case of lighting up homes. Using solar energy directly through daylighting systems might use around 80 % of solar energy available which is much more efficient than 1st conversion of solar power into electrical energy. An intelligent method to use solar power is to create direct use of solar energy through daylighting and passive sunlight technologies, and after that, utilizing the highest efficiency solar modules for the remaining needs of energy.

Table 3: Comparison of Solar Energy Module (220 W)

Tier	ID	Manufacturer	Density	Efficiency	STC
1	HIT-N220A01	Sanyo Electric	15.23	17.64%	220
1	SPR-220-WHT-U	Sun Power	14.95	17.68%	220
1	KD220GX-LFBS	Kyocera Solar	12.95	15.40%	220
1	PLUTO220-Udm	Suntech Power	12.7	14.97%	220
1	SPV 220 SMAU-1	Schuco USA	12.52	15.02%	220
3	CS6O-220PE	Canadian Solar	11.83	14.20%	220
3	ES-e-220-fc3	Evergreen Solar	11.61	13.99%	220
3	ND-220UCJ	Sharp	11.47	13.99%	220
4	PS220P-20/U	Phono Solar	11.39	13.52%	220
4	ET-P660220	ET solar Industry	11.32	13.52%	220
4	SLK60P6L SLV/WHT 220Wp	Silikens Modules	11.27	13.55%	220
4	YL220P-29b	Yingli Green Energy	11.22	13.46%	220
4	TSM-220PAD5	Trina Solar	11.21	13.44%	220
4	PV-UJ220GAS	Mitsubushi Electric	11.2	13.35%	220
4	BP3220Q	BP Solar	11.04	13.20%	220
4	Perform Poly 220	Schott Solar	11.02	13.15%	220
4	RE C220PE	REY Solar	10.99	13.33%	220
5	SL-200-220	Solyndra	7.57	8.81%	220

Keys of table chart follow as below:

- ***Manufacturer***: Brand or Solar Company;

- ***ID*****:** module name or identification code
- ***STC*****:** (W)- Rating of Standard Testing Conditions (under specified lab conditions)
- ***Density*****:** (W)- per-area Efficiency (or output per area)
- ***Efficiency*****:** (%)-per input Output daylight irradiance using STC (energy conversion efficiency)
- ***Tier:*** - Efficiency Tier or groups of Solar Panel (1 denotes highest: 5 denotes lowest)

Technicians working on sunlight module efficiency argued that a 40 % efficiency level is the highest level that might be accessed by typical 'silicon materials' in many sunlight panel cells. Despite concentrating on preparing more competent panels, emphasis must be on manufacturing PV panels at a low cost. Yet, modern technologies have developed solar panels that are less costly and incredibly 80% efficient.

4. Measures to Improve Solar Energy Efficiency

According to modern research, by considering the efficiency of the following measures solar energy panels can be increased significantly.

4.1 Gold Nanoparticles layer

According to the research of UCLA, Japan, and China; the addition of gold nanoparticles in organic PV panels will raise the solar efficiency level (around 20%).

4.2 Fiber Optics in Solar Energy

Fiber optics recommends insulation protection, and leakage protection converts the unwanted signal into powerful equipment, tracks solar panel capabilities, and provides a quality and reliable power system. It covers long link distance energy connections as compared to the copper wire. Components of Fiber optic are usually used for controlling high electrical energy and switching current devices, with feedback signals and reliable control.

4.3 Connecting Panels Parallel

Parallel wiring of solar panels; links each solar panel with its energy converter despite transferring electrical energy via a panel series to a solitary converter.

5. Solar Energy Storage Solutions

Night-time darkness and cloudy climate disrupt the availability of solar energy. Many types of research recommend mass storage opportunities, large battery banks, and pumping water as a storage solution. Usage of new materials, superconducting magnets, and flywheels can significantly improve the capacitor's effectiveness and provide suitable energy storage (Ranjan et al., 2007). Mimic is the natural capture of sunlight through photosynthesis in plants (stores sunlight in chemical molecule bonds). This way of utilizing sunshine to prepare food can be copied to produce energy or fuel. By creating catalysts, the attractiveness of solar fuel-production cell storage systems can be improved.

5.1 Artificial Photosynthesis Method

Researchers of the Massachusetts Institute of Technology (MIT) introduced a completely new photosynthesis storage way, which splits water into oxygen and hydrogen for creating an artificial photosynthesis method. The economic viability of this method will revolutionize the entire energy market.

5.2 Usage of Superconductor Sunlight Collectors

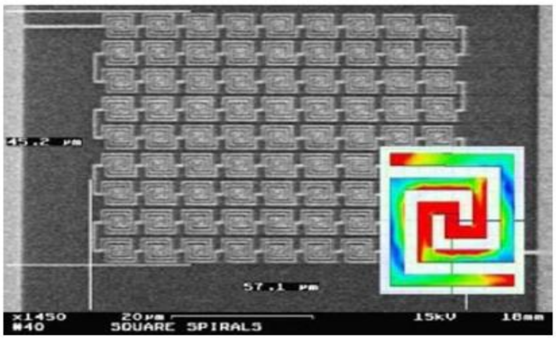
Solar energy Thermal collectors are designed according to the climate of the Northern areas. These collectors convert solar power into heat even from low temperatures (50°C), applicable even in cloudy atmospheres (durable and easily maintained even in Wind, rain, snow, cold and hail resistant). It is easily installable and reduces the amount of reducing time consumes to produce energy.

Figure 2: Superconductor Sunlight Collector

5.3 Solar Energy in Night-time

Devices using billions of sunlight collecting antennas ("nanoantennas") are in progress, which can ultimately offer a sunlight power collector that is responsible for mass output employing flexible sheets. It will generate electrical energy at night time. However, it's currently not possible but when this becomes possible lightweight skins would be initialized to control all sorts of current devices and gadgets (from iPods to the electrical cars) at an advanced competence level as compared to that traditional PV cells panel.

Figure 3



A nanoantenna is an electro-magnetic collector planned to absorb given wavelengths. According to Missouri University research, newly initialized antenna equipped sunlight sheets can harvest approximately 90% of the sunlight (while current panels harvest only 20% of available light). Rectifying antennas and Nantennas work in the same manner.

6. Benefits Attached with Solar Energy

6.1 Enormous Long Term Benefits

According to International Energy Agency (2019) report, solar energy technologies sustains huge long-term benefits (enhance sustainability, lower pollution, keep prices of fossil fuel lower, and reduce costs of extenuating climate change) in the coming era. It will raise the energy security of a country because solar energy is an inexhaustible, indigenous, and typically import-independent energy resource. All these benefits are reliable globally.

6.2 Reduce Electricity Bills

Installation of solar energy panels will result in a significant reduction in electricity bills. As most of the power usage has been covered by solar energy.

6.2.1 Renewable Energy Source

Solar energy is one of the most imperative renewable energy sources.

6.2.2 Diverse Application

In the world of technological growth, solar energy is one of a kind of diverse application.

6.2.3 Low maintenance costs

Another advantage of solar energy harvesting is that it contains low maintenance costs.

7. Downsides Attached with Solar Energy

7.1 Not Completely (100%) Reliable

When the sun isn't shining, there's no energy generation. The energy generation is usually influenced at night time and in the winter season.

7.2 Initial Capital Costs are High

Though solar panel installation will result in enormous long run benefits, upfront costs of solar panel installation can be punitive.

7.3 Problem of Efficiency

Generally, the efficiency of energy harvesting increases with generator size. It is because; often harvesters of energy fabricate an AC power that ought to be rectified. Utilization of diodes to rectify the power needs to deal with threshold voltages of junctions (shows an energy loss). The higher the rectifier input voltage, the higher the energy efficiency conversion.

7.4 Difficulties when Shifting

Shifting or transfer of solar panels from one place to another place is not so easy.

7.5 Pollution

Solar panels have a noteworthy lifespan of about a half century. However, resources that are used to produce solar panels can cause pollution. There is no option to recycle or reprocess the PV panels. These materials disposals cause severe effects on the environment.

7.6 Negative Energy Balance

Sun is unpredictable. So, solar energy can't have relied on as an imperative power source for a nation's economy. We still have to rely on other energy sources like fossil fuels.

7.7 Installation Area

For home users, installation of solar energy does not need huge space (rooftops are OK). But for big firms, it requires a large installation area.

7.8 Expensive Solar Energy Storage

In the market of solar energy system production, competition is not so high. House owners are not allowed to install their solar energy systems, due to govt. regulations. Therefore, designers are disinclined to endorse creative unproven designs of sunlight houses. Moreover, builders think of it as a non-profitable and non-salable business. Oil and Fossil fuel corporations, are organized in such a manner that discourages the proliferation of alternative energies like solar energy.

8. Conclusion

After this research, we can conclude that solar energy efficiency combines three benefits as compared to other energy sources. First, sunlight energy is a renewable or non-depleted energy source. Second, it is affordable, easily distributable, and simply connectable to current electrical grids. Third, solar energy can be locked for long term electricity prices and rates even if prices of on-grid utilities soar. Moreover, usually average Solar Panel efficiency (200÷220W) lies between 20%-30%. And if we consider the 1 kilowatt (kWh) solar energy system cost it shows € 0,29 roughly.

By using gold nano-particles and changing the way solar panels connect (the parallel connection between each solar panel to its energy converter despite transferring current to a single converter), solar energy efficiency can be increased. By using flywheels or superconducting magnets (convenient power storage), mimic which naturally captures sunshine via photosynthesis in the plants and trees (stores sunlight in chemical molecules bonds), storage of solar energy can surely be increased. To uplift the storage of solar energy at night time nantennas can be used (that converts infrared sunlight into eclectic units efficiently).

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