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Review Article

Reviewing Energy Efficiency with the Development of Luminescent Solar Panels

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Abstract: As our fossil sources of electricity reduce consistently, then looking for alternative electricity solutions turns into crucial. Solar cells often made from expensive materials, which is why much research focused on finding cheaper materials to reduce the overall cost of solar energy. Another way to overcome this problem is to use a solar concentrator - a cheaper light-absorbing material that covers a large area, which absorbs, directs, and focuses the light to a smaller area that contains actual solar cells. The interest in exploiting solar electricity for photovoltaic energy has grown dramatically in the latest years, furthermore essential improvements inside the solar cells' efficiency with luminescent up or down converters have currently anticipated theoretically. While solar cells are still expensive, fewer of them needed to produce a certain amount of electricity because they receive more sunlight. This paper gives, in short, evaluate the usage of luminescent solar concentrator (LSC) as opportunity electricity has low fees and comfortable as compared with photovoltaic solar panels, reviewing extra benefits in actual existence applications primarily in high structures home windows and displays of electronic devices.

Keywords: Clean Energy, Photovoltaic (PV) Energy, Power System, Renewable energy.

1. Introduction

Recently, fossil fuel is the world's highest energy source, day after day, and rising energy demand will cause problems for power suppliers, such as grid instability and even outages. The need to produce further energy in combination with interest in clean technology results in improved efficiency of using renewable energy in power distribution systems [1].

The significant part of the Earth's carbon budget utilizes a significant impact on the global carbon cycle is Fossil fuels; thus, they merit special consideration. Fossil fuels can define as carbon-rich materials that produce thermal energy during exothermic oxidation reaction with the oxygen of the air, and release CO2 as an outcome of this reaction see Figure 1.

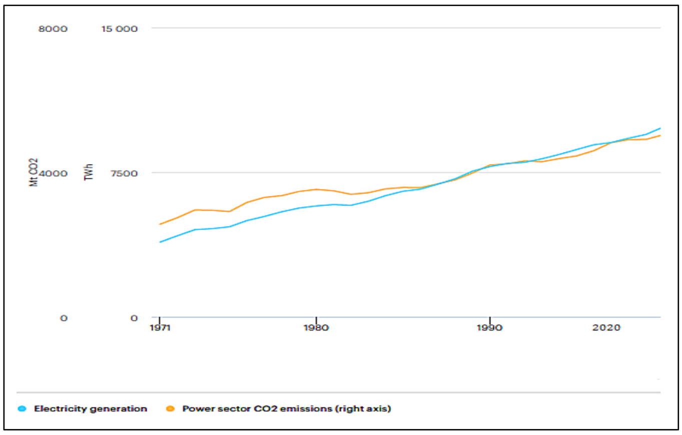

Figure 1. CO_2 emissions from electricity generation and power sectors in developed economies, 1971-2019

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Necessary forms of fossil fuels are Natural Gas, oil, coal, and peat [2]. In conventional power systems production, plenty of power stations placed in appropriate geographical locations and provide enormous power then moved over long-distance transmission lines to large customer centers. The quality of the power system continuously controlled by monitor centers to make sure of the voltage and frequency. According to the evolving of the new power system, various distributed generation (DG) units built, Usage of both non-renewable energy and renewable energy technologies like wind turbines, and wave's energy, photovoltaic (PV) energy, small hydropower, fuel cells and combined heat and power (CHP) gas/steam power plants. With a high degree of convergence, renewable energy options can use rapidly in distribution networks over the next decade [3].

If the use of fossil fuels can be dramatically reduced, and recognizing that nuclear power is not a long-term option, the question remains whether the potential energy supply will be made accessible and stable. The first stage is to improve the efficiency of energy usage dramatically, i.e., usable energy must be generated from a much smaller amount of significant energy, "then carbon dioxide emissions reduced," see the details by UNDP [4], as shown in Table 1. Renewable energies will be the key to this growth since they are the only option that can cover the energy required by Earth in a climate-sustainable manner [5].

Table 1. Assessment of energy payback periods with emissions from numerous energy technologies.

Technology	Payback Time of Energy (months)	CO_2 (ton/GWh)	SO_2 emission (kg/GWh)	NO_2 emission (kg/GWh)
Gas (CCGT)	0.4	370–420	45–140	650–810
Coal fired	1.0–1.1	830–920	630–1370	630–1560
Micro-hydro	9–11	16–20	38–46	71–86
Large hydro	5–6	7–8	18–21	34–40
Wind turbine	-	-	-	-
Small hydro	8–9	10–12	24–29	46–56
Mono-crystalline	72–93	200–260	230–295	270–340
Photovoltaic	-	-	-	-
Amorphous	51–66	170–220	135–175	160–200
Multi-crystalline	58–74	190–250	260–330	250–310

The sun has taken into consideration as an exceptional supply of radiant energy, and the plentiful supply of energy. It emits electromagnetic radiation with a median irradiance of 1353 W/m2 on the planet's surface. Place this into consideration, where the energy generated by the usage of 25 acres solar surface was collected, and there might be adequate energy to supply the future power call for the sector. There are primary alternatives while dealing with solar energy. The first is photovoltaic that direct conversion of energy and converts solar radiation into energy. The second is solar thermal, where solar radiation has used to supply heat to the thermodynamic system, generating mechanical energy that can transform into electricity. In commercial markets available photovoltaic systems, efficiencies vary from 10 to 20 percent, where efficiencies of up to 30 percent can reach with the solar thermal systems [6].

Several advantages have seen in the luminescent solar concentrators (LSCs) case, like the capability to operate with radiant light, lightweight, cost savings, and transparency. These above features make LSCs very appropriate for use in modern building architectures, which use several colored windows and panels [7].

Nowadays, a luminescent solar concentrator (or LSC) is known to be a safe source of energy from well-establishing sun radiation in urban structures. The LSC is essentially a plastic light guide combined by fluorescent dye molecules or using a transparent polymer light guide covered with a thin polymer sheet doped with the fluorescent dye. By absorption of the fluorescent pigment, the LSC absorbs a portion of the incident solar radiation. Then the light is either re-emitted by the fluorophore at a longer wavelength or lost as heat to the atmosphere of the light source. The re-emitted light would be guided to a way beyond the polymer light guide's 'capture cone' and run away over the top surface or bottom, or trapped by total internal reflection through the plate [8].

Regardless of the progress of photovoltaic (PV) systems in recent decades, the conversion of solar energy into electricity is not fully active yet, and some cost challenges have found. Luminescent Solar Concentrators (LSCs) are Photon-management tools. Besides, focus the sunlight on photovoltaic cells with low-cost polymer-based systems and reduce solar energy prices see Figure 2. Through the photoluminescence process, the short wavelength of sunlight can shift to long-wavelength light. [9].

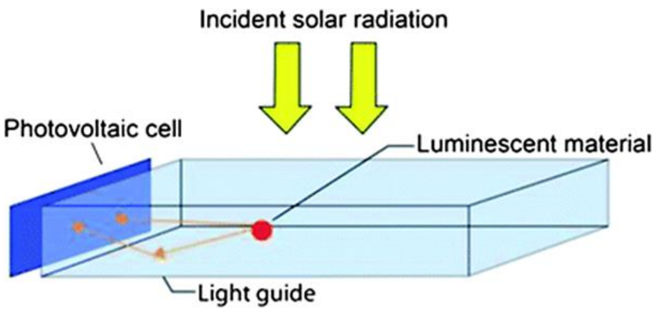

Figure 2. Shows schematic drawing of simple LSC panel

The key driver for introducing an LSC is to switch the full range of costly solar cells needed in a regular flat-plate PV panel with a cheap polymeric collector, then decrease the part cost (in $/watt) as well the solar power cost (in $/kilowatt. Hour). A significant benefit in matching LSC technology with other concentrating systems is focused equally on direct and diffuse solar radiation processing. That means there is no need for sun tracking — increasing more future cost savings and making LSCs an ideal alternative for building integrated photovoltaic (BIPV). Moreover, the electricity conversion LSCs have thermal converting applications, daylight, and hybrid thermal-photovoltaic systems that produce great electricity and remove heat from the LSC plate [10].

2. Background of Photovoltaic Potential (PV)

Photovoltaic implementations are usually infinite in basic. For the PV system, there are no location exclusion criteria because they may set anywhere. Nevertheless, their growth still restricted by high investment costs. The analysis found that most regions benefit from this technology. Iraq has a global incidence irradiance that is more than 1.800 kWh/m2/year in Figure 3. Using PV is highly competitive with traditional fossil fuel generation due to low, localized, and distributed off-grid communities and applications. Solar energy for many locations around the world indicated lots of benefits for different sectors. In rural areas, for example, providing clean water, hot water, and electricity from solar energy is the technologically feasible approach for life in rural, where regularly low maintenance solar systems needed comparison with complicated PV systems [11].

On the other hand, the installation of photovoltaic cells on Community Street lights was inefficient because the cells had a low-performance aspect, and the use of dusty days characterizes Iraqi weather. Moreover, the power from photovoltaic systems is still expensive as compared with conventional energy, these considerations have worked and marked the scope of usage of photovoltaic cells, while the cells deployed in restricted applications such as homes rooftop systems, neighborhood water pumping stations and regions which are difficult to reach the electricity grid [12].

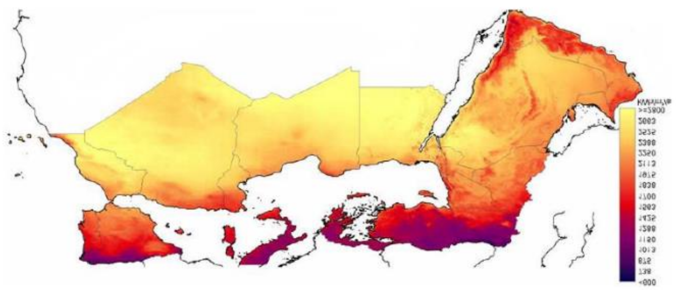

Figure 3. Annual irradiance in the Middle East region

Photovoltaic modules can provide clean, stable energy and an environmentally sustainable power source. Furthermore, the costs of photovoltaic energy technologies are slowly decreasing as consumer demand, and the development of PV systems increase [13].

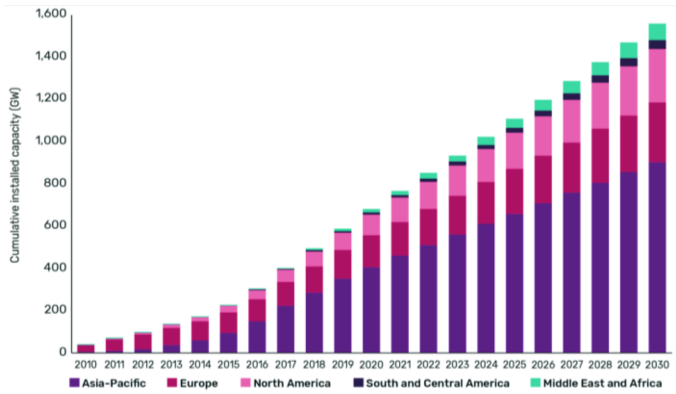

Figure 4. Cumulative global solar PV installed capacity by region, 2010-2030 (Source: GlobalData Power Intelligence Center)

The Asia-Pacific (APAC) is the largest regional market in terms of cumulative capacity with a share of 58.1% of global solar PV capacity in 2018. In terms of net annual additions, APAC alone installed 64.5GW of solar PV, which represents 70.8% of net installations in the same year. APAC is expected to remain the largest market during the forecast period 2019 to 2030 due to an increase in capacity installations, led by countries such as China, India, and Japan [14].

3. Impact of Luminescent Solar Panels

The low energy density of solar radiance enables the use of solar power to consume enough of the sun's energy over large surface areas to reduce a large proportion of non-renewable energy consumption. The challenge to large-scale deployment could overcome by creating a low-cost, flexible, photovoltaic PV technology that can be built into window panels in residences, skyscrapers, and cars, enhancing the quality of flexible surfaces that have already been used [15].

From 2005 onwards, 85 percent of the world's PV production used single crystal and multi-crystalline Si, and 94 percent used other Si technologies (such as a-Si, Si ribbon). As an abundant photovoltaic material, Si has numerous benefits, non-toxicity and passivation are simple. Crystalline photovoltaic systems of first-generation with comparatively weak efficiencies even suffer from very higher material prices. Second generation devices have a relatively low cost but suffer from comparatively weak efficiencies, unfortunately. The prototype of the third generation will be the best of these two generations and would benefit from being both highly effective and low-priced. Such a system is the development in second-generation thin-film processing with energy efficiencies over an average of 31% of the thermodynamic limit close to 93% [16], [17].

Considered in recent years, the use of solar energy safely and economically is a high- goal and is projected to be much more significant in the future. Costs are also the big unsustainable element for the extensive utilization of the solar energy supply. The usage of polycrystalline silicon, amorphous thin silicon films, or other semiconducting materials such as (copper indium gallium selenide) Cu (In, Ga) Se2 (CIGS), collected with dye- solar cells, has or is projected to have a significant impact on the cost of development, but more work is required in all sides of solar energy conversion. One solution is to break down this massive challenge into easy-to-use elements, like the absorption of solar photons and the transition of absorbed solar energy into electricity [18].

In the late 1970s, the first studies and researches on LSCs have published, and through the early 1980s, the technology has been studied strongly through the limitations of fluorescent organic dyes hindered further development. The peak conversion efficiency applied to a large-scale LSC (40 cm = 40 cm = 0.3 nm) was £ LSC = 4.0 percent for a two-stack array containing a shorter wavelength emitting plate combined for gallium arsenide mixed-film thin-film LSCs of smaller sizes (14 nm = 0.3 cm) achieved £LSC = 3.2 percent using (Gallium arsenide) GaAs systems Si solar cells £LSC = 4.5 percent. It determined that the peak conversion efficiency of LSCs that gathered sunlight in the range of 300–900 nm was 8–12 percent. An LSC comprises of a flat transparent matrix containing luminescent particles, like organic dyes of quantum dots (QDs), or semi- that are distributed randomly within it. The luminescent particles absorb light entering the plate and then re-emit the light isotopically. A fraction of the re-emitted light is at an angle less than the critical angle and can out to the air [19], see Figure 4.

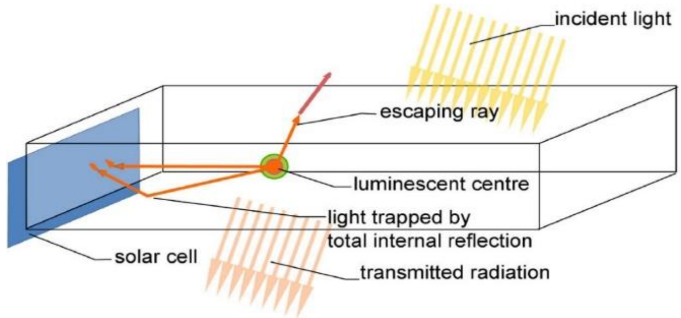

Figure 5. Show the movement of incident photon radiation into LSC panel

Today's crucial case in global solar photovoltaic energy technologies is already reducing the cost per unit of generated power, where the original work and studies on achieving high conversion efficiencies go together with study to reduce manufacturing costs. Significant improvement appeared in recent years, which lead to a total installed capacity of 67.4 GW worldwide at the end of 2011 and module costs ranging from 0.8-2 Euro/Wp, depending on technologies. This has also contributed to the cost of energy rising to the level of ~0.2 Euro/kWh with customers charging certain European countries today. Nonetheless, the cost of producing electricity from conventional fossil-fuel power plants is still far from ~0.04 Euro/kWh [20].

The LSCs with a luminophore configuration function by using the luminophores Stokes shift according to thermodynamics aspects. The thermodynamic limit for the concentration of photons inclines exponentially with the luminophores Stokes shift. For reference, in luminophores, the thermodynamic concentration limit that absorbs at 500 nm and emits at 600 nm is about 11.500.000 an optimal lens can concentrate sunlight by a factor of 46.200, and effective concentrator systems typically work with a few hundred to a few thousand concentration factors depending on difficulties in measuring sensitivity, lens resolution, and thermal degradation. The luminescent solar concentrator solves both difficulties: it does not need lenses or trackers, and the heat produced by high-energy photons dispersed in the LSC instead of concentrating on the photovoltaic cell. Within the thermodynamic limit, a higher voltage concentration of photons in the photovoltaic cell that occurs by restoring all the energy lost to the Stokes shift. Such high concentration is difficult in action, and LSC systems have limited yet close to 10^6 concentration factors.

The incomplete trapping of the amount yields of luminescence light and nonentity fluorescence induced by the difference between ideal and real luminescent solar concentrators [21]. The source of this question is an extreme overlap between the absorption of luminophores and the emission spectra. These can be reabsorbed by other luminophores when a luminesced photon passes through the LSC. Any reabsorption cycle presents a chance of loss, such as no-degradation or leakage into the cone of escape. Of this reason, LSC concentration ratio stability is still long before the thermodynamic limit. To meet the thermodynamic limits of luminescent concentrators, the luminescent light needs to be caught in the polymer and directed to the solar cell for maximum effective light trapping, a limited emission range luminophores, and a massive change of the Stokes shift. Light trapping tests and research is limited by a lack of colors that satisfied these criteria.

According to these tests, meeting the thermodynamic concentration limit will require a luminophores with a large change in Stokes shift, high quantum yield, lower absorption and emission variation, and a limited emissions range [18]. Next to last, it investigated the impact of the waveguide edge on efficiency. The possibility of trapping light refracting off the waveguide at the edge is strong with rough untreated edges. Treating the edge to raise reflectivity to prevent trapping light from escaping at the edges of the panel and used to optimize the amount of light that the PV cell absorbs see Figure 5. Ideally, a 100 percent reflective surface would be built to remove this condition of failure entirely [19].

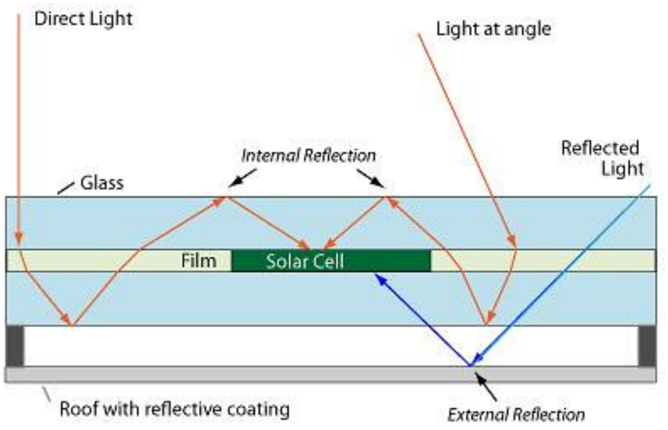

Figure 6. Using of reflecting coating to reflect and trap the escaping photon

Full internal reflection in a medium with refractive index R can occur as light hits at angles, which is larger than the critical angle at the air boundary matrix. φ_c is the critical angle is calculated through the function below:

$$\varphi_c = Sin^{-1}\left(\frac{1}{R}\right) \tag{1}$$

While the light amount which will be fully reflected internally in an LSC (L) plate is given by:

$$L = \frac{(R^2 - 1)^{\frac{1}{2}}}{R} \tag{2}$$

Solar cells, or also often called photovoltaics, are devices that can convert sunlight directly into electricity. Solar cells can be referred to as the main actor to maximize the enormous potential of sunlight energy to earth, although in addition to being used to produce electricity, energy from the sun can also be maximized heat energy through the solar thermal system. Solar cells can be analogous to devices with two terminals or connections, where when conditions are dark or not enough light functions as a diode, and when illuminated with sunlight can produce voltage. When irradiated, generally a commercial solar cell produces a dc voltage of 0.5 to 1 volt, and a short-circuit current on a milliampere scale per cm2. This voltage and current are not enough for various applications, so generally, several solar cells are arranged in series to form solar modules. One solar module typically consists of 28-36 solar cells, and in total, produces a dc voltage of 12 V under standard irradiation conditions (Air Mass 1.5). The solar modules can be combined in parallel or in series to increase the total voltage and output current according to the power needed for a application.

4. Conclusion

Design and use of luminescent solar concentration panels have significant benefit over PV solar panels, there is no need for monitoring or cooling, and expensive solar-cell modules tend to occupy even smaller areas. Improvement of such devices (LSC) relies on the techniques used to minimize the interference of radiation photons by using lumiphores or dye dots and whether such photons can be captured and returned to PV cells again. LSCs are highly concerned about the affordability of modern luminescent materials, Semiconductor quantum dots (QDs), rare earth materials, and semi-conductive polymers, for example. The use of materials like photonic layers and liquid crystals may reduce losses. Besides, thermodynamic simulation and ray-trace analysis advances and techniques have enabled more work to enhance the findings.

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