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Research Article

Renewable Energy for Sustainable Growth: Perovskite Photovoltaics as an Emerging Technology

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Abstract

Solar energy is abundant and sustainable form of energy. Clean form of energy, Reduced utility cost, Suitable for urban and rural areas. Long diffusion lengths and high absorption coefficients, flexibility, lightweight, and transparency, perovskite materials hold economic advantages. Lead-based perovskites produce harmful products like Pbi2 harming the nervous, reproductive, blood, and kidney system. To solve these issues, lead-free perovskites has emerged as a new area of focus. Solar cell performance depends upon depletion width, carrier lifetime and recombination rate. Lead-free perovskite solar cell applications and its excellent thermochemical stability compared with organic–inorganic perovskites.

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KEYWORDS: Renewable energy, Perovskite solar cells (PSCs), Lead-free perovskite, SCAPS-1D simulation.

1. INTRODUCTION

Finite Fossil fuel-based energy s.ources are causing environmental issues such as global warming and climate change. Renewable Energy (RE) technologies are naturally replenished such as solar, wind, hydro, biomass, geothermal energy have been introduced to generate electricity is an essential alternative to traditional fossil fuels and promote energy security. Renewables contributed significantly to the global energy mix in 2021, with 10.2% in the thermal sector, 3.4% in the transport sector, and 27.1% in the power sector (REN21, 2021. Renewable energy sources since they are pollution-free, easily accessible, less expensive, and more abundant on the planet. India's large population and rapidly expanding economy have significant energy requirements. In terms of both power generation and consumption, the nation is third in the world.

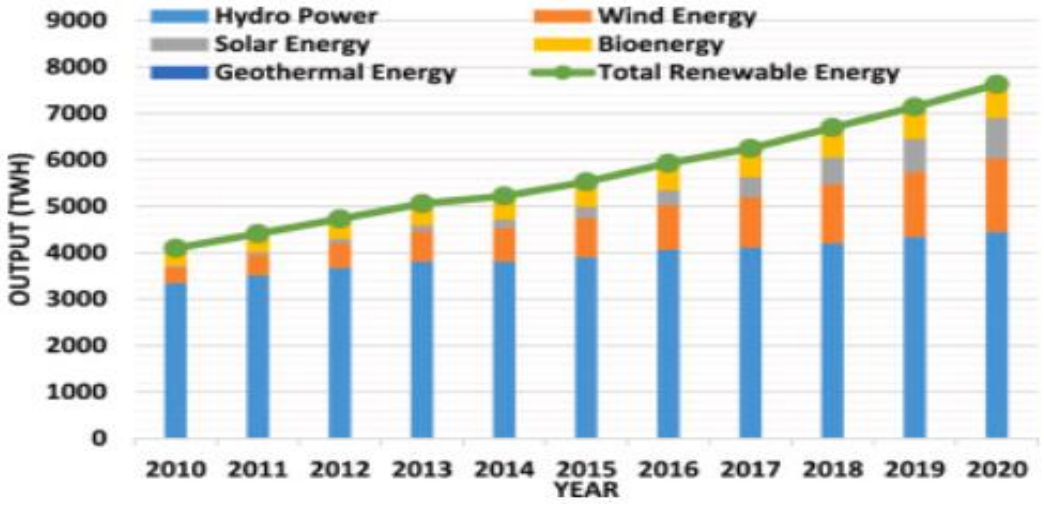

Figure 1: Total Renewable Energy Usage

Types of Renewable Energy-

1. **Solar Energy-**The generation of solar power is achieved through the utilization of photovoltaic cells or concentrated solar power systems, capturing and converting sunlight.
2. **Wind Energy-**Wind energy is produced by capturing the kinetic energy of the air moving through wind turbines. Wind farms are built in areas with continuous wind to generate electricity.
3. **Hydropower**-Hydropower is the power produced by flowing water. It is essential to build dams to capture and control the flow of water that then drives turbines to generate electricity.
4. **Biomass**-Biomass energy is derived from organic materials such as wood, agricultural residues and animal manure. It can be used to generate heat or electricity through processes such as combustion, gasification.
5. **Geothermal Energy-** Geothermal energy uses the heat of earth's rocks to generate electricity. It involves touching a hot underground pool and using steam or hot water to power a turbine.

Advantages of Renewable Energy-

1. ***Sustainability****:* Renewable energy is inexhaustible, ensuring continuity for future generations
2. ***Environmental Benefits****:* Renewable energy produces almost no greenhouse gas emissions, thus reducing pollution and health effects
3. ***Energy Security:*** Diversifying energy sources with renewables can enhance energy security and reduce reliance on imported fossil fuels.
3. ***Job Creation****:* The renewable energy sector can create new job opportunities in manufacturing, installation, maintenance, and research
4. ***Economic Growth****:* Investing in renewable energy infrastructure can stimulate economic growth and promote technological advancements

Challenges in Renewable Energy Development in India-

1. **Policy and Regulatory Barriers**
   - States need a solid policy structure.
   - Renewable energy requires a solid regulatory framework.
2. **Institutional Brriers**
   - Insufficient or few institutions exist to guide workforce for new renewable infrastructure projects
   - To implement policies in India's renewable sector, increased coordination and collaboration across ministries, institutes, and organizations are necessary
3. **Economic Barriers**
   - The budget for renewables development in India is not given on schedule
   - Financing is a crucial concern when authorizing renewable initiatives

4. Social Barrier

- India is a populated country with a population density of 382 per square km, meeting the need for abundant land for renewable energy is problematic
- 70% of India's population lives in villages, Villagers are unfamiliar with renewable energy methods

Table 1: Generation of Solar Cell-

First Generation	Second Generation	Third Generation
Monocrystalline silicon • Monocrystalline silicon solar cells made of high purity single crystals. • Monocrystalline had higher efficiency, higher cost than polycrystalline silicon solar cells. **Polycrystalline silicon** • Polycrystalline silicon solar cells with non-uniform crystals.	**Cadmium Telluride (CdTe)** • Cadmium Telluride based solar cells fabricated by Bonnet and Rabnehorst recorded an efficiency of 6% in 1972. • Recorded an efficiency of 22.1% in January 2022. **Amorphous thin-film silicon (α-Si:H)** • Carlson and Wronski at RCA Lab reported a 2.4% efficiency in 1976. • Reported a 14.0% efficiency in 2022. **Copper Indium Gallium Selenide (CIGS)** • CIGS is primarily used in industries. • Reported a 23.4% efficiency in January 2022.	**Dye-sensitized solar cells** Dye sensitized solar cells contains dye for absorbing of light. • Recorded a 13.0% efficiency in January 2022. **Quantum dot solar cells** • Quantum dots are materials that absorb light. • Reported an 18.1% efficiency in 2022. **Perovskite solar cells (PSC)** • Perovskite solar cells used an organic-inorganic lead halide material for light absorbing.
Advantage: First generation solar cells have stability and high efficiency. **Drawback:** It has high manufacturing cost.	**Advantage**: It has Low manufacturing costs. **Drawback:** It has lower efficiency and presence of toxic materials in perovskite absorber material such as Cd which creates an environmental Issues for animals and humans.	**Advantage:** It has low cost of manufacturing and high efficiency. **Drawback:** It has fast degradation and presence of toxic materials such as Lead in perovskite absorber layer creates environment issues and problems to humans.

Innovation and Future Directions-

Emerging Technologies (Perovskite Solar Cells)- The emergence of next-generation technologies promise to overcome limitations in efficiency, scalability, and geographic deployment. Among the most promising innovations are perovskite solar cells have potential in reshaping the global energy landscape.

Perovskite Solar cells-

Perovskite solar cells (PSCs) have emerged as one of the most exciting breakthroughs in photovoltaic (PV) technology. Laboratory-scale PSCs have achieved efficiencies exceeding 25.7%, (NREL, 2022). Perovskites are lightweight, flexible, and high absorption coefficients and long diffusion length. Significant challenges for perovskites long-term stability, lead toxicity. Perovskite solar cells have emerged and grabbed the attention of researchers all over the world with their unprecedented growth in efficiency and low manufacturing cost. Perovskite solar cells are a next generation solar technology using a perovskite – structured compound like (organic-inorganic lead /tin halides) as a light absorbing layer Perovskite has chemical formula ABX3.

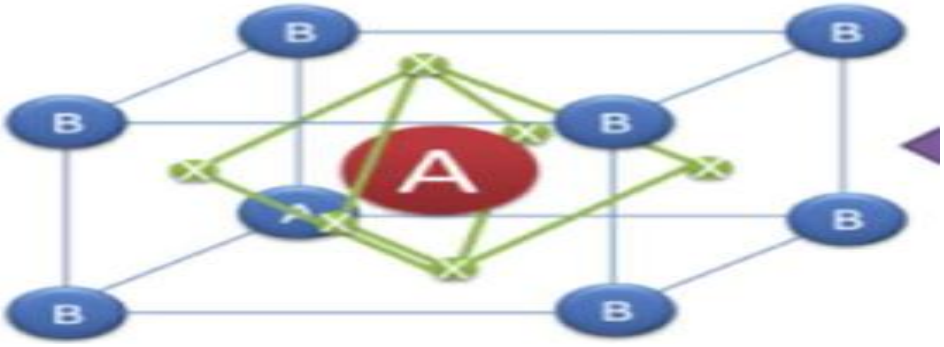

Figure 2: Perovskite Crystal Structure

2. OBJECTIVE

Lead-free Perovskite solar cell Numerical Simulation by using SCAPS-1D-

SCAPS-1D Solar Cell Capacitance Simulation software used to simulate characteristics of Perovskite Solar cells. Dr. M. Burgelman of the University of Gent in Belgium, enables the design and simulation of up to seven heterojunction layers. the spectrum used in all simulations was the AM1.5G spectrum, the incident light power was set at 1000 W/m^2, the operating point voltage set to 0 V, and the temperature was set at 300 K. Continuity and Poisson equations are used in this software. (SCAPS) solves the Basic semiconductor equations in 1-Dimension under steady state condition.

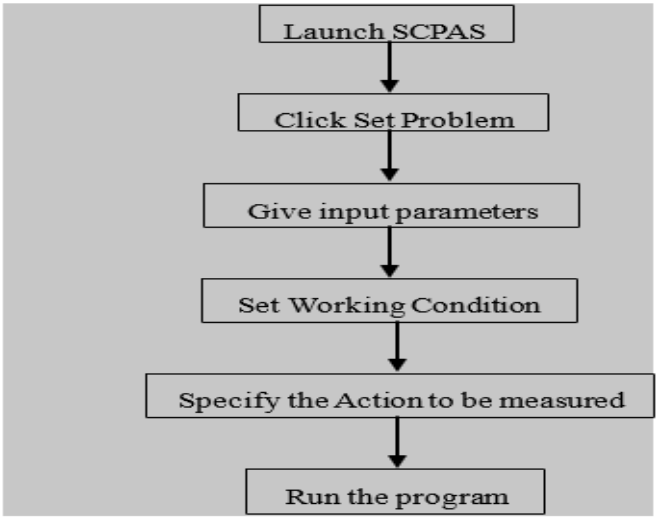

Figure 3: SCAPS-1D Software Working Procedure

3. METHODOLOGY

We identify highly efficient lead-free perovskite materials by SCAPS-1D Simulation for improving efficiency. Perovskite solar cell will be fabricated using fluorine doped conducting glass (FTO) as substrate. A layer of ZnO paste will be spread on this glass substrate for 30 min at 500 ^{0}C and cooled at room temperature. The working electrode containing ZnO will be sensitized using spin-coated solution of CH_3 NH_3 SbI_3.

Characterization of Perovskite Material-

1. **X-Ray Diffraction-** XRD is used for relates the perovskite peak with reported XRD peaks for better peaks characterization.
2. **Scanning Electron Microscopy**- SEM is used for measuring the morphology of the perovskite material.
3. **Raman Spectra-** The peak position confirms the formation of the perovskites by Raman Spectra characterization.

4. RESULT AND DISCUSSION

1. **Current-voltage Characteristics-** We simulated lead-free perovskite solar cell I-V characteristics by SCAPS-1D simulation.
2. **Quantum Efficiency**- We measures Lead -free perovskite solar cell efficiency by SCAPS-1D software.
3. **Effect of defect density on solar cell performance-** Defect density influence on the lead-free solar cell efficiency. So, we simulate effect of defect density by SCAPS-1D Software.

5. CONCLUSION

Progress in lead free Perovskite solar cells- Perovskite material based on lead have high efficiency. But Due to toxicity nature of lead, we replaced lead by Sn (tin). But Sn based perovskite material have low efficiency than lead. so, we focus on Tandem Solar Cells in near future.

Tandem Solar cells- Future of Perovskite solar cells have high efficiency and stability than lead-free perovskite solar cells. Tandem solar cells made up of Si-perovskite, Perovskite-perovskite absorber layers with different band gaps are examples of common tandem solar cells. Highest achieved efficiency of Tandem Solar cells is 34.85% (2025).

Stability of perovskite solar cells: Proper encapsulation might be the best choice. Instability in lead is still an issue. For improve stability against temperature, moisture and light exposure. The ETL and HTL absorber materials, efficiency and proper encapsulation of the current generation of perovskite solar cells have all improved.

REFERENCES

1. Ang TZ, Salem M, Kamarol M, et al. A comprehensive study of renewable energy sources: classifications, challenges and suggestions. Energy Strateg Rev. 2022 Sep;43:100939.
2. Singh N. Review paper on renewable energy. Int J Res Appl Sci Eng Technol. 2023 Sep;11(9).
3. Singh T, et al. Renewable energy in India: comprehensive analysis of opportunities, barriers and policy recommendations. Int J Creat Res Thoughts. 2024 May;12(5).

4. Ndubuisi OG, et al. An evaluation of renewable energy technologies and their applications in electricity generation. Int J Innov Sci Eng Technol Res. 2025 Jul-Sep;13(3):1-11.
5. Nav PV, et al. Perovskite solar cells: literature review. NeuroQuantology. 2022 Nov; 20:717-730.
6. Mishra K, Chauhan RK, et al. Performance optimization of lead-free inorganic perovskite solar cell using SCAPS-1D. J Opt Soc India. 2023.
7. Tripathi M, Mishra VV, Sengar BS, Ullas AV. Lead-free perovskite solar cell by using SCAPS-1D: design and simulation. Mater Today Proc. 2022.
8. Kataray T, et al. Integration of smart grid with renewable energy resources: opportunities and challenges—a comprehensive review. Sustain Energy Technol Assess. 2023 Aug;58.
9. Baro M, et al. SCAPS-1D simulation of highly efficient perovskite solar cells using diverse charge transport layers. J Electron Mater. 2023.
10. Alsalme A, et al. Optimization of photovoltaic performance of Pb-free perovskite solar cells via numerical simulation. Molecules. 2023; 28:224.