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Impact of Solar Energy in Sustainable Development of India

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Abstract: Sustainable development of any country aims to make a development that cannot only meet the demands of the present but can also set up the future generation's needs and requirements. Emerging global warming, unfavorable climatic conditions, dependence on fossil fuels, and many other factors pose significant challenges to sustainability in India. To get rid of all these issues, solar energy can play a versatile role in the sustainable development of the country. India is fortunate to have an abundance of solar energy. It is the cleanest energy source on the planet, produces zero carbon emissions, and is the best replacement for energy from fossil fuels. This paper discusses the impact of solar energy in developing a sustainable India. Ways of harnessing solar energy, like solar panels, solar streetlights, solar water heaters, solar signals, and so on, are discussed.
Keywords: Sustainable development, smart cities, solar energy products, smart city strategies & solutions, and Government initiatives.

Introduction

1. **Sustainable development in India:** Smart and sustainable development aims to renovate cities' operational efficiency without negotiating the requirements of forthcoming generations and maintains a healthy environment with optimum resource utilization.
2. **Smart Cities Mission:** On25 June 2015, the Government of India launched the Smart Cities mission, by adopting a futuristic approach for developing 100 cities, including 2-tier and 3-tier cities in the country. Its main objective is the transformation of the cities by providing valuable infrastructure and, a good quality of life to the Indian citizens, and availing clean and green planet by application of smart solutions. The central Government provides financial assistance to the cities under Smart cities criteria, up to 100 crores per city per year. Our country has 6 fundamental principles on which the smart cities are formed:
1. **Community at the Core:** a city that uses digital technology and advanced solutions to upgrade its population.
2. **More from less:** Maximum outcomes through limited resources.
3. **Cooperative and competitive Federalism:** Cities are selected through competition and flexibility for the implementation of the projects.
4. **Integration, Innovation, and Sustainability:** Smart city projects are formed to find innovative solutions for the sustainable development of the population and environment together.
5. **Technology as means, not the goal:** Technology is selected according to modification required in a city, it may differ city by city as per the need of improvisation.
6. **Convergence:** Combination of objectives and resources of smart cities such as Amrut – Urban Transformation, Swachh Bharat (cleanliness), HRIDAY (Heritage city development), Digital India, skill development, etc.

Smart Solutions of Smart Cities:

E-Governance and Citizens services
- Public information, Grievances handling, Redressal
- Electronic Service Delivery
- Citizens-City's Eyes and Ears
- Citizens Engagement
- Video crime monitoring

Energy Management
- Renewable Sources of Energy
- Smart Meters and Management
- Energy efficient & Green building.

Waste Management
- Waste to Energy Fuel
- Waste to Concept
- Waste water to be treated
- Recycling and reduction of C&D waste.

Urban Mobility
- Smart Parking
- Intelligent traffic management
- Integrated Multi Model Transport.

Water Management

- Smart Meters & Management
- Leakage identification, Preventive maint.
- Water quality monitoring

Others

- Tele Medicine and Tele Education
- Incubation/Trade facilitation centers
- Skill Development Centers

Fig.1. Smart Cities Solutions

Smart City Strategies

- **Retrofitting-** Replanning of already built-up area with smart solutions to make it well organized and comfortable
- **Redevelopment-** Replacement of old built-up environment with the enhanced version of infrastructure
- **Greenfield-(Smart from scratch)**- Sustainable, efficient, and liveable environment on undeveloped land in urban and rural areas, by adopting advanced technologies.
- **Pan city-** Selected smart solutions to the existing city-wide infrastructure.

Impact of Solar Energy in Smart Cities Mission: A Smart City is the development of a planned city comprising all the amenities for the citizens full of information, communication, and upgraded technologies (i.e. internet of things, Artificial intelligence), nevertheless, it should also be environment friendly. To be future-focused, the population of countries' villages, towns, and cities will increase with more demand for energy consumption, and to justify the needs of future generations, the worldwide government is seeking smarter solutions for more power generation and lack of dependency on fossil fuels. To bring technology expansion and sustainability together, the Government of India has mandated that up to 10% of the power supply will be derived from solar energy sources. In this respect, the Government has targeted up to 80% of the buildings will be converted into green buildings by implanting solar power panels, solar water heaters, solar lights, etc. for the generation of electricity in a clean form. In India, solar power energy is the most substantial source of energy out of the other renewable resources. It eradicates the dependence of the country on non-renewable resources and moves to green and clean resources.

Review Of Literature

1. Telang, S., Chel, A., Nafdey, R., & Kaushik, G. (2021) The article "Solar Energy for Sustainable Development of Smart City" is published in the book "Studies in Systems, Decisions and Control". The researchersreveal that by 2021, the Indian government intends to build a sizable solar project to satisfy the country's rising electricity needs. Smart Cities will require small-scale solar parks, and solar power can be utilized for household cooking, traffic signals, streetlights, water heaters, and pumps.

2. Mishra, R. K., Kumari, C. L., Janaki Krishna, P. S., & Dubey, A. (2022).
The article "Smart Cities for Sustainable Development: An Overview", is published in the book "Advances in Geographical and Environmental Sciences". The researcher discussed that cities all around the world are facing serious issues as a result of population expansion, economic restructuring, and climate change. Efforts are being made to create sustainable and intelligent cities. Development nations such as India face difficulties with delayed investments, scheduling, coordinating, and allocating funds for rural infrastructure.

3. Mahesha, C. R., Ramalingam, M., Sujith, S., Kalyanasundaram, P., Soni, N. B., Nalinashini, G., ... & Mohanavel, V. (2022)
The researchers in their article "Sustainable Cooling and Heating in Smart Cities usingSolar Energy SystemPlanning" conclude that Smart city elements can efficiently use renewable resources and improve energy efficiency, benefiting disadvantaged communities. Proper planning and finance can lead to widespread adoption of sustainable energy technologies, enhancing economies, safety, and quality of life by reducing corruption and implementing innovative government strategies.

Research Methodology: The present research isdescriptive in nature. The data has been derived from secondary sources, i.e., books, journals, and government websites like MNRE, Smartcities.gov, etc., to highlight the role and importance of solar energy appliances in the development of Sustainable India.

Objectives Of The Study:

1. Intention to move focus towards benefits of solar energy products for the success of smart cities mission.
2. To bring attention to the contribution of solar products toa sustainable environment.
3. To highlight, energy conservation held after the adoption of solar energy appliances.
4. To bring attention to the issues and challenges that occur in the installation of solar-powered products in smart cities mission.

Limitations Of The Study: As it is descriptive research, there may be some variations in data collected through secondary sources from the actual database.

Types And Role Of Solar Energy Products

Smart cities rely on solar energy goods to meet sustainability targets. These products improve urban living conditions by utilizing efficient and sustainable technologies.

1. Solar Energized Infrastructure

- **Solar-powered buildings**: In smart cities, it is targeted

to optimize the use of energy, minimize dependence on power grids, and reduction in operational costs by installing solar panels on the rooftops of buildings.

Fig.2- Solar Rooftop Panels

- **Solar Streetlights:** To cut down on energy use and carbon emissions, solar-powered LED streetlights are becoming a growing trend. These lights are linked to a central system that employs real-time data to optimize their operation through the use of sensors.

Fig.3- Solar Streetlights

- **Solar Signals:** under the smart cities mission, traffic signals are also controlled through solar panelized signals, which is again a virtuous step towards sustainability.

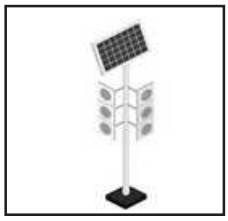

Fig. 4-Solar Signals

- **Public Places:** In the smart cities mission, public spaces like gardens, bus stops, and others are also filled with solar-energized amenities, like lighting, charging stations, solar parking sheds, and information kiosks.

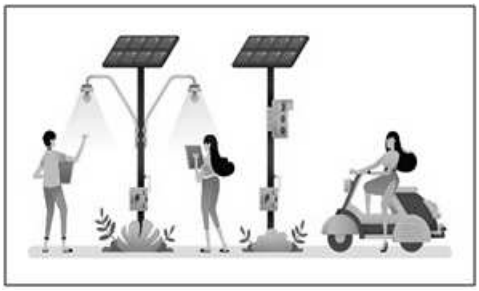

Fig.5- Solar Amenities in Public Places

- **Solar Water Heaters:** Solar water heaters have replaced high-wattage geysers and gas geysers used for heating water. The solar heating panels collect heat from the sun and transfer it to an insulated storage tank for heating water. The adoption of solar water heaters has reduced huge electricity bill amounts and dependence on geysers for the water heating process.

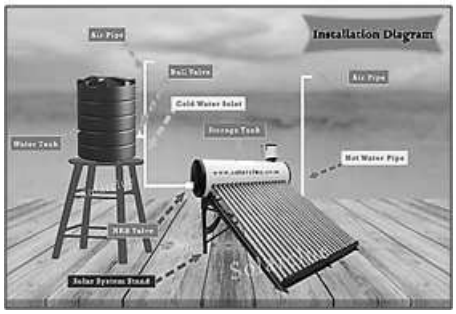

Fig-6 Solar Water Heaters

2. Smart Grids

- **Convergence with Smart Grids**:In smart cities, demand-responsive management, real-time monitoring, and efficient energy distribution are made possible by the pairing of solar energy systems with smart networks. Refeeding surplus solar energy back into the grid may boost the city's overall energy efficiency.

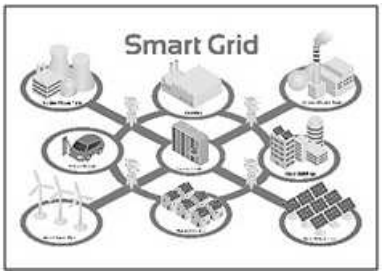

Fig.7- Smart Grids

- **Microgrids**:Microgrids, or small-scale power networks that can function independently or in tandem with the main grid, are made possible in smart cities only with the help of solar energy products. If the main grid fails, this boosts resilience and offers dependable energy.

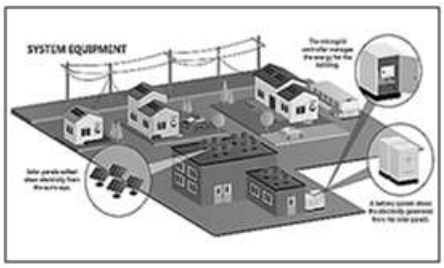

Fig.8-Microgrids

3. Electric Vehicles (EV):

- Solar EV Charging Stations: As smart cities promote EV vehicles, solar-energized EV charging stations are installed. These stations not only reduce carbon footprints but also help to address the power shortage issues.

ig.9- EV Vehicle Charging Stations

- Solar-energized public transport:Urban pollution and energy expenses can be decreased by using solar energy to power public transit vehicles like buses and trams.

Fig.10-Solar Energized Public Transport

4. Power Storage System:

- **Battery Storage:**Automated battery storage systems are a common feature of solar energy products in smart cities, enabling the daytime storage of surplus solar energy. This energy can be used at night or during peak hours, promising a steady supply of electricity and eliminating the demand for fossil fuels.
- **Energy Management System (EMS):** These systems optimize the use of solar energy in smart cities by managing energy storage and consumption in real time using artificial intelligence and data analytics.

5. Environmental Monitoring and Management:

· **Solar Powered Sensors:** Smart monitoring sensors (IOT devices) used for monitoring air quality index, water level, and weather forecasting, are also powered by solar energy. These sensors provide real-time data to the city management system and maintain clean energy in urban space.

- **Waste Management:** To cut costs and increase efficiency, smart cities employ solar-powered waste collecting systems and compactors.

Fig.11-Smart waste management system

6. Economic and Social Impact:

i. Job Opportunities: Installation of solar energy productsincreases the scope of employment in manufacturing, installation and maintenance, and other related sectors.

ii. Energy Independence: The emergence of solar energy products has reduced the dependence on grid lines and conventional energy i.e. Coal, gas, oil, etc.

iii. Cost Reduction: "Let the sun pay your electricity bill', solar energy has not only reduced dependence on grid lines but also helps in reducing electricity bills by installing solar panels and supplying surplus energy to public grids.

iv. Sustainable Urban Planning: Optimization of solar energy in smart cities, creating farms, and using solar energy for cooling and heating systems has made a sustainable environment for the inhabitants in urban cities.

Achievements Of Solar Power Products For Smart Cities Mission:

1. India has gained 5th position in solar energy installed capacity as per the Global Status report of REN 21 Renewables, 2024.
2. India's solar energy potential is estimated to be 748 GW, as per the National Institute of Solar Energy (NISE). It has increased 30 times in the last 9 years and become 85.47 GW as of June 2024 from 2.6 GW since 2014.
3. The Government of India has approved 57 city parks with an approx. capacity of 37.49 GW across the country.
4. India added approx. 8 GW of rooftop solar capacity by March 2024; it has already achieved up to 70 GW by the end of 2023. Out of this, around 2.5 GW has been installed in Smart Cities Projects till March 2024.
5. Utility Solar Scale projects have contributed up to 60% of the total solar capacity of India, cities like Rajasthan, Karnataka, and Gujarat are foremost in this pathway.
6. Over 1.2 million solar streetlights have been installed under the smart city project.
7. Approximately, 500 solar-powered EV charging stations have been established across smart cities.
8. The Government of India putting more focus on the installation of Solar floating panels. The Tumakuru smart city District has 80 to 100 acres of floated panels at Bugundanahalli Lake Reservoir in the Tumakuru District of Karnataka.

Most Successful Solar-Powered Smart City In India:

- **Diu Smart City-** Its first city in India to run on 100% renewable energy during the daytime. The city now saves 13000 tonnes of carbon emissions every year and managed to reduce power tariffs by up to 15%. Equipped-9MW solar park spread over 50 hectares and 79 Government buildings with installed solar panels as of 23 April 2018,according to a report from Press Information Bureau.

Challenges Towards The Implication Of Solar-Powered

Smart Cities:

1. **Large land area required** for the installation of solar parks, or solar power plants, becomes more challenging in highly populated and large agricultural lands.
2. **Dependency on weather** is another face-off before the installation process, as solar energy does not harness equivalent energy outcomes in every season.
3. **Energy Storage is required** during non-sunny days, which can be done through battery storage, but it has high cost and technical challenges.
4. **High initial cost required** for the installation of solar-powered panels.
5. **Secured financing** can be difficult, mostly in an area that is developing or underdeveloped, there may be some uncertainties about Government policies or long-term returns.
6. **Erratic policies and regulatory barriers** may also be proved as the biggest hurdle towards the mission, as new/modified policies may change the rate of subsidies, tax benefits, and tariffs. Also, lengthy approvals may delay investment and development in solar panel installation.
7. **Biodiversity** can be the main issue in the success of solar-powered smart cities, as it can affect the ecosystems, wildlife, and natural vegetation. Proper assessment and mitigation are required to reduce its impact.
8. **Maintenance and operations** over a while are needed in solar panels as they lose their efficiency by up to 0.5 to 1% annually. Also, dust and soil over the panels may affect the productivity of panels, which becomes very challenging to clean onto larger spread areas.

Suggestions And Findings:

1. **Consistency in Government policies** related to solar energy and smart city framework, proper and fixed guidelines for subsidies, installation, and incentives. Also, **streamlining Government approvals** and simplifying procedures can make the mission more rapid and successful.
2. **Advancement of energy storage solutions** such as batteries for efficient utilization of surplus energy in non-sunny hours.
3. **Promote Research and development in solar technology** to cut down the cost, and improvisation in efficiency.
4. **More exploration in hybrid systems** to remove the loopholes in case one fails, the other will work and both together increase productivity. In respect of it, Solar power should be combined with other renewable resources. Like sun and wind energy.
5. **More public awareness is needed**to increase the installation process frequently, promotional activities like educational campaigns, and people engagement programs should be initiated more often.
6. **Should be focused on sustainability**, installation should be done by keeping in mind that it will not harm the ecosystems and communities.
7. **Encourage private and public sector collaboration** to increase innovations and technology.
8. **Global Collaboration** should be welcomed to enhance the best practices, technological advancement, and educational knowledge.

Conclusion: As we are all aware, the future will be more advanced in technology and advancement always requires a supply of efficient energy for its implication. The mission of Smart Cities is based on Digital India with a sustainable development concept, and solar power products have played a very crucial role in making it successful. To make cities of India highly digitized and with technically upgraded infrastructure, and to keep themclean and eco-friendly, solar-powered products can be proved as smart decisions. Though there may be some challenges,they can be addressed through innovative ideas, government policies, more solar promotional programs, and careful planning to get long-term advantages.

References:-

1. Telang S, Chel A, Nafdey R, Kaushik G. Solar energy for sustainable development of a smart city. In: Security and Privacy Applications for Smart City Development. 2021. p. 155–69.
2. Mishra RK, Kumari CL, Janaki Krishna PS, Dubey A. Smart cities for sustainable development: An overview. 2022. p. 1–12.
3. Mahesha CR, Ramalingam M, Sujith S, Kalyanasundaram P, Soni NB, Nalinashini G, et al. Sustainable cooling and heating in smart cities using solar energy system planning. Energy Rep. 2022;8:826–35.https://doi.org/10.1016/j.egyr.2021.12.149
4. Industrial Outlook. Renewable energy - Authored article [Internet]. [cited 2025 Apr 28]. Available from: https://industrialoutlook.in/renewable-energy-2/authored-article/
5. Invest India. Renewable energy [Internet]. [cited 2025 Apr 28]. Available from: https://www.investindia.gov.in/sector/renewable-energy
6. JMK Research & Analytics. Annual India solar report card FY2024 [Internet]. 2024 [cited 2025 Apr 28]. Available from: https://jmkresearch.com/renewable-sector-published-reports/annual-india-solar-report-card-
7. Ministry of New and Renewable Energy (MNRE). Solar energy [Internet]. [cited 2025 Apr 28]. Available from: https://mnre.gov.in/solar/#
8. Ministry of Power, Government of India. Annual reports - Year wise [Internet]. [cited 2025 Apr 28]. Available from: https://powermin.gov.in/en/content/annual-reports-year-wise-ministry
9. Smart Cities Mission, Government of India. Smart Cities Mission [Internet]. [cited 2025 Apr 28]. Available from: https://smartcities.gov.in/