

Integration of Balcony Solar Systems for Intelligent Sustainable Energy in Apartments

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Abstract:

Environmentally friendly power is energy derived from natural sources that are renewed at a higher rate than they are consumed. Producing sustainable power makes far lower emissions than burning fossil fuels. Solar energy is the most plentiful of all energy assets and could be harnessed in shady climate. A private roof and a large financial commitment are requirements for a typical solar system. Due to a lack of roof space, millions of renters and flat owners are unable to take use of solar energy. To get over these hurdles, solar panels mounted on balconies and window sills can be used. A particular type of small solar power plant that may be put on a patio or balcony, is made up of several solar modules that combine with an inverter and additional parts to produce electricity from sunlight. In a mid-size house with LED bulbs, a 400-watt piece of equipment can be powered by a solar panel coating on the balcony for 6-7 hours of illumination. Balcony power plants are economical, ecologically friendly, and less reliant on the public electrical grid. Although the balcony solar business in India is still in its infancy, it might grow rapidly due to a number of factors, including rising energy prices, advances in technology, and support from the government. For people without access to rooftops, they offer a useful and effective option that lets them lower their carbon footprint and save money on electricity costs.

Keywords: Solar energy, Balcony Solar system, Solar module, Solar PVs.

Introduction:

Energy is perceived as a key source of economic growth and a major contributor to wealth creation. Three categories have been established for the energy resources: nuclear, renewable, and fossil fuels^[1]. The most major contributors to environmental emissions on our planet are methane, carbon dioxide, and carbon monoxide, which are released during the production and use of fossil fuels i.e., petrol, coal, coal products, petroleum products, natural gases, crude oil, gasoline that are frequently utilised for transportation, the production of energy, and other purposes.^[2,3] According to global statistics on greenhouse gas emissions, the power industry's CO₂ emissions decreased by 1% in 2019; however, the Covid-19 pandemic caused that number to drop by 7% in 2020. These trends suggest that the decline in coal-fired energy generation is being pushed by declining energy needs, the rise of renewable energy sources, and a move away from fossil fuels.^[4] The Climate Change

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Conference, COP26, was held in Glasgow, UK, in 2021 in response to UN recommendations. Through the delegates of the 197 nations, they came to an agreement whereby they agreed to work towards lowering their reliance on fossil fuels and coal. Creating energy systems that safeguard and enhance the environment and public health was the main agenda of the conference.^[5, 6]

Over the past 20 years, there has been a worldwide effort for research and development in the area of renewable energy sources and systems. Power that comes from renewable natural resources is more environmentally beneficial than non-renewable energy. The best alternative available to meet the demand for electricity is to use renewable energy sources such as Fuel cells, microturbines, solar PV systems, wind power generating systems, and other sources. Solar energy is the most plentiful of all energy assets and could be harnessed in shady climate. It offers many benefits, including readily available, reliable, low maintenance requirements, long lasting, and lack of pollutants.^[7] According to Husain et al. (2018)^[8], solar energy is the most plentiful energy source that can satisfy the demands of a society resulting from sustainable economic development. Recent advancements have made solar energy systems widely accessible for both residential and commercial use, with the added benefit of requiring less upkeep. The government might provide tax breaks and rebates to make solar energy economically feasible. As one of the main renewable energy sources, solar energy is becoming more and more popular in wealthy nations. The building plans that are now in place account for photovoltaic cells and related circuitry. India's average yearly temperature ranges from 25°C to 27.5°C due to its location between the Tropic of Cancer and the Equator. India therefore has enormous solar potential.

Roof-mount solar panels are a great option as they are so simple to install on residential or commercial roofs. The solar photovoltaic (PV) panels are secured and sunlight is absorbed by the solar racking, which is directly fixed on the roof surface to produce energy. When exposed to sunshine, it may be mounted on any type of roof structure with ease. However, a conventional rooftop solar system requires a private roof and a significant financial commitment. More homeowners in India are finding themselves living in high-rise buildings with little to no access to their own rooftops as the country's urbanisation rate rises. This is a problem for people who want to switch to solar energy in order to lower their electricity costs and carbon impact. Thankfully, to overcome these obstacles, balcony solar systems are becoming a competitive option for Indian city people. A specific kind of small solar power plant that may be installed on a balcony or patio is composed of multiple solar modules that work in tandem with an inverter and other components to generate electricity using solar radiation. Balcony solar panels offer a special chance to maximise available area and produce clean, renewable electricity in city settings. We'll look into balcony Solar's benefits, space needs, and other factors in the present paper.

1. What is Balcony Solar systems:

A balcony photovoltaic system is a compact photovoltaic system that is installed on a terrace, balcony or building façade and is just required to be plugged into a power outlet. This is a type of

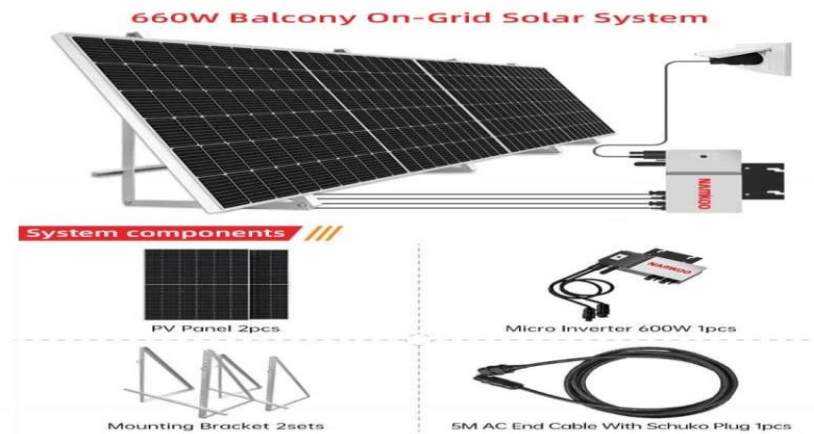
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decentralised energy generation that benefits all parties involved, where the electricity produced is either consumed immediately on the property or supplied into the grid.^[9] There are several varieties of solar panels for balconies, such as thin-film, polycrystalline, and monocrystalline panels. Polycrystalline panels are less expensive but marginally less efficient than monocrystalline panels because they are constructed of several silicon crystals as opposed to a single silicon crystal, which gives monocrystalline panels their high efficiency and durability. Because of their flexibility and low weight, thin-film panels are perfect for balcony installations where space and weight are important considerations.^[10]

2. Components of Balcony Solar System: The parts of a balcony PV system are as follows:

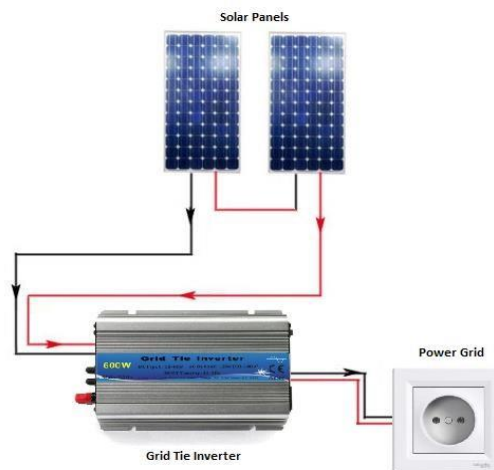
- **Photovoltaic or solar module:** Sunlight-absorbing, lightweight panels that produce direct current electricity (DC).
- **Inverter:** Direct current is used here at first. This self-generated power needs to be transformed into alternating current in order to be used in a household. This is accomplished with a strong inverter that is fastened to the balcony PV system.
- **Mounting System:** Adapts the panels' angle for optimal exposure to sunlight by fastening them to the balcony.
- **Optional Battery Storage:** Holds extra energy for use in the absence of sunlight.
- **Monitoring and Control System:** Provides real-time tracking of energy output and consumption that enable users to track the system's performance, monitor energy production, and optimize its efficiency.



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3. **Functioning of Balcony Solar system:** Balcony solar systems use a few simple methods to collect sunlight and turn it into electricity:^[11]
- **Solar Panel Absorption:** Silicon-based photovoltaic cells are used in the solar panels on the balcony to absorb sunlight. Sunlight exposure triggers the photovoltaic effect in these cells.
 - **Photovoltaic Effect:** When sunlight moves electrons in semiconductor materials (usually silicon), the solar panels produce direct current (DC) electricity.
 - **DC Electricity Generation:** When the solar panels are under direct sunlight, they generate DC electricity. Sunlight intensity, angle, and panel size are some of the variables that affect how much electricity is generated.
 - **Inverter Conversion and power distribution:** To make DC electricity compatible to power household appliances, electronics, or other devices, an inverter transforms it into alternating current (AC). It can be connected to the electrical grid as well, allowing any excess electricity to be fed back into the grid for credit or future use.
 - **Managing Extra Energy:** When a system produces more electricity than is required, the extra energy can be any of the following:
 1. Net meters: Returned to the grid to accrue credits or payback.
 2. Battery Storage: Power is kept constant even when the sun isn't shining by being stored in batteries for later use.



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4. Installation Process and Requirements

It is important to assess any location for the best sun exposure, shade from surrounding structures or trees, and the structural stability of a balcony to handle the weight of the panels before installing balcony solar panels. A thorough site assessment can guarantee safe installation and help optimise energy production. Balcony solar panel mounting options include:

- I. **Railing Mounts:** These brackets or clamps provide a strong and safe mounting solution by fastening the solar panels straight to the balcony railing.
- II. **Wall Mounts:** To fasten the solar panels to a balcony's solid wall, utilise wallmounted brackets. It need drilling into the wall.
- III. **Freestanding Mounts:** The solar panels can be used on balcony without fastening them to any existing structure by using freestanding mounts or frames. These mounts can be attached to the balcony floor, or they can have bases that are weighted.



Railing, Wall and Freestanding Mounts

5. Power efficiency of Balcony Solar System

It is a wise investment to install balcony power plants on balcony. A 400-watt piece of equipment can be powered by a solar panel coated on the balcony of a mid-size house with LED bulbs, providing light for six to seven hours. Depending on the conditions and time of day, two 160-watt solar PVs mounted on a balcony could provide anywhere from 10 to 190 watts. It can be utilised for a variety of household electronics. The excess is fed into the municipal electricity grid if there is no current consumption. A solar-powered charging station for devices such as computers, phones, wireless earphones, a few 12V emergency lights, etc. can be made on the balcony using solar panels and a battery. That equates to about 25 cents of energy for any residential plan.^[12] It may produce 700–800 kWh of electricity annually and pay for Senex 800 watt balcony solar system in 3–4 years.^[13] According to research done by Seme et al. (2024), the power efficiency of a balcony solar PV system with an installed capacity of up to 600 W that was attached as a plug-in production device pays for itself in a reasonably short amount of time—between 4 and 9 years.^[14] By building a 1.2 kW balcony photovoltaic system and a 2 kWh battery pack for each of the 9 residences in 4 apartments in Seoul, Kim et al. (2020) assessed the energy savings from electric power and discovered an average electric

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power consumption saving rate of almost 40%. The balcony PV solar system, in their opinion, will be crucial to reaching the goal of required zero-energy home.^[15] Speath et. al. (2023) presented an economically viable solution to increase self-consumption by installing Balcony solar systems consisting only of one or two solar panels, a grid-tie inverter plugged into a standard power socket, a load-controlled battery storage and they claimed that it has been successfully tested under real conditions for a one year.^[16]

6. Advantages of Balcony solar systems:

- 1) **As an alternative to rooftop solar systems:** Balcony solar systems enable people to embrace solar energy if they reside in homes or apartments without a separate roof.
- 2) **Space utilisation:** By utilising spaces that would otherwise go underutilised, these panels enable the creation of clean, renewable energy sources in tiny places like balconies.
- 3) **Easy installation:** Thanks to its small size and modular design, installation may be completed swiftly and simply without specialised permits or labour-intensive work. Stainless steel ties are typically used to secure solar panels for balconies to the balcony railing.
- 4) **Energy cost savings:** As cities' usage grows, so do their electricity expenses. Balconies equipped with solar panels can greatly lessen their reliance on the power company, which lowers their electricity costs.
- 5) **Environmental sustainability:** By producing clean energy at home and encouraging a more sustainable and responsible energy strategy, balcony solar systems help reduce greenhouse gas emissions.
- 6) **Versatility:** Solar panels for balconies can be used for a wide range of energy-related applications, such as charging electronic devices, powering automated irrigation systems, and lighting outdoor lights and appliances at home.
- 7) **Energy Independence:** Since balcony solar panels may produce power directly from the balcony, they offer energy independence and a sense of self-sufficiency by reducing reliance on the conventional grid system.
- 8) **Emergency Backup Power:** By storing extra energy in batteries or connecting to the grid via net metering, balcony solar panels can provide as a dependable backup power supply in the case of power outages or grid problems. This can be especially helpful in places where frequent power outages or natural disasters are common.

7. Disadvantages of Balcony Solar systems: Balcony solar systems, while convenient, come with several disadvantages:

- 1) **Limited Space:** The size of the balcony often restricts the number of panels, limiting energy production.

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- 2) **Shading Issues:** Nearby buildings, trees, or other obstructions can cast shadows on the panels, reducing efficiency. When there are clouds, there will be a decrease of 20-30% in electricity production.
- 3) **Aesthetic Concerns:** Some homeowners' associations or building regulations may have restrictions on visible installations.
- 4) **Structural Limitations:** Not all balconies are designed to support the weight of solar panels and associated equipment.
- 5) **Permitting Challenges:** Depending on local regulations, getting the necessary permits can be complicated.
- 6) **Energy Storage Needs:** Without a battery, you may not be able to store energy for nighttime use, limiting self-consumption.
- 7) **Lower Efficiency:** Smaller systems may not generate enough electricity to cover all energy needs, resulting in lower savings.
- 8) **Maintenance Access:** Cleaning and maintaining panels on a balcony can be more difficult than on a ground-mounted system.
- 9) **Inverter and Wiring:** Managing the inverter and wiring can be tricky in a compact space, potentially requiring professional installation.
- 10) **Potential for Theft or Vandalism:** Being in an accessible location might increase the risk of damage or theft.

8. The Current State & Future of Balcony Solar in India:

The balcony solar market in India is still in its nascent stage but are gaining traction in India, especially in urban areas where space is limited. Many homeowners are looking for alternative energy solutions to reduce electricity bills. The Indian government has introduced policies to promote solar energy, including subsidies and incentives for residential solar installations, although these often focus on larger systems. In June 2024, the Ministry of New and Renewable Energy (MNRE) revised its PM Surya Ghar scheme guidelines to include balcony solar and building-integrated photovoltaics (BIPV) under the scheme. Subscribers are eligible for central financial assistance (CFA) of up to ₹78,000 for up to 3 kW systems.^[17] Innovations in solar technology, such as lightweight and flexible panels, are making balcony installations more feasible and efficient. A variety of startups and established companies are offering balcony solar solutions tailored to residential customers, increasing competition and innovation in the market. Collaborative projects or community solar programs in India, could emerge, allowing multiple households to share a larger solar installation, even if on a balcony. While regulations vary by state, many local governments are beginning to establish guidelines for small-scale solar installations, including balcony systems. Here are a few examples of balcony solar systems in India, along with some companies that offer these solutions:

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1. **Loom Solar:** Loom Solar's balcony-mounted solar panels are compact and come in various wattages (typically 100W to 300W). Easy installation with plug-and-play options, suitable for apartments. They also provide battery storage options. Website: Loom Solar
2. **Solar Universe India (SUI):** SUI offers balcony solar kits that include solar panels, inverters, and mounting structures. These kits are designed for easy installation and can power small appliances or contribute to grid supply. [Solar Universe India](#)
3. **Pahal Energy:** Pahal Energy provides customized balcony solar solutions, focusing on urban setups. They offer installation services and assistance with regulatory compliance, including net metering. [Pahal Energy](#)
4. **Sunkalp Energy:** It offers small solar systems specifically designed for balconies and rooftops. Their solutions are tailored for energy efficiency and can be integrated with existing home systems. [Sunkalp Energy](#)
5. **Tata Power Solar:** Tata Power Solar provides small-scale solar systems for residential use, including balcony setups. They offer robust customer support and maintenance services along with their products. [Tata Power Solar](#)

These examples highlight the growing market for balcony solar systems in India, making it easier for urban residents to adopt renewable energy solutions.

9. Conclusion:

In conclusion, balcony solar systems provide an affordable and effective way for Indian urban homeowners to adopt renewable energy by producing power. With the right research and planning, individuals without access to rooftops or limited space can effectively reduce their electricity costs while contributing to sustainability efforts. Before considering for a balcony solar plant, it's advisable to take into account the particulars of living arrangement, such as the quantity of sunshine which balcony receives, the space that may be used for installation, and any applicable laws or regulations.

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