

Accelerating Urban Energy Transitions: The Critical Role of Solar PV in Achieving 100% Renewables

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1. Introduction

The transition from fossil fuel energy sources to renewable energy sources is crucial in the fight against climate change. In 2022, over 36.8 Gt energy-related CO₂ emissions were noted annually worldwide, the use of which exacerbates climate change and poses a severe health hazard related to air pollution and environmental degradation [1]. According to the International Renewable Energy Agency [11], to stay on the 1.5°C Pathway of the Paris Agreement, renewable electricity capacity must increase over threefold by 2030.

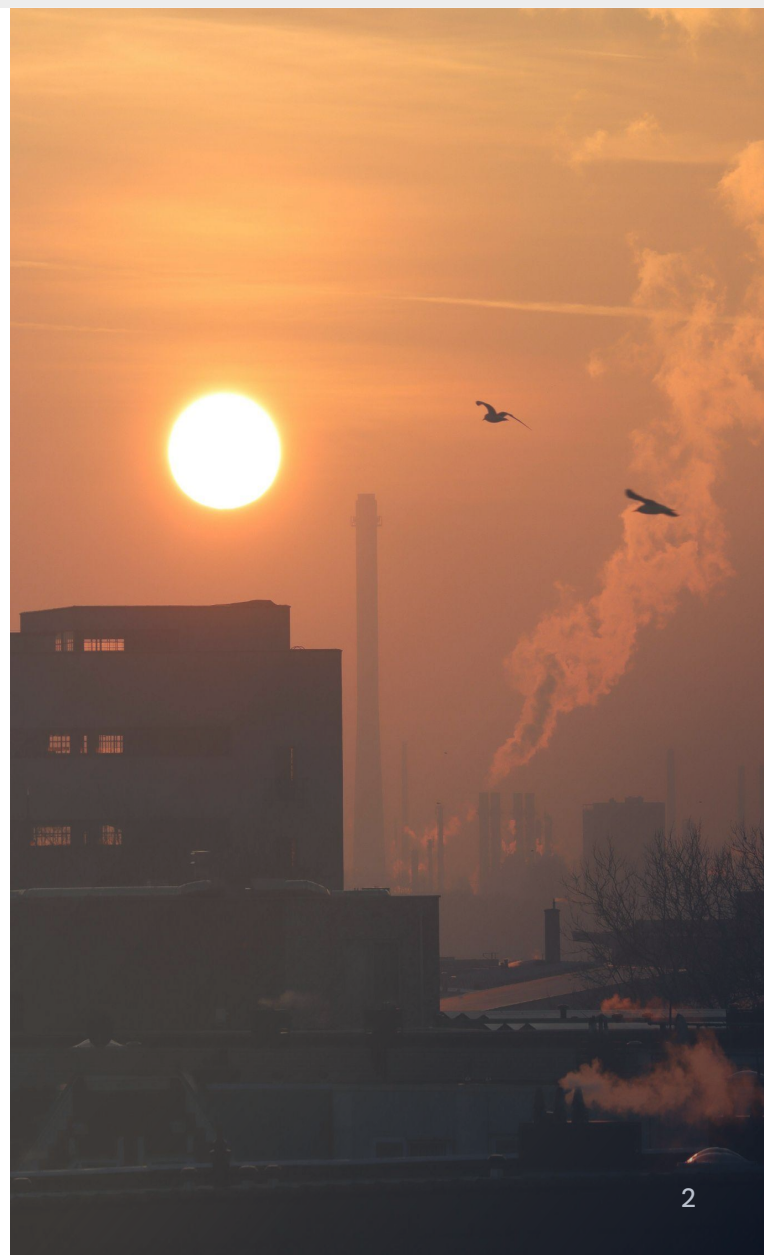
This article, therefore, discusses the potential of solar photovoltaic technology as one of the critical solutions to such challenges and assesses the role of solar PV in urban energy transitions to demonstrate how cities can actually use this technology in order to meet ambitious climate targets, improve energy security and support global sustainable goals.

2. Importance of Renewable Energy in Urban Settings

Urban areas are an integral part of the global energy transition. Due to their extensive economic activities and growing populations, these cities consume large volumes of energy and are significant contributors to GHGs. Therefore, there is an urgent need to transition away from fossil fuels to renewable energy sources.

This transition will not only reduce CO₂ emissions and mitigate air pollution but also create healthier and more sustainable urban environments for the future.

Current energy landscape: The current energy systems are heavily based on fossil fuels, leading to significant CO₂ emissions and environmental degradation. According to UN-Habitat, in 2022, cities used 78% of the world's primary energy and are responsible for 60% of greenhouse gas emissions [2]. This high dependence on fossil fuels underscores the need to shift towards renewable energy in order to address the consequences of climate change on humankind and sustain cities.



Benefits from Renewables:

1) Environmental Benefits:

- **Reduced GHG emissions:** renewable energy sources, such as solar and wind, emit close to zero GHGs when they are running, hence the protection of the climate.
- **Better air quality:** renewable energy, as opposed to the use of fossil fuels, reduces air pollution, thus creating healthier urban settings.
- **Less habitat destruction:** Renewable energy projects can also disrupt land use and natural animal habitats. Many technologies require huge amounts of water. While renewable energy sources reduce greenhouse gas emissions and air pollution, careful planning and implementation are required to further reduce the ecological footprints [17].
- **Preservation of ecosystems and species:** biodiversity conservation by reducing reliance on fossil fuels, renewable energy helps protect ecosystems and the species that depend on them.

2) Economic Benefits:

Renewables majorly contribute towards economic benefits largely through cost stability and job creation. Unlike with fossil fuels, renewable energy resources such as solar and wind turbines have negligible fuel costs and lower operating costs, hence providing consistent and often lower energy costs with time for cities and residents.

For instance, according to the International Renewable Energy Agency, solar and wind are currently the cheapest sources of power generation in most regions of the world. The cost of solar PV has fallen as much as 85% since 2010.

From an employment perspective, the renewable energy industry creates a significant amount of jobs. It provided employment for about 13.7 million people in 2022, and thus, according to IRENA's 2023 Renewable Energy and Jobs report, opened opportunities for manufacturing, installation, operation, and research, therefore contributing to the development of the local economy. This underlines how renewables development increases economic resilience and sustainability. [18]

Benefits from Renewables:

3) Social Advantages:

- Improved public health: cleaner air, a direct result of reduced fossil fuel use, translates to fewer health problems from pollution for public health.

- Energy access security: Renewable energy technologies can offer reliable energy access in underserved or remote urban areas, contributing to energy security.

Renewable energy sources, like solar and wind, have huge environmental, economic, and social benefits but also pose some challenges. Whereas renewable resources reduce GHG emissions, improve air quality, and preserve ecosystems, local ecosystems are disrupted, habitat damages can occur, noise, and visual impacts associated with the deployment of their technologies. Ongoing development such as wildlife-friendly turbines and floating solar farms has greatly reduced these impacts. Economically, renewables reduce energy cost and add jobs, but there may also be a need to re skill in transition industries. Socially, they improve public health and energy security; integration into grids might be challenging. Technological progress continues to address these issues, ensuring a sustainable energy transition.

How can cities help with the energy transition?

Cities and local governments have a critical role in driving the local energy transition. They can set ambitious climate targets, implement renewable energy solutions, and promote energy efficiency and conservation measures at local level. Throughout this transition, local and regional governments have key responsibilities in:

- Setting and enforcing local policies on climate: Cities can set leading targets and policies that make them forerunners in the more extensive diffusion of renewable energy.
- Supporting renewable projects: Cities can support local renewable projects and spur investment and innovation in clean energy technologies.
- Engaging with stakeholders: Active collaboration among national governments, private sector partners, and community organizations is the only way to ensure the successful deployment of renewable energy solutions.

While cities in developing countries may be constrained to playing a lesser role in policy-making or in the development of large-scale renewable energy projects, they can still play a very important role in implementation, collaboration, and facilitation.

In tune with national policies and through capacity-building programs, local governments can bridge the gap between national goals and local needs. Even within their limited authority, they can lead feasibility studies, engage stakeholders, and implement impactful pilot projects. It can jointly identify and implement specific solutions at a local scale, focus on energy efficiency, and develop local renewables.

In cooperation with national and regional governments, public-private partnerships, and active stakeholder engagement, cities emerge as important drivers of the energy transition, even in governance-constrained environments.

The energy transition offers significant environmental benefits as well as strong economic and social advantages. Embracing renewable energy, energy efficiency, and conservation measures will increase energy security and affordability, improving pathways to sustainable and resilient urban environments.

While the energy transition brings considerable environmental, economic, and social benefits, there are indeed its associated costs and challenges.

Transitioning toward renewable energy means great upfront investments in infrastructure, technology, and capacity building. These include grid modernization, installation of renewable energy systems, and decommissioning of existing fossil fuel-based systems. There are also social and economic implications in the process, such as addressing job losses in the old energy sectors and just transition for all parties concerned.



On the other hand, long-term savings associated with reduced fuel cost, improved energy efficiency, and health expenditure due to lower pollution generally outweigh the initial investment, according to research studies conducted by various agencies like the International Renewable Energy Agency. Strategic planning, financial support mechanisms, and inclusive stakeholder engagement will be required to overcome these challenges and maximize the net benefits of the energy transition [14,15,16].

3. Solar PV as a key solution: Transforming the urban energy landscape

Solar Photovoltaic (PV) technology stands out as a vital technology solution to the growing energy demands of urban environments.

Solar energy, being a renewable energy resource, is the most abundantly available resource and offers a cost-effective and efficient avenue for electricity generation, which is crucial for transforming urban landscapes. The potential of solar PV lies in the fact that earth receives more solar energy in an hour compared to what the world consumes in a year.

If only 0,1% of this energy were converted at an efficiency of 10%, for instance – it would provide an equivalent of four times the world's electric capacity [3] . This gives evidence as regards the potential of solar PV to meet current energy demands many fold.

Understanding solar PV technology: Solar PV technology in urban settings and highlighting its role in the clean energy transition.

It thus plays an important role in fulfilling the upcoming demand for energy in cities with perfect integration of available infrastructure.

PV systems make use of semiconductor-based cells to convert sunlight into electricity; this is scalable in nature and, thus, adaptable according to requirements into various urban applications.

Other technological advances include high-efficiency modules of over 25% [4], while innovative approaches such as BIPV systems—which act as facades and rooftops for high-rise buildings—have increased their applicability in very dense urban areas.

Cities can further accelerate the adoption of rooftop solar policies by enabling net-metering frameworks and optimizing urban rooftop potentials, as the IEA emphasizes, which can meet up to 30% of electricity demand in densely populated cities like Tokyo or New York.

Realizing this vision requires strategic urban planning, incorporating energy-efficient designs, public-private partnerships, and targeted financial and logistical strategies to overcome barriers. More than 11 TW of renewable capacity development will be needed to meet the global climate objectives, such as the 1.5°C target under the Paris Agreement, indicating the urgent need for scaling solar PV solutions worldwide [5].

The current solar PV installations doubled from 2022 installations, making 1,581 gigawatts (GW) minimum installed cumulative capacity by the end of 2023 [6].

Although positive, solar capacity additions must be far more ambitious if climate goals are to be met. The myriad uses of solar energy—from large ground-mounted installations to rooftop solar systems—make the case for investing and innovating in this area all the more compelling. In this effort, solar PV technology is of the essence, as it has enormous potential for reducing CO₂ emissions from fossil fuel generation.

According to IRENA's Renewable Energy Capacity Highlights 2023 report, global solar PV capacity needs to grow significantly beyond the 1,581 GW installed by the end of 2023. In a 1.5°C scenario, IRENA projects that installed solar capacity needs to surpass 12,000 GW by 2050, representing an annual growth rate of around 15–20% over the coming decades to account for the lion's share of renewable energy. IRENA (2023). Similarly, the IEA's World Energy Outlook 2023 puts forth that deployment in solar PV will have to go up tenfold to achieve net-zero targets.

More precisely, for the 1.5°C pathway, by 2030 there is a requirement for 6,000 GW of solar PV—nearly four times what was currently installed today (IEA, 2023). Vast amounts of untapped potential exist in cities for solar energy.

This implies that 15–30% of urban electricity needs could be covered by the optimal deployment of rooftop solar PV systems in cities such as New York, Paris, and Tokyo in 2030 [IEA]. That again determines how important it would be for solar PV in urban settings to accelerate towards clean energy. It is clear that increased solar PV in urban areas can greatly help meet local demand and will be fundamental in climate strategies globally for considerable cuts in emissions related to fossil fuel-based power generation.

Applications and scalability in urban environments:

One of the greatest strengths of solar PV lies in the fact that it is flexible, modular and scalable in small urban installations and larger applications. The ability to install PV systems on rooftops, building facades, balconies, parking lots, or any other available space in an urban environment further adds to the flexibility offered by these systems. This adaptability allows cities to integrate solar energy seamlessly into their existing infrastructure. A 1 kWp solar system typically requires around 5 square meters of roof space, though this can vary depending on the efficiency of panels and the system design [7].

Water bodies: Canal top



Surfaces: Transparent



Rooftop



Agrivoltaics



Roadside



Buildings: Integrated

Figure 1. Diverse solar PV applications

Imagine solar panels everywhere as shown in Figure 1: on rooftops, building faces, water and within agriculture as agrivoltaics. From ground-mounted arrays to floating installations and bifacial panels, and many more – help urban environments in sustainable transition utilizing solar energy.

Urban spaces are categorized based on their suitability for the solar photovoltaic deployment, enhancing the versatility of solar PV. Ground surfaces, such as roads, side walks, parks, and parking lots, offer expansive areas that receive direct sunlight, making them suitable for solar PV installations.

Parking lots present large and flat surfaces that are often underutilized and ideal for solar PV deployment. Building surfaces, including roofs, facades provide good opportunities for solar panel installations. Roofs, whether flat or sloped, are commonly used for solar PV, while facades can be equipped with panels depending on the building's orientation and shading.

Any intermediary spaces like balconies and courtyards offer further potential for solar energy generation, as they are less commonly used. Various settings for installation of solar PV are represented in Figure 2.

This kind of adaptability and ability to utilize various urban surfaces make solar PV a critical component and cities maximize their solar energy potential by effectively utilizing ground and building surfaces.

The other critical factor is the cost-effectiveness of PV systems. Solar PV offers an economically viable solution for urban energy requirements by having low operation costs and electricity generation competitive with fossil fuel prices. These systems require minimal land use, which is particularly advantageous in densely populated areas.

The typical electricity generation cost for utility scale solar PV projects in 2022 was approximately US \$ 0,049, as the trend decreased from previous years [8].

Emerging building-integrated PV, floating solar PV, agrivoltaics, and road-integrated PV are unlocking new opportunities to tap urban areas. These innovative solutions are efficient in harnessing the available space in urban areas and, therefore, place cities as hubs for sustainable energy.

Solar PV will continue to increase its role in the power grid, but the challenge with this lies in the intermittency of the technology itself, bound by location's resource potential and existing grid infrastructure. These barriers can only be overcome by advancement in large-scale electricity storage technologies to address variability.

Besides, other strategies under active development to ensure a reliable and resilient energy supply include grid optimization, better resource assessment techniques, demand-side management, and hybrid systems integrating solar with other renewable resources.

Enabling policy environment and planning for solar energy integration:

Local and Regional Governments in cities and regions play an important role in creating a framework that supports the deployment of solar PV technologies, including incentives for installations, streamlined permitting process, and integration of solar energy into broader urban planning and development strategies.

IEA underscores the importance of enabling policy to foster global renewable energy capacity. Existing regulations, policy environments, and planning stages to achieve global ambitious goals for using solar energy enable higher deployment. The current global renewable capacity is expected to reach 7300 GW by 2028 [9].

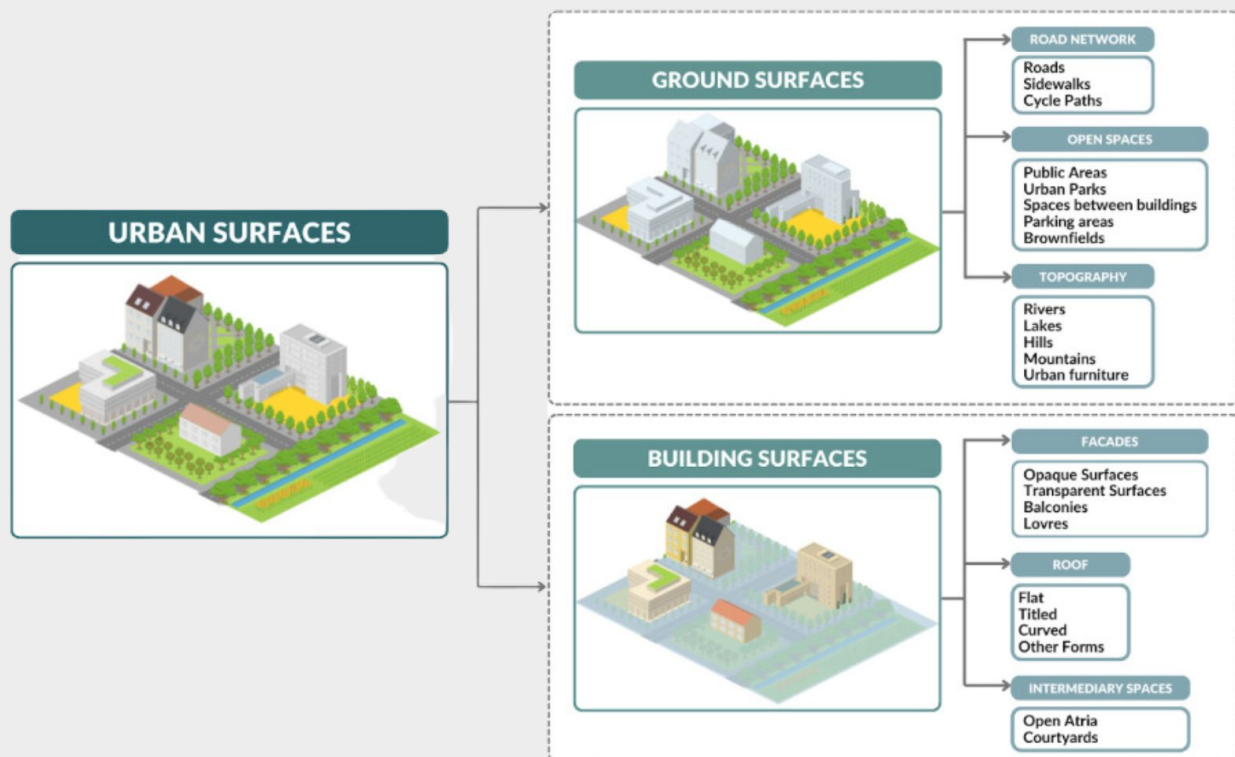


Figure 1. Own elaboration based on surfaces uses in solar neighborhoods: IEA SHC Solar neighborhood planning, IEA 2022 [12]

While the deployment of solar photovoltaic systems presents huge potential in urban areas, their deployment in open areas such as roads, parks, and parking areas in developing countries faces several problems. Among these is inadequate maintenance, incidents of theft, and other social problems that critically affect the operations of solar photovoltaic installations and render such options non-viable or less sustainable in these countries.

Other challenges may be related to the deployment of rooftop and façade-mounted systems, including structural limitations, shading issues, and variable community acceptance. Minimizing tampering would be a matter of design considerations, use of sophisticated technologies like anti-theft mechanisms, and raising public awareness and community participation to protect the systems and ensure their continued use. These challenges, when identified alongside the opportunities, create a balanced perspective and drive innovation in deploying solar energy solutions.

4. Harnessing Solar PV for 100% Renewable Cities

Solar PV is a feasible and sustainable solution that can be uniquely adapted to different urban contexts. Solar PV technology is uniquely positioned in view of the dual challenges of climate change and urban energy demands. Due to its scalability, cost-effectiveness, and environmental benefit, tapping into renewable energy sources, like solar photovoltaics, has been called in principle in mitigating climate change, improving energy security, and attaining global sustainability.

This article has explored the potential of solar PV and also delves into how cities can practically implement this technology as part of their energy transitions. [Smart Energy Solutions for Africa \(SESA\)](#)'s focus on co-developing innovations with local partners, enhancing replicability and integration solutions [13].

This approach ensures that cities not only adopt solar PV in theory but also implement it effectively, creating sustainable and scalable energy systems that benefit both urban and rural communities. By leveraging the insights and experiences of the project like ICLEI's [100% Renewables Cities and Regions Roadmap](#), this article provides a comprehensive guide for local governments to develop tailored strategies and roadmaps to become 100% renewable energy. It focuses on effective local policies, multi-level governance, and capacity-building [10].

Call for Action: Cities and regions that are interested in showcasing their leadership in implementing local renewables have the opportunity to exchange knowledge and experiences, access various opportunities, and inspire others by joining [the 100% Renewables Cities and Regions Network and Energy Compact](#).

By joining these 100% renewables initiatives, participating local and regional governments and other stakeholders gain access to ICLEI's technical support and services including peer exchanges, various knowledge products and tools, and capacity-building opportunities.



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