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# Integrating Building-Integrated Photovoltaic (BIPV) Systems: a Study of Integrating BIPV into Buildings in Iraq, Including Technical Considerations, Economic Feasibility, and Potential Environmental Benefits

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**Abstract:** To increase renewable energy output and achieve low carbon footprints for buildings, Building-Integrated Photovoltaic (BIPV) is a promising technology. To alleviate power outages and cut down on emissions of greenhouse gases, this article examines Iraq's options for utilising renewable energy. Using the present state of renewable energy sources as a starting point, it proposes ways to make the most of them. Moreover, it suggests ways to install building-integrated photovoltaic (BIPV) systems and talks about how their demand is on the rise.

**Keywords:** renewable energy, pollution, power generation, Building Integrated Photovoltaic (BIPV)

## Introduction

To safeguard the environment and reduce greenhouse gas emissions, BIPV paves the way for zero-energy buildings that rely on renewable and sustainable technologies [1]. Due to the fact that PV system performance is affected by the amount of light transmitted through the building, there is a strong correlation between the electrical, thermal, and optical aspects of BIPV systems that have been studied [2]. Therefore, in order to offer viable solutions to significant energy and environmental crises like electrical energy shortage, environmental damage, and climate change, research and development focussing on the aesthetic, economic, and technical barriers is strongly encouraged, especially because BIPV technology helps to reduce the consumption of traditional fossil fuels [3]. In 2023, the world's renewable power capacity added about half a gigawatt (GW) to its total, the highest rate of growth in the previous 20 years. Even if renewable capacity gains in the US, Brazil, and Europe were record highs, China's acceleration was phenomenal. In 2023, China installed more solar PV than the entire globe in 2022, while its wind installations increased by 66% compared to the previous year. Three halves of the renewable capacity gains globally were attributed to solar PV alone [4]. The capacity of power plants and other installations to generate electricity from renewable sources is known as renewable power generation capacity. The data represents the installed and connected capacity at the end of the calendar year for the majority of nations and technologies. An IRENA survey, official national statistics, reports from trade groups, other papers, and news stories are some of the places that have contributed to the data set [5].

The technology of BIPV structure

Despite the abundance of solar mounting methods on the market today, only a select number offer truly versatile solutions for usage in structures. Bolts and associated intermediaries are standard components of most current BIPV mounting systems [6]. Holddown plates made of aluminium alloy secure the photovoltaic components, as seen in Figure 1 [7]. The next step is to secure the plates to the substructures using bolts. The frame-exposed BIPV systems are the only ones that can use this mounting mechanism, and installing it quickly isn't an option because of all the bolt connections and intricate cables. Consequently, this mounting system's buildings lack aesthetic appeal. A new kind of photovoltaic component was suggested in 2011 to make the building more aesthetically pleasing and to make replacement and maintenance of the components easier and faster.

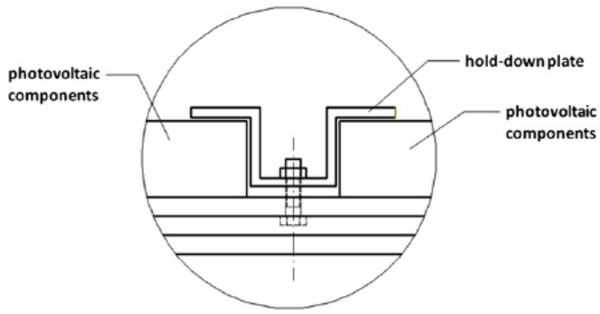
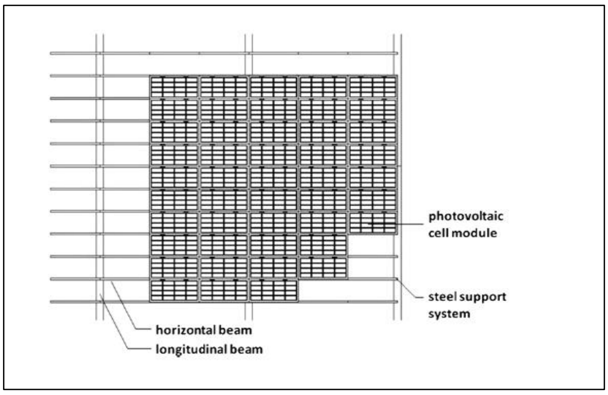



**Fig. 1. The schematic of a middle-pressure plate photovoltaic system [6]**

Fig. 2 shows the components of this innovative solar structure, which are easy to repair and replace. It consists of photovoltaic cells and a steel framework. According to Figure 3, a steel support system allows solar cell modules—which include photovoltaic panels, two models of the upper-spring connection and two models of the under-fixed connection—to be tightly integrated with buildings. Two springs and a sliding block make up the upper-spring connection model, with the electric circuit's "anode-cathode" contact points located at the model's end (Fig. 4). The spring is attached to the sliding block at one end and the solar panels at the other end by means of a U-bracket. The U-bracket provides a smooth surface for the sliding block to slide across. On top of that, this model has an auto-lock feature that, when pressed down and released, can secure photovoltaic cell modules to the steel support structure. Regularity and spacing are provided by the under-fixed model. Both horizontal and longitudinal beams make up the steel support system. Figure 5 depicts the longitudinal beams as having an I-bar shape. At the side of the horizontal beam is where the electrical circuit box of the I-beam is located. There is a direct connection between the buildings and the opposite side of the I-beam. As seen in Figure 6, the photovoltaic cell module connectors and the electrical circuit box are concealed within the horizontal C-beam beam. connections on the C-beam serve as "anode-cathode" points of contact for the photovoltaic cell modules, and the upper-spring and under-fixed versions of the modules are inserted into these connections to mount the modules on the beam (Fig. 7). You can mount electrical circuit boxes on I-beams and C-beams to run wires. The modules of photovoltaic cells are attached to the buildings using the steel support system. Fig. 8 displays architectural renderings of a photovoltaic wall and roof [6].



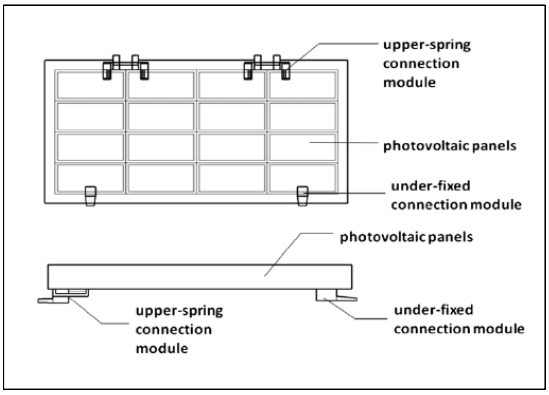
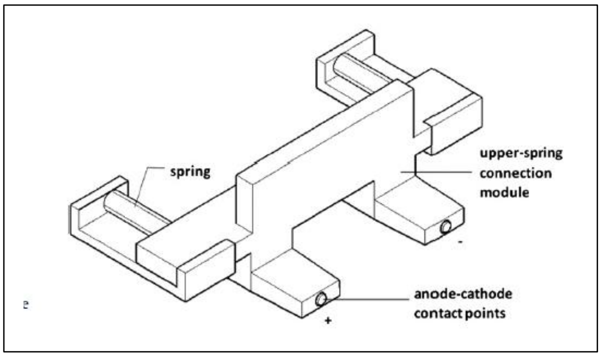




**Fig. 2: Photovoltaic component design.**

**Fig. 3: Photovoltaic components.**



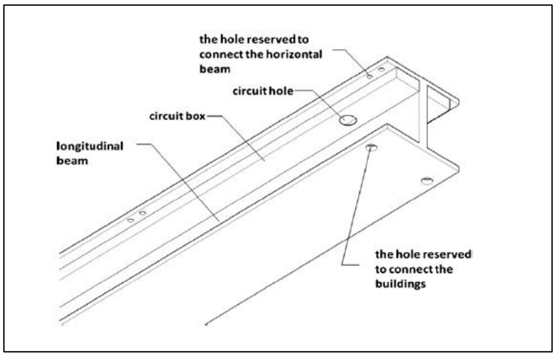




**Fig. 4: Upper-spring connection module.**

**Fig. 5: Details of the longitudinal beam.**

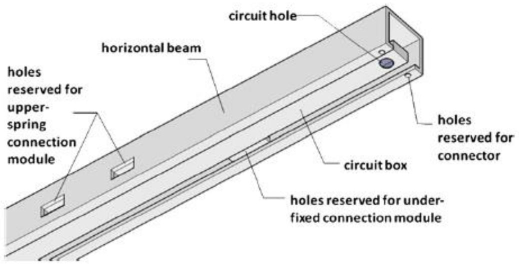



**Fig. 6. Details of horizontal beam.**

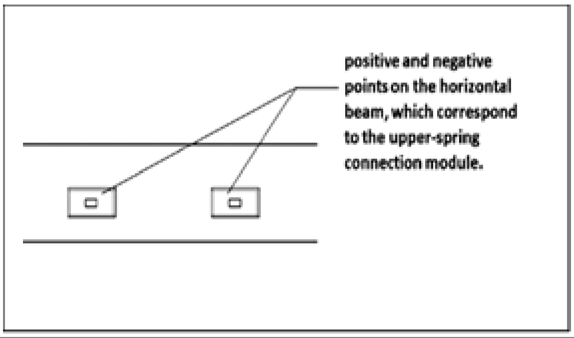



Fig. 7: "Anode–cathode" contact points of the electric circuit at the horizontal beam.

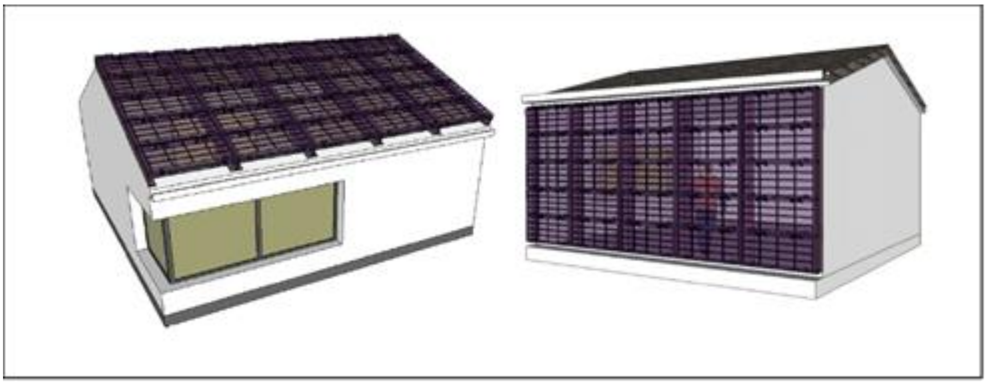


**Fig. 8. Architectural pictures of a photovoltaic roof and photovoltaic wall.**

Resource availability

This includes analyzing data related to renewable energy resources ( Solar radiation for solar energy)

***Solar Energy***

The summers in Iraq are famously long, thanks to the country's abundance of sunshine. Only Baghdad, Iraq, captures more than 3,000 hours of sun energy every year [2]. Sun irradiation for electric power generation is highest in the western desert of Iraq, in contrast to the annual worldwide average horizontal surface radiance of 170W/m2. The Iraqi deserts generate an average power density of 270W/m2 to 290W/m2, reaching a maximum of 2310kWh/m2/year, as reported by the German Aerospace Centre [3]. Due to the country's long summer days (14 hours on June 21), Iraq is able to generate a significant amount of electricity from solar power [2]. A 500 MW station may be constructed in a year using solar fields, which is significantly faster than other power plant types [4]. The first, known as photovoltaic (PV) systems, convert sunlight directly into electricity; the second, known as solar thermal power systems or concentrated solar power (CSP), takes the energy from the sun and turns it into heat, which may be utilised to create electricity [4]. In places far from utility grids, where conventional power sources are unavailable, photovoltaics can provide much-needed electricity. It has multiple potential applications, including communication towers, outdoor street lighting, and providing residences with light electrical loads [5]. Although solar energy is available year-round, particularly in the summer when demand for electricity is highest, Iraq does not make good use of it to generate electrical power, with the exception of a few minor initiatives like street lighting. In order to meet the growing need for energy while simultaneously reducing pollution and making use of clean renewable energy, it is now essential to employ photovoltaic cells to power distant places and CSP stations to generate large capacity. It is possible to utilise solar water heating systems throughout the winter to decrease electrical energy use, in addition to using solar energy to generate electrical energy [4,5].

Iv . Consider the availability of trained workers for installation and maintenance, as well as the country's emphasis on technological advancement and the digital Internet, as you assess the viability of renewable energy technology in Iraq.

V. Research the rules and policies that are in place to guide the expansion of renewable energy sources.

With ongoing policy support in over 130 countries, renewable electricity capacity additions hit an expected 507 GW in 2023, up over 50% from 2022. This marked a notable shift in the worldwide development pattern. The solar PV and wind markets in the People's Republic of China grew at the fastest rates in 2023, accounting for 116% and 66% of the global acceleration, respectively. The generation costs of solar PV and wind power are cheaper than those of fossil fuel and non-fossil alternatives in most countries, and governments are still supporting these sources, so they will make up a record 96% of renewable power capacity increases during the next five years.

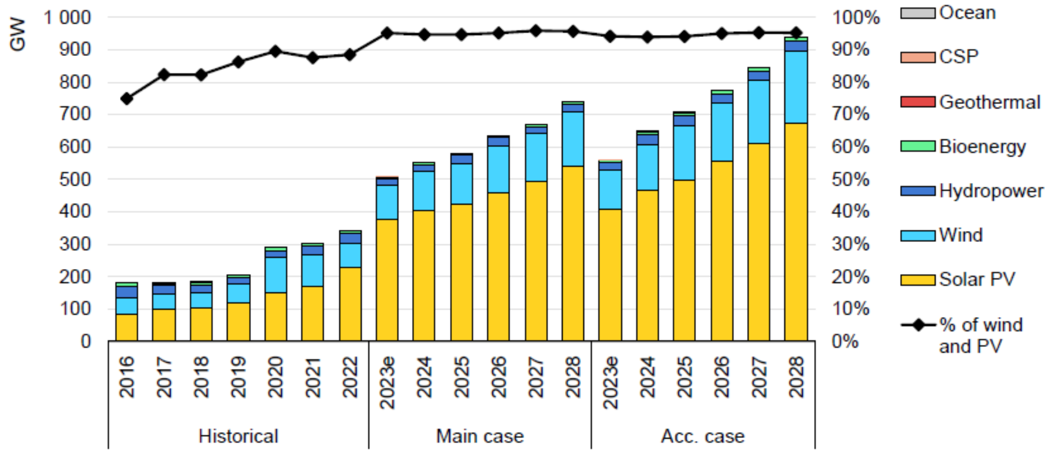



**Fig. 9: Renewable electricity capacity additions based on technology and segment**

Forecasts indicate that the addition of solar PV and wind power would more than quadruple by 2028 compared to 2022, setting record after record until reaching about 710 GW. As can be seen in figure 9 [6].

Potential renewable electricity generation growth outpaces worldwide demand growth for the predicted period. Renewable energy sources comprise 42% of global electricity generation, with 25% coming from wind and solar PV combined. Even in the year 2028, hydropower is still the leading renewable energy source for power. Though hydropower accounts for the vast majority of renewable energy in 57 nations, these nations account for only 14% of the world's power demand, so there is a clear need for rapid expansion of renewable electricity generation in many nations. Even though they will meet 17% of the world's demand by 2028, 68 nations will rely on renewables as their primary source of electricity generation.depicted on figure 10 [7]

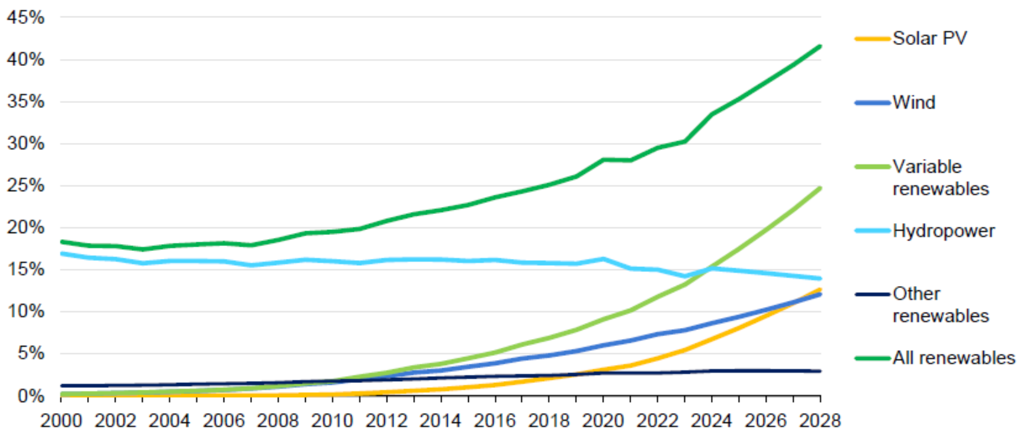



**Fig. 10: Electricity generation by technology, 2000-2028**

VI. Analysing the operational benefits, possible profit sources, and expenses of renewable energy projects in comparison to conventional energy is an important part of evaluating their economic feasibility.

Solar panels' price is the main concern. The silicon used in most panels is today quite expensive, despite the fact that solar cells in the early 1950s cost 286 USD/W and achieved efficiencies of 4.5-6% [8]. This is due to the substantially increasing demand for these panels. To combat this, developers have begun to use thinner silicon and other materials in an effort to keep costs down.

As demand increases and manufacturers ramp up production, the price of solar panels falls as a result of economies of scale. This trend is projected to continue in the coming years. The typical cost per installed watt, including panels, inverters, mounts, and electrical components, was around USD 6.50–7.50 in early 2006. The price of power from solar cells will approach that of traditional power plants by the year 2050 [7]. Solar cell technology (also called photovoltaic cell technology) The evolution of solar cells is commonly believed to have happened in three distinct generations, with the third generation being in its early stages and undergoing ongoing research and development. Additional development is underway for the two preceding generations, which are still in use today [7]. Nearly 90% of all cells produced are made using first-generation technology, which are also the most often employed in commercial manufacturing. They are frequently characterised as efficient but expensive.

There has been little success in lowering production costs due to the substantial energy and labour inputs required by these. These photovoltaic cells employ a single junction to convert light into energy; they are made of silicon semiconductors. Their payback time is between five and seven years, and they reach cost parity with fossil fuel energy generation when they approach the theoretical limiting efficiency of 33 percent. Still, most people don't think first-generation cells can deliver energy more cheaply than fossil fuel sources because of how capital-intensive their production is. Solar cells of the second generation have been under heavy development since the turn of the millennium. People typically say that these cells are cheap and inefficient. The energy needs and manufacturing costs of first-generation cells have been addressed by developing second-generation materials. Among these, you can find cadmium telluride, amorphous silicon, micromorphous silicon, copper indium gallium selenide, and amorphous silicon. Vapour deposition, electroplating, and the use of ultrasonic nozzles are alternate manufacturing techniques that drastically cut down on energy-intensive production procedures [9]. Rapidly manufactured printed cells are a popular illustration of second-generation cells. Although the conversion efficiency of these cells is only 10-15%, the decreased costs make it a favourable trade-off per unit of energy produced. It is projected that second-generation solar cells will overtake first-generation cells in terms of market share in 2012, continuing a trend that began in 2008 with second-generation technology. In the future, second-generation solar cells may be more economical than using fossil fuels [10]. Researchers are presently looking into third-generation solar cells. Products are not available just yet. Aiming to merge the first generation's low production costs with the second generation's strong electrical performance is the goal of third-generation technology. Utilising cutting-edge technology, we aim to create thin-film cells with efficiencies ranging from 30 to 60%. It is too soon to tell for sure, but some say that third-generation cells could hit the market around 2020. Among the technologies linked to third-generation solar cells are tandem cells, multijunction photovoltaic cells, nanostructured cells (to increase voltages or carrier collection), and improved incident light usage (including infrared collection at night) and excess thermal generation (UV light). the eleventh

VII. Environmental impacts: Minimal positive effects on the environment, such as lessening the effects of air pollution and greenhouse gas emissions.

There is a direct correlation between the energy sector and the environmental problem. The amount of carbon dioxide ($CO_2$) emissions released into the atmosphere by gas flaring alone is around 30 million tonnes [12]. Baghdad has levels of $PM_{2.5}$, a kind of air pollution that is especially harmful to humans, that are seven times higher than the maximum levels advised by the World Health Organisation. Air pollution is a problem because people rely too much on diesel-powered neighbourhood generators1. Research on air pollution has shown that diesel and petrol engines produce more than half of the carbonaceous aerosols [12]. More motivation to switch to a cleaner, more efficient grid-based power source is created by this.

VIII. Market Demand: Find out how much interest there is in new energy services, such as decentralised power solutions, off-grid electricity, and other on-grid energy initiatives, during the night.

The Iraqi government places a high premium on resolving power outages in order to satisfy peak demand during the summer months. There is cause for cautious hope in this regard, since various choices exist to address the urgent deficiencies (Figure 11). We have looked at these possibilities and thought about how to implement them so that they work with the long-term strategy for a cost-effective and dependable system. Dealing with the urgent matter at hand is critical, but it shouldn't be at the expense of working towards more distant goals at the same time. Prioritising energy conservation and efficiency programs should take precedence over supply-side approaches since they can achieve both short- and long-term objectives. For instance, prioritising the immediate and other time frames in the strategic plan should include supporting high-efficiency cooling equipment. There needs to be an attempt to free up supplies for the most necessary purposes, in addition to conservation and efficiency. To ensure that more homes have air conditioning during the warmest parts of the day, it is important to encourage consumers to move non-essential demand away from peak hours wherever possible. Campaigns to raise consumer awareness of energy-efficient appliances and the possibility of lower power costs may be necessary to achieve this goal.

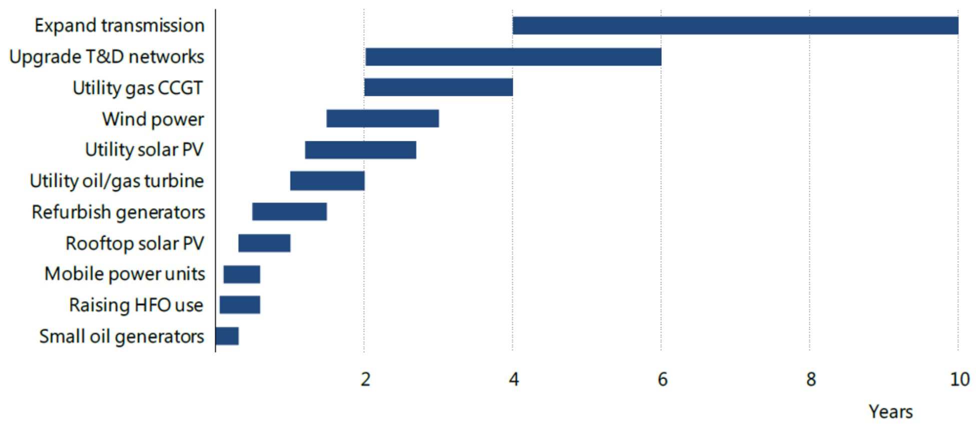



**FIG.11 Alternatives to current power generation methods organised by project duration [13]**

## IX. Conclusion and recommendations

Solar, wind, geothermal, and hydropower are just a few of the renewable energy resources that Iraq is abundant in. But fossil fuels are the lifeblood of the country's energy infrastructure. Climate, desalination plants, population expansion, high energy demand, and reliance on fossil fuels all contribute to the country's high pollution rate. Sustainable development in all its aspects—economic, social, and environmental—is the goal of Iraq's state-sponsored 2030 Vision. The growth of renewable energy sources can bolster initiatives to achieve the SD Goals, as sustainable energy is a crucial component of any effective sustainable development plan. In its current state, however, the renewable energy sector encounters numerous technical and economic obstacles. Some of the biggest problems include the weather, people's ignorance about renewable energy's benefits, and the cheap and plentiful fossil fuels. The nation needs to do more in the areas of renewable energy resource mapping, renewable portfolio standards, renewable energy academic curriculum development, smart grid technology, renewable energy research and development, regulation to limit emissions of greenhouse gases, and smart grid technology. Current BIPV is limited in look and functionality due to financial and technological limitations. Based on our investigation and analysis of the cases, we have determined:

1. Although the form of high combinations is very attractive architecturally, it may not be functionally, economically, or technologically advantageous, therefore it is not true that tighter integrations of BIPV are desirable. Consequently, we need to ensure that the appearance of BIPV is appropriate for our needs.
2. The field of solar technology has advanced tremendously as a high-tech enterprise. As time goes on, the price of photovoltaics drops, the efficiency of photovoltaic cells rises, and new varieties of photovoltaics are developed. Current goods may become obsolete in the next decade due to the lightning-fast pace of innovation in solar components. On the other hand, depending on the building's significance, its lifetime must be fifty years or longer. So, photovoltaic components don't have to endure as long as structures, but they should be easy to maintain and replace.
3. Photovoltaic components come in a variety of shapes and sizes, but they still have a ways to go before they meet standards, and the procedures for installing, maintaining, and replacing them are cumbersome. So, to make BIPV easier to maintain and replace, we suggest a new structural design scheme. The concept is based on the integration of electrical circuits and steel support systems, as well as the principles of self-locking and dry batteries. Solar panels like these can even be mass-produced in factories and then installed at a later date.

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