

# *Solar Powered Hydroponics and Vertical Farming: A New Frontier*

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## **ABSTRACT**

Solar-powered hydroponics and vertical farming represent innovative solutions to address the growing challenges in agriculture caused by population growth, urbanization, and land scarcity. These modern techniques enhance crop production by integrating solar energy with resource-efficient systems like hydroponics and vertical farming. Solar integration reduces carbon emissions, conserves resources, and lowers energy costs, making the approach both sustainable and economically viable. Advanced technologies such as agrivoltaics, IoT, and automation further optimize land use and improve efficiency. By adopting these eco-friendly practices, farmers can enhance food security, reduce environmental impact, and promote a sustainable future in agriculture.

## **INTRODUCTION**

**T**he global population and urbanization are increasing at a very rapid rate thus decreasing the land under agriculture. By 2050, the population is expected to reach 9.7 billion and world has to produce 50% more

food, thereby requiring an additional arable land that is simply not available (Anonymous 2020). Traditional soil-based agricultural production systems face serious threats from these challenges, making food production a

real challenge today. Soil-based farming practices need to be supplemented by more efficient and environmentally-friendly forms of modern farming (Lambin and Meyfroidt, 2011). Liquid culture, also known as hydroponics, is one such specialized technique for growing plants without soil. On the other contrary, urban farming has already been experiencing difficulties resulting from land scarcity and high costs. We are in despair need of game-changing solutions to this enormous global problem (Muller *et al.*, 2017). However, integrating solar power with hydroponic systems offers a sustainable approach to agriculture by combining renewable energy with efficient, soil-less cultivation methods. This synergy addresses the above challenges that impacts the traditional farming practices. Thus, hydroponics and vertical farming represent transformative innovations in agriculture that provide sustainable and efficient solutions.

### Need for Sustainable Agriculture?

- **Rising Global Population:** By 2050, the global population is projected to reach 9.7 billion, requiring a 50% increase in food production. Conventional agriculture alone may struggle to meet this demand.
- **Climate Change Impacts on Traditional Farming:** Unpredictable weather patterns (droughts, floods, extreme heat) reduce crop yields. Rising global temperatures affect soil fertility and water availability.
- **Land and Water Scarcity Challenges:** Rapid urbanization, industrialization, and infrastructure expansion are shrinking the availability of fertile land for agriculture. Overexploitation of groundwater, inefficient irrigation practices, and climate change-induced droughts are aggravating water scarcity.

### Importance Of Solar Powered Hydroponics and Vertical Farming:

Solar-powered hydroponics and vertical farming combine two sustainable technologies to create a highly efficient and eco-friendly food production system. By integrating solar energy, these farms can operate off-grid, making them viable in urban areas, deserts, and even remote locations.

1. **Addressing Food Security-**With the global population expected to reach 10 billion by 2050, traditional farming may not produce enough food. These methods enable **year-round farming** and higher crop yields in smaller spaces
2. **Efficient Use of Resources-Water Conservation:** Hydroponic systems use **90% less water** than soil-based farming. **Land Efficiency:** Vertical farming can grow more food per square foot by utilizing vertical space.
3. **Overcoming Climate Change Challenges-**Traditional farming is vulnerable to droughts, floods, and extreme weather. Controlled indoor environments in vertical farms ensure stable food production regardless of climate conditions. Cities with limited land can produce food locally, reducing dependency on rural farms.
4. **Pest and disease control** as it is a soilless medium.
5. **Potential for Space Exploration-**NASA and other space agencies are exploring hydroponics and vertical farming for growing food on Mars and the Moon. These methods could sustain future space colonies.

## What Is Hydroponics?

The term "hydroponics" originated from the Greek word- "hydro," which means water, and "ponos," which means labour. It is a method of growing plants without soil by using a nutrient-rich water solution to deliver essential minerals directly to the plant roots. This innovative cultivation technique allows plants to thrive in controlled environments with optimized conditions for growth. Peat moss, charcoal, gravel, rock wool, perlite, coco peat, and coconut coir are only some of the inert media used in hydroponic systems to support plant roots. Although the technology sounds cutting edge, the history of hydroponics dates back to the famous Hanging Gardens of Babylon, one of the Seven Wonders of the Ancient World. The Euphrates River was diverted into channels that ran down the walls of the grand garden.

Hydroponics has been recognized as a viable method of producing vegetables (tomatoes, lettuce, cucumbers and peppers) as well as ornamental crops such as herbs, roses, freesia and foliage plants.

### Types of Hydroponic Systems:

1. **Nutrient Film Technique (NFT):** A continuous flow of nutrient solution is circulated over the roots, ensuring constant nutrient delivery.
2. **Deep Water Culture (DWC):** Plant roots are suspended in a nutrient-rich oxygenated water solution for efficient absorption.
3. **Ebb and Flow (Flood and Drain):** The grow tray is periodically flooded with nutrient solution, which then drains back into the reservoir.
4. **Drip System:** Nutrients are slowly delivered directly to the plant base through drip emitters.

5. **Aeroponics:** Plant roots are suspended in air and misted with nutrient-rich water, maximizing oxygen exposure.

### Popular Crops Grown Using Hydroponics:

Leafy greens (lettuce, spinach), herbs (basil, mint), tomatoes, cucumbers, and peppers and strawberries and other small fruits.

### What is Vertical Farming?

Vertical farming is an innovative agricultural method that involves growing crops in vertically stacked layers, often integrated into controlled environments like buildings, warehouses, or shipping containers. This technique maximizes space utilization and allows for year-round cultivation regardless of external weather conditions or it is multi layered production of plants to increase yield/area where growth factors such as light, temp, humidity etc. are precisely controlled to produce high quantities of high-quality fresh produce year-round, completely independent of outdoor conditions.

Vertical farms commonly use soilless growing methods like hydroponics (water-based), aeroponics (mist-based), or aquaponics (fish-waste nutrient systems). This farming represents a promising solution for future food security, particularly in urban environments with limited arable land. It aligns well with sustainable agriculture practices by promoting resource efficiency and minimizing environmental impact.

### Crops Suitable for Vertical Farming:

Leafy greens (lettuce, kale, spinach), herbs (basil, parsley), strawberries and other small fruits and microgreens and edible flowers.

### Concept of Solar Power in these systems:

Although there are numerous advantages of hydroponics and vertical farming in terms of land use efficiency, water use efficiency with

maximised space utilization and year-round production along with no or less incidence of pest and diseases. Despite the numerous advantages, several challenges and opportunities need to be addressed to enhance its sustainability and widespread adoption. One of the primary challenges is the higher energy requirements of hydroponic systems compared to conventional farming. The need for artificial lighting, climate control, and pumping systems contributes to increased energy consumption, which can have environmental and economic implications.

That's why we need to shift to some sustainable way for energy consumption that is we can go for solar energy. Solar power integration offers several advantages in these systems like energy source for LED lighting, pumping power for irrigation systems, power for water desalination, battery storage for power backup, for climate control and ventilation, reducing carbon footprints and offering off-grid farming possibilities.

### How does solar powered hydroponics work?

In the solar powered hydroponics system, power is converted from the radiation formulated by nuclear fusion in the sun. It produces a large amount of energy, and is generated with the installation of huge panel plates. The solar powered hydroponics system is based on the photovoltaic effect. It is a process where solar energy is converted into electricity using solar cells (energy packets). Solar panels are oriented at specific angles to ensure the rays fall directly on the panels. This system detects the temperature, humidity, pH level, and light autonomously via each sensor present in it. The solar powered hydroponics system aims for growing more nutritious food with least or no use of soil. This technique assists farmers to increase their efficiency of agriculture. The power supply is enhanced after the addition of the solar powered hydroponics system.

### Challenges and limitations

Despite the benefits, there are some limitations of this system. High initial investment, energy storage and efficiency issues are the major limitations. Moreover, there is dependency on sunlight variation and technical expertise is required which poses a greater challenge to the farmers.

### CONCLUSION

The incorporation of solar energy into agriculture presents a multitude of advantageous outcomes in terms of both economic and environmental aspects. Advanced methodologies such as agrivoltaics, solar-powered sensors, Internet of Things (IoT), and vertical farming with solar integration optimize land utilization and enhance resource efficiency. Solar energy mitigates carbon emissions and preserves finite resources, rendering it economically feasible for farmers. Farmers can decrease energy expenses and improve sustainability by embracing solar technologies, utilizing financial incentives and engaging in agrivoltaic projects. Through the adoption of solar technologies, farmers can diminish their impact on the environment, improve their economic sustainability, and actively contribute to a more ecologically friendly and enduring planet.

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