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Aeroponic tower garden solar powered vertical farm

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Abstract. This review paper is written in order to specifically examine, explore, and evaluate vertical farming (VF) with the application of solar power as the powering sources for the entire farm. Nevertheless, a huge number of 2 billion individual suffers from micronutrient deficiencies and other related major health problems led by it. Moreover, with vertical farming processes we can offer a massive key sustainable food resource along with many advantages compared with horizontal farming (HF) processes, such cutting the need of water up to 95% while providing an efficient use of almost any space and many much more positives that will be discussed. Some positives are eliminating risks of biotic, abiotic, and climate issues. On the other hand, VF known to consume a huge amount annually of power per square meter in farming field of 3500 kW h, which is considered as a major setback for this process. However, with efficient use of green renewable power resources alternatives such solar panels, we are able to cut-down the power consumption dramatically to offer a true sustainable food resource for us and for next generations. Therefore, the purpose of the paper is to discuss vertical farming VF using solar power to create a sustainable food resource.

Introduction

We all familiar with conventional farming, however when it comes to vertical farming, a limited number of people heard about this term. Vertical farming (VF) is a process to produce food by the use of vertical dimension for hydroponic growing of crops with indoor controlled-environment agriculture (CEA). In addition, these methods such vertical farming designed to play a role in facing these major crises such the scarcity of water and the major growing in our population [1,2,3]. Moreover, in compact cities, the pressure on food resources rises, since typical farming lands are limited. Nevertheless, researchers predict an increasing need of 25%-70% in the crops demand by 2050 which we have to supply. However, with the decreasing availability of growing lands while the condition of climate getting worse, the demand in VF a rises [4]. VF uses the application of LED lights, heaters, ventilation and air conditioning (HVAC), sensors, software, internet of things (IOT), drones, applications and many more factors to create an efficient growing environment for crops. All this to plant in a vertical stack of crops layered up each other in order to save space, energy, and water. VF Systems generally categorized onto two main systems, one is green walls and cylinder shaped vertical growing space. A Hydroponics branch known as hydroponics uses water as the solvent to produce vegetables without using soil. As a result, this technique offers significant advantages that enable farming everywhere without the need for soil.

However, it is projected that there would be a larger lack of areas and soils suited for agricultural. Because there is no requirement for soil, this method has several advantages that make it possible to farm everywhere. On the other hand, the Aquaponic farming technique, mixes farming with aquaculture. It is also utilized in hydroponic systems that incorporate fish tanks. Thus, the nutrients required by plants in a growing tray are provided by fish waste. Lastly, using only a little amount of sodium water, the farming technique known as Aeroponic VF grows plants in a misty atmosphere without the use of soil or any growth medium has considered to be the best option in our case.

Vertical farming as the name refers uses multiple vertical layers of crops laid indoor a warehouse where crops will find an artificial growing environment simulating horizontal farming. Additionally, this simulated indoor environment includes factors such light needed, temperature required, humidity level, concentration of carbon dioxide, water amount, and nutrients. Moreover, by keeping in mind every playing role result in producing a large number of crops produced precisely with high quality and freshness sustainably 100% indoor [5]. Prices of food keep increasing due to multiple reasons and the increase in food scarcity. Though, the cost of traditional HF less than up keeping and installation of greenhouses, still they widely increasing due to the extension of the growing season they provide while offering various products to be possibly grown without worrying of the external factors. VF known to consume a huge amount of power. In general, buildings consume about 40% of the total power consumed, while 40% - 50% of that consumed by lighting. As result, the application of renewable started to attract more attention in this field. In addition, the study shows 56% - 89% of potential savings [6].

Hydroponics Systems

Facts shows that by 2050, our world population expected to grow up to 9.7 billion people, while almost 70% of this population expected to live in cities. With that being said, the scarcity in lands and appropriate farming soil expected to increase. Hydroponics is a hydro cultural branch that grows crops eliminating soil with solutions of mineral nutrient in water solvent. As a result, this method offers major positive impacts which allow farming in any place without the need for soil [7]. That being said, it is anticipated that there would be a greater shortage of suitable farming soil and lands. A hydro-cultural branch known as hydroponics uses water as the solvent to produce vegetables without using soil [8]. As a result, this technique offers significant advantages that enable farming everywhere without the need for soil. Additionally, the most popular VF system in the world is hydroponic. Fig 1. is demonstrating Hydroponic System.

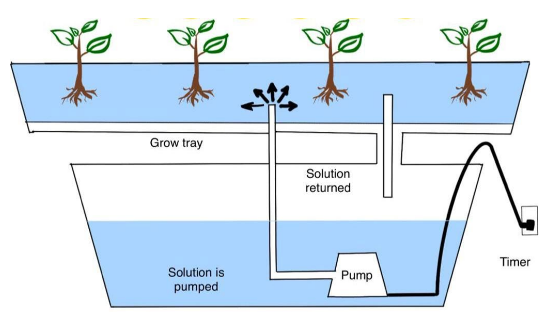

Fig 1. *Hydroponic System*

Aeroponic Systems

The farming method known as aeroponic VF produces plants in a misty environment without the need of soil or a growing medium other than a tiny quantity of nutrient-rich water. This kind of farming differs from hydroponics and conventional agricultural methods. Aeroponic systems use 90% less water than hydroponic systems, according to a comparison of the two. Furthermore, because this VF technique contains vitamins and minerals, it's claimed to be healthier [7]. Fig 2. is demonstrating Aeroponic System.

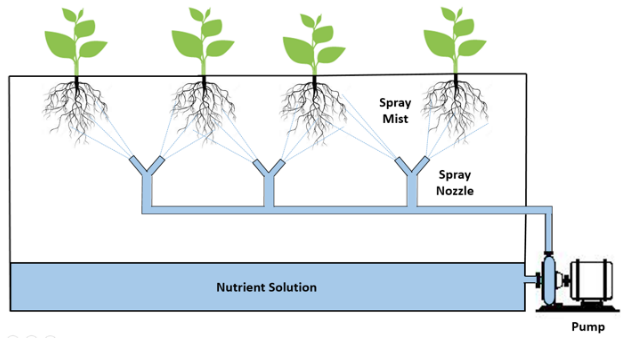

Fig 2. *Aeroponic System*

Aquaponic Systems

This agricultural method combines agriculture and aquaculture. It is also used in hydroponic systems that include fish tanks into one system [2]. Having said that, fish excrement is utilized to supply the nutrients that plants in a growing tray need. Remember that the water is then recycled after being filtered by crops to remove fish excrement. One major feature of this method is that, after the initial month of intense monitoring, pH and ammonia levels only need to be checked once a week when the system is up and running effectively. Fig 3. is demonstrating Aquaponic System.

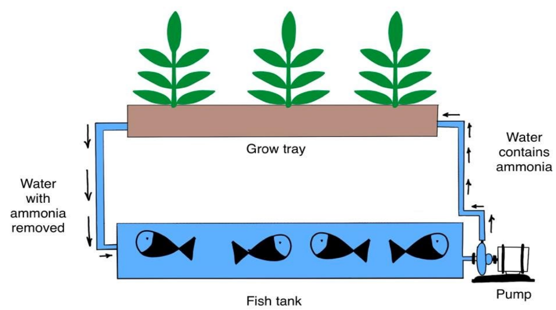

Fig 3. *Aquaponic System*

An aeroponic system is ideal since it enables you to cultivate your garden anywhere you like, indoors or outside. They are better for the environment than traditional gardens since they consume less water and electricity. Although not every plant can grow in an aeroponics system, you still have a huge selection to pick from!

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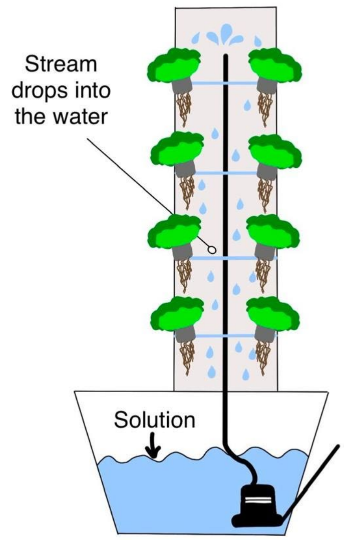

Fig 4. *Vertical Garden Column Type*

Tower gardens column type are the latest agricultural revolutions in the Western world, and they spread after cultivating roofs with vegetables and fruits and after cultivating balconies, which are agricultural methods such as plastic pipes, wooden cylinders, or wooden pyramids. Their processing and cultivation differ according to the crop, or the type of leafy vegetables or fruits such as strawberries. And parsley, mint, basil and coriander. Note that the plastic cylinders are also carried in plastic pockets with one hole, and the pockets are filled with seedlings of plants to be cultivated. The tower may consist of a number of cylinders connected from the bottom to collect irrigation filtrate and fertilizers. Basically, side openings are opened in the cylinder, by sawing it with a straight line, exposing it to heat, and pulling it out, forming a pocket. The pockets are separated from each other horizontally and vertically according to the type of crop and the length of its plants. The cylinder is filled with an agricultural medium instead of soil, and a perforated hose is inserted into it passing through the middle of the cylinder. To provide plants with irrigation and fertilizers, these towers are usually placed in kitchens, near and far from windows, according to their need for light. They are characterized by high productivity per unit area. A 4-inch cylinder with a length of two meters can carry 40-50 plants.

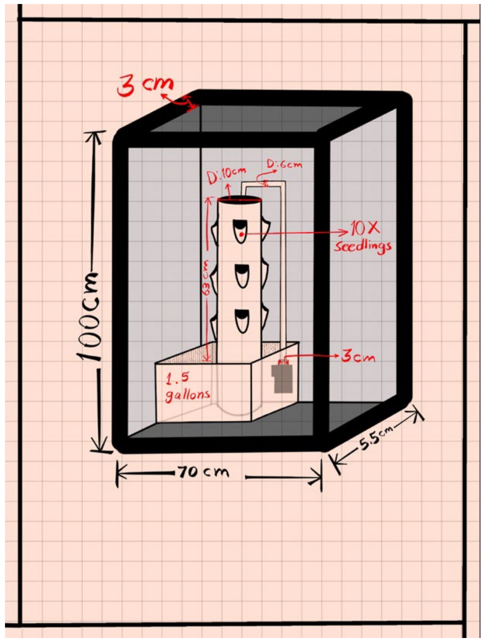

Fig 5. *Aquaponic Tower Garden System*

Simulation

The measurements and final building design are provided. Because of its high yield strength and stiffness, carbon steel was chosen as the primary structural material for the initial prototype. Carbon steel was the best choice since the structure was going to support over 140 kg of dead weight and a sizable amount of living weight from the atmosphere [8,9,10,11,12]. With dimensions of a length: 1.5 m, width: 1 m and height: 1.56 m [13,14,15,16,17]. By providing several degrees of service for checking and validating the application, Ansys makes it simple to check that it is functioning correctly on the computer and operating system [18]. When your system changes, such as when the operating system is upgraded or new math or vector libraries are installed, we can benefit from this testing. With reference to the project boundaries and data, ANSYS-FLUENT was used for the simulation of the tower garden system [19].

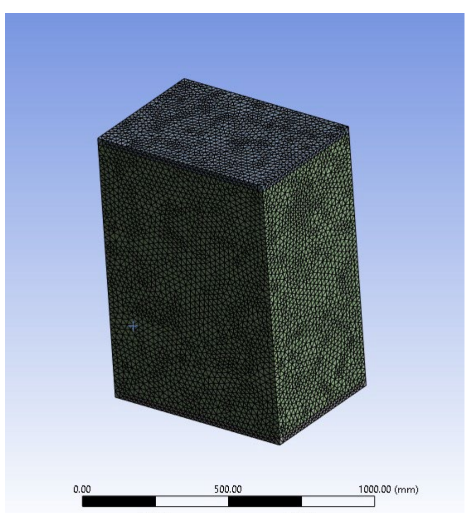

Fig 6. *512K Elements Mesh for The System*

As fig 6. shown, the type of elements used is the tetrahedral, and the number of elements is 329723, and the number of nodes is 64762.

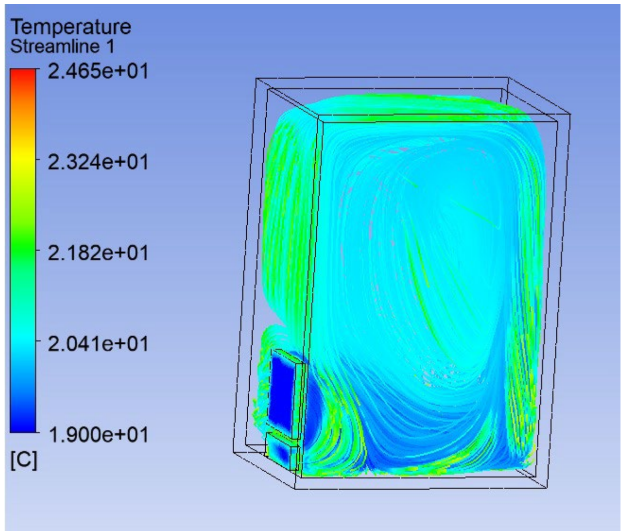

Fig 7. *Air Temperature Streamline*

Fig 7. is showing how the air is going in to the system, and how temperature is changing while air is flowing & distributed.

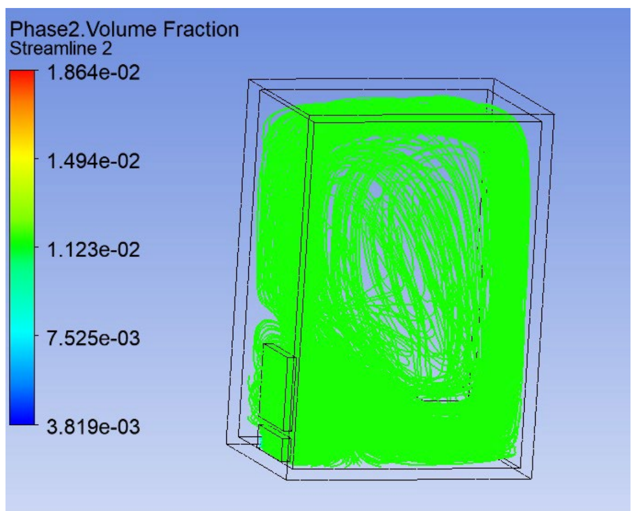

Fig 8. *Water Vapor Streamline*

Fig 8. is showing how the water vapor is going in to the system, and how temperature is changing while vapor is flowing & distributed.

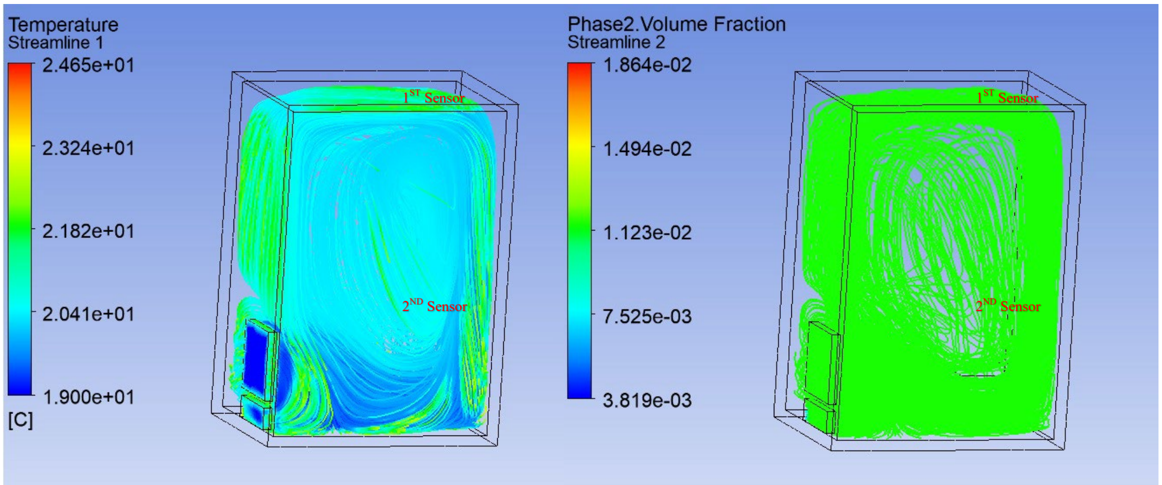

Fig 9. *Humidity & Temperature Sensors Placing*

However, for the prototype we are going to use to place one sensor only since it is for demonstrating purposes. In other words, the control system will be programmed to sense and check the humidity and temperature of the environment inside the prototype using one sensor placed inside at the top.

System Design and Control System

Polystyrene is a waterproof and thermoplastic substance that acts as a sound and temperature insulator, sometimes referred to as Styrofoam. The two variations have differing cost and performance ratings. The R-value of the more costly XPS is R-5.5. It makes up around 7% of the whole thermoplastic industry, making it one of the most popular commodity plastics. [20,21,22] Furthermore, the suitable environment for the lettuce to grow is that for vegetables require high relative humidity between 75 and 95 percent, with an average of 85 percent, and that the majority of vegetables grow best between 18 and 24 degrees Celsius on average lights [23]. It makes up around 7% of the whole thermoplastic industry, making it one of the most popular commodity plastics. Undoubtedly, it is one of the most significant styrene copolymers (PSAN) is poly(styrene co-acrylonitrile).

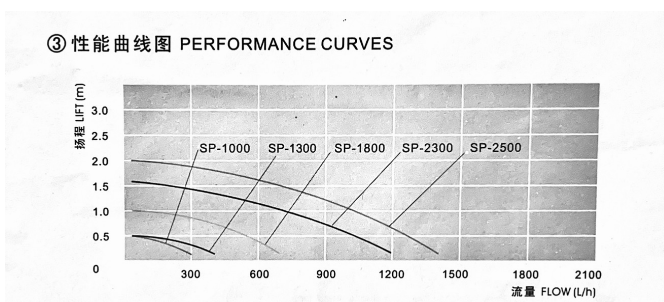

Fig 10. *The Chart of Pump*

And the amount of water to pump and the irrigation rate is 1.5 gallons per hour, or GPH = 5 liters per hour. In reality, the process of vertical farming depends on understanding the heat load. For instance, it was shown that a conditioning procedure of short days followed by 7- 9 hours at 21/12 °C (day/night) will increase the amount of fruit produced (41%–152%) annually compared to non-conditioned controls [22,24]. Thus, the suitable option for the submersible pump that could find in the stores was with a voltage of 230V and 13W with a maximum flow rate (Qmax) is 700L/h and a max head (Hmax) is 1.0m.

Tab 1 Engineering standards

BATTERY SIZING DATA	Solar System	Project load
Load Power 50W + Future 5W	55	200
Voltage (V) 24	24	12
Load Current (A)	2.291666667	16.6666667
Backup Time hours(BT) 120	120	120
Aging Factor (AF) 1.25	1.25	1.25
Design Factor (DF) 1.1	1.1	1.1
Temperature Compensation factor @ 25 C 1.05	1.05	1.05
Battery Ah @ 120 (A8= A3*A4*A5*A6*A7)	397.03125	2887.5
Selected battery Sizing	405	3000
Battery Bank C120 In Wh 9840	9720	36000
B PV SIZING DATA		
Total Days in month	30	30
Daily Peak hours in worst month	5	5
Recharge Time	30 Days	30 Days
Recharge Hours= Total days in monthX Daily peak hours	150	150
Peak PV output as per vendor (A)	9.1	9.1
Daily PV peak output (Ah/ Day)	45.5	45.5
Load current (A)	2.291666667	16.6666667
Battery inefficiency factor (BIF)	1.15	1.15
Battery charging current= (BATTERY AH*BIF)/RECHARGE HOURS	3.105	23
Daily Load Power (Ah/Day)	55	200
Daily Battery charging Power = Battery charging currentXDaily Peak hours	15.525	115
Total daily Power (Ah/ Day)= Daily Battery charging Power+ Daily Load Power	70.525	315
Adjusted Daily Power (Ah/ Day)= Total daily PowerX Aging(1.1)X Dust (1.1)+ Future (20%)	99.44025	444.15
No. of Parrallel Modules	2.1855	9.76153846
Selected No. of Parallel Modules	3	10

System Testing and Analysis

Fig 10. is highlighting the Connection of the control system. The control system designed using four relays to control the powering of each component of the prototype. On the other hand, the humidity & temperature sensor is the key element for controlling the system as shown in previous shown code. We added the screen to show the current readings of sensor in order to have observation of current environment inside the system.

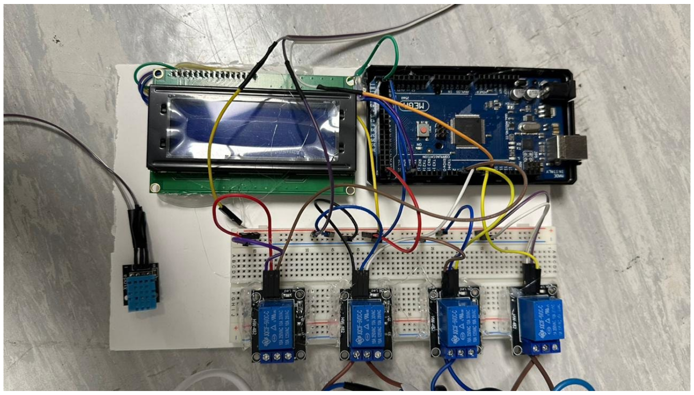

Fig 11. *The Control System of The Prototype*

Once the prototype was completed, I started at the main project. Choosing the Styrofoam for insulation to provide the suitable environment for the lettuce to grow in within the average humidity of 75-85%, and temperature between 18-24 °C on average lights. Moreover, the voltage provided by the growth lights is and 220-240V with wattage of 16W and it is the same voltage for the evaporative cooler AC with 65W. And for the submersible pump, the suitable option that could find in the stores was with a voltage of 230V and 13W with a maximum flow rate (Qmax) is 700L/h and a vertical lift or max head (Hmax) is 1.0m. Also, the humidifier has the voltage of 240V and 25W. And the dehumidifier that has been chosen is breathable design for moisture obsorption and moisture drainages are efficient, high usable material, economical and environmentally friendly. And its power is up to 25W and it recovers about 0.4kWh to dry. And the humidifier designed with a filter effectively removes impurities from water with a capacity of 3 liters. Furthermore, its ultrasonic system efficiently produces a high-blur effect. With a knob, this humidifier allows you to set the fog intensity. Once the setup finished, through the central conduit, the low-wattage submersible pump in the reservoir forces the nutrients solution to the peak of the tower garden. The fertilizer solution then uniformly cascades over the exposed plant roots as it descends down the interior of the tower garden. A timer makes sure that this procedure is repeated continually so that plants receive the right dosage of oxygen, water, and nutrients at the ideal moment.

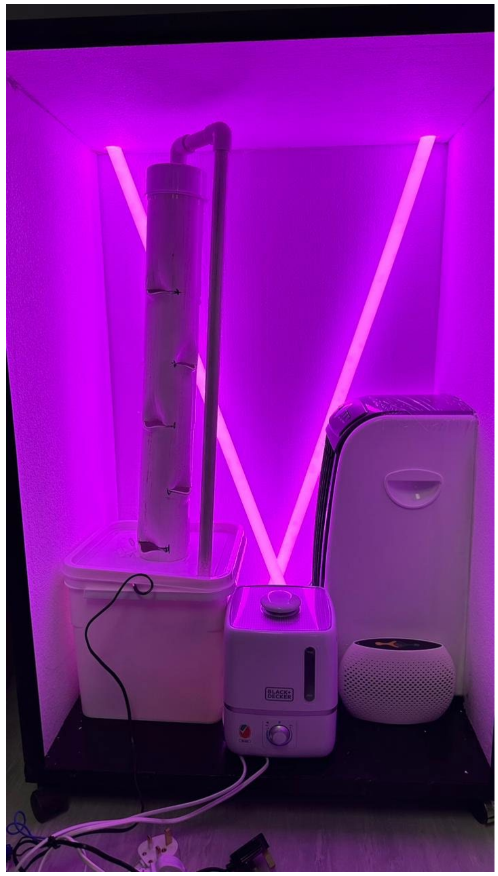

Fig 12. *The Prototype*

Conclusions

In conclusion, vertical farming innovates the agricultural industry by enhancing food production in an optimum space inside a regulated environment without wasting natural resources. Furthermore, sustainable food sources are not readily available for a number of reasons. One practical solution to the food shortage may be vertical farming operations. With this project, we aimed to build a scalable industrial-grade vertical farming unit that has been accessible to everyone, balanced, and sustainable. Therefore, we begin by selecting the kind of vertical farm (Aeroponic) since it requires fewer soil, uses less water, and produces crops with a better yield. Then, when we build the structure, we take insulation and inside systems like the HVAC, lighting, and irrigation systems into account. Additionally, we choose Polystyrene (XPS), for waterproofing substance and insulating sound and temperature. Moreover, we look for artificial lighting, most often electric lighting, therefore we utilize LED grow lights since they provide the necessary light intensity while using less electricity. We use an evaporative cooler as part of our heating, ventilation, and air conditioning (HVAC) system to provide the proper humidity level and temperature for the plants inside the farm. Additionally, to meet our power needs, we combined solar PV panels with batteries and a hybrid electrical system. To offer a proper environment for growing and harvest, we were able to monitor and assess temperature, relative humidity, CO2 concentration, light intensity, and power usage through this research. This project has the potential to develop a system for monitoring and controlling. As well as an alternative to structure and insulation, think about adopting stiff composite insulators. Also, improving the design of the grow towers inside the unit. Include HVAC ducting in the device.

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