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Addressing World Food Shortages through Vertical Farming and Efficient Microgrid Design

Introduction

This feasibility study aims to tackle the problems of food shortages and high food prices in regions that are either incapable of producing food, or, where the cost of produce can be lowered. Vertical farms, or PFALs (Plant Factory with Artificial Lighting), can be used to produce food in local areas, utilizing solar energy capabilities and an efficient microgrid design to feed electricity back to the farm. This study aims to determine if we can offset the high operating utility costs of vertical farms through renewably generated electricity.

Background

Vertical farms/PFALs are an efficient solution to a growing global problem: food scarcity. PFALs can be be built in any environment, with year-round production, and productivity over 100 times that of field grown produce[1]. They provide safety, security, consistency of supply, and price stability of fresh vegetables[2]. These features make it desirable for areas undergoing food scarcity, or, remote regions where transportation costs significantly increase commercial produce costs. PFALs have undergone 2 main criticisms: (1) high initial costs, (2) high yearly operating/production costs. The breakdown of production costs are detailed in Figure 1.

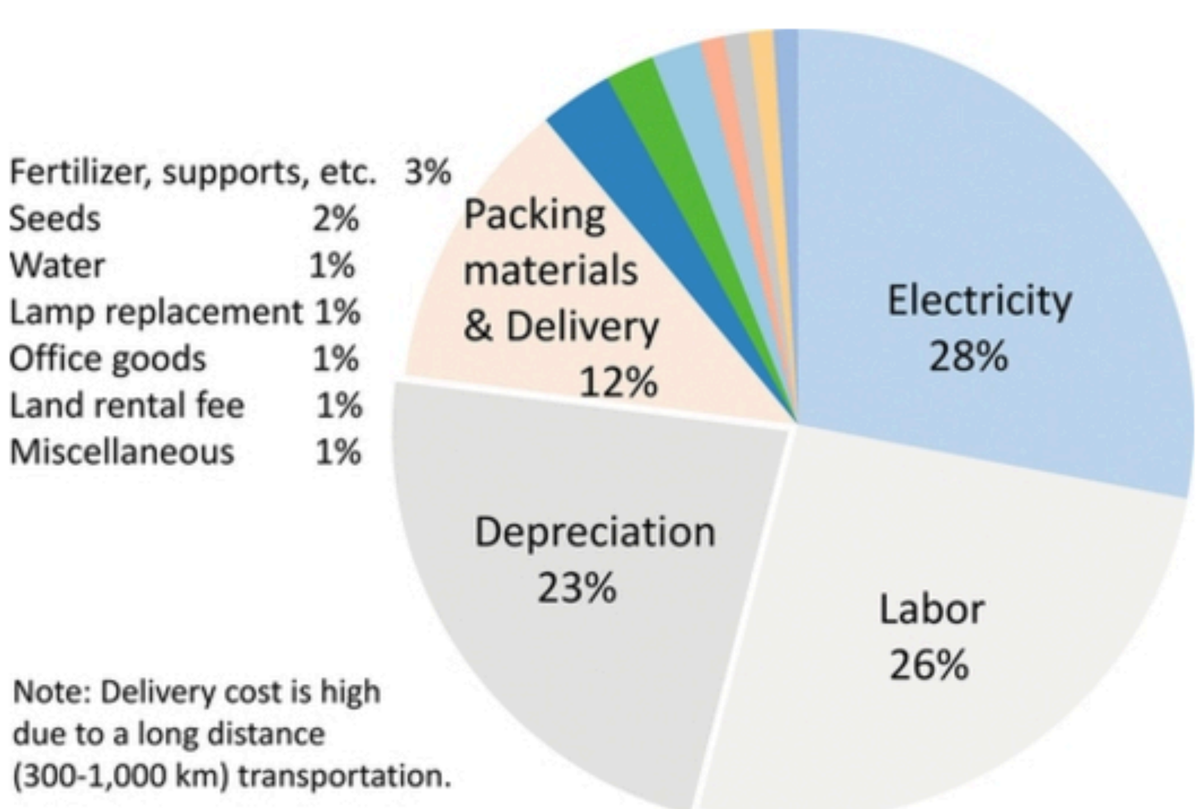

Figure 1: Production costs by components of a PFAL with a daily production capacity of about 7000 leaf lettuce heads (80 g fresh weight/head). Ohyama (2015).

Core Assumptions

On average, ***30% of production costs are due to LED lighting[3]***. I calculated costs for medium-sized PFAL businesses based on data provided by the Spread Co., Japan and China University PFAL[4].

- PFAL size: 700m^2 (Medium)
- Time taken from transplanting to harvest of head (80g): 22 days
- Yield: 3 million heads of lettuce per year.

Data Analysis

Initial Investment	**Cost (US$)**
Building	333,333.33
Cultivation facilities	1,708,333.33
Electrical facilities	2,020,000.00
Infrastructure	100,000.00
Total Initial Inv	***4,161,666.67***
Operating Costs/yr	
Depreciation	166,666.67
Utilities	300,000.00
Personnel	208,333.33
Materials	166,666.67
Transportation	58,333.33
Total Yearly Costs	***900,000.00***
Yearly Revenue	***1,200,000.00***

The cost of leafy produce in the USA was determined as $0.4/head. With a production of 3M heads of lettuce per year, we can yield $1.2M revenue.

Electricity cost ($) = Wattage consumed (kWh) x Hours (hr) x price ($/hr) / 1000

The daily electricity cost was determined as **$106.4/day**. The daily electricity consumption was determined as **970.32kWh/day**.

This leads to a requirement of **40.43kWh consumed at $0.11/hr.**

Table 1: Initial Investment, Yearly Operating Costs, and Revenue

Tesla Powerpack's were used as storage batteries for the microgrid, taking solar energy from 100kW solar panels. The Powerpack's have a capacity of 210kWh, with 50kW continuous. Assuming an average sunlight of 4hrs/day, the Electrical facilities cost in Table 1 found:

Category	**Cost (US$)**
Powerpack cost ($398/kWh)	1,930,936
Solar panels cost ($3.36/W)	97,808.256
Total Electrical facilites	**2,028,744.256**

Table 2: Electrical Setup Costs for Powerpack and Solar Panels

These added initial costs of $1.9M would allow us to ultimately save **4,851kW** per month, yielding savings of nearly **$53,000.00 per month**. This would **reduce the operating cost by only 6%**, a minimal savings over a course of a year.

Conclusion

Vertical farms are a great solution to a global problem, however technology has not yet been able to prove their viability. LED improvements and farm automation could reduce as much as 40% of these operating costs, with renewable technology efficiency improvements helping us truly move towards a sustainable farm model.

[1] (Kozai, 31-32), [2] (Kozai, 45-46), [3] (Kozai, 50-51), [4] (Kozai, 382-383), Kozai, Toyoki; Genhua, Niu; Takagaki, Michiko; *Plant Factory: An Indoor Vertical Farming System for Efficient Quality Food Production*. Tokyo: Academic Press, 2015, Print.