Pure Roots Urban Farm: Assessing the Energy Demands of Indoor Vertical Farming

Final Community Project Report

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In collaboration with Pure Roots Urban Farms

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INTRODUCTION

This project was done in collaboration with Pure Roots, a company established in 2018, that builds and operates indoor vertical farms in urban settings across Canada. Originally based in Saskatoon, Pure Roots is currently building its first vertical farm facility in Surrey. In the next 2 years, Pure Roots aims to build 7 new facilities around Canada. The main issues that Pure Roots is addressing are the challenges of community food security that relate to traditional food production and distribution channels (Pure Roots, n.d.). Community food security itself is defined as "a situation in which all community residents can obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes self-reliance and social justice" (Hamm and Bellows, 2003. P.37). Currently, urban communities rely heavily on long-distance transportation of "fresh produce" which accounts for 11% of carbon emission in conventional farming (Lynch et al., 2010). Pure Roots aims to narrow the gap between farm and table by serving their target consumers, within each farm's urban community, freshly harvested local produce that is traceable, nutritious and high quality in the most sustainable way (Pure Roots, n.d.).

Indoor vertical farming produces a smaller carbon footprint (CF), and has high water and land use efficiency, while producing an equivalent amount of fresh and nutrient-rich products compared to traditional outdoor farming (Sheng, 2018). It is also a movement toward self-reliant communities, especially in the case of emergency (e.g. COVID-19) where distribution systems are interrupted (Molin & Martin, 2018). Within the specific short-term scope of our project, we aim to assess the CF, energy usage and costs of Pure Roots' growing facility in Surrey so that it can have a better understanding of their energy consumption and CF. In addition, we aim to search for alternative methods that allow Pure Roots to lower their costs and energy emission to improve the efficiency of their facility. The energy and environmental performance of vertical farming (Node Farm) in the urban setting were previously studied by Molin & Martin (2018). Major energy-dependent operations of indoor hydroponic farms have also been reported by Gentry (2019). Both studies provide a useful base model and factors for the execution of this project.

METHODS

Data was collected throughout the term by corresponding with Pure Roots and by conducting literature and material research on their plans. Pure Roots provided information on their growing technology, plant specifications, building plans, and operating procedures. Energy and CF estimates in this project were based on Vates and Scots Blue Curled kale grown in each module. Additional data for analysis, evidence, and comparison purposes were primarily researched in scientific journals or corporate websites.

Pure Roots and AeroGrow (its engineering team) provided us with sensitive information on their technology and specifications. To honor the privacy and confidentiality of the information provided by related parties, each group member signed a non-disclosure agreement.

We kept up communications with Lena, our correspondent in Pure Roots, throughout the whole project and asked her for feedback regarding our direction and methods. To see if we achieved our outcome, a 1-5 scale satisfaction scale assessed by Pure Roots at project completion was used as evidence of achieving our outcomes.

Energy Calculation and Cost

Energy in Pure Roots' Surrey farm is solely sourced by electricity from BC Hydro. A list of electronic components (ECs) and their quantities were provided by Pure Roots. The power wattage of each EC was identified either through online specification sheets or by Pure Roots. Required on-times were either provided by or assumed then confirmed by Pure Roots.

Analysis of energy consumption was done in Microsoft Excel spreadsheets, based on sections: 3 modules and Front of House (FOH). FOH refers to the area outside the modules where ECs are not used to grow crops; this includes store-front lighting, cooler displays, washers, and dishwashers. ECs in each section were further separated based on function, e.g. lighting, HVAC, water conditioning, nursery, irrigation, and monitoring & control systems (MCS). To estimate energy demand, parameters were calculated based on the power, unit quantity, on-time per day and duration of each EC, with formulas in Table 1. Annual energy consumption and cost were calculated by adjusting module durations to 1 year and summing each section, respectively. According to BC Hydro, business electrical bills consist of a daily basis charge, peak demand charge, electrical rate, 5% GST, and 7% PST (BC Hydro, 2020).

Carbon Footprint

CF in Pure Roots was mainly produced from BC Hydro electricity and consumable input production. An equivalent (eq) CO_2 factor from BC Hydro was used to estimate the CF from energy production, while an eq CO_2 factor for each consumable adapted from literature values was used to estimate CF from consumable inputs. The CF to produce Vates and Scots Blue curled kale was compared to the CF of conventionally farmed Chinese kale.

Table 1. Formula to calculate each parameter used to estimate electrical consumption and cost, and CF

Parameter	Unit	Formula
Power per day	kWh/day	Power × Unit quantity × On-time per day
Cost per day	CAD/day	Power per day × Electrical rate
Total power per EC	kWh	Power per day × Duration
Total cost per EC	CAD	Cost per day × Duration
Gross total cost	CAD	Sum of total cost per EC
Peak energy demand	kW	Maximum sum of power at once
Basic charge	CAD	Basic charge rate × Duration
Demand charge	CAD	Peak energy demand × Demand charge rate
Grand total cost	CAD	Gross total cost + Basic charge + Demand charge + 5% GST +7% PST
CF from electricity	kg CO_2	Sum of total power per EC × Duration × Electrical CF rate
CF from consumables	kg CO_2	Sum of consumable unit × consumable CF rate
Total CF	kg CO_2	CF from electricity + CF from consumables

Feasibility of Solar

Products from Lightleaf Solar were chosen to assess the feasibility of solar based on a preliminary discussion between Pure Roots and the vendor. We considered two universal types of solar panels from Lightleaf: 100W solar panel and 150W panel (LightLeaf Solar, n.d.). According to the solar energy map in Canada, "a 1KW solar system in Surrey would produce about 996 kWh/yr" (Solar Energy Maps Canada, 2020). Pure Roots provided their roof space (302 m^2) for their facility in Surrey and the estimated installation price. Based on this information, the maximum number of panels, total power produced, costs and CF saved for both 100W and 150W solar panels were estimated.

Cocopeat as an Alternative

We have seen several advantages behind using rockwool as a substratum for the growth of crops. These include its ability to remain chemically inert and to reduce the amount of irrigations needed to refresh itself. However, rockwool is neither renewable nor biodegradable (Allaire et al., 2005). Literature research was done to further investigate if cocopeat should replace rockwool in regard to cost, environmental impact, and crop growth.

RESULTS

Energy Calculation and Cost

Pure Roots expects each module will yield 7,796 lbs of kale in 182 days, requiring 118,771.93 kWh of electricity and costing 11,878.49 CAD for electricity. ECs in the FOH are estimated to consume 15,157.54 kWh annually. If all three modules were to grow kale year-round, the entire facility is estimated to consume 727,789.09 kWh and cost 73,387.29 CAD annually for energy, averaging 3.46 CAD per kg kale produced.

A breakdown of energy consumption to produce kale per module per 182 days in Figure 1 highlights 70.74%, 15.25%, and 11.51% consumption from lighting, water conditioning, and HVAC, respectively. Energy consumption for nursery, irrigation and MCS are minute, accounting for 2.4% altogether.

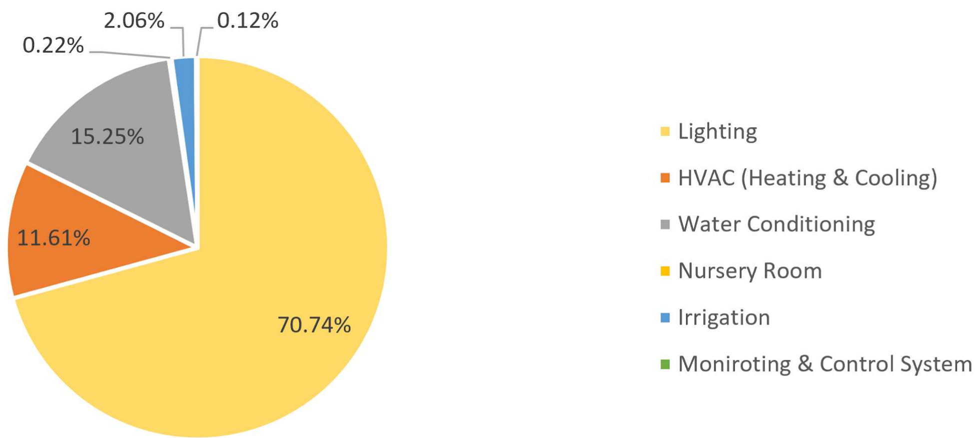

Figure 1. Energy consumption breakdown per module for kale production

Carbon Footprint

CF from energy production and consumable inputs are 1,306.49 (98.9%) and 14.55 (1.1%) kg CO_2 eq per module per 6 months, respectively; total of 1,321.05 kg CO_2 eq. The direct production of Vates and Scots Blue curled kale estimates **0.373 kg CO_2 eq per kg kale**, lower than the production of conventionally-farmed Chinese kale estimated at 0.402kg CO_2 eq per kg (Yuttitham, 2019). CF of Chinese kale was the closest estimate to large-leaf kale available in scientific journals. The largest proportion of CF in conventional farms is from chemical fertilizers (51%) while in Pure Roots' vertical farm, is from lighting (67.1%) (Yuttitham, 2019). By eliminating fertilizer run-offs, fertilizer usage in Pure Roots contributed a small proportion of CF (1.06%).

Feasibility of Solar

Based on our calculation for energy consumption, the total power per day for Pure Roots is 1999.309 kWh/d. As shown in Table 2, 150W solar panels from Lightleaf are more efficient in terms of finance, CF and total power produced for the 302 m^2 roof space in Surrey. However, since solar panels usually last 25-30 years (Richardson, 2019), an estimated pay off time of 50 years indicates that solar panels are not considered feasible in terms of finance with the current amount of space.

Table 2. Comparison of Lightleaf 100W solar panel and 150W solar panel

Product	100W solar panel	150W solar panel
Size per product (m^2)	0.61525	0.8881
Maximum number of panels possible on roof	490	340
Installation cost (CAD)	147,257	170,000
Avg total power per day (kWh/day)	133.77	139.06
% of energy allowed by roof area	6.69%	6.96%
Electricity cost saved per day (CAD/day)	8.12	8.44
Breakeven time (yr)	50	56
CF saved per day (kg/day)	1.47	1.53

Cocopeat as an Alternative

Plants grown using cocopeat produced 56.2% of sellable crops per plant and yielded 445.6 g per plant (Luitel, 2012, pg. 105). When compared to rockwool, cocopeat enabled crop yield to increase by 0.7% and a 5.2% increase for marketable crops (Luitel, 2012, pg. 106). To put this into perspective, one research indicated that bringing 15 plants into a randomized treatment yielded 571.5 g of crop from cocopeat and 567.8 g from rockwool (Luitel, 2012, pg. 105). Cocopeat can also be reused 3-4 times and decomposed into biomass.

As appealing as the product seems to be, there are a few complications. It has a high water retention capacity, thus providing low aeration and reducing oxygen diffusion to roots (Awang et al., 2009).

Success Indicator

Our indicators are based on feedback from Pure Roots. Pure Roots evaluated its satisfaction on four outcomes based on 1=very unsatisfied, 2=unsatisfied, 3=neutral, 4=satisfied, 5=very satisfied. The outcomes of assessing (1) energy consumption and cost, (2) CF, and (3) feasibility of solar panels were rated 5, very satisfied. The outcome to (4) recommend proper alternatives with evidence was rated 4, satisfied. Assessment of Cocopeat could have had more evidence relatable to Pure Roots. The energy assessment spreadsheet framework was adopted and further used for other projects by Pure Roots.

DISCUSSION

The significance of our findings within the broader context of food system issues expounds and hopes to address food injustice and food insecurity that exists in local communities. In a broader sense, this contributes to the development of technology that can be used to aid more self-reliant communities that do not rely on fresh produce through long-distance transportation. It is important to aid local communities especially during emergencies, such as the COVID-19 pandemic.

The energy breakdown agreed with Molin & Martis (2018, pg. 5), who showed that the largest source of environmental impacts in vertical farms was the energy for lighting. In relation to the project intermediate and long-term outcomes, our cost estimation and energy breakdown provided a strong direction for Pure Roots to further modify their lighting designs as a priority. Suggestions include using less lighting or alternate forms of lighting. Our cost estimate also allowed Pure Roots to manage its microeconomics more accurately.

The roof area of 302 m^2 is far too low to consider adding solar panels as a feasible alternative. This is also because BC hydro rates are currently very low. Pure Roots could look into different types of renewable energy that may also be considered feasible such as wind, geothermal, biomass, and hydropower (Renewable Energy, n.d.).

Cocopeat is a feasible alternative to rockwool in terms of its crop yield, reusability, and biodegradability. However, it is crucial to know how to effectively use cocopeat as bedding material. Pure Roots will have to develop a transition plan, including suppliers. Further research into overall impacts of low aeration and reduced oxygen diffusion in the roots is needed.

There are limitations to the methods we conducted. Data used was secondary, provided by Pure Roots, journals or based on assumptions. Literature values may not fully represent on-site conditions in Surrey or of Pure Roots, thereby raising errors due to recall bias. A site-visit in Surrey would have improved our method design and assumptions greatly, but the facility has not yet been built. A more extensive life-cycle assessment later with the constructed facilities and Aeropod modules to measure CF would lead to more accurate results.

CONCLUSION

Overall, this project has helped Pure Roots with a greater insight of their total energy costs and efficiency with their Aeropod technology. It has shown a thorough analysis of the CF an indoor vertical farm produces and compared it with the CF from conventional farms.

The analysis contributed to a greater understanding of energy consumption and efficiency behind indoor vertical farming. It also provided feasibility of incorporation of solar and cocopeat into these farms, which are limited fields in research. There can still be more research and testing done on ways to reduce costs and CF from lighting, which is currently information absent from our report. Further research behind reduction of power usage with lighting and Aeropod technology will greatly help these companies that produce indoor vertical farms as it is a significant amount of the costs. Eventually, it would help urban communities, providing nutritious, traceable and high-quality products through a more sustainable approach in comparison to outdoor conventional farming.

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