Putting the Green Back in Growing

A Renewable Energy Strategy for Controlled Environment Agriculture

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Global population growth, freshwater scarcity and shrinking arable land serve as dire warnings that a global food crisis could be on the horizon. A population forecast of 9.7 billion people by 2050 implies a need for an additional 269 million acres of arable land under current agricultural practices, an area larger than the country of Brazil and an amount that simply does not exist. New agricultural systems need to be developed to address inevitable food shortages. Controlled environment agriculture (CEA) offers great promise in many food and medicinal crop categories to improve food security, food quality and food distribution. CEA includes a variety of agricultural settings to produce plants and their products including greenhouses and high-tech indoor farms (Khandros, 2018).

The primary challenges related to CEA are high capital costs, the cost of labor and, most significantly, the cost of energy. CEA facilities consume a great deal of energy for lighting, humidification, dehumidification, cooling, heating and air circulation. It's this high energy consumption footprint that attracts criticism to indoor agriculture in general. Reducing this grid energy consumption dramatically will make CEA even more viable as an important solution for global food security.

This paper explores the potential for leveraging a renewable energy strategy to bring a non-stacked indoor farm facility to net zero energy consumption, lower its overall health and environmental impacts, and simultaneously deliver a financial benefit to the farm itself. A 20,000 square foot prototype non-stacked indoor farm with a co-located 3MW solar farm will be analyzed based on industry energy consumption data.

Controlled Environment Agriculture (CEA)

While CEA can help address food security questions, it does come with one major drawback: a very large energy footprint. One comparative metric that brings this into focus is energy usage intensity (EUI.) I like to think of EUI as a miles per gallon (MPG) rating on a building type. We generally know what MPG ranges to expect with different vehicle types and EUI gives us a similar sense of "fuel" efficiency when it comes to the built environment. Figure 1 illustrates the EUI ratings of the top five most energy use intensive building types as reported by the Energy Star program, with fast food restaurants being the highest consumer of energy per square foot (EPA, 2018). Using data from a U.S. Department of Energy study on horticultural lighting systems and their energy consumption, I was able to derive an EUI rating for the most energy intensive building type in the CEA industry: a non-stacked indoor farm using high intensity discharge lighting (HID) (US DOE, 2017). Using the reported data, I calculated lighting electrical costs as representing 50% of the total energy budget. The resulting analysis shows that this type of CEA facility is even more intensive in its energy use than a fast food restaurant, exceeding it by 28%. In fact, of the three three major types of CEA facilities, supplemented greenhouses, non-stacked indoor farms and vertical farming, non-stacked indoor farms represent only 41% of the total grow area but account for 89% of the energy consumption (US DOE, 2017). Looking for an

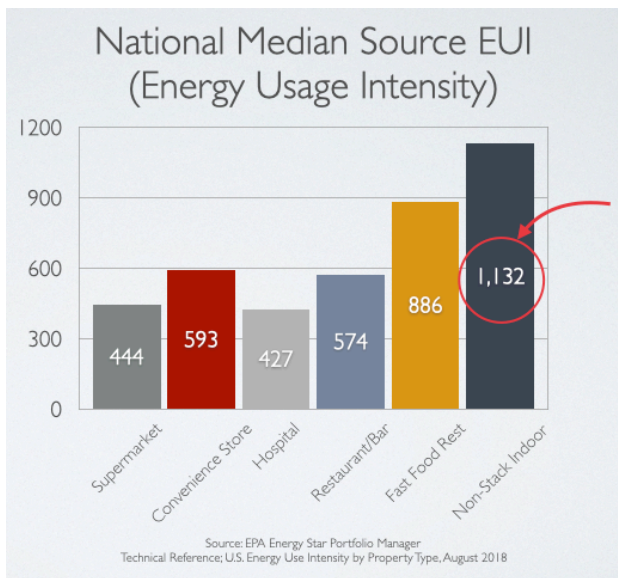

Figure 1

opportunity to impact overall CEA energy consumption through a renewable energy strategy, I have focused on non-stacked indoor farms as the greatest challenge.

Non-Stack Indoor Farm Prototype

The prototype facility is designed as a 20,000 square foot, non-stacked indoor farm with an associated solar farm sited on a 10 acre parcel in Schertz, Texas. Non-stacked indoor farms are commonly used for relatively simple growing applications or where tall plants are involved. As seen in figure 2, plants are grown in a single layer on the floor or on grow tables and receive 100% of their light for photosynthesis from electric lighting (US DOE, 2017). The power need for this facility is calculated to be 4,380,880 kWh per year, or $40.14 w/ft2 at the site. The parcel location enjoys the advantage of high voltage transmission lines being located on the property itself which makes it an excellent candidate for a renewable energy strategy.

Figure 2
Non-stack indoor farm example:
The Lettuce Farm

Renewable Energy Strategy

For the renewable energy strategy, all major technologies were explored. Wind resources are ample for power generation but local ordinance restrictions and the inability to install sufficient scale to meet the energy need eliminated wind energy as a candidate. Geothermal resources are also surprisingly abundant at this location but the energy need is too small to justify the high costs of drilling relative to the projected installed capacity. And without a neighboring industrial waste heat source, organic ranking cycle (ORC) technology was also not viable. Solar photovoltaic (PV) power was chosen for the renewable energy strategy for several reasons: 1. the solar resource in the region is favorable, 2. sufficient generation capacity to bring the facility to zero net energy can be installed at the site, 3. solar PV is a very common renewable energy technology used in the region ensuring adequate engineering support and a large base of experienced local installers, 4. the local utility provider currently offers a substantial solar rebate on top of the federal tax credit, 5. there is a local solar PV module manufacturing facility less than 30 miles from the proposed solar farm, and using panels from the local manufacturer entitles the facility to an additional solar rebate premium, and 6. Texas also has a renewable energy property tax exemption that applies to solar installations eliminating a potential additional property tax liability for the facility (Texas Comptroller).

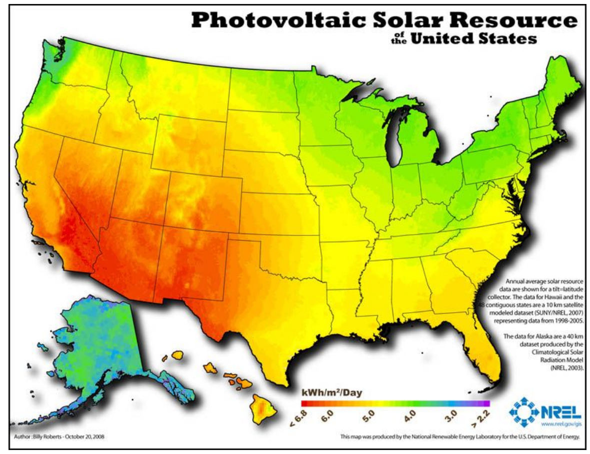

Figure 3
Solar irradiance value of 4.86 kWh/m2/day at the site

Solar Farm Specifications

The solar farm is designed to be a 3MW facility using generation I monocrystalline solar photovoltaic modules that have already been approved by the local utility provider. The PV farm will cover approximately 6 acres and is expected to enjoy a solar irradiance value of 4.86 kWh/m2/day (Boxwell, 2019). The panels will be installed facing due South and will be fixed at the optimal year round angle of 61 degrees. Total annual power production is anticipated to be

4,524,083 kWh using a derate factor of 85%. The installed price is projected at $1.78 per Watt/dc installed. The farm will be interconnected to the local grid on a net metering strategy versus seeking a purchase power agreement from the local utility.

Financial Metrics

The capital cost of the solar farm is projected to be $5,325,000 without local utility rebates or other state and federal incentives and is illustrated in figure 4. As a co-location strategy, the land owned by the CEA facility would be contributed as equity eliminating a cash requirement for financing. The financing structure is targeted to be a 4.00% APR with 25 year amortization to match the anticipated life of the PV asset. The annual capital costs are forecasted at $340,864 with annual operating costs of $53,250. With an annual energy spend at the CEA facility projected to be $499,420, the solar farm will generate an annual energy cost savings of $105,306 or 21% less than grid consumption at $0.114/kWh.

Capital cost of project	$5,325,000
Loan term (matched to the asset life)	25 yrs
Rate	4.00%
Annual capital costs	$340,864
Annual operating costs	$53,250
Production cost per kWh	$0.087
Annual Energy Usage	4,380,880 kWh
Payback period	10.66 years

Figure 4
Financial metrics without incentives

When local utility and federal tax credit incentives are applied to the solar farm, the value to the CEA enterprise is even more compelling. The local utility, CPS energy, offers rebates at $0.60 per AC Watt for the first 25kW and $0.40 per AC Watt for kW over 25 when using locally manufactured solar modules (CPS Energy). This reduces the initial capital cost of the project from $5,325,000 to $3,820,000 and reduces annual capital and operating costs from $393,814 to $295,206. This reduces the annual production cost per kWh of from $0.087 to $0.065, a savings of 25%. The federal tax credit of 26% further drives the financial logic of the project and drops the payback period from 10.66 year to 5.66 years (US DOE, 2020).

Non-incentivized capital cost of project	$5,325,000
Local utility rebate	$1,505,000
Incentivized capital cost of project	$3,820,000
Incentivized annual capital costs	$241,956
Annual operating costs (held constant)	$53,250
Production cost per kWh	$0.065
Annual Energy Usage	4,380,880 kWh
Federal tax incentive	26%
Federal tax credit applied to incentivized capital cost of project	$993,200
Payback period	5.66 years

Figure 5
Financial metrics with local rebates and federal tax incentives
Source: Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics

Land Rights

The solar farm is designed to be a co-located installation along with the CEA facility. As such, it would be part of the fee simple ownership structure of the entire project. The land on which the solar farm sits would be contributed as equity for the solar farm loan.

Potential Hurdles

The potential hurdles to overcome have more to do with politics, zoning and negotiated contracts than the actual financial or technical feasibility of the project. With a net metering strategy, an agreement with the local utility provider would be needed to interconnect with the high voltage power lines that are present on the property. Zoning ordinances can have constraints on the installation of larger scale renewable energy generation on parcels like the one chosen for the prototype facility that are zoned for general business. The difficulty of overcoming objections by code officials or the public at planning and zoning meetings should never be underestimated. Receiving the proper entitlements and contracts therefore represent the greatest risks to development of the solar farm.

Local Electrical Grid Mix

The local electricity fuel mix is comprised of 45.4% natural gas, 18.3% coal, 14.5% wind, 7.4% solar photovoltaic, 0.3% landfill gas and 14.1% nuclear (CPS). The meaningful contribution to electrical generation from wind and solar renewables not only minimizes health and environmental impacts from grid power generation, it would help this project because of the community acceptance and experience with these renewable energy technologies. Wind and solar farms are not unusual in the region. This can facilitate both community engagement as well as provide the competent professionals to design and install the proposed solar farm.

Nothing is sustainable if it is not beneficial to people and the environment, as well as being economically viable. The environmental and health benefits of the 3MW solar farm are equally as compelling as the financial proposition. The following health and environmental impact analyses were completed using the ReCiPe Midpoint Hierarchist method and derived from the Ecoinvent database.

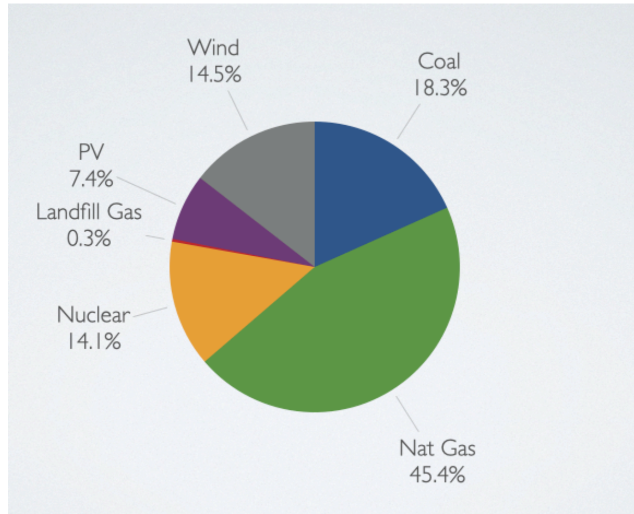

Figure 6
Local grid mix

Greenhouse Gas Emissions Reductions

Given the local grid mix, the solar farm would reduce carbon emissions by 91% from approximately 2,330 metric tons of CO2 to 214 metric tons of CO2. This represents a reduction of 2,116 metric tons of CO2.

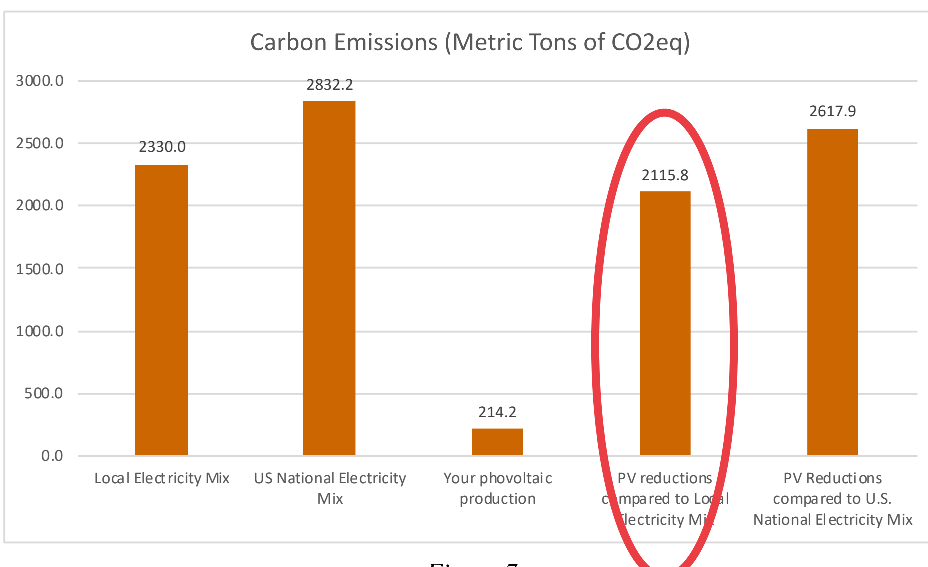

Figure 7
Greenhouse Gas Emissions Reductions

Health Benefits

In terms of disability adjusted life years, the solar farm would reduce the burden of disease and disorders 81% from 13.9 years to 2.6 years lost to illness, disability, or premature death. A reduction of 11.3 years.

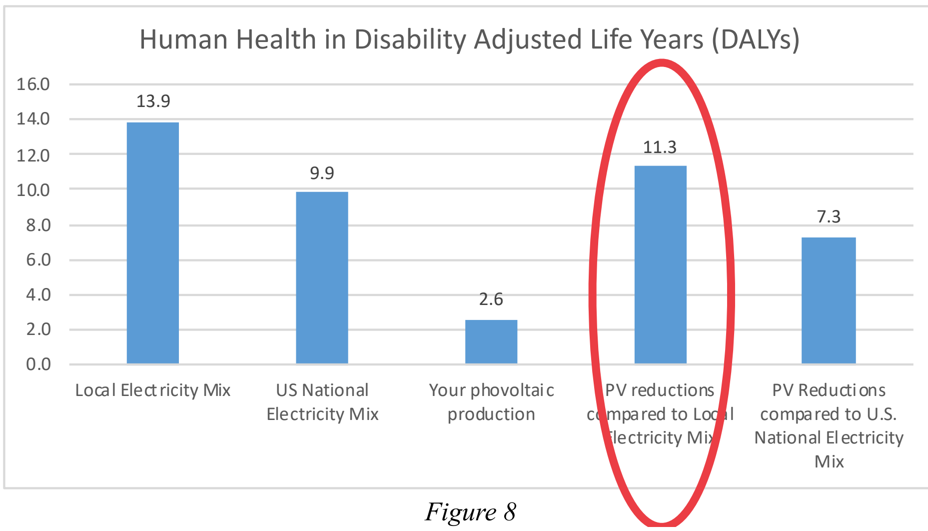

Figure 8
Disability Adjusted Life Years Reductions

Ecosystem Damages in Species Years

In terms of ecosystem damages, no species years ecosystem damages were calculated either for the local grid mix or the solar farm so I show no beneficial impact from the solar farm.

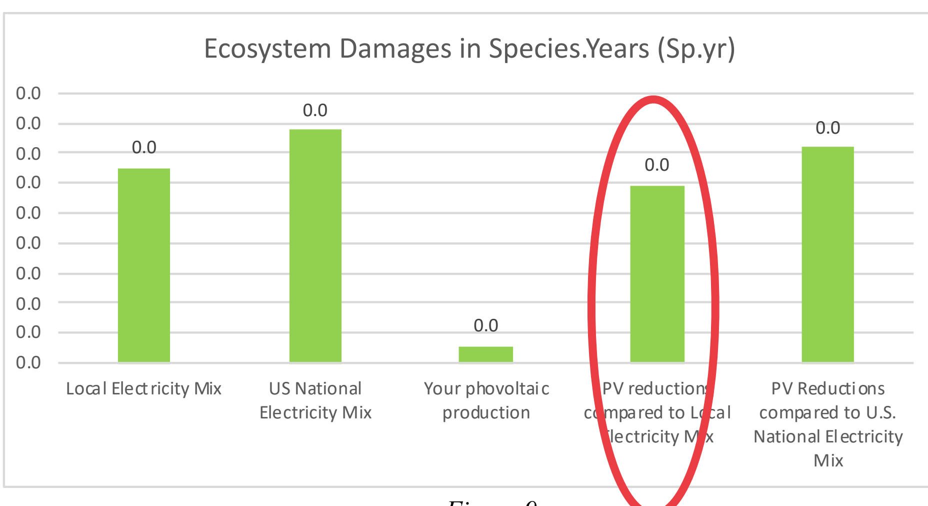

Figure 9
Ecosystem Damage Reductions

Resource Scarcity Damages

In terms of resource scarcity damages, the solar farm reduces resource depletion costs by 92%, dropping it from $428,668 to $33,436, a savings of $395,232.

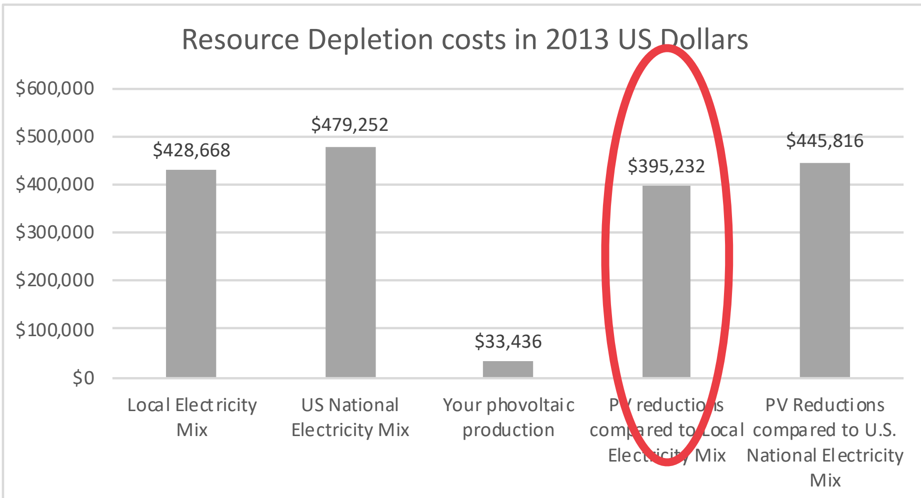

Figure 10
Resource Depletion Reductions

Conclusion

While CEA is an important and growing part of the solution for global food security, the very high energy use intensity associated with these facilities also brings significant tradeoffs involving environmental and human health impacts which must be addressed. The evidence is compelling for an associated renewable energy strategy as part of the capital development model for indoor farms of all types, bringing them to true triple bottom line success.

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