Controlled Environment Agriculture: Growing Local Food, Capturing Carbon with Flexible Onsite Power and Advanced Controls

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Abstract

Controlled environmental agriculture (CEA) in both high tech greenhouses and vertical growhouses offer a potentially extraordinary yet undeveloped opportunity to support the FRQIHUHQFH WKHPH ³&OLPDWH 6ROXWLRQV Equity is at the heart of the CEA story as it offers locally grown produce to promote food resiliency, shrink food deserts, and support job creation. With appropriate business models, it may stimulate entrepreneurship or community ownership in historically underserved communities as well as rural, ex-urban, RU ³LEXUEV´ FLWLHV DQG WRZQV WKDW KDYH VXIIHU activity.

This paper will comprehensively address technologies, design, operations, and industry trends in CEA. CEA requires onsite power tightly integrated with advanced controls, sensors, communications, climate management, lighting, and mechanical systems within a multi-factor constrained optimization ecosystem. CEA may use natural gas, but properly designed and operated systems can do so in an environmentally superior manner, capturing carbon from onsite generation and using it as a resource to accelerate plant growth. Focusing on the Northeast US context, we take full account of CEA research at Cornell, the GLASE Center, and RD&D innovations at other Northeast Land Grant institutions. With distributed generation and advanced controls, these needs can be addressed, and power exl12 7926 oower exl12 7926 c

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food, heat, and electricity. By marrying high-tech controlled environmental agriculture (CEA) operation with the electric grid, communities can secure both food resiliency and resilient, reliable electricity and heat. Our focus will be high-tech greenhouses, and how they might be designed for optimal societal benefits when paired with on-site generation of heating and electricity through combined heat and power (CHP). CHP systems have long been recognized for their ability to provide resiliency at critical infrastructure sites and locations like multifamily senior complexes, hospitals, and center of refuge stations (Hampson et al. 2013). CHP systems can also play a key role in providing food resiliency to communities. Recent disruptions, including those caused by the COVID-19 pandemic, supply chain issues, exacerbated by the war in Ukraine KDYH KLJKOLJKWHG WKH WHQXRXV QDWXUH RI WKH Z occurrences, whether man-made or natural, can seriously disrupt world food supplies and inventories.

In the same way that decentralized energy systems can be

plants

sector is an important contributor to the national economy with $1.8 billion in farm gate sales and approximately $1.4 billion in exports in 2020 (Crops and Horticulture Division 2021, 1). Vegetable crop production is highly concentrated with tomatoes, peppers and cucumbers accounting for 93.7% of total harvested area as shown in Table 2.

Table 2. Harvested area of greenhouse vegetables by commodity in square meters

	2016	2017	2018	2019	2020	2020 Share, %
Tomatoes	5,990,278	6,356,198	6,579,782	6,346,327	6,063,023	33.50%
Peppers	5,385,939	5,625,383	5,615,729	5,760,318	5,895,708	32.60%
Cucumbers	4,005,746					

province moved toward phasing out incentives for natural gas equipment and systems. This effectively ended provision of capital or operating benefits for distributed power systems at greenhouses (V. Gagnon, Business Manager Public Sector Conservation, IESO, pers. comm., June 2, 2022).

Table 3. Industry needs for onsite power and ability to time-shift electric and thermal load

	Low Flexibility	Medium Flexibility	High Flexibility

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respond to electric grid signals, especially in combination with CHP.

The Potential Equity and Public Health Benefits of Growing Local Food

The equity benefits of CEA are quite real but will not occur organically. There are significant public health benefits that might be realized by providing fresh, high-quality foods in neighborhoods which presently have no access to these goods. However, siting a commercial CEA operation within or near a food desert is offers no guarantee that the local community will have better access than before.

In a presentation on Controlled Environment Agriculture and Food Security, Cornell Professor Chuck Nicholson notes that food security has many dimensions. Two important dimensions are physical access and economic access (Nicholson 2021). Food security in the United States has little to do with a lack of sufficient supplies of food and more to do with physical and economic access. According to Nicholson, anecdotal reports and conversations VXJJHVW &($ LQ µIRRG GHVHUWV´ KDV QRW LQFUHDVHG DFF because the products themselves are still sold through the traditional retail outlets (Nicholson 2021).

When implementing CHP into CEA projects, it is important to keep in mind who is reaping the food and monetary benefits of the project. Primarily, the goals for these projects should be to keep the benefits in the community rather than larger corporations or entities. To achieve this, it will require a conscious effort from the industry and those organizing these projects. Food security also should be consciously considered when making decisions on future CEA projects.

Unfortunately, there is some doubt on the effectiveness of CEA in providing food security to individuals as well as the benefits reaching the immediate community. This doubt is fueled by high energy costs, supply chain costs, and the need for more evidence (Nicholson 2021). To improve food security, it is imperative to consider business models which maintain availability, access, and utilization of food over time (Jones et al. 2013). A combination of the proper business model with the implementation of CHP is key. Three structures this section will focus on are (1) benefit corporations, (2) nonprofits that would qualify under 501(c)(3), and (3) municipality partnerships.

A benefit corporation is a corporate structure where the corporation does not only have a fiduciary responsibility to shareholders but is also required to pursue a social benefit. This means that if the corporation is not upholding their community benefit responsibilities, the shareholders have the right to act (Noked 2012). The idea would be to have the CEA project ensure the benefit that the community would be well served and reap the rewards of the project. Such a business structure could attract investors who would be attracted to the positive community impact. Also, an LLC can be written into a benefit corporation, making the structure rather simple and accessible.

However, business corporations have flaws in their current structure. A primary concern is that there is no external enforcement mechanism in place when the benefit corporation does not adhere to their established community benefit. This means that enforcement must be done solely within the company and amongst shareholders, which can cause a conflict of interest. Also, the CEA project would likely have to rely on loans and funds from wealthy donors to get started due to their initial cost. Such a barrier can make ownership by an underserved community tough (Nicholson 2021). These flaws must be kept in mind when wanting to consider a benefit corporation.

and the Russian invasion of Ukraine

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