Professors' Corner - Using Private Lands for Production of Renewable Energy: Opportunities and Limits

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Controlled Environment Agriculture (CEA)

Controlled Environment Agriculture (CEA) is an advanced and intensive form of hydroponically-based agriculture where plants grow within a controlled environment to optimize horticultural practices

Appropriately designed CEA is capable of delivering:

i. Sustainable and resilient food production systems

ii. Localized energy production

iii. “Conjoining” food and energy/grid resiliency

Greater Yields | Less Environmental Impact

CEA, in the form of the High Tech Greenhouse has demonstrated 5 to 7 times the amount of produce per acre with dramatically less (80%) water usage and pesticide **use**[1]

Studies have shown that CEA in high-tech greenhouses is one of the most sustainable forms of agriculture currently available as measured by the Sustainable Development Goals (SDGs) introduced by the United Nations in their 2030 Agenda for Sustainable Development [2]

Radical Change in Energy Markets

Many states have embraced an emissions free power grid and eventually a carbon neutral economy across all sectors

New York's Climate Act mandates 100% zero-emission electricity by 2040 and Net zero emissions statewide by 2050 **3**

Even with an unprecedented buildout of Solar, Wind and Energy Storage, there remains a large seasonal energy gap that must be filled to ensure reliability

NYISO 2023-2042 System Outlook

Generating capacity will need to triple to meet energy goals & growth [4]

3X today's 37 GW of installed generating capacity, or 100-130 GW will be needed to meet demand by 2042. Contentious debates slow the development of Solar Farms, Land-Based and Off-Shore Wind, and the necessary Transmission and Distribution Infrastructure that brings the power for the source to the consumer

20-40 GW of DEFRs needed to replace current 25 GW of fossil-fuel generation by 2040

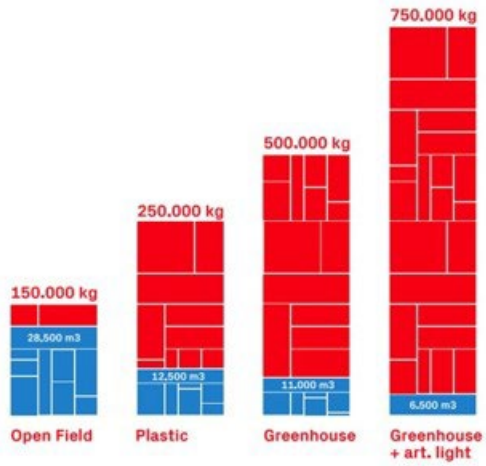
DEFRs are critical to address the attributes needed to run the grid

A zero-emissions grid requires technologies that can fill in when wind and solar are unavailable. These renewable resources can pose challenges to grid operators balancing supply and demand in real time.

Energy, Water, Food Nexus

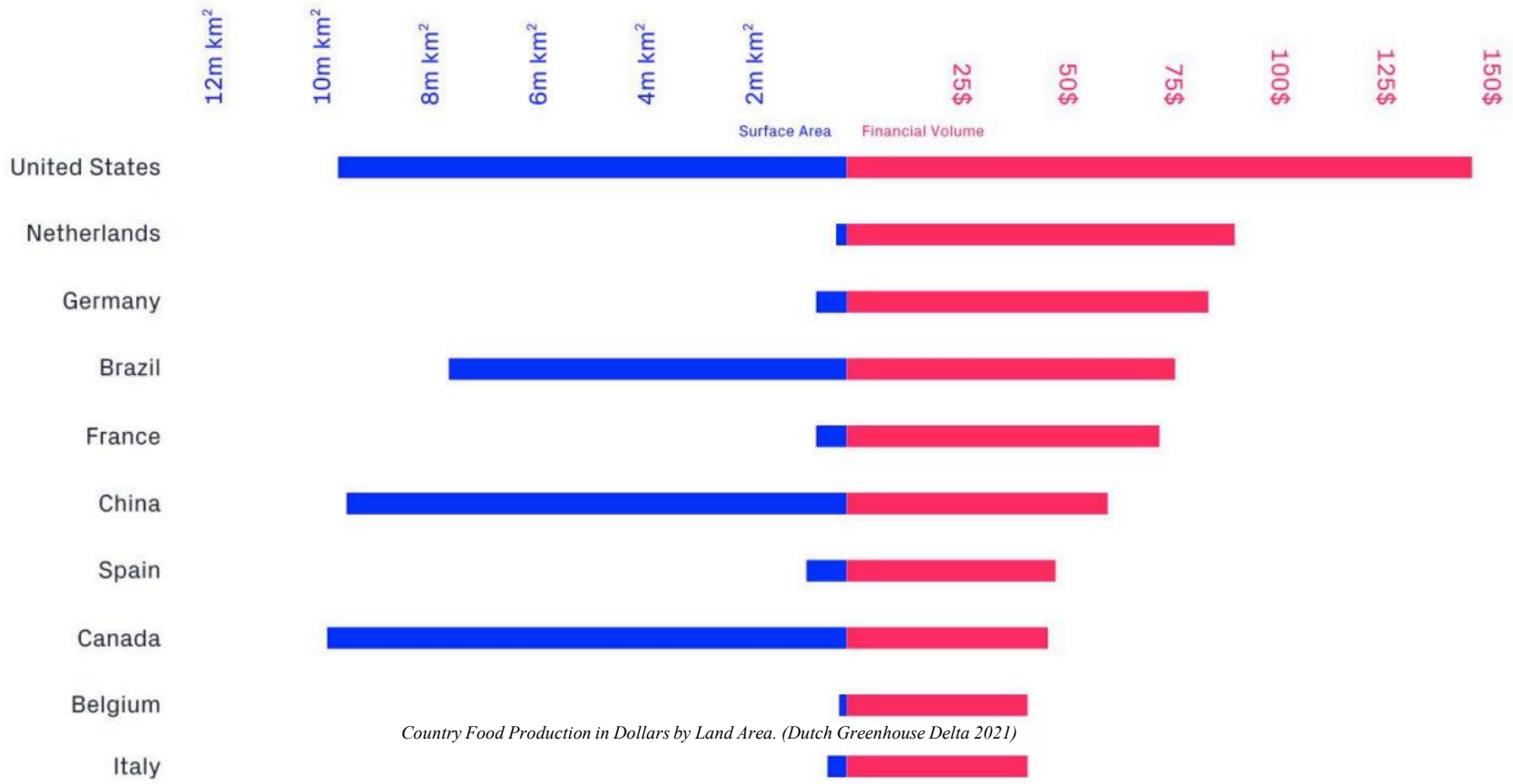
It can be done,
it has been done

The high-tech greenhouse delivers 5 times the output while consuming nearly 78% less water.



Tomato production on one hectare vs. water consumption (Dutch Greenhouse Delta 2021).

Success of CEA in the Netherlands



Country Food Production in Dollars by Land Area. (Dutch Greenhouse Delta 2021)

CEA – (how) Flexible the Loads ?

Lighting	LED lighting can be ramped more easily than HPS lighting. Plants can tolerate variations in lighting amount and schedule. Alternating red and blue light with tomatoes to reduce peak demand.
Ventilation and Fans	Horizontal and vertical fans are utilized to create different crop zones in the same greenhouse. The use of variable flow drive fans allows flexible usage. Vertical fans that provide boundary separation in lettuce crops can be flexibly timed.
Thermal Energy	Thermal batteries allow decoupling greenhouse thermal generation and utilization allowing flexible timing of cogenerated heat and power.

***Source*: Afzali et al. 2021; Bhuiyan and van Iersel 2021; Frijns 2022; Hao 2021; Nicholson et al. 2022.**

	Low Flexibility	Medium Flexibility	High Flexibility
Low On-Site Need	Commercial	-	-
Medium On-Ste Need	-	Manufacturing	-
High On-Site Need	Hospitals	-	CEA

Within the class of dispatchable resources, the most reliable resources are those that are already online. Particular value will be paid for assets that are online, serving a load and are able to shed some load and inject into the grid (Swider, NYISO Webinar 1/29/2022.

CHP and CEA: *Conjoining* Food & Energy for Resilient and Sustainable Communities

- Locally grown healthy food
- CHP for site energy resiliency, redundancy, & reliability
- Thermal storage for peak shaving
- Heat recovery for greenhouse, carbon sequestration from engine feeds plants
- Goodwill toward community
- Educational program opportunities

Circular Economy: Grow local food, use wasted heat from Data Centers, industries, businesses

- Circular economy and “shared resources” way of thinking
- several homes, businesses, greenhouses or farms create a communal district (district energy)
- the “waste” from one source (heat in data center) is a resource for another (greenhouse)

Integration of CHP w/ CEA – Renewable Power & Heat

HoSt's 2020 State-of-Art Biomass CHP Plant: Produces 15 MW thermal + 3.4 MW electrical power

- Biomass-fired combined-heat-and-power (CHP) plant recently commissioned in Andijk, Netherlands
- Produces heat and electricity from ***prunings***, providing renewable heat to six greenhouse companies.
- Independently conducted emission measurements, certified by a public authority, certify this biomass plant's NOx emission reduction >99%. Achieved using HoSt's ultra low-NOx innovative combustion technology, precise combustion temperature control, and highly automated control.
- CO_2 from flue gases can be captured for use in greenhouses for crop growth, for sales, or storage in liquid or gaseous form.
- Excess heat and electricity can be supplied to district thermal or electric microgrids.

Foothill Greenhouse LLC

- Foothill Greenhouse is a third-generation family owned/operated business, Ontario
- Onsite power with 20kW of PV and 3.2 MW CHP system. The site captures and recirculate 100% of their irrigation water to use fertilizer efficiently[1]
- Wood-waste and CO2 Recycling, consumed by plants in the greenhouse[1]
- This 15 acre farm can produce about 2400 tons of cucumbers, ~ 8 times more than field grown cucumbers
- NOTE: Feb 6th 2023 this site received unanimous approval from Town to build new 1.2 MW CHP to serve as Grid Asset in Ontario. See Source: https://www.jenniferanstey.ca/post/king-township-council-meeting-february-6-2023

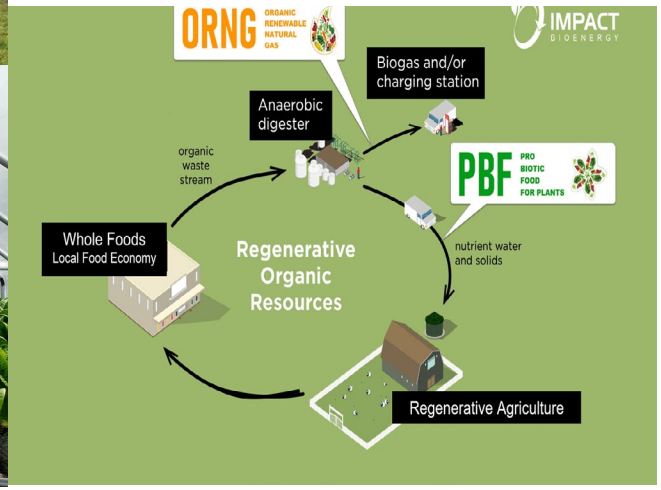
1. https://www.foothillgreenhouses.com/eco-initiatives.php

CHP → CEA: At small scale to village scale

***Impact Bioenergy's Vashon Island, WA Bioenergy Farm*:**

- **Food wastes →**
- **Biogas as Fuel +**
- **Greenhouse nutrients and heat**
- **CHP option**

Village Scale: This site uses a cottage industry's food production waste to produce biogas for heat and renewable natural gas for sale, as well as plant nutrients. A greenhouse is integrated on top of the biogas digester.



Images and Graphics Courtesy of Impact Bioenergy

Innovations: Hybrid Application, Efficiency, Decarbonized Solutions

AGR Chear Farm Glass house, Cambridgeshire U.K. that supplements CHP heat with water source heat pump heat.

- 33MWth Heat Pump System
- 9 MW CHP, 3 high efficiency engines with CO2 recovery
- Will qualify for the Renewable Heat Incentive (RHI)

Varegro, a horticultural company in Ootrozebeke, West Flanders.

- 40,000m2 site. The (Cummins) HSK78G supplies the site with 2MW of power
- Electricity for lighting, the heat produced for heating and the exhaust gasses cleaned and used for CO2 fertilization.
- The heat buffer allows Varegro to influence the variable energy market and support the grid network. The electricity is sold back to the grid in a flexible manner which offers greater fuel savings for Varegro.

Seacliff Energy Corporation (Seacliff) anaerobic digestion (AD) facility in Leamington, Ontario, Canada

- First privately-owned, commercial-scale anaerobic digestion (AD) plant in Canada.
- Integrated with an adjacent 300,000 square foot commercial organic greenhouse
- Exports green electricity to the Ontario utility grid, produces renewable heat for greenhouse and anaerobic digester operations, and fertilizer as a by-product for local organic farming operations in a sustainable, closed-loop, system.
- Permitted capacity of up to 110,000 tons per year of source-separated organics (SSO), industrial, commercial, and institutional (ICI), and liquid waste streams.

CEA Integration in Districts

Q-Scale data center with Greenhouse utilizing residual Heat Lévis, Que. the company claims that it will "produce 2,800 tonnes of small fruit and more than 80,000 tonnes of tomatoes per year" in greenhouses to be constructed adjacent to the facility.[5]

Toundra Greenhouse, Resolute Paper Mill, CO2 Solutions Partnership – Phase one of a $100 million, 34 hectare, agrothermic industrial park has been completed. Heat and CO_2 produced from the Resolute pulp mill are used to heat and supplement greenhouse CO_2 in a 8.5 hectare greenhouse. CHP is under consideration to serve electric loads and provide heating for upcoming industrial tenants.

Sweden: An agreement between Agtira and Greenfood $27.8 million ($US) has been signed for a cucumber cultivation plant in Boden. The facility will be one of eventually a total of ten around the country.
"The potential to recover residual heat from data centers and other industries is a huge and often unused resource" [6]

Companies in Netherlands, Japan and Sweden [7] are investing developing CEA sites adjacent to data centers. Containing Greens (Luleå, Sweden), an award winning project uses waste heat to grow vegetables that will help feed communities in northern Sweden year-round. [8]

Key Stakeholders and Involved Parties

- Energy Regulators and Policy Makers
- Grid Operators (e.g. NYISO) and Utilities
- Community organizations and Environmental Justice concerns
- State / Local Agencies managing food waste initiatives
- Affected industries and trade associations
    - Greenhouse Lighting and Systems Engineering Consortium
    - Onsite power companies and RNG industry
    - Farms - food waste generators – waste management enterprises

Implementation and Opportunities to Effect Change

CEA with CHP can be designed to create Multiplicative Benefits

conjoining local food (food resiliency) local generation (energy resiliency)

District Energy further augments benefits

actively managing, across property lines, broad portfolios of energy demands / supplies

Urgency in developing local / dispatchable / appropriate generation

(e.g. NY) will require dispatchable emission free generation / load flexibility

Regions facing local grid challenges are valuing CEA/CHP like resources

(e.g. several greenhouses expect to participate in Ontario IESO newly required markets)

In the words of the NYISO the scale of the need is “unprecedented”

This work is important, impactful innovative and *actionable* !

Conjoining Food and Energy/Grid Resilience

Food Resiliency is affected by: i. unpredictable shifts in climate ii. War, Covid exogenous shocks iii. long supply chains from farm to table iv. shortages of key inputs, especially water

Grid/Energy Resilience is affected by i. unpredictable shifts in climate ii. War, Covid, exogenous shocks iii. long supply chains for critical components iv. **heated debates over key inputs, land use, competing claims**

"Conjoining" Food / Energy, In a Circular Economy Structure

Farmland, Rural Character and the Clean Energy Transition

"Sunblocked: Resistance to Solar in Farm Country". *Across the country, rural communities are pushing back against large-scale solar development.*

New York County Protests Using Farm Land for Solar Projects. *opposing the siting of the proposed NextEra Energy Resources High River Energy Center, a 90-megawatt solar energy project*

Hoosick locals call for halt on large-scale solar farm plans. HOOSICK, N.Y. (WRGB) — A plan to build a large-scale solar farm in the town of Hoosick is not sitting well with some of its residents, and now they're hoping the town board puts a pause to it.

Clean Energy Transmission Battle Pits Speed Against Worker, Farm Protections. *The Assembly and Senate want to beef up labor standards and farmland protections for clean energy projects. Developers say that would slow down the energy transition.*

Cornell Study Professor Richard Stedman *ROCHESTER, N.Y. (WROC) — When it comes to local support versus opposition against large scale solar farms there are a number of factors at play in the divide that may surprise you. One university sought out to find out more.*

An Epic Battle Over 1 Mile of Land in Wisconsin Is Tearing Environmentalists Apart **Conservationists and green energy developers square off, with big consequences for the climate**

Consider "all" available options

Agrivoltaics

Agrivoltaics — putting solar panels on farmland

shading the cattle of a rotational grazing pasture … cooler microclimates below panels and less evaporation, as well as larger leaves …more efficient photosynthesis and greater protein production

Doesn't address the enormous difference in energy system footprint

3 - 4+ acres/MW for utility scale PV [9]*.*
And PV lacks certain critical attributes necessary for grid operation.

CEA

CEA allows for much greater yields/acre. *Precise control of temperature, humidity, CO2 levels.. Much less water usage and pesticides*

CEA is expensive, high upfront capital costs. High levels of energy consumption, much more technically complex process, skills requirements

Onsite Power footprint. ***3 MW's in a 4.000 – 5,000 sq.ft space (0.1 acre/MW)***

End Notes

1. Dutch Greenhouse Delta 2021

2. Zhou, D., Meinke, H., Wilson, M., Marcelis, L. F. M., & Heuvelink, E. (2021). Towards delivering on the sustainable development goals in greenhouse production systems. Resources, Conservation and Recycling, 169.

3. New York Climate Act Final Scoping Plan. December 2023. Executive Summary page

4. 2023-2042 System & Resource Outlook Datasheet. 20-Year Outlook Forecasts Transmission & Resources Needed to Meet Policy Objectives

5. Waste Heat Trapped by Major Greenhouse Grower. https://www.greenhousecanada.com/waste-heat-tapped-by-major-quebec-grower-31899/

End Notes

6. Pontius Lamberg, https://www.hortidaily.com/article/9516261/sweden-cucumbers-grown-on-residual-data-facility-heat/ date: Mon 3 Apr 2023

7. Revolution in agriculture: smart greenhouses Lulea (Sweden), working on secondary heat. Revolution in agriculture: smart greenhouse Lulea (Sweden), working on secondary heat (Mar. 27, 2023

8. Bringing Leafy Greens to Northern Sweden https://www.arcticwwf.org/the-circle/stories/bringing-leafy-greens-to-northern-sweden/

9. source: Bolinger, M. and G. Bolinger. 2022. "Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density."