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Combined Heat and Power (CHP) Adds Food Resiliency to the Menu

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Acknowledgements

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Agenda

- DOE CHP TAP Intro
- CHP and Controlled Environment Agriculture (CEA) Perfect together
  - Why CEA
  - Why CHP
- Integration of CHP, with CEA
  - Examples
- CHP operations with CEA
  - Decarbonization
- CEA & CHP in District Energy Systems
- Driving Factors for CEA/CHP & District Energy (DE)
  - World Events (COVID, War) / Climate – Environment Policies / Local conditions (challenges)
  - Supply Constraints, Production Cutbacks, Price Adjustments
  - NYISO DEFR Needs & Infrastructure Food and Waste Management
  - Ontario IESO demand congestion

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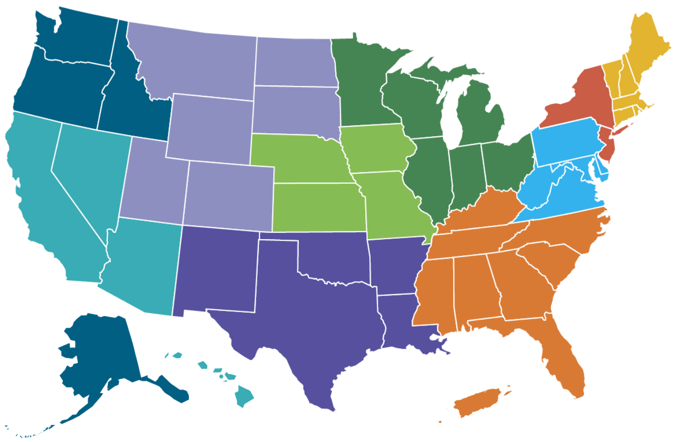

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US DOE CHP Technical Assistance Partnership Services

- **End User Engagement**

  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.

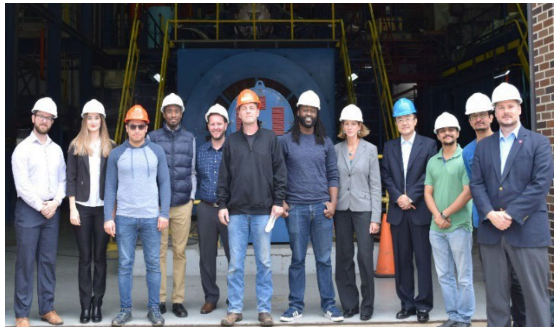
- **Stakeholder Engagement**

  Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation's resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.

- **Technical Services**

  As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.

www.energy.gov/chp

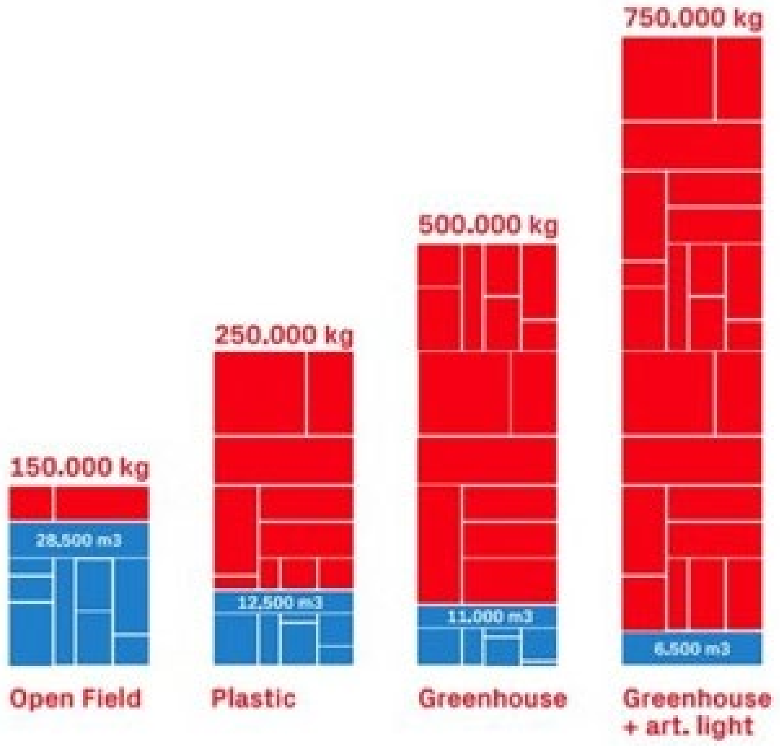


National Manufacturing Day 2019 at the University of Illinois at Chicago

Energy, Water, Food Nexus

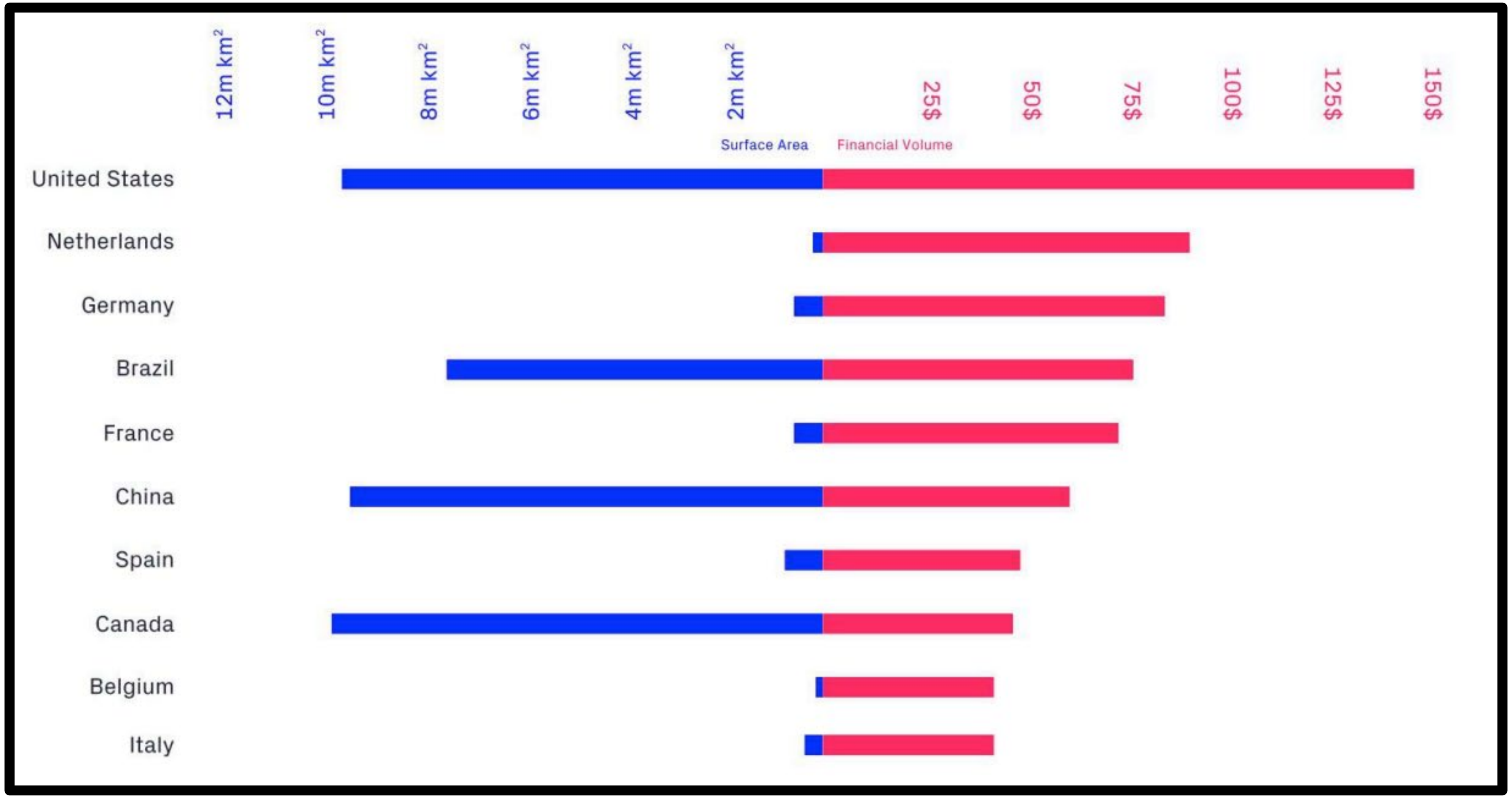
It can be done,
it has been done

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



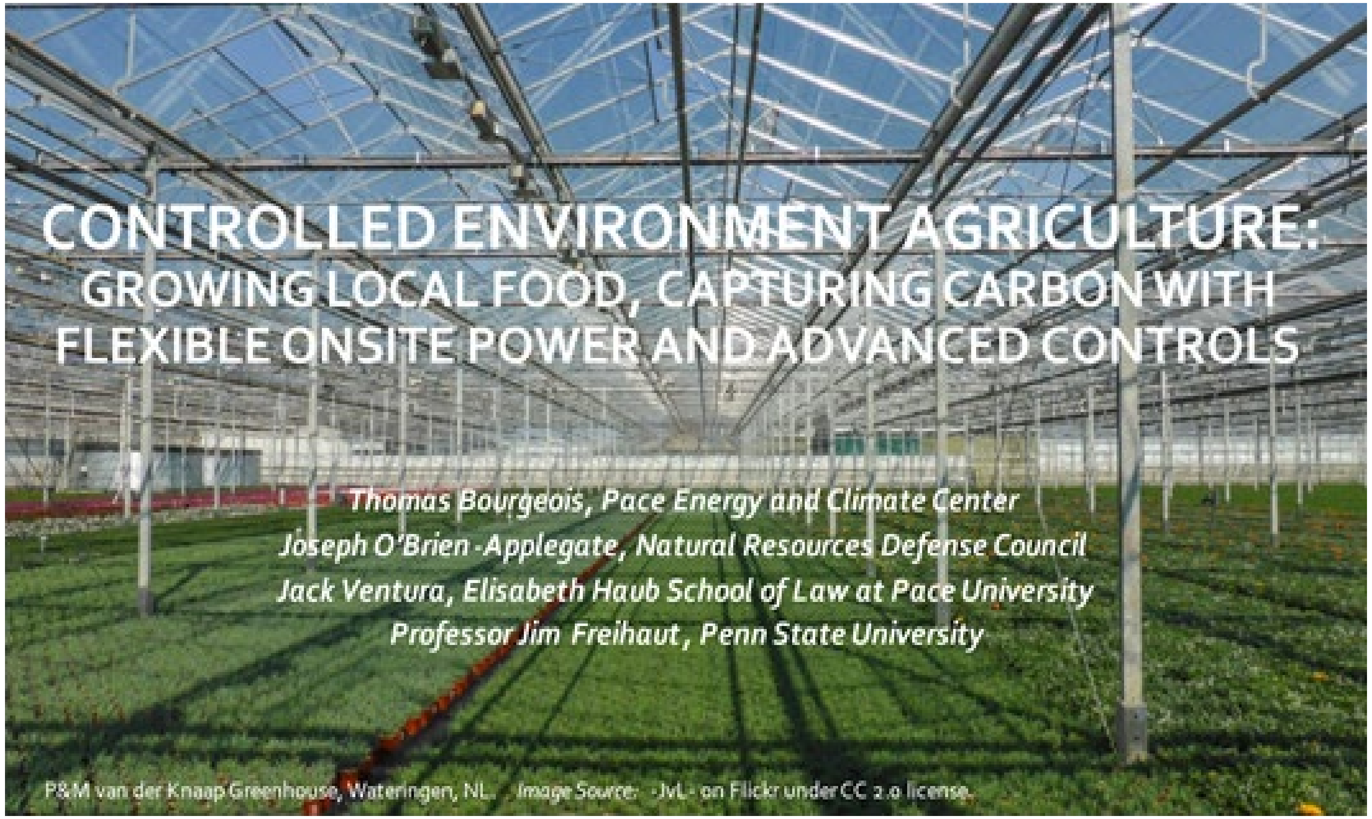
Tomato production on one hectare vs. water consumption (Dutch Greenhouse Delta 2021).

Success of CEA in the Netherlands



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

CHP and CEA: Conjoining Food & Energy for Resilient 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

CHP/CEA – Cost Savings

- Utility load data collected for 26-acre semi-closed glass greenhouse, located in MD, growing tomatoes on the vine and cherry tomatoes.
- Modeled system included 2,858 kW RICE prime mover with exhaust heat recovery, CO_2 utilization, hot water heat recovery, thermal storage in an electrical load following configuration.
- Utility rates of $0.105 / kWh displaced, $0.9343 / therm natural gas, $0.027 / kWh maintenance cost.
- System would operate for 2,426 hrs / year, generating 6,794,838 kWh at overall efficiency of 84.4 % LHV with 100% of produced heat used by greenhouse.
- This scenario would result in **savings of $239,734 / year (13%)** in utility costs while providing resiliency (electric & thermal) and improving crop yield through greenhouse CO_2 injection.
  - Crop CO_2 uptake estimated at 30%, with a CO_2 cost of $0.136 / lb, yields estimated additional **CO2 cost savings of $279,273 / year.**

Source: ASHRAE 2023 Winter Conference – CEA, CHP, and TES: Ultimate in Grid Resilience and Efficiency – Richard Sweetser | President, Exergy partners Corp

Why CHP at CEA

- CHP produces electricity, heat, cooling, and CO_2. Utilizing these energy streams results in increased efficiency (> 75%) of the fuel source (natural gas or low carbon fuel) reducing utility costs and providing several ancillary benefits.
- **Cost Savings** – Utilities (lighting, dehumidification, space conditioning) represent the second largest cost associated with CEA behind labor.
- **Resiliency** - Local power generation provides resiliency while eliminating grid transmission and distribution losses [5.3 % US Average[1]]
  - Systems can be designed to black start and operate in island mode isolated from the utility grid.
- **Emissions Reduction** – High CHP efficiency can deliver emissions reductions compared to baseline options (local grid and onsite boiler) when operated on fossil natural gas.
  - When Carbon Capture Utilization and Sequestration (CCUS) systems are deployed with CHP captured CO_2 can be injected into the greenhouses for enhanced plant growth or liquified to produce food grade CO_2.
  - CHP systems are fuel flexible and can operate on natural gas, biogas, renewable natural gas, hydrogen, and various fuel blends delivering further decarbonization.
- **Grid Support** – Siting CHP at CEA provides significant opportunity for grid support, stability, and demand response through a combination of dispatchable generation and load / operational flexibility. These grid support services enable increased renewable generation in the energy mix.
  - Load Flexibility – Depending on crop types variations to lighting schedules [within certain parameters] have minimal impact on crop growth. This allows load to be shed for demand response events.
  - HW Storage – Thermal energy produced during power production can be stored as hot water to be utilized at other times of day.
- Utilization of organic waste for low carbon fuel.

[1] *https://www.epa.gov/system/files/documents/2023-01/eGRID2021_technical_guide.pdf*

CEA – Flexible 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.

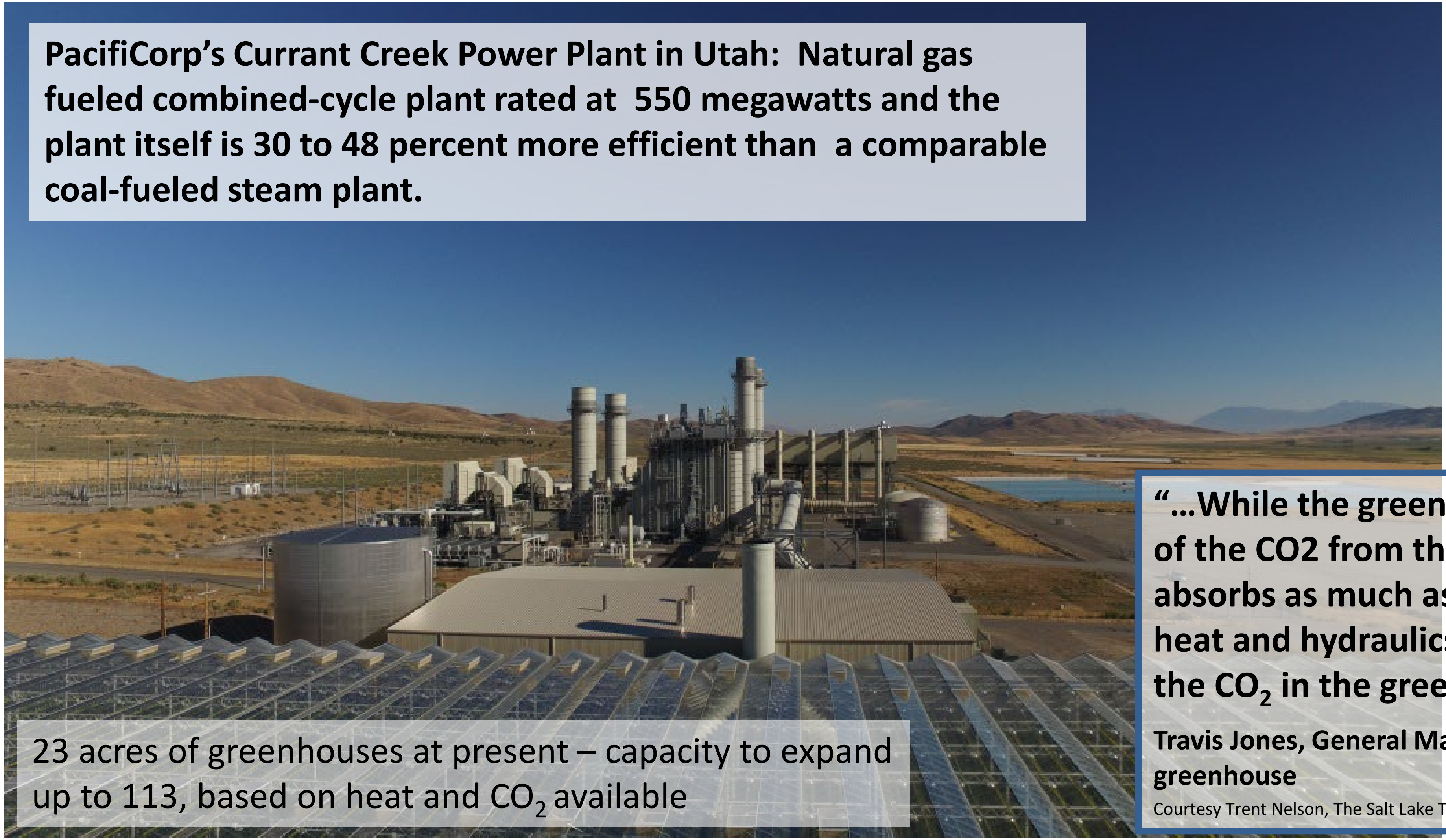
Integration of CHP w/ CEA

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 of 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.

Source: Biomass Magazine, June 26, 2020
Courtesy: David Van Holde, PE, CEM, Director US DOE Northwest CHP TAP

Integration of CHP w/ CEA



PacifiCorp's Currant Creek Power Plant in Utah: Natural gas fueled combined-cycle plant rated at 550 megawatts and the plant itself is 30 to 48 percent more efficient than a comparable coal-fueled steam plant.

23 acres of greenhouses at present – capacity to expand up to 113, based on heat and CO_2 available

"…While the greenhouse doesn't absorb all of the CO2 from the primary stacks, it absorbs as much as it can — using some for heat and hydraulics, and some to double the CO_2 in the greenhouse air."

Travis Jones, General Manager Longvine Mona greenhouse

Courtesy Trent Nelson, The Salt Lake Tribune, 10/6/2021.

Photo Courtesy of Houwelings Group, Courtesy: David Van Holde, PE, CEM, Director US DOE Northwest CHP TAP

Foothills Greenhouse LLC

https://www.foothillcogen2.ca/

Great Northern Hydroponics

https://www.greatnorthern.farm/about-us/

Many Applications Worldwide[1]

Some Case Study Examples:

Netherlands - Has 25,000 MW of installed generation, *of which 3,000 MW is CHP units in greenhouses:*

- *Prominent* - produces 20% of Dutch tomatoes at 35 sites - almost 741 acres, with CHP
  - Have 150 MW of CHP installed, from different manufacturers - 202 kW/acre
  - In 161 acres, they use artificial lighting to grow year around.

United Kingdom:

- *Westlands Greenhouse* - 1.5 MWe; 59 acres grow specialty edible flowers, tomatoes, etc.

Ontario, Canada:

- *Rosa Flora Greenhouses* – 1.6 MWe, running since 1992. Added 4 MW; growing flowers
- *Foothills Greenhouses* - 3.3 MWe; 15 acres growing cucumbers ~30 min north of Toronto
- *Raversbergen* - 2.7 MWe; Primarily heated by recycled wood, growing flowers; sell all elec.
- Most are selling all power to IESO - More greenhouses and power sales contracts in process

1: Examples from: https://www.cogenerationchannel.com/en/video/category/applicazioni-greenhouse/

Innovations : Hybrid Applications, 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.

CHP/CEA – Emissions
Dutch Greenhouses and On-Site Power

2020 production of electricity using natural gas fired CHP in greenhouse horticulture in the Netherlands was 10.3 billion kWh. Deploying CHP in greenhouse horticulture the Dutch reduced total CO_2 emissions by approximately 1.76 million tons (Smit and van der Velden 2021).

Energy/Environmental Impacts	Lifetime Low Estimate	Lifetime High Estimate	Annualized Low Estimate	Annualized High Estimate
Electricity savings (MWh)	65,223	79,717	3,261	3,986
Fuel savings (MMBtu)	231,876	593,206	11,594	29,660
Estimated GHG emission reductions (metric tons)	44,601	70,504	2,230	3,525

Projected Environmental Impacts of Agbiotic Project #1. *Source*: NYGB 2020.

Benefits of District Energy (DE) & CEA / CHP

- Dispatchable generation resource and flexible load for microgrid balancing.
- Excess electric and thermal generation from serving greenhouse loads can be used to serve district energy loads.
  - Greenhouses have minimal electric and thermal loads during the summer so CHP can serve increased electric (air conditioning) loads and run absorption chillers.
  - Excess heat from CHP HW loop
- Food production located near population and load (electrical, thermal) centers.
  - Reduces emissions associated with food transportation.
- Close proximity to large food waste sources provides ability to produce low carbon fuels (biogas or renewable natural gas) to run CHP when anaerobic digestion is included in CEA / CHP system.

DE May Smooth Price Adjustments

- COVID, War, energy/labor/materials disruption force price spikes
- DE may lower volatility with ability to switch to alternative fuels, large storage capacity, combination of electricity producing and consuming unit
- DE facilitates transport of thermal energy , less waste /higher energy efficiency.
- Storage actively run. mix of heat production optimally managed to the situation.[1]

Example Case: Danish District Energy Company Hvide Sande[2]

Actively Managing Broad portfolio better manages energy price shocks. Production Units CHP 2 x 3.7 MWe m 4.9 MWt 3 X 3 MWe Wind Turbines, Heat Pump 5 MWt, PV 9,500 m2, hot water storage 3,200 m2

[1] *Source: Hanne Kortegaard Stochel DBDH*
[2] Source: https://online.flippingbook.com/view/505294643/10/

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.[1]
- 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,"

- Pontus Lamberg, operations manager at Agtira (Data center) [2]

[1] https://www.greenhousecanada.com/waste-heat-tapped-by-major-quebec-grower-31899/
[2] https://www.hortidaily.com/article/9516261/sweden-cucumbers-grown-on-residual-data-facility-heat/ date: Mon 3 Apr 2023

Decarbonization / Energy Markets /Grid Reliability

- Short term reliability margin are "thinning" to 2026 [1]
  - NYC reliability margin narrows to 50 MW in 2025
  - ***"even the slightest deviations from expected conditions, load forecasts, or project delays could trigger future reliability needs" - NYISO***
- Total Installed Capacity must Triple (95 GWs) to meet the 2040 Goal[2]
  - New York currently has 37 GWs of generating capacity
  - Roughly 7 years from now, an estimated 20 GW's of additional renewable generation needed
  - 12.9 GWs of new generation have been developed since 1999

[1] *2022-RNA-Datasheet.Pdf*
[2] *NYISO 2021-2040-Outlook-Datasheet.Pdf*

DEFRs are Critical for a Reliable Grid

- Dispatchable Emission-Free Resources (DEFRs) must be developed and added at scale to reliably serve demand when intermittent generation is unavailable [1]
  - 25 GWs to 42 GWs of DEFRs required in 2040 Policy Scenarios
  - DEFRs must be developed and deployed at scale well before 2040
  - *"There will be a great need for DEFRs to meet the flexibility and energy supply needs of the future system" – NYISO*
- CHP is a proven DEFR when operated on zero (low) carbon fuels.
- CEA's flexible load characteristics can serve the same purpose as DEFR's by reducing grid load.

[1] *NYISO 2021-2040-Outlook-Datasheet.Pdf*

Ontario IESO Illustrates CEA & CHP As Grid Solution

Challenge: Significant grid congestion in SW Ontario due to high concentration of industrial facilities and high energy users. **Ontario requires an additional 4,000 MW of electricity supply between 2025 and 2027.**

Solution: Long term generation procurement (ELT1 / LT1) RFP Released by IESO in 2022.

- Procurement target of 4,000 MW of new efficient, dispatchable, year round resources including hybrid electricity generation and storage facilities > 1 MW that can provide > 4 hrs of continuous output.
- IESO is looking to procure a diverse portfolio: 2,500 MW of storage, contributions from other non-emitting resources such as hybrids and biofuel resources, and up to 1,500 MW of natural gas to relieve grid congestion
- Open to variety of dispatchable generation technologies with largest carveout for BESS with significant portion for CHP
- Program provides reserve payment to participate in program and for response to demand event calls (15-year contracts)

ELT1 and LT1 Programs are resulting in:

- Existing greenhouses w/ CHP expanding installed capacity
- New greenhouses proposed to include CHP and participate in program

LT1: Long Term Request for Proposals; ELT1: Expedited Process for Long Term Request for Proposals

E LT-1 RFP: Example Greenhouse Resources

Under Sun Acres Green Energy – Plant 2, The expansion of additional natural gas fired CHP engine with an electrical output of up to 3.3 MW. The engine. Efficiency of ~90% or greater where the waste heat from the engine is recovered and utilized to heat Under Sun Acres' production greenhouse.[1]

Soave Hydroponics Company ("Soave Cogeneration") intends to participate in the IESO's E LT1 RFP to expand our existing cogeneration facility by 6.6 megawatts (MW). This will help support increased reliability to the Kingsville area. The IESO has identified Kingsville as a priority location for new projects in Ontario.[2]

Foothill Greenhouses intends to seek a new contract with the IESO under the E-LT1 program to install an additional 1.4MW Natural Gas fueled Cogeneration plant.[3]

[1] https://undersunacres.com/cogen-exp/

[2] *https://soave-cogeneration.com/assets/documents/CommunityAndIndigenousEngagement.pdf*

[3] https://www.foothillcogen2.ca/

Summary

- CEA with CHP can be designed to create multiplicative benefits conjoining local food (food resiliency) and local generation (energy resiliency).
- District Energy further augments benefits actively managing, across property lines, broad portfolios of energy demands / supplies.
- Urgency in the need for State climate action (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)

All: Driving Factors for CEA with CHP and incorporating District Energy Systems

Thank you. Questions?

CHP
Technical Assistance
Partnerships

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For more information about the TAPs:

https://betterbuildingssolutioncenter.energy.gov/chp/chp-taps

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