U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Packaged CHP Accelerator Webinar
CHP and Controlled Environment Agriculture

September 22, 2021

Agenda

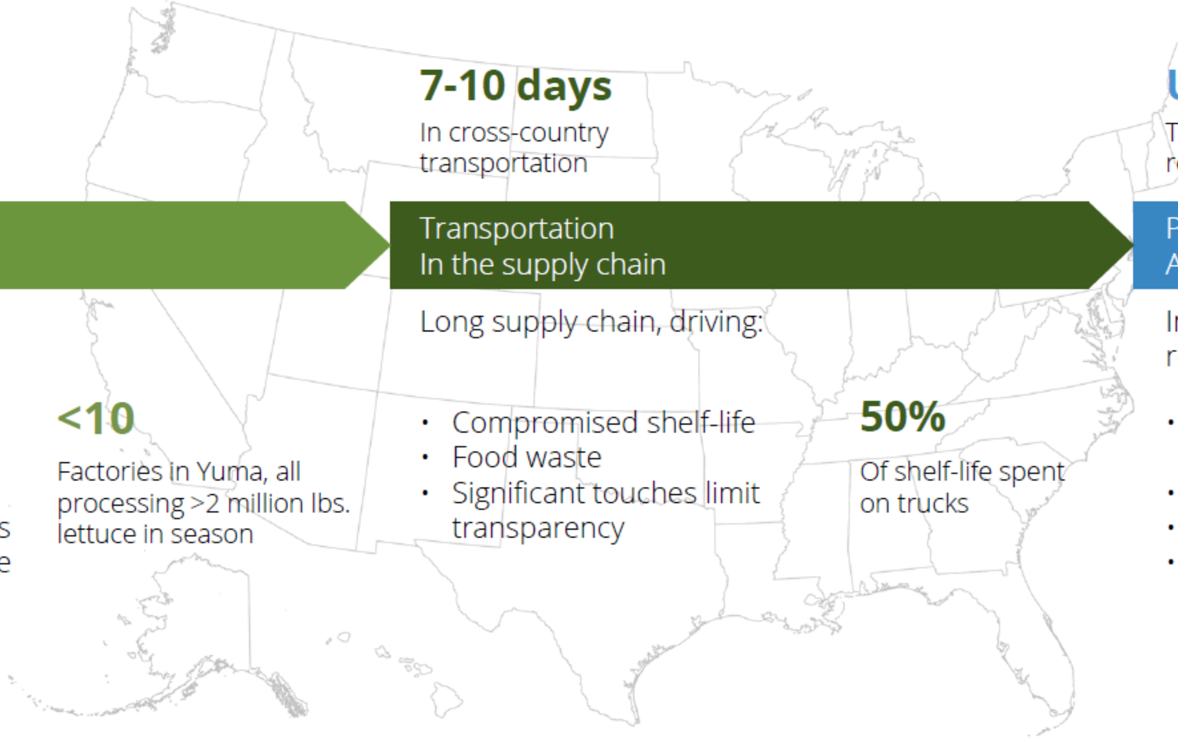
- Introduction
- Controlled Environment Agriculture Overview – Richard Sweetser
- Case Study: Houweling's Tomatoes – Aaron Tasin
- Case Study: Intergrow – Dick Kramp
- Packaged CHP eCatalog Update

Richard Sweetser
Exergy Partners, Corp

U.S. DEPARTMENT OF ENERGY

Food challenges are driven by limitations of outdoor production and consumer geography

Example: Lettuce



>95%
of US lettuce is grown in California and Arizona

Production
On the farm

Limited environmental control, driving:

- Climate exposure
- Field loss exposure
- Food safety risk
- Resource intensiveness
- Limited ability to iterate (e.g., scale organic) or diversify

<10
Factories in Yuma, all processing >2 million lbs. lettuce in season

7-10 days
In cross-country transportation

Transportation
In the supply chain

Long supply chain, driving:

- Compromised shelf-life
- Food waste
- Significant touches limit transparency

50%
Of shelf-life spent on trucks

Up to 40%
Total production wasted at retailer and consumer levels

Promotion
At the retailer

Impacting outcomes for retail/foodservice and end consumers:

- Inconsistent quality and supply predictability
- Seasonal availability
- Limited transparency
- Conflict w/ consumer ideals (e.g., sustainability, local claims)

Rising
Food safety incidents

Source s2gventures: Growing Beyond the Hype: Controlled Environment Agriculture, https://www.s2gventures.com/reports/growing-beyond-the-hype%3A--controlled-environment-agriculture

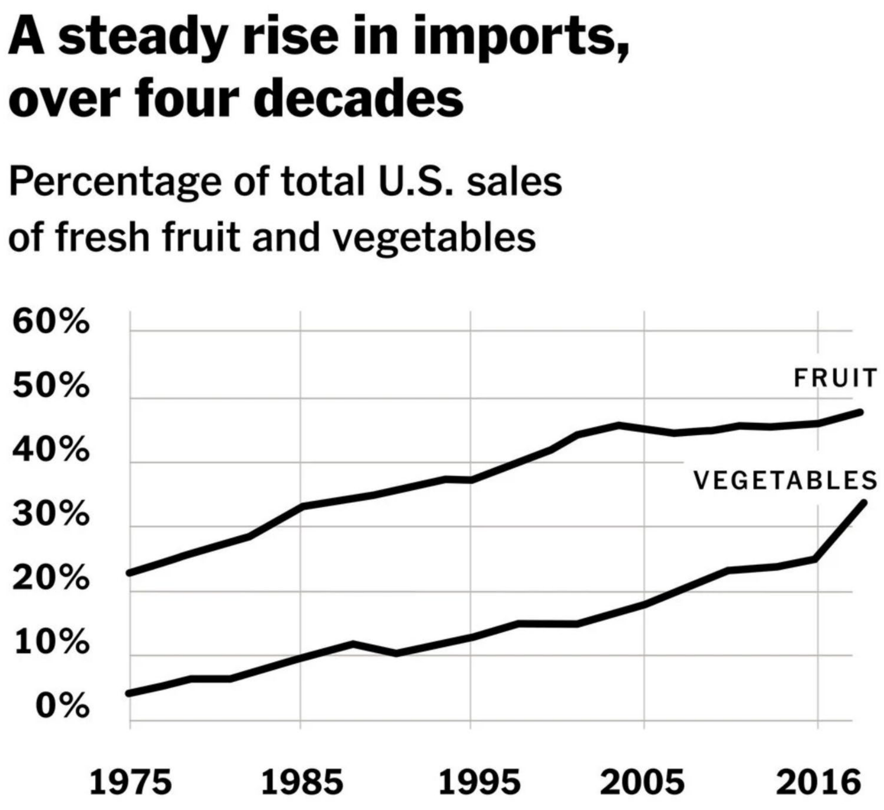
Food Waste

- About 16% of food in North America is lost during processing and distribution, according to UN estimates.[1]
- 2-5% of all food products are lost because buyers reject shipments due to cosmetic imperfections, surplus, or other issues like improper transportation or handling.[1]
- 10% or 43 billion pounds of food in grocery stores will never make it off the shelf. For produce, about 12% of fruit and 11.5% of vegetables are never sold.[1]
- The U.S. Department of Agriculture (USDA) estimates the value of food loss for retailers and consumers each year to be over $161 billion.[1]
- EPA estimates that over 75 billion pounds of food waste reaches landfills and combustion facilities annually, constituting 22% of discarded municipal solid waste.[1] This food waste is a significant contributor to GHG emissions.

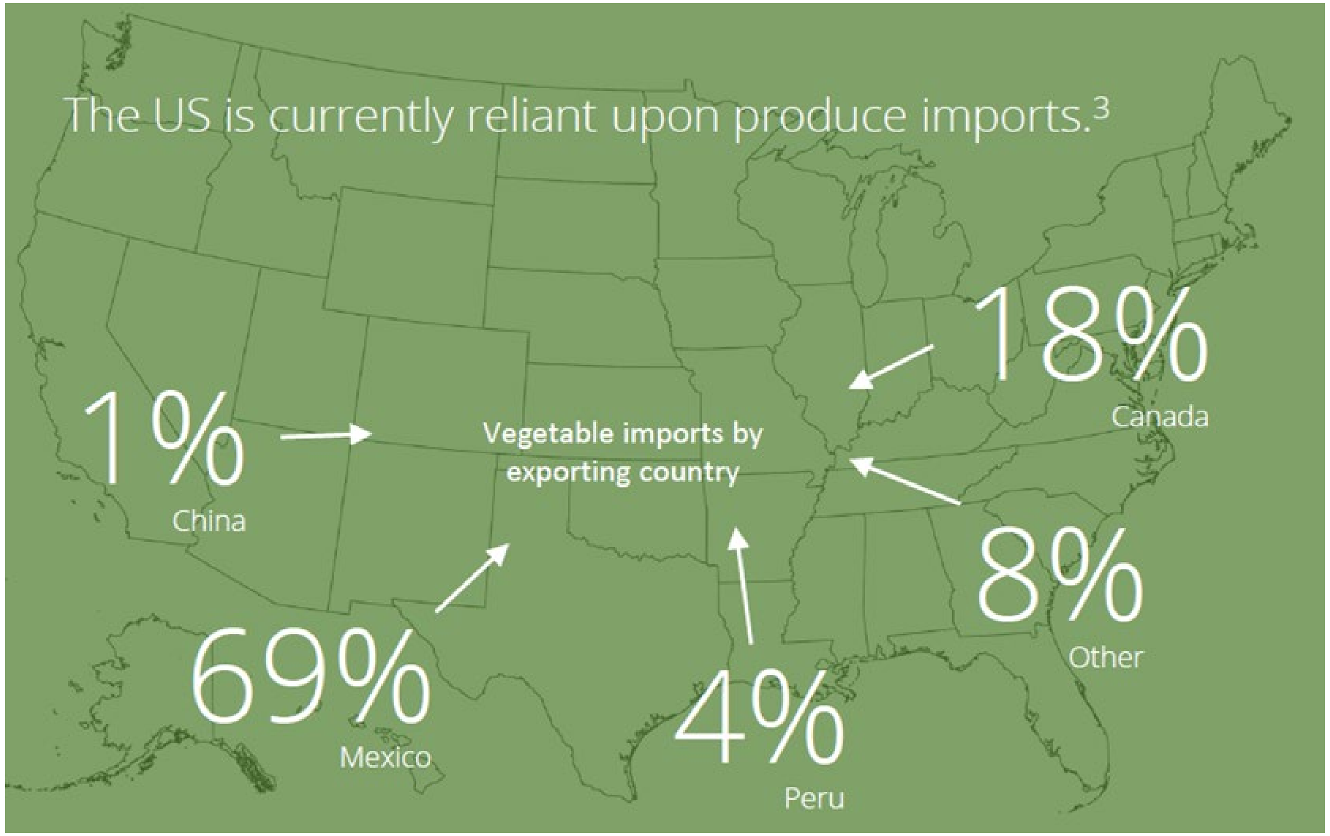
[1] https://www.questrmg.com/2019/08/08/food-waste-statistics-the-reality-of-food-waste/
[2] https://www.epa.gov/sites/production/files/2019-09/documents/epafoodwaste_factsheet_2019-11.pdf

Food security for the US

53% of Fresh Fruit and 32% of Fresh Vegetables are Imported and Imports are Growing Significantly



Source: https://www.nytimes.com/2018/03/13/dining/fruit-vegetables-imports.html

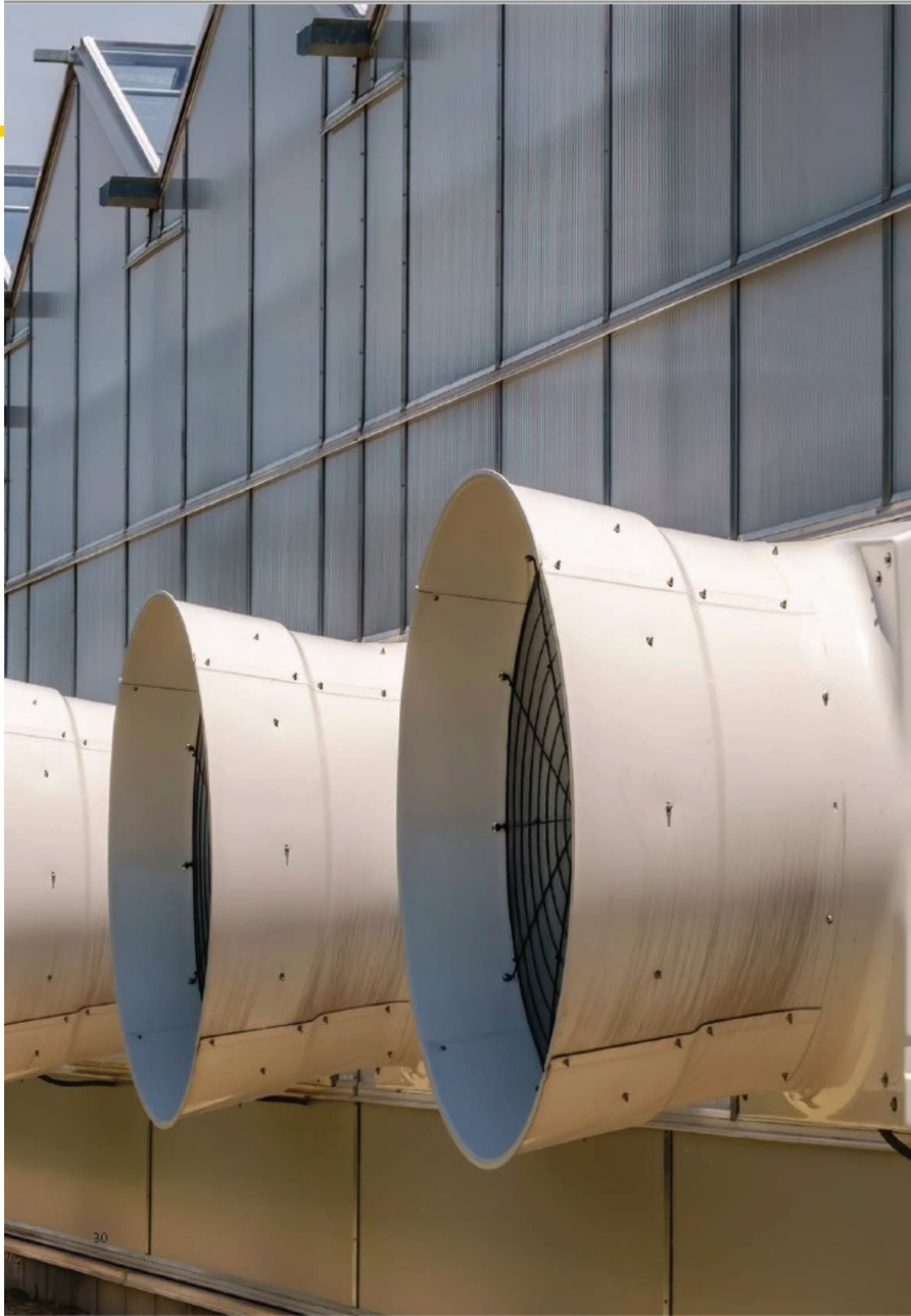


Source s2gventures: Growing Beyond the Hype

Controlled Environmental Agriculture (CEA)

- Modern day semi-closed greenhouses and vertical farms provide an enclosed growing environment that can be controlled year-round. This allows for intensive agriculture with much greater annual yields than outdoor field production.

- Controlled environment includes lighting, heating, cooling and dehumidification. Heating is most commonly created by distributing hot water throughout the facility.



Source: AG incotech, A Modern Solution to Sustainable Food, https://agincotech.com/portfolio/greenhouse-report/

CEA and Combined Heat and Power (CHP)

CHP can provide hot water, chilled water for vertical farms and greenhouses. Greenhouse can also use hot clean exhaust gas heat and CO_2 dosing to increase crop yield and reduce CO_2 emissions.* CHP is seen as a sustainable pathway for CEA to offset the high lighting and space conditioning loads when compared to field farming plus transportation. CEA with CHP can substantially reduce food's carbon footprint today using NG and RNG. Many of today's CHP systems are technically ready for hydrogen and other no carbon fuels being developed.

Semi-Closed Glass Greenhouse

Vertical Farm

* exhaust gas heat and CO_2 dosing is for semi-closed greenhouses

CEA Directly Supports 13 of 17 UN Sustainable Development Goals

1 NO POVERTY

A growing CEA industry can provide year round jobs that can lift people out of poverty.

2 ZERO HUNGER

Higher crop yields (15 [GH] to 390 [VF] times conventional land based farming) requires less space. VFs can be located anywhere.

3 GOOD HEALTH AND WELL-BEING

VFs and GHs can facilitate increased consumption of fresh fruits and vegetables essential for good nutrition.

6 CLEAN WATER AND SANITATION

VFs and GHs can reduce water use by 70 to 95% versus convectional farming without runoff that contributes to water pollution.

7 AFFORDABLE AND CLEAN ENERGY

GHs use the sun when available. VFs and GHs using CHP save energy and natural gas CHP in GHs can even use CO_2 in exhaust to enhance crop growth.

8 DECENT WORK AND ECONOMIC GROWTH

A growing CEA industry can provide year round jobs that can lift people out of poverty. CEA jobs more stable and better than seasonable farm labor jobs.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

U.S. VF industry has prompted significant investment and farming innovation. U.S. GH industry is less developed, but is rapidly growing in investment and innovation.

10 REDUCED INEQUALITIES

VF industry, in particular, can focus in on city centers largely where lower socioeconomic groups live and work. This provides good jobs and good food at the same time.

11 SUSTAINABLE CITIES AND COMMUNITIES

VFs can focus in on city centers and GHs can locate near urban communities using a smaller footprint than conventional farms supplying consistent food sources despite volatile weather.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

CEA significantly reduces food waste throughout the food chain. CHP based CEA provides responsible energy and GHG footprints for food production.

13 CLIMATE ACTION

VFs and GHs with CHP can substantially reduce food's carbon footprint today using NG and RNG. Today's CHP systems are ready for hydrogen and other no carbon fuels.

14 LIFE BELOW WATER

Agricultural runoff is a major polluter of streams, rivers, lakes, water sheds and oceans. CEA can eliminate this issue.

15 LIFE ON LAND

CEA can substantially increase fruit and vegetable yields without requiring more agricultural land or deforestation.

4 QUALITY EDUCATION

5 GENDER EQUALITY

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

17 PARTNERSHIPS FOR THE GOALS

VFs refers to Vertical Farms
GHs refers to Greenhouses

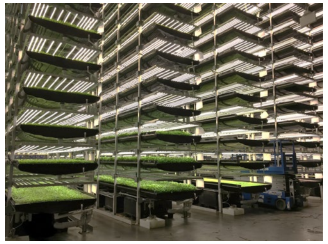
Vertical Farming Challenges

- **High start-up costs:** Costs for equipment, real estate, electricity, marketing, setting up microfarms, hardware, software, automation.
- **High Energy costs:** Requires high amount of energy to power artificial lighting, heating, cooling and dehumidification, automation, and robotics.

High-Tech Automated	Greenhouse	Vertical Farm
Total Building Area (ft^2)	138,000	53,500
Total Growing Area (ft^2)	113,400	116928
Yield ($lb/ft^2/yr$)	12.2	13.03
CapEx ($/lb/yr)	4.1	7.69
OpEx ($/lb/yr)	0.98	1.47
Capital CapEx	**$5,671,654**	**11,714,748**

Source: https://www.agritecture.com/blog/2021/1/25/understanding-capital-expenses-for-vertical-farms-and-greenhouses

- **Vertical farming sector is struggling with bankruptcies**
- **Energy costs can range from 50-70% of COGS; labor costs can range from 20-30% of COGS**
- **Yield per kWh could prove to be a key indicator of the potential profitability**



- Limited range of crops which can be grown commercially and economically
- Majority of vertical farms **primarily grow leafy greens, microgreens, and / or herbs** at this stage. Few farms have also started growing fruits and vegetables such as strawberries, tomatoes, and cucumbers.

- **80% of light energy can be wasted as each crop has different threshold for optimizing photosynthesis.** For example, a sweet potato plant needs only 64% (LED) light energy for optimal photosynthesis.

Vertical Farming Status

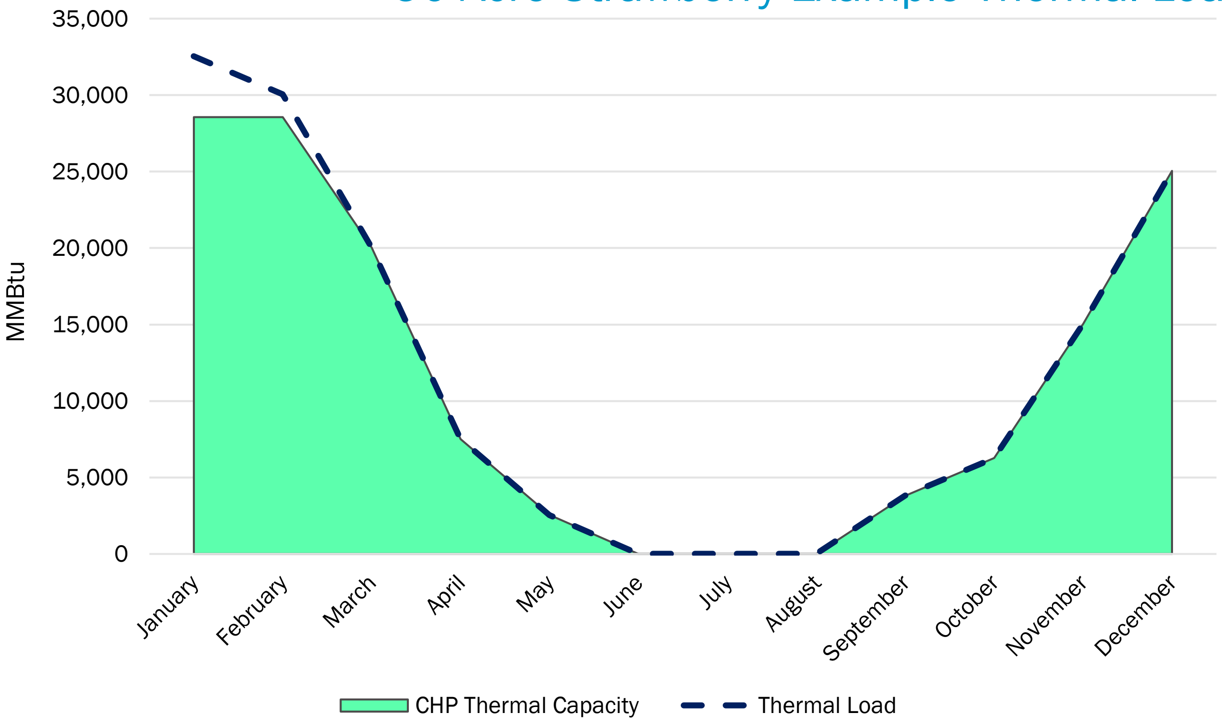
- Vertical farms have to pay for all the light that their crops see, a significant added cost that often occupies high percentages of operational costs.
- In addition, a specialized HVAC system must be designed and implemented to neutralize the heat emitted by the lights. Additional dehumidification capacity is also required with design setpoints relative to the transpiration rate of the crops being grown. HVAC is often the second-highest, non-labor expenditure for VF operations and when dehumidification is added into the mix, overall HVAC operational costs can even exceed lighting electricity costs.
- As LEDs become more efficient, less power will be required to cool the space and the economic scenario for VFs becomes more attractive as two of the highest operational costs have been reduced
- To date, no U.S. VFs have incorporated CHP systems. CHP systems can provide power, cooling and dehumidification required by the crop transpiration and even heating in cold climates to directly improve the energy operating cost and reduce GHG emissions. Because of the VF high CapEx, PPAs might be a good solution provided the VF's finances are stable.

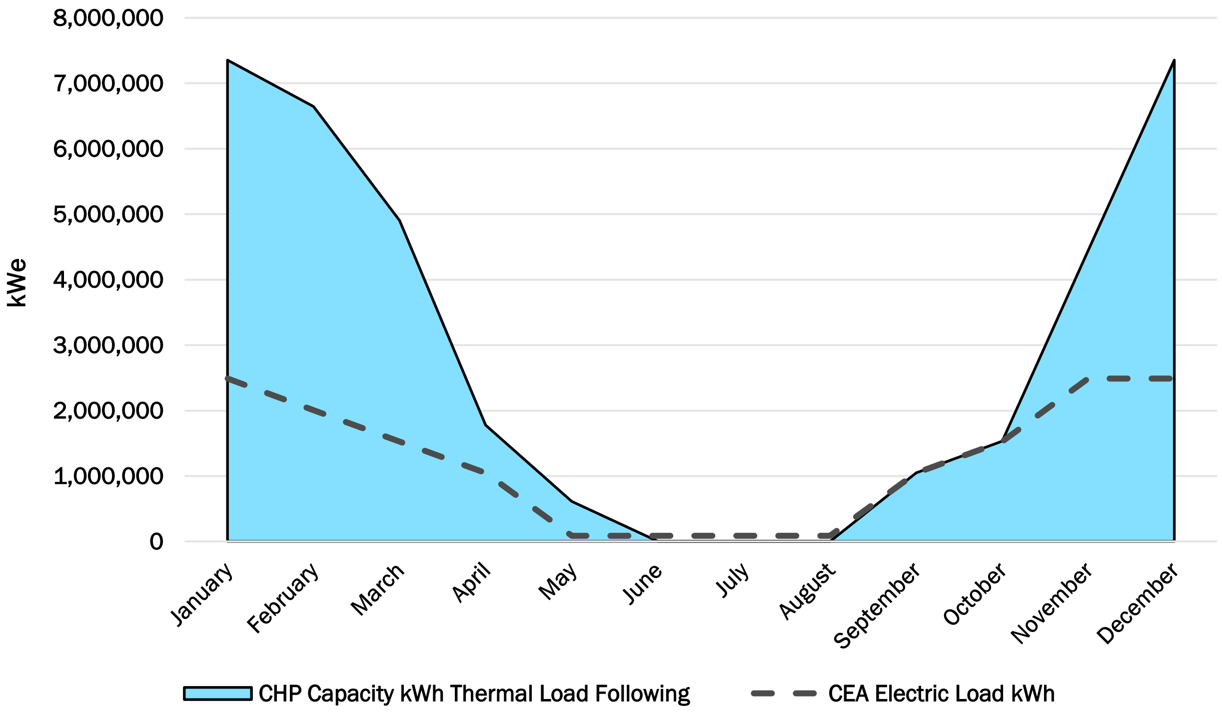
CEA Greenhouse Status

"Globally, there are significant early stage growth areas, with the most prevalent being the U.S. When we compare Europe, which has a sophisticated CEA economy, and the U.S., there is a large gap in adoption. The U.S. is at the forefront of technology for this sector, but still in its infancy in terms of production." James Archer Founder & CEO, Ag Incotech

Semi-Closed Greenhouse and CHP Challenges

50 Acre Strawberry Example Thermal Load Following Exporting to the Grid





CHP Electric Power (kWh) per year

- 14,970,000 kWh serving CEA Greenhouse load
- 20,712,116 kWh exported to the grid

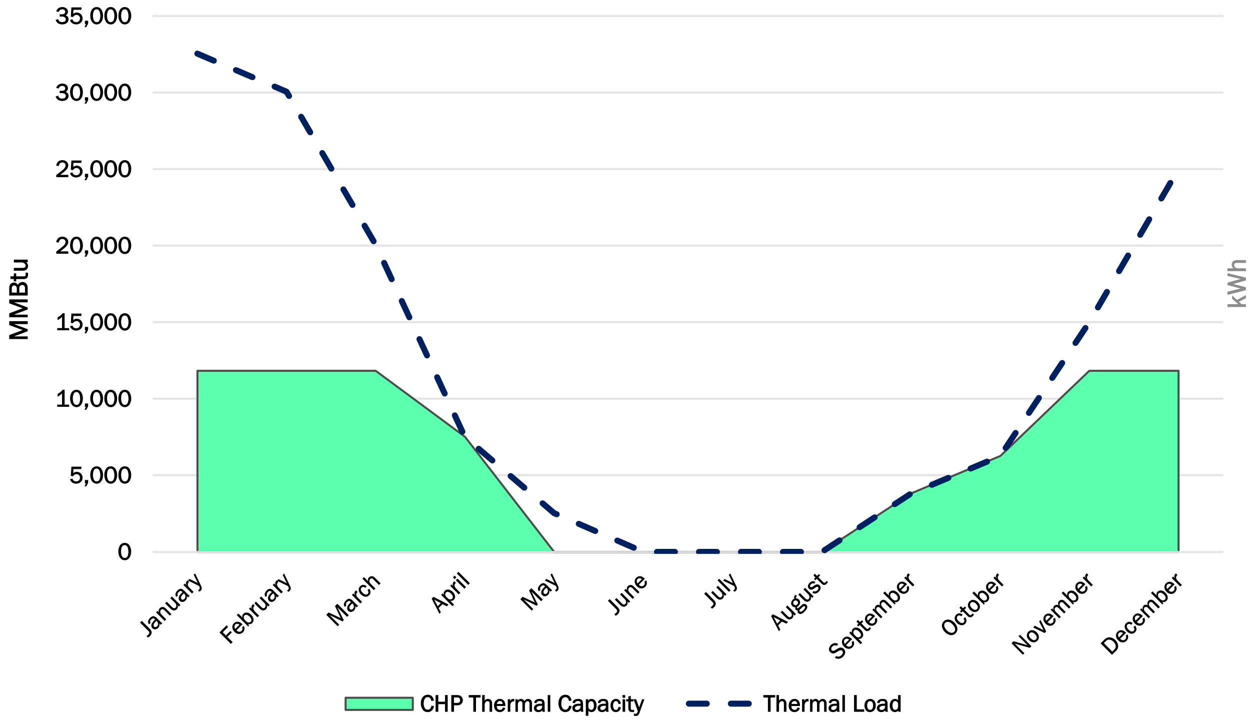
CO_2 Reduction per Year using Marginal PJM Grid @ 1,152 CO_2 lbs/MWh

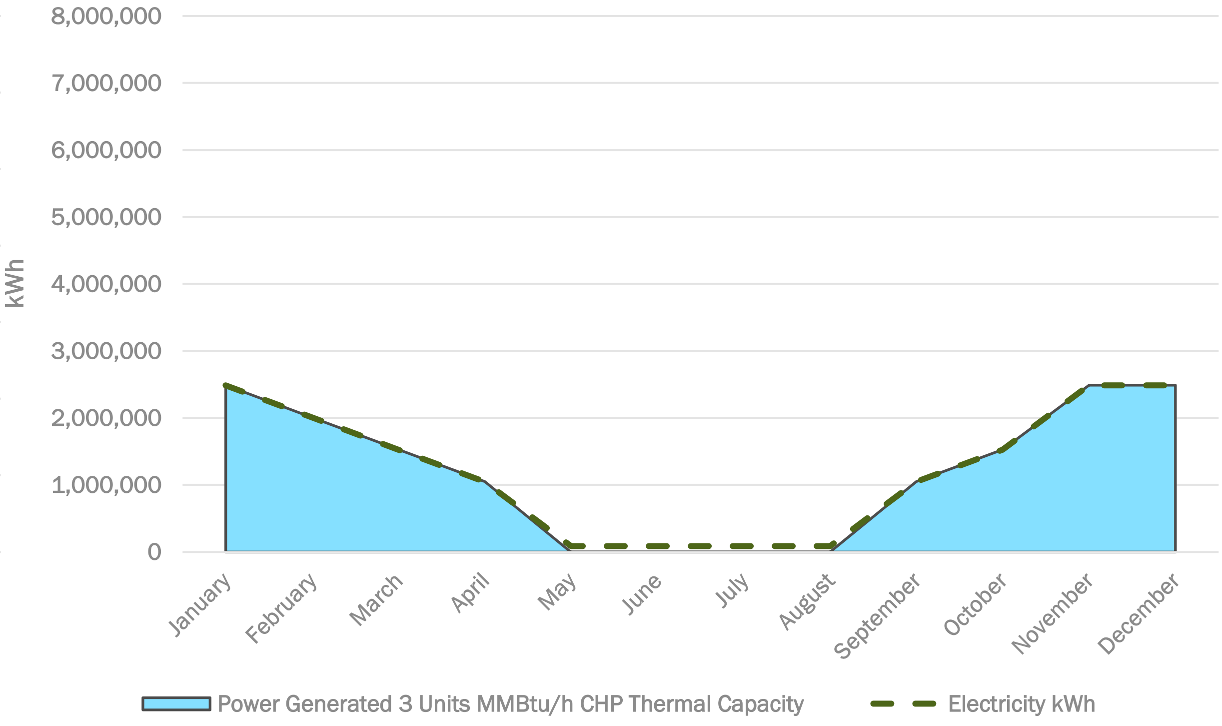
- 61% CO_2 reduction verses BAU Boiler plus PJM Grid* at 0% CO_2 Crop Capture (11,256 tons)
- 112% CO_2 reduction verses BAU Boiler plus PJM Grid* at 50% CO_2 Crop Capture (20,564 tons)

Natural Gas at the Margin for PJM in PA

Semi-Closed Greenhouse and CHP Challenges

50 Acre Strawberry Example Electric Load Following No Export to the Grid





CHP Electric Power (kWh) per year

- 14,620,000 kWh serving CEA Greenhouse load
- 350,000 kWh imported from the grid

CO_2 Reduction per Year using Marginal PJM Grid @ 1,152 CO_2 lbs/MWh

- 19% CO_2 reduction verses BAU Boiler plus PJM Grid* at 0% CO_2 Crop Capture (3,519 tons)
- 44% CO_2 reduction verses BAU Boiler plus PJM Grid* at 50% CO_2 Crop Capture (7,993 tons)

Natural Gas at the Margin for PJM in PA

Comparing Electric and Thermal Load Following

- Thermal load following CEA Greenhouse CHP reduced CO_2 emission by a factor of ~3.20 (by 7,737 tons) over electric load following with no crop CO_2 uptake.
- Thermal load following CEA Greenhouse CHP reduced CO_2 emission by a factor of ~2.57 (by 12,571 tons) over electric load following with 50% crop CO_2 uptake.
- Keys to accelerating CEA Greenhouse with thermal load following CHP is to value the low carbon energy that CEA Greenhouses can provide, For example:
  - Allow net metering for CHP systems applied to CEA greenhouses because of low carbon energy production with several pathways to no carbon energy generation,
  - Establish feed-in tariffs that recognize the value of low carbon energy generation,
  - Energy credits that value the actual CO_2 emissions of CEA Greenhouse / CHP systems, and/or
  - Develop simplified, transparent and quick interconnection processes, especially for Packaged CHP systems

CEA Greenhouses in the US with CHP

- Houweling's Tomatoes in California, 128 acre greenhouse, 1 MW Solar PV, 13 MW Natural Gas Engine CHP, 3 million gallons hot water storage, and 2.3 MW backup gen sets

- Intergrow Greenhouses, 70 acre greenhouse growing Cherry Tomatoes, Tomatoes On the Vine and Beefsteak tomatoes, one 2.4 MW_e CHP plant and 10 MW_{th} biomass boilers

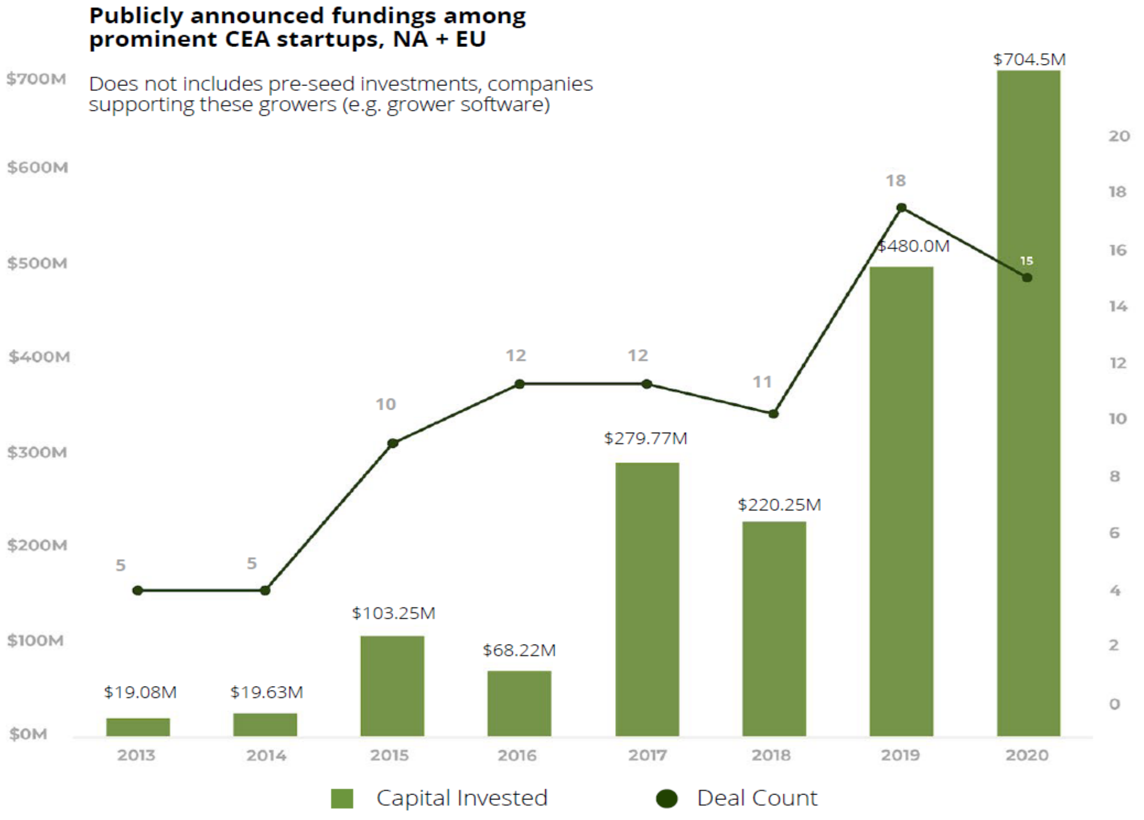
- SunSelect in California, 64-acre greenhouse, which produces tomatoes and bell peppers, 6.6 MW, 3,000 kg/h of CO_2,

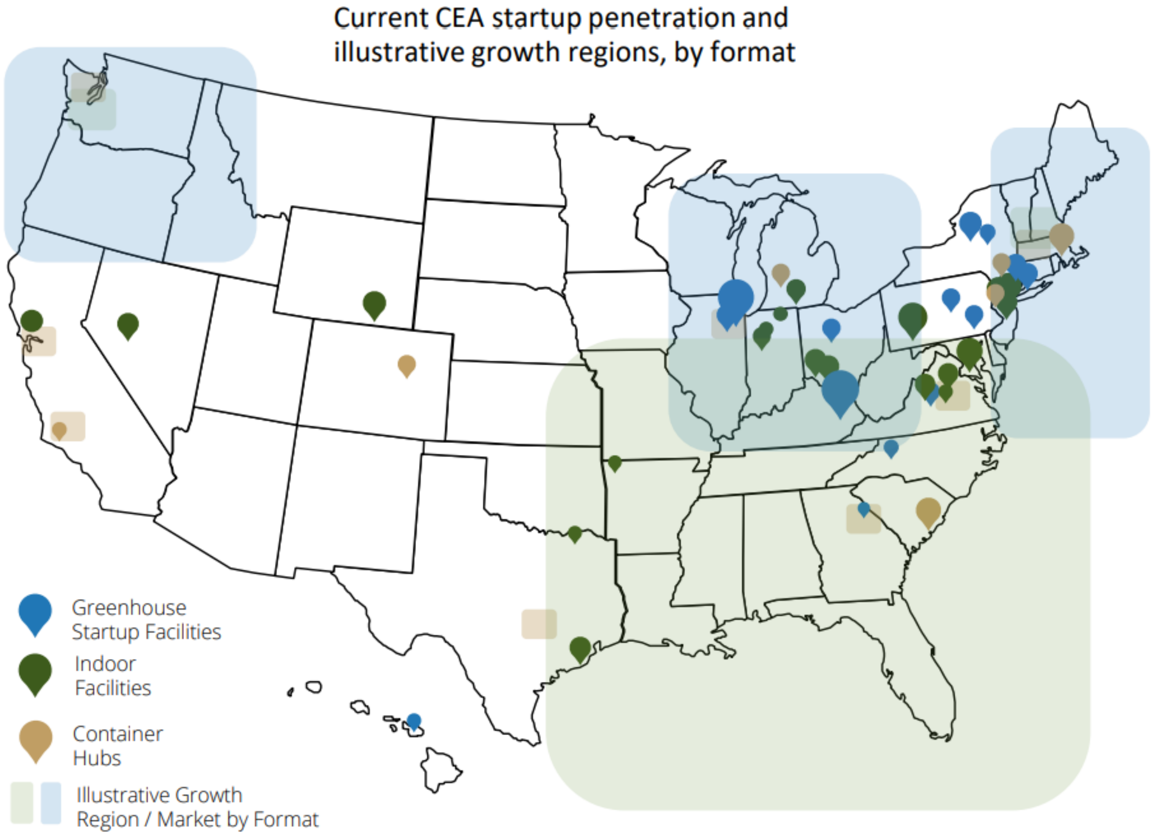
Investment Trends

- North America is considered the largest market for new indoor farming technologies.
  - Good market price points for fresh produce
  - Low cost of energy for lighting and heating
  - Low cost of capital
- There is a willingness to pay for fresher and more healthy food, the biggest premiums are placed on ‘local’ food.
- CEA facilities create a more automated production chain and reduce the labor requirements against yield.
- In a world where there is decreasing availability of arable land, CEA is a critical farming method.

Source: AG incotech, A Modern Solution to Sustainable Food, https://agincotech.com/portfolio/greenhouse-report/

Investment Trends





Source s2gventures: Growing Beyond the Hype

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U.S. DEPARTMENT OF ENERGY

Houwelings Tomatoes Case Study

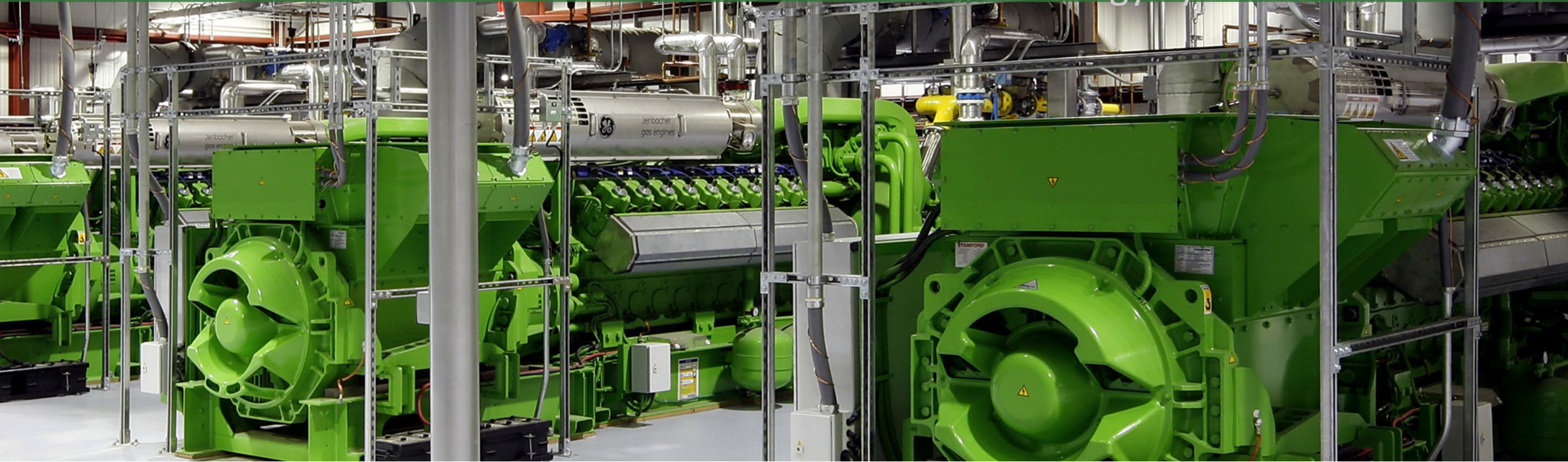
Packaged CHP Accelerator CEA Presentation

Sept 22, 2021

Presenter: Aaron Tasin

Northeast Energy Systems

Western Energy Systems



Agenda

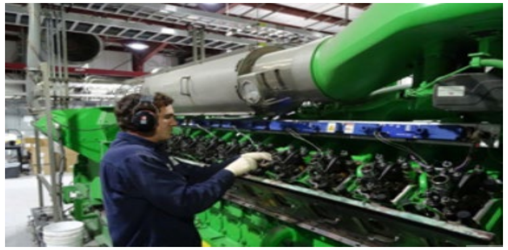
1. Company Overview of NES-WES
2. Company Overview of Houweling's Tomatoes
3. Houweling's Tomatoes Camarillo Facility Sustainability Info
4. Houweling's Tomatoes Camarillo Facility CHP Info
5. Methods for CO2 Fertilization in Greenhouses
6. Why CHP for Greenhouses

NORTHEAST — WESTERN™
ENERGY SYSTEMS
Power Systems Specialists

JENBACHER INNIO Distributor & Service Provider | Q8Oils | STAMFORD | AvK | hugengineering

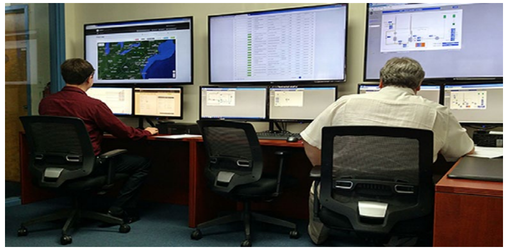
Engine Sales

-INNIO Jenbacher Channel Partner
-Over 210 engines installed and running



Maintenance

Full engine and Balance of Plant maintenance throughout their lifecycle



Remote Support & Monitoring

Remote monitoring and phone support

Project Management & Engineering

From project order to commissioning

Operations

Full or partial plant operations as an option

Training

Fully certified training team

Proven onsite power solutions. Local product support.

NORTHEAST – WESTERN ENERGY SYSTEMS
Power Systems Specialists

Installed Base, Offices, and Technician Locations

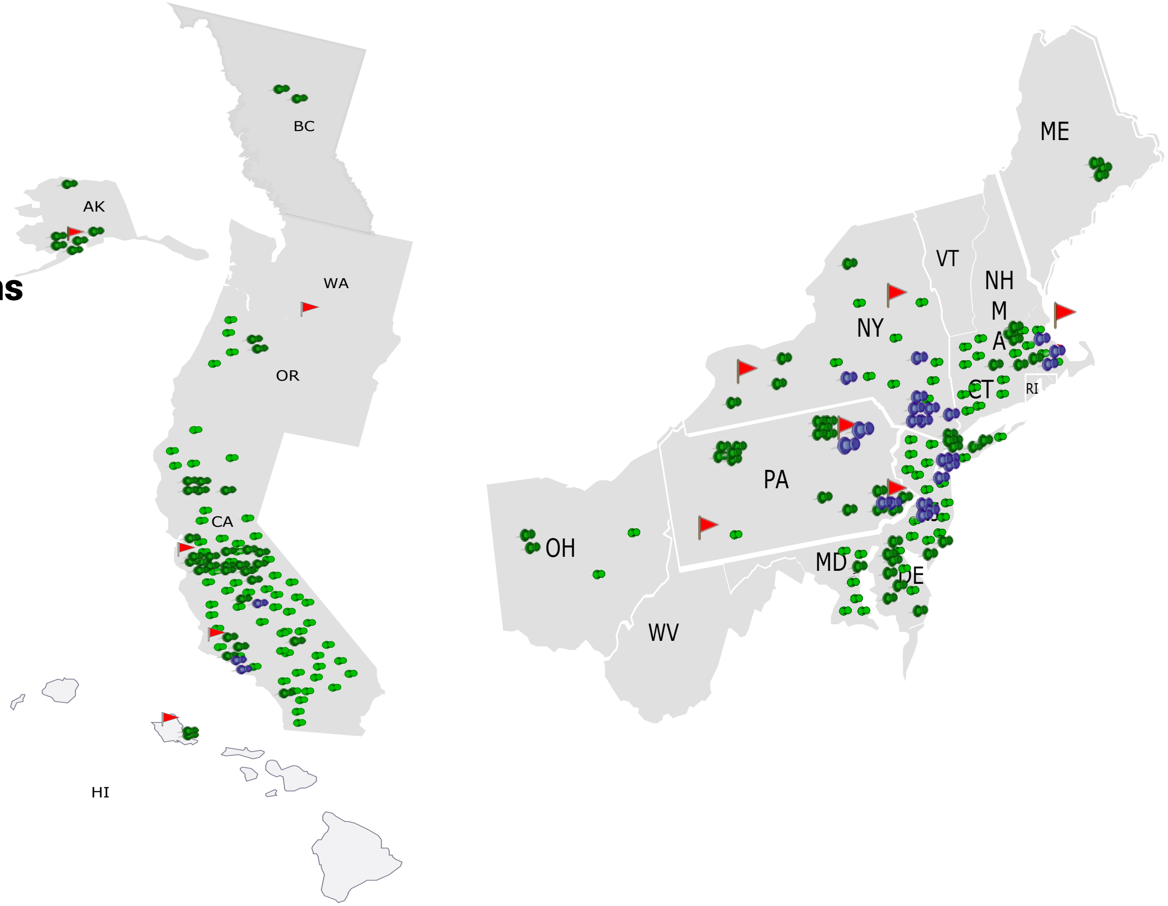
NES-WES Product Support group currently maintains approximately 210 Jenbacher gas engines with a combined electrical output of over 400,000kW. Over 70% of the installed base has signed a maintenance agreement with NES-WES.

Office Locations

- Philadelphia, PA
- Bristol, Pennsylvania
- Woburn, Massachusetts
- New York, NY
- Brea California
- Hayward, CA
- Anchorage Alaska

Resident Technician Locations

- Boston
- Southern Vermont
- New York City
- Northern Connecticut
- Southern Connecticut
- Northern New Jersey
- Philadelphia
- Northern California
- Central California
- Southern California
- Anchorage, Alaska



Houweling's Tomatoes

Company Info

- ✓ Family owned, world renowned greenhouse vegetable grower
- ✓ Facilities in Camarillo, CA; Mona, UT; and Delta, BC Canada
  - ✓ Camarillo, CA and Delta, BC have CHP
- ✓ Grows full compliment of Tomatoes as well as cucumbers
- ✓ Established Camarillo facility in 1996 as Houweling's flagship greenhouse
- ✓ 125 acres under glass
- ✓ Camarillo facility employs 450 people

Houweling’s Tomatoes

Greenhouse Benefits

- ✓ Greenhouse has “grow lights” which provides a healthier more robust growth and can help increase growth of tomatoes by 40%
- ✓ Greenhouse benefits:
  - ✓ Greenhouse needs 24 times less land than field farming for tomatoes
  - ✓ Hydroponic Greenhouse growing of tomatoes uses about 1/60th the amount of water as land farming
- ✓ Provides fresh tomatoes year-round, close to the consumer:
  - ✓ Reduces transportation cost
  - ✓ Reduces vehicle emissions to get to the consumer
  - ✓ Provides local jobs

Houweling's Tomatoes

Camarillo Facility Sustainability Info

- ✓ 5 Acres of Solar PV (1,000 kW)
- ✓ Rainwater is captured and cleaned with RO
- ✓ Greenhouse needs lots of Energy and CO_2
  - ✓ Installed CHP to reduce energy costs, energy waste, and recapture CO_2 for beneficial use
- ✓ Approx. $35 million dollar energy system
- ✓ CHP System can provide full power to the Greenhouse even when the grid is down
  - ✓ Assures that crop will grow as planned
- ✓ Provides power back to the grid to help the grid

Houweling’s Tomatoes

CHP Info of Camarillo Facility

- ✓ Electricity production:
  - ✓ 13MW (3 x 4.3 MW) INNIO Jenbacher Gas Engines
- ✓ Thermal Energy Provided:
  - ✓ Heat is recovered from engine exhaust, oil cooler, and engine cooling system
  - ✓ 16MW of thermal energy is provided by the CHP
- ✓ Exhaust Gas is cleaned to meet most stringent emissions requirements in the world.
  - ✓ <2.5ppm NOx
- ✓ CO2 from the exhaust gas is repurposed for fertilization and sent into the Greenhouse
  - ✓ About 16,000 lbs/hr of CO2 is provided

Houweling’s Tomatoes

CHP Info of Camarillo Facility

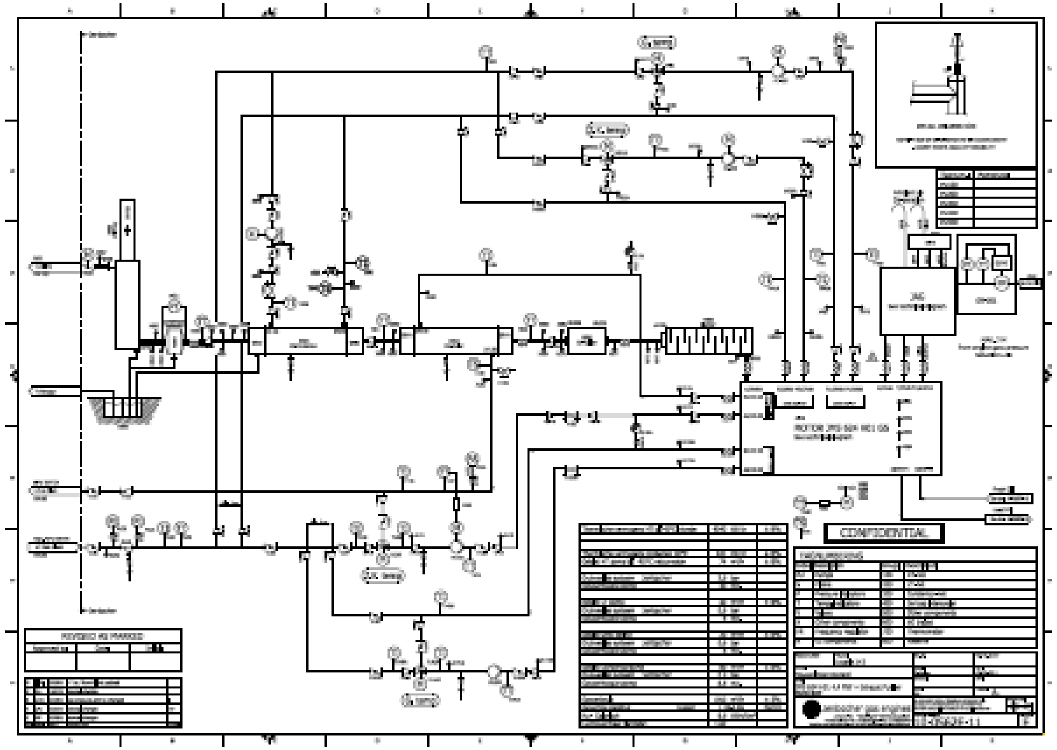
- ✓ Overall efficiency of Energy In vs Energy Used is 90%
  - ✓ (vs 33% of grid electricity and 85% boiler)

- ✓ System was designed to capture as much as 9,500 gallons of water a day from in the exhaust which provides even more efficiency, *not in 90% figure above*

Houweling's Tomatoes

Design Process

- ✓ System was designed to replace boiler that was providing heat and CO_2
- ✓ Design process took approximately 1 year
- ✓ Manufacturing of CHP system and installation took about 16 months.
- ✓ Interconnection process with local utility and contract to sell power back to the grid took approximately 3 years.



Houweling's Tomatoes

Operating Info

- ✓ System only operates when Greenhouse needs electricity and CO_2. Excess power is sold to the grid.

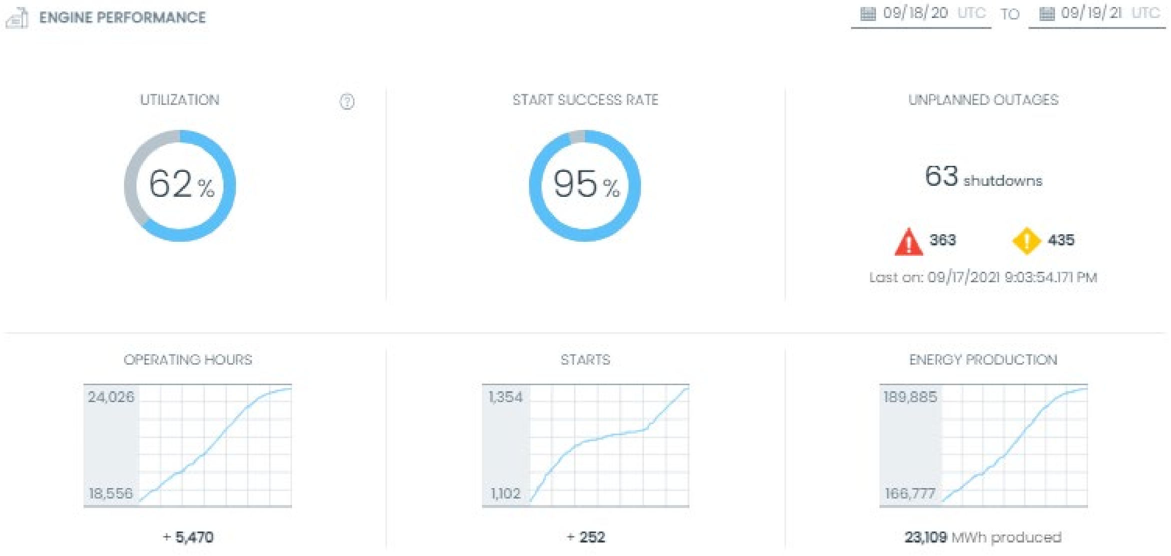
-or-

- ✓ If the grid needs power and the CHP system is not running, it will be turned on to provide power to the grid.

- ✓ Availability of system averages over 99% of the time that Houwelings needs power, or the grid needs power

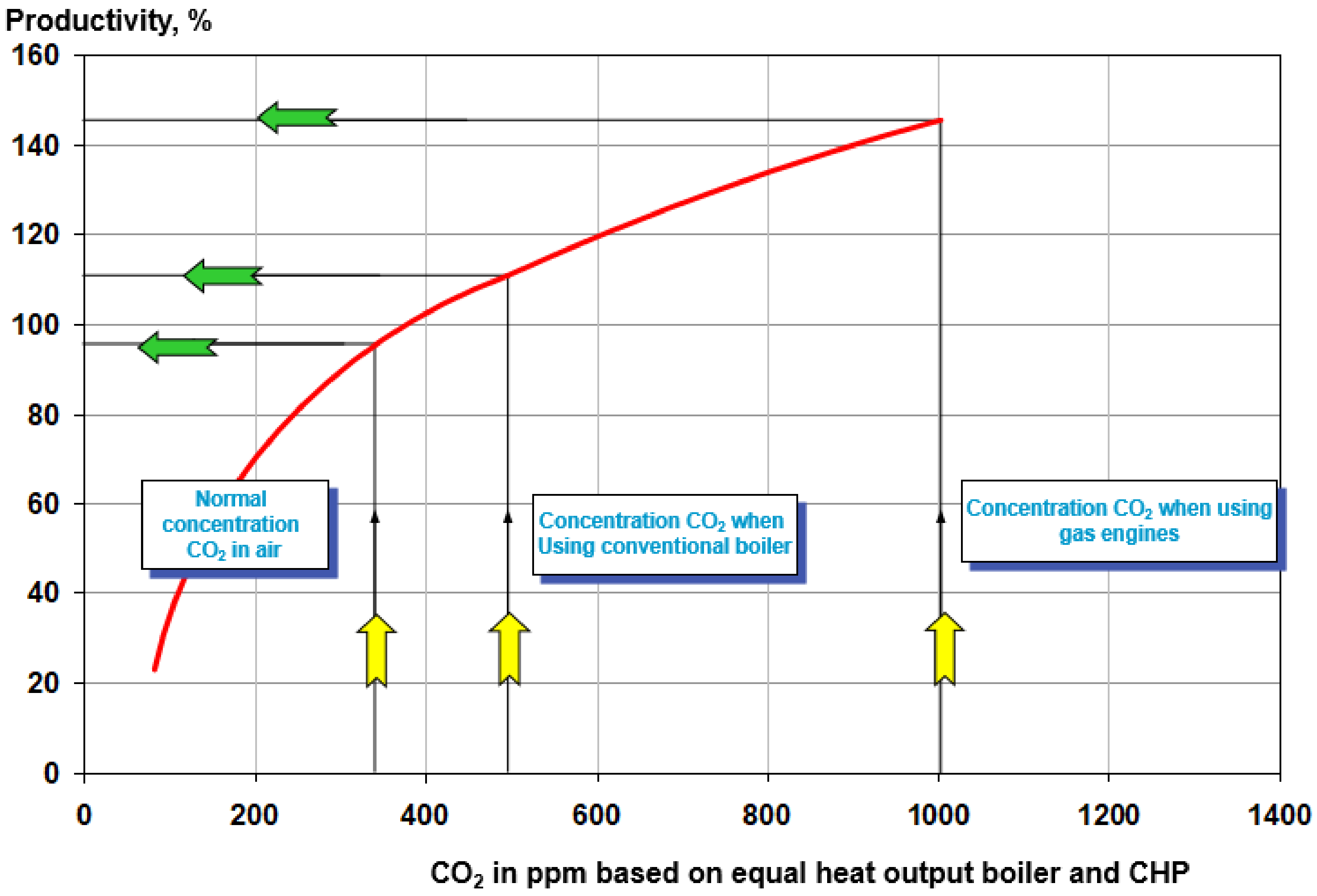
- ✓ Last 12 months, engines have run >5,400 hours (out of 8,760 hours)

- ✓ Systems currently have over 24,000 operating hours



Influence of CO2 for Crop Production

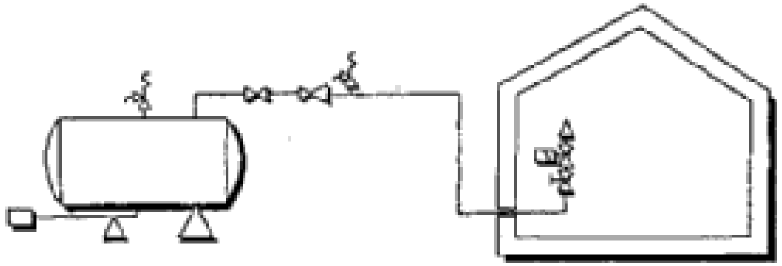
It is possible to raise the CO2 level in the greenhouse twice as high in comparison to a conventional boiler with the same heat output using an exhaust gas cleaning system in combination with our gas engine. This way the positive influence on the crop production can add up to 30% or even more!



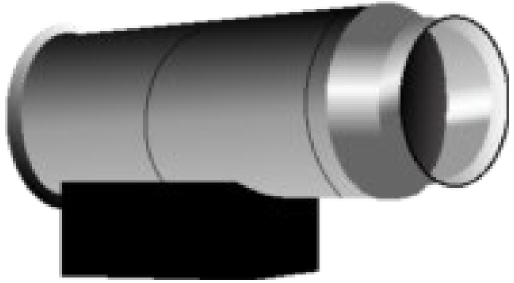
Why CHP for Greenhouses

Methods for CO_2 fertilization of Greenhouses

- ✓ CO2 Bottles
  - ✓ Simple
  - ✓ Low-cost installation
  - ✓ Expensive CO2
  - ✓ No secondary benefit
- ✓

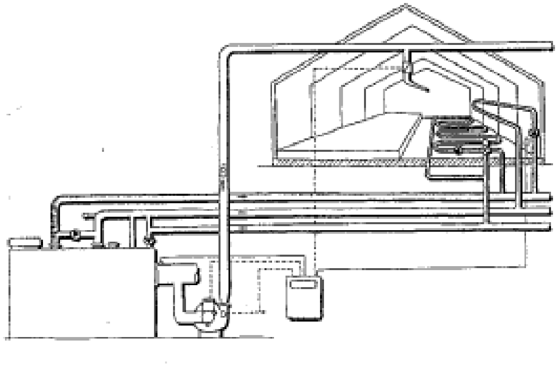


- ✓ Gas Burner
  - ✓ Simple
  - ✓ Low-cost installation
  - ✓ Clean CO2, small levels of other pollutants
  - ✓ Secondary benefit is that heat is provided



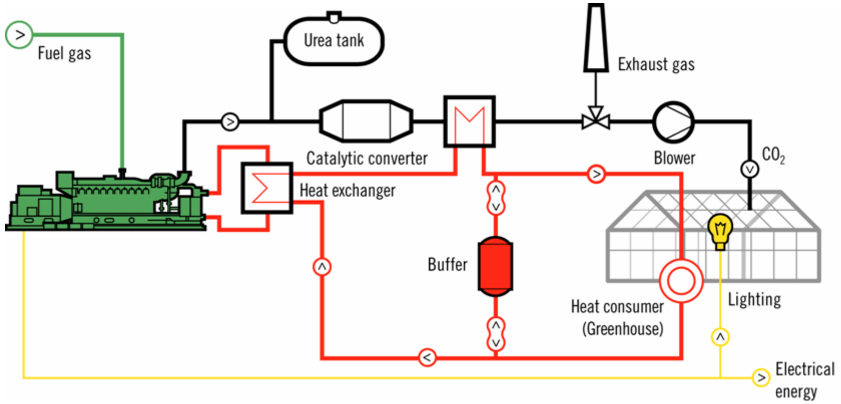
Why CHP for Greenhouses

Methods for CO2 fertilization of Greenhouses

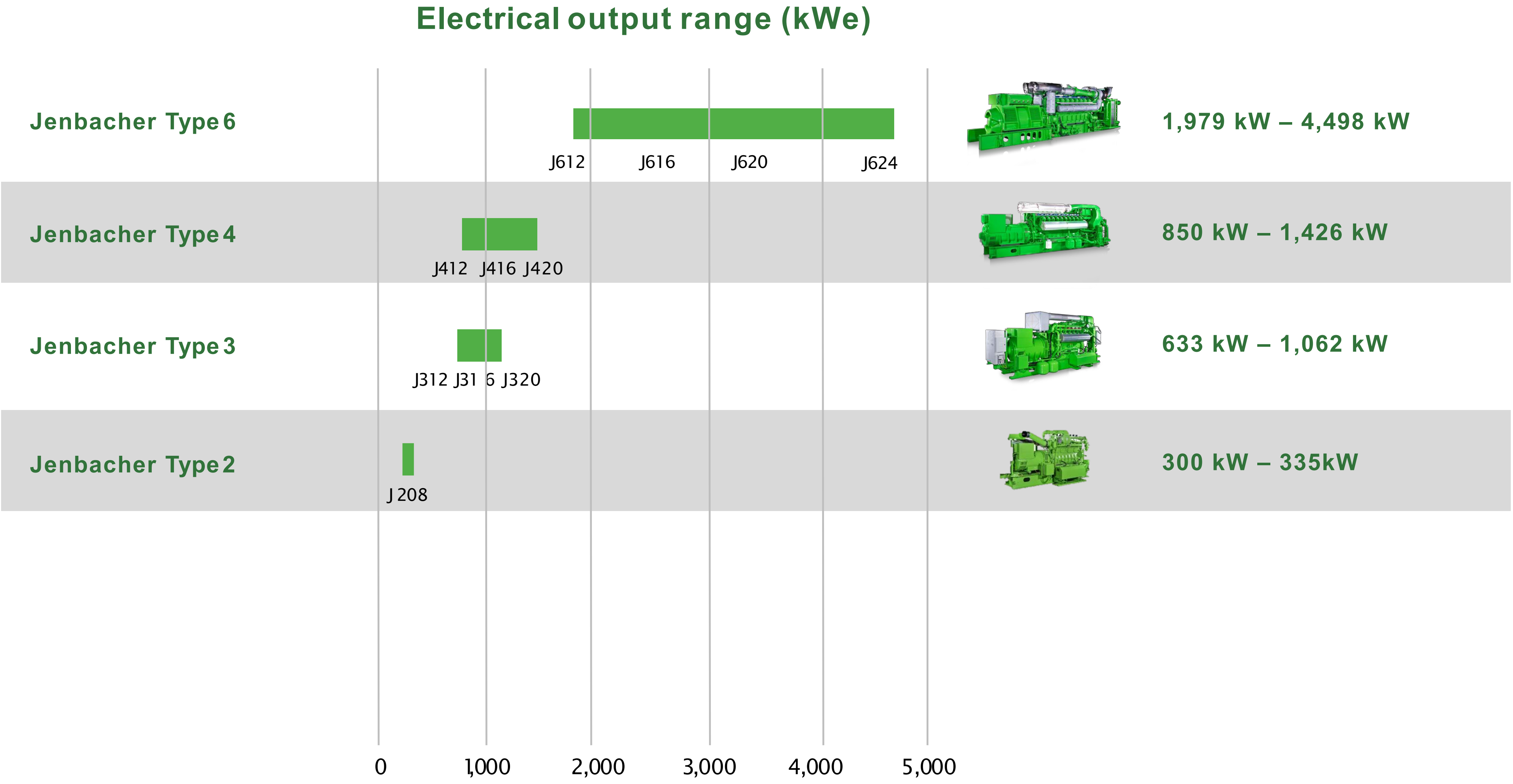


- ✓ Boiler exhaust gas system
  - ✓ Complicated
  - ✓ Relatively high-cost installation
  - ✓ Clean CO2, small level of other pollutants
  - ✓ Secondary benefit is that heat is provided

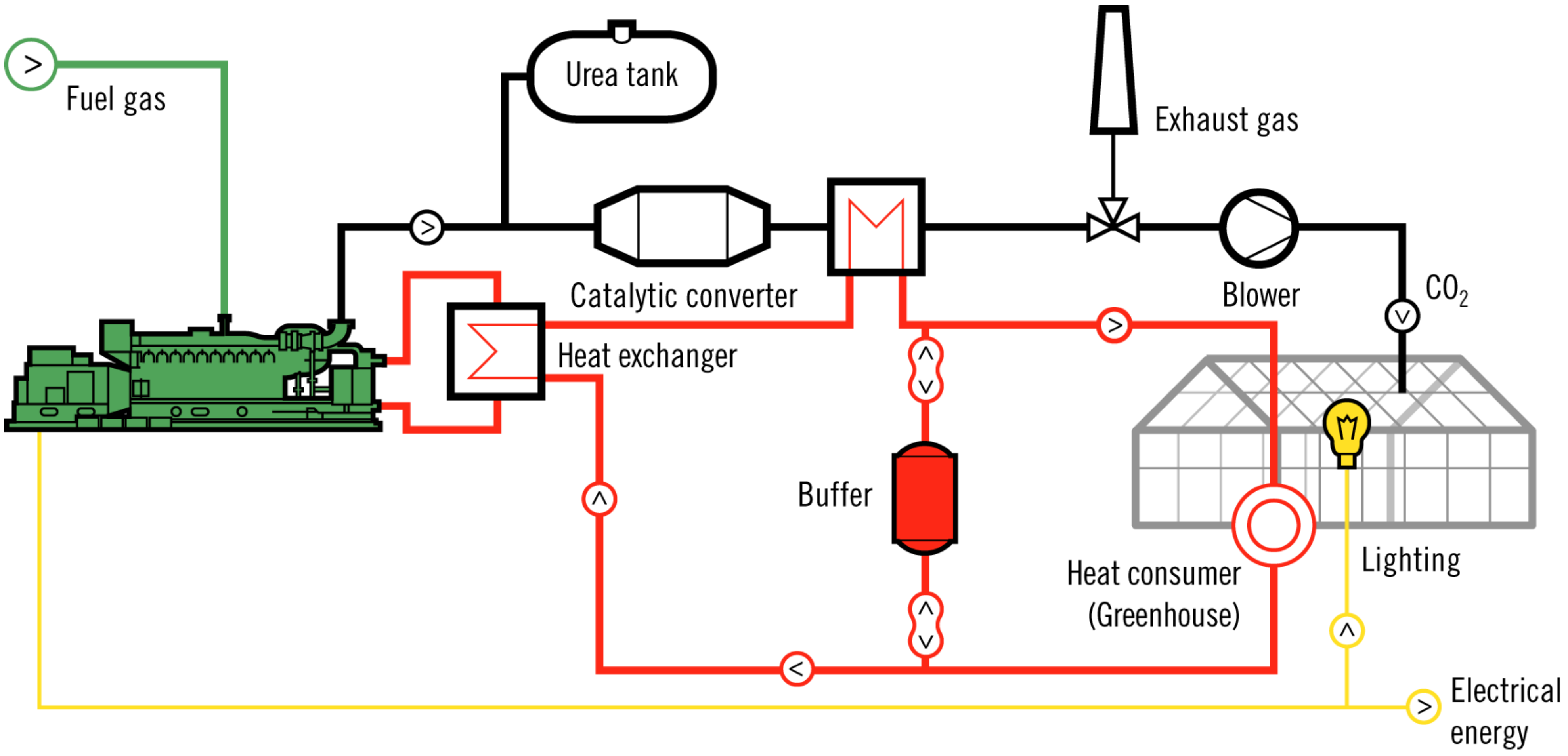
- ✓ CHP
  - ✓ Complicated
  - ✓ High-cost installation
  - ✓ Clean CO2, ultra low level of other pollutants
  - ✓ Secondary benefit is that heat is provided
  - ✓ Additional benefit is that electricity is provided
    - ✓ This electricity would have been produced elsewhere creating non-recoverable CO2 and other pollutants



Gas gensets for CHP



The Greenhouse Concept



Thank you!

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Dick Kramp
AB Energy

U.S. DEPARTMENT OF ENERGY

Case study

INTERGROW ALBION NY

THE COE FOR GREENHOUSE APPLICATIONS

The AB global Center Of Excellence
for greenhouse - cultivation cogeneration solutions
based in the Netherlands with more then 30 years of
global experience in greenhouse-cultivation cogeneration
Global Support of local AB entities in developing greenhouse
cogeneration projects

AB
COGENERATION WORLD

HOW TO SIZE CHP IN THE CEA SECTOR

- **Different crop, different energy demand:**

  Vegetables, flowers, cannabis, algae

- **Different growing technology, different energy demand:**

  Greenhouses = conventional, semi closed, closed, glass or poly

  Vertical farms

  Indoor farms

- **What is the goal:**

High total efficiency	**Following the heat demand**	**Electricity as waste**
Off set grid power	Following the electricity demand	Heat as waste
Power production	No grid power available	

AB COGENERATION WORLD

INTERGROW – ALBION NY

Application:	Greenhouse (CHP + CO2)
Fuel:	Natural Gas
Power Output:	2,400 kW
Thermal Output:	9.4 MBTU/hr
Completion Year:	2014
Greenhouse area:	16 Ha / 40 Acres
Crop:	Tomato

Albion, New York

CHP FOR INTERGROW

- INTERGROW installed 10 MWe of grow lights to produce their winter crop
- Utility could only supply 8 MWe of power
- CHP to supply 2.4 MWe power for grow lights
- Avoidance of grid upgrade by Utility, timeline / capital investment
- CHP is running in island operation, 2,500 operating hours (Oct – May)
- Simultaneous supply of heat and CO_2
- Very short development and engineering time
- Construction time 10 months
- Grid parallel to supply power to the grid was not feasible, low feed in tariff
- System designed to run in parallel with the grid in future
    - Complicated / time consuming grid application process

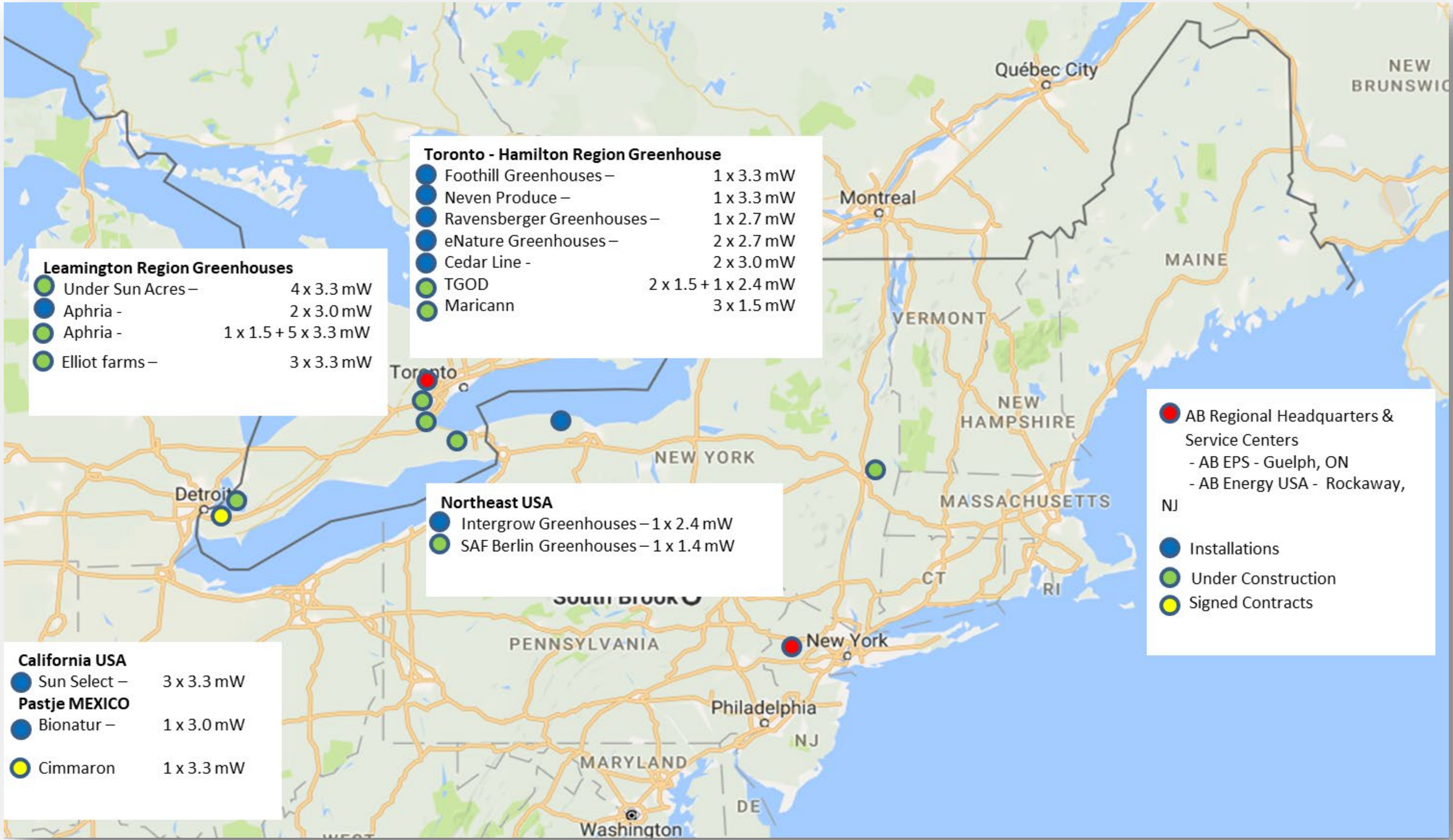
TYPICAL LAYOUT OF AN ECOMAX GH

TYPICAL LAYOUT OF AN ECOMAX GH

AB
COGENERATION WORLD

TYPICAL LAYOUT OF AN ECOMAX GH

CEA EXPERIENCE IN NORTH AMERICA +100 MWe



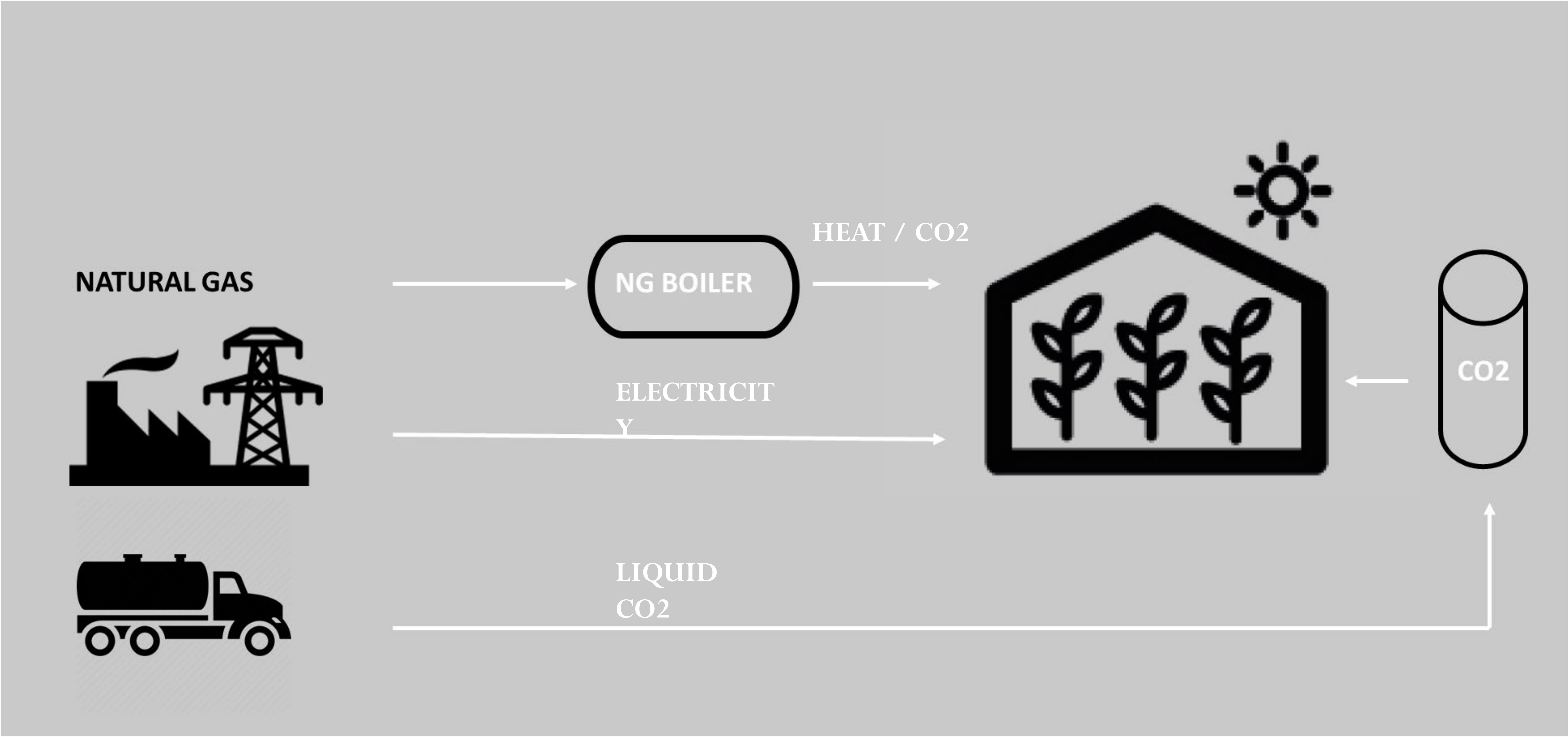
2021 signed 26 MWe new CEA projects on both East coast and West coast

CEA IN COMBINATION WITH CHP

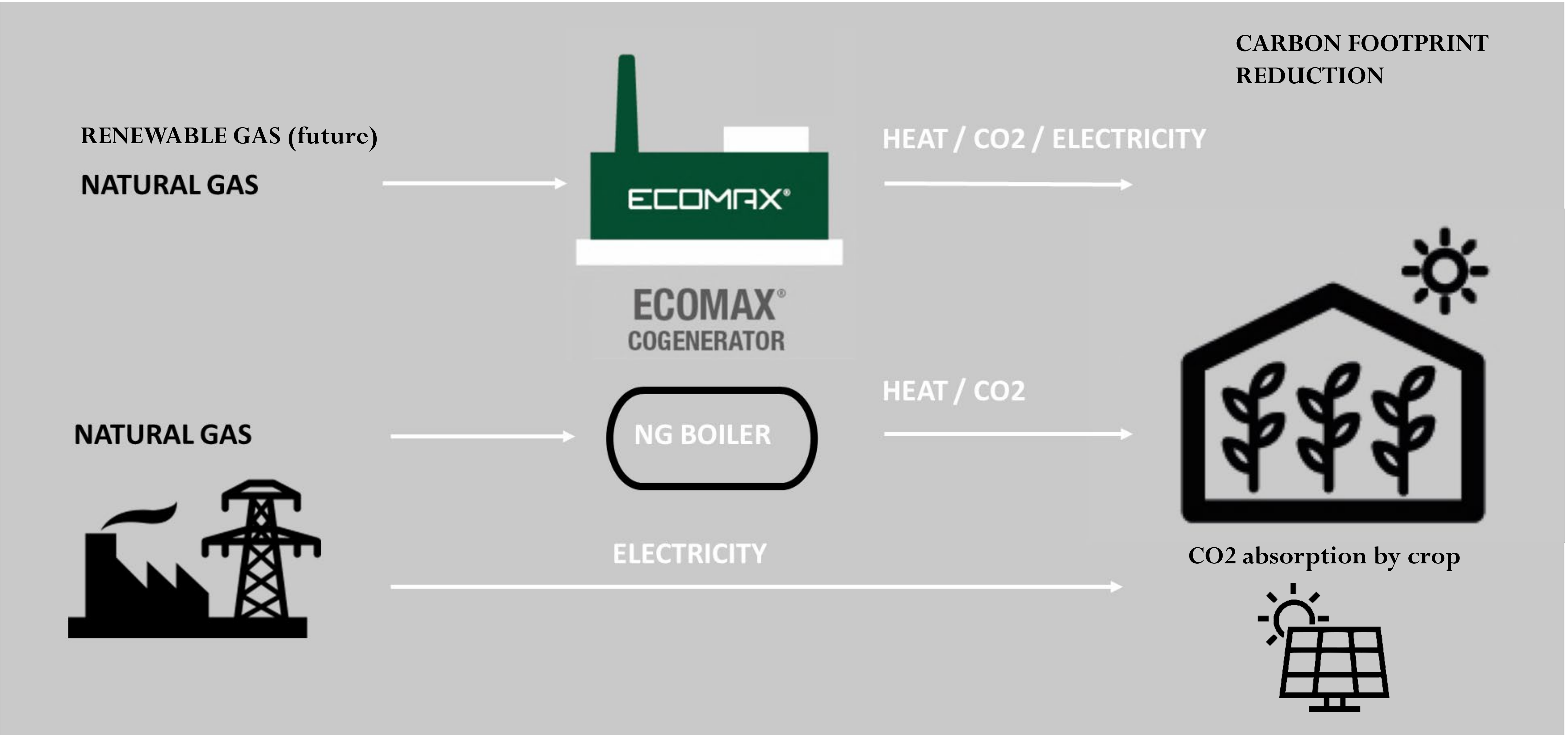
- Offsets carbon footprint (less transportation, more energy efficient)
- Increases power resiliency
- Creates additional income by suppling power to grid
- Ready for demand and response programs to create additional income
- Can run independent from grid
- Maximizes the usage of renewable sources
- Ready to run on other energy sources (RNG, Hydrogen, Solar, Batteries)

COGENERATION WORLD

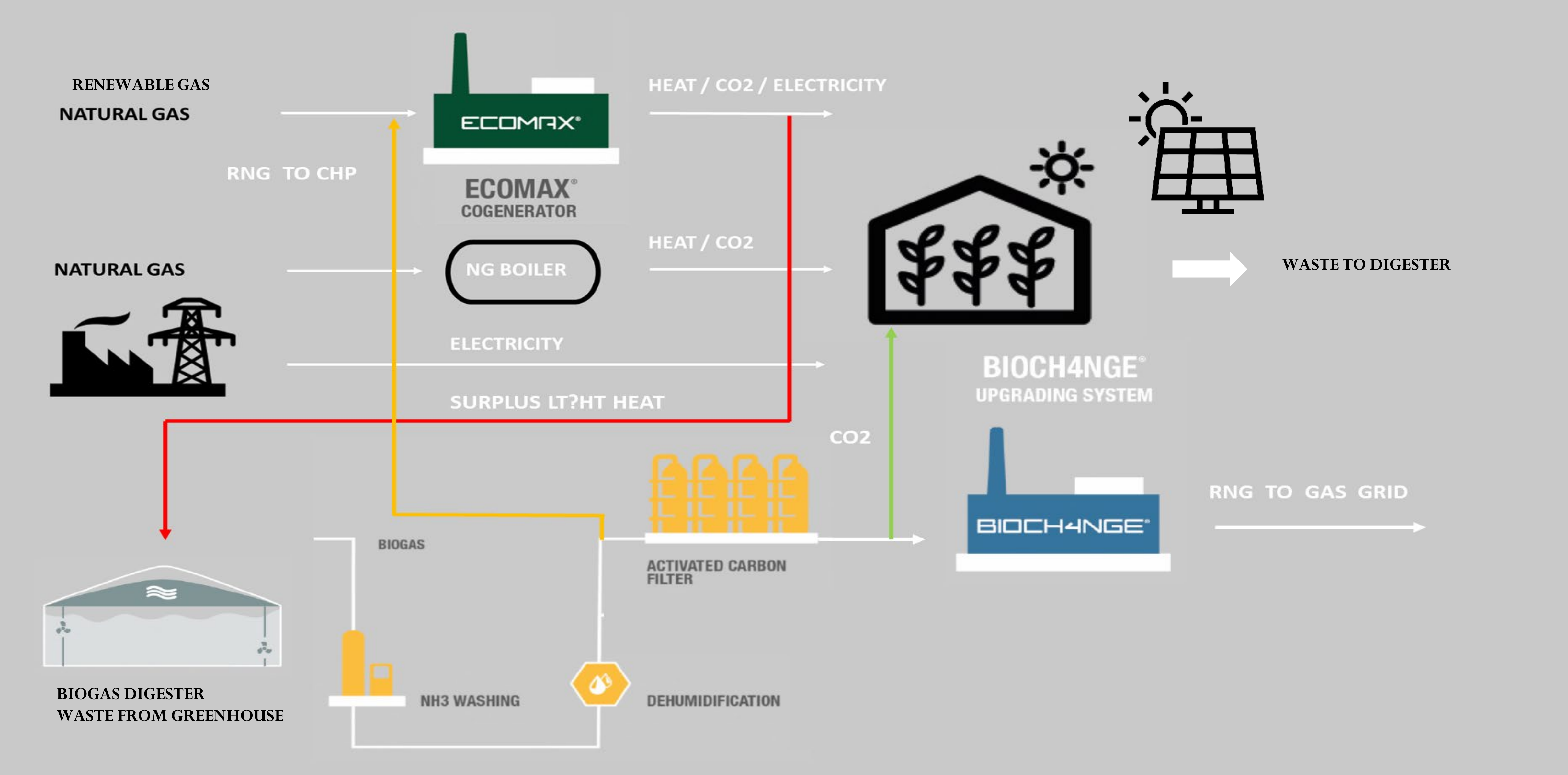
The Greenhouse Business as usual



The Greenhouse with CHP



The Greenhouse with CHP and bio digester



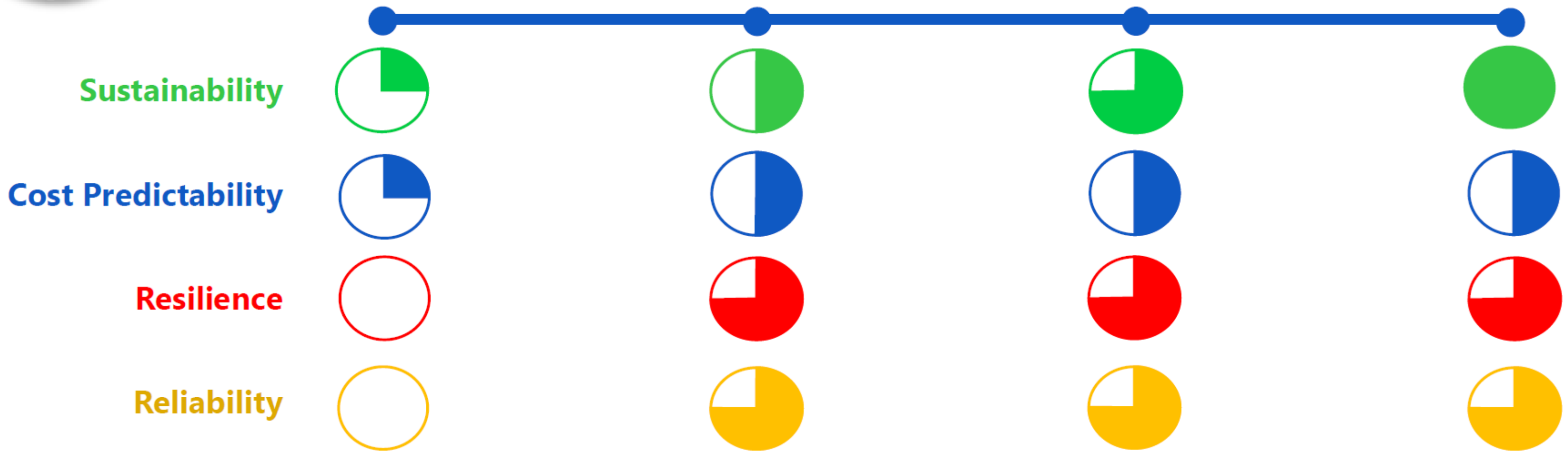
THE DECARBONIZATION TRANSITION

Base Case
Utility electric

Option 1
Utility electric + Combined Heat & Power (CHP) on natural gas

Option 2
Utility electric + CHP on renewable natural gas (RNG)

Option 3
Utility renewable electricity + CHP on RNG



	Characteristics	Base case	Option 1	Option 2	Option 3
Objectives	Cost predictability	Poor	Medium	Medium	Medium
	Cost of energy today	Low	Low	Medium	High
	Sustainability (GHG reduction)	Poor	-19% from BAU	-23% from BAU	**-100% from BAU**
	Reliability	Low	Medium-High	Medium-High	Medium-High
	Resilience	Low	Medium-High	Medium-High	Medium-High

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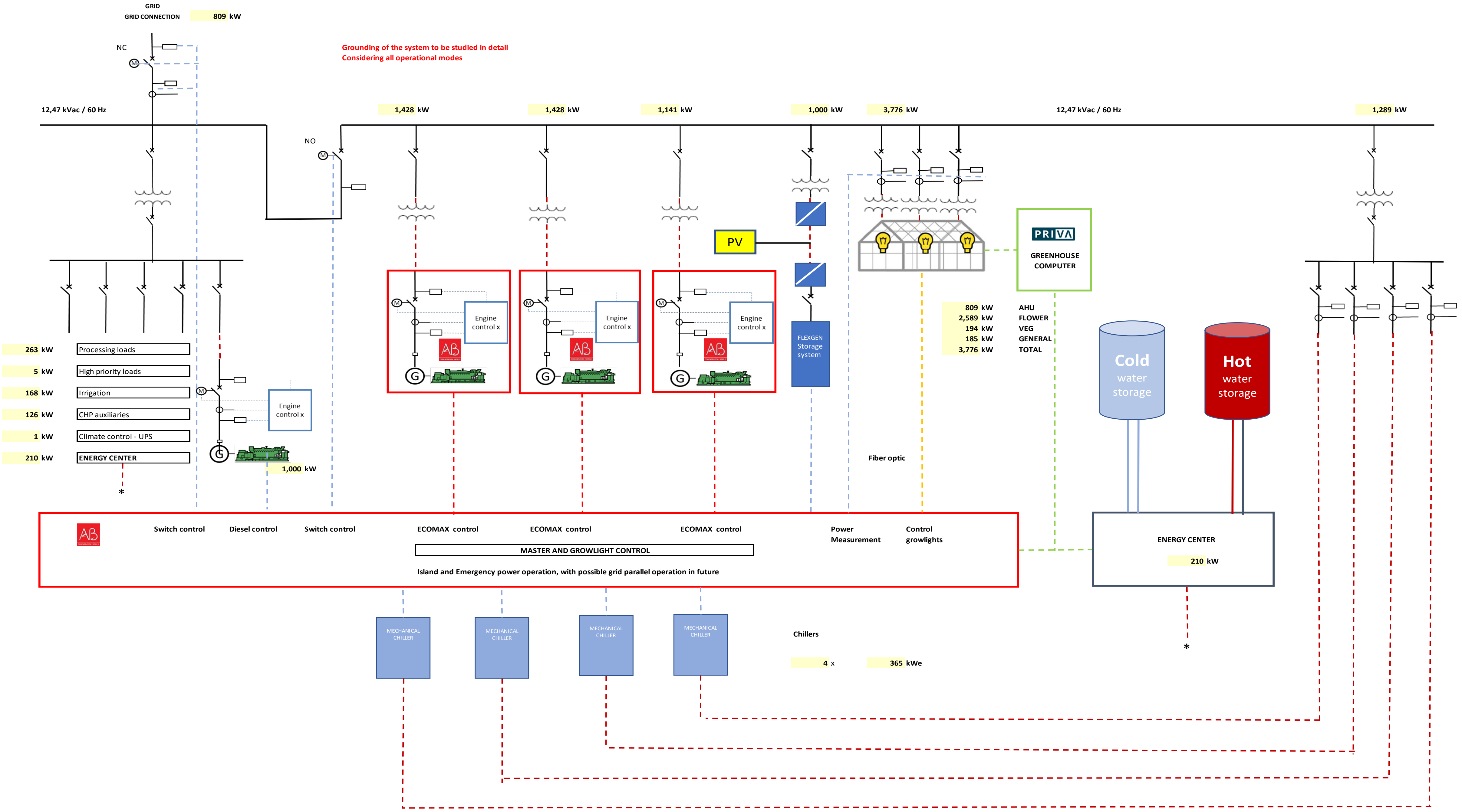
DIFFERENT TECHNOLOGIES WILL CREATE THE FINAL SOLUTION



TECHNOLOGY TO CAPTURE CO2 TO BE RE-USED INSIDE GREENHOUSES

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THANK YOU!

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