

On-Site Energy Summit
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Combined Heat and Power for Greenhouses

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Commercial Agriculture (Greenhouses)



Freedom from industrialized food

- ✓ More transparency how food is grown
- ✓ Food security
- ✓ Improved freshness

Reduction of food miles

- ✓ Reduced transportation emissions
- ✓ Farm to table concept
- ✓ Grown close to the population centers

Sense of community

- ✓ Local jobs
- ✓ Part of economy

Improving connection between people and food

Greenhouses an excepted practice in Europe



High concentration areas of people with limited space for traditional agriculture

Ability for countries to deliver fresh produce 12 months of the year that is locally grown

- ✓ Reduction in transportation emissions
- ✓ Not dependent on rouge nations for food supply
- ✓ Food security
- ✓ Help create the flower industry in the Netherlands

Most commercial greenhouses in Europe use CHP

- ✓ A partnership with local utilities
- ✓ 14% of power generation base from greenhouses
- ✓ Utilities depend on greenhouse generation

Uses local labor

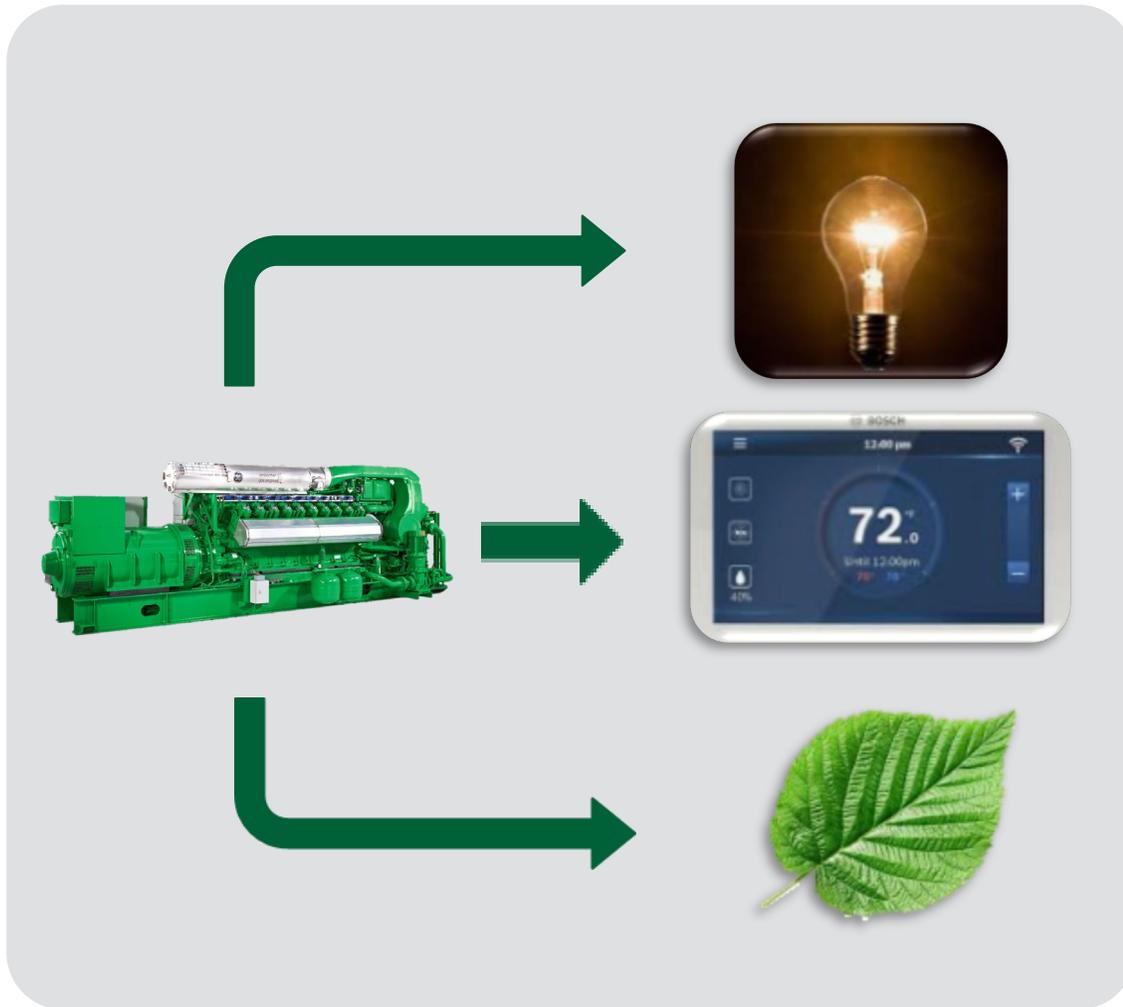
Partnership with the community and utilities

Reasons for increased use of greenhouses for food production in the North America

- *Greater yield per acre using greenhouse and hydroponics compared to field grown crops*
- *Uses 20% of the water required compared to field grown crops*
- *Uses ¼ less chemical and organic fertilizers (no leaching into the sub soil)*
- *Reduces nitrate and phosphorus leaching into rivers and streams*
- *Little to no pesticides required vs field grown crops*
- *Vegetables can be grown close to the market areas reducing transportation costs*
- *Fresh vegetables available all year round*
- *Security of the food supply, grown locally*



Combined heat and power in greenhouses

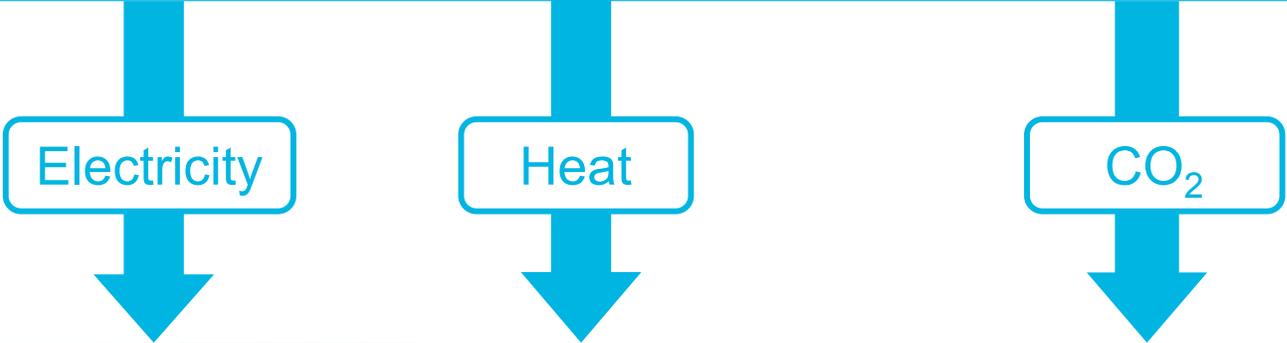


Simultaneous production of:

- Electricity
 - To power your lights/pumps
 - Sell to utility
- Thermal
 - Heat or cool your facility
- CO₂
 - For plant fertilization

Extremely efficient way to meet the energy demands of your greenhouse

Combined heat and power concept in greenhouses



❖ Ultra-low emissions. NO_x, CO, C₂H₄ reduced for CO₂ for usage in greenhouse plant fertilization



Combined heat and power in greenhouses

Illumination of Greenhouses- grow lights

-increases growth of the plants

-improves and stabilizes quality of plants throughout



Combined heat and power in greenhouses

Illumination of Greenhouses

–increases growth of the plants

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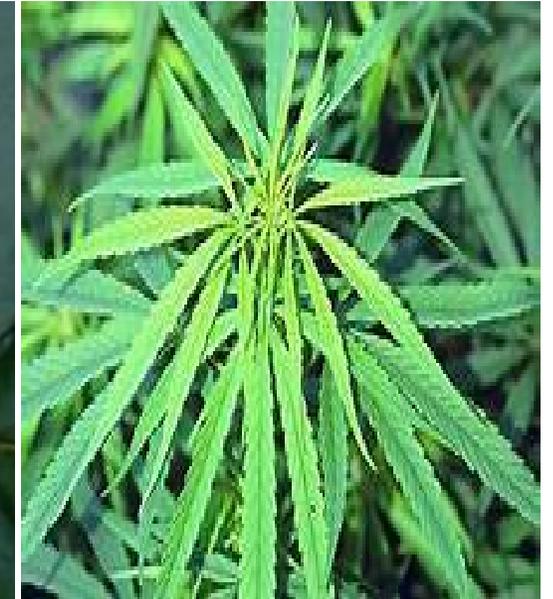
- **1 Lamp 675 W**
 - typical 308-315 lamps/acre
 - 225-245 kW/acre
 - 50 acre greenhouse can use 15 to +20 MW of power
- **Tomatoes illumination during winter days and part of the night**
- **During summer conditions rely on natural sun light when possible**
- **Roses Illumination day and night**
- **Cannabis 24 x 6 1/2**



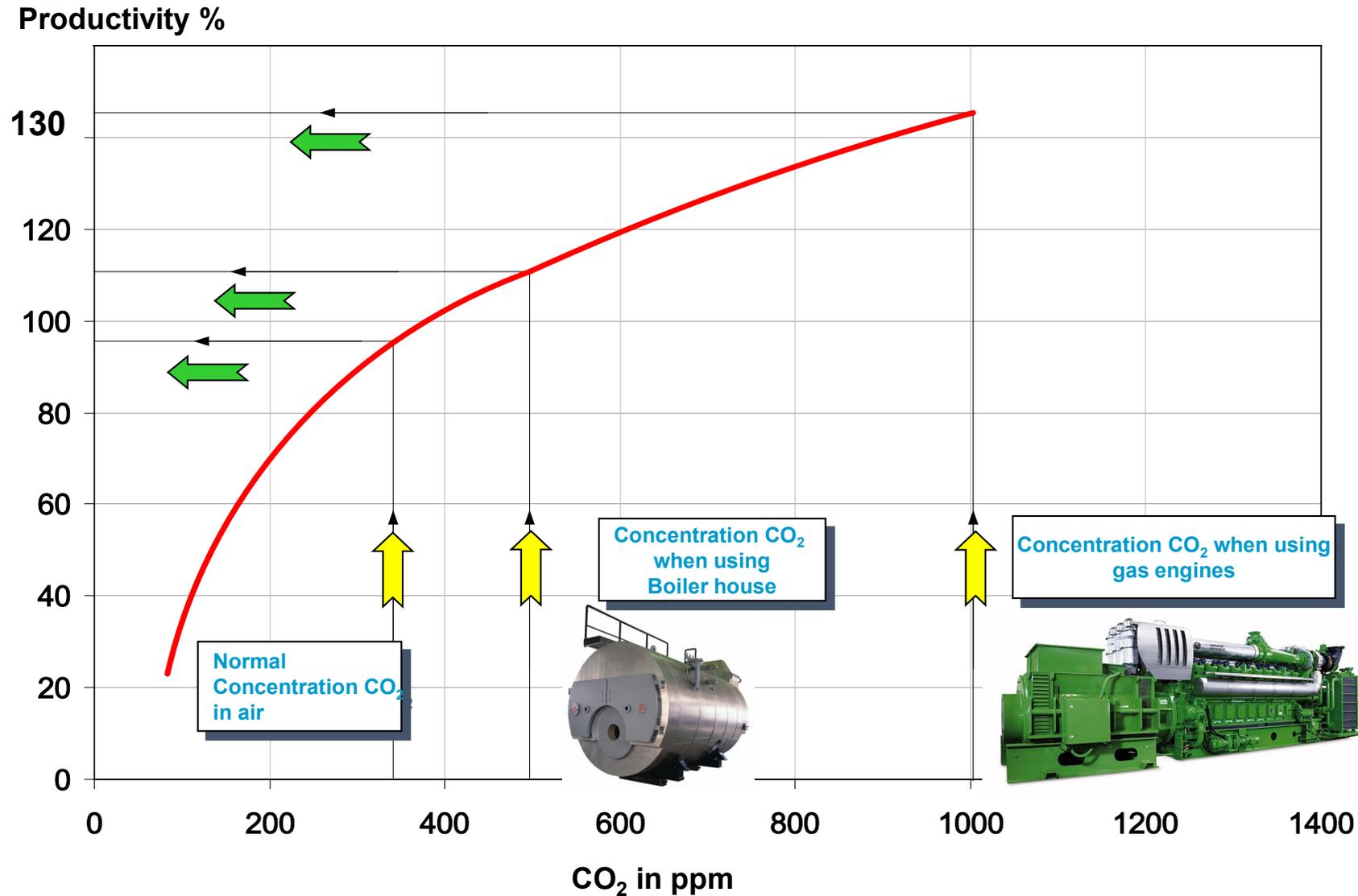
Influence of CO₂ vs. crop production

Almost all kind of plants can be fertilized with CO₂

- Vegetables like tomatoes, cucumbers, peppers, leafy greens
- Flowers like roses, chrysanthemums
- Cannabis



Influence of CO2 vs. crop production



CHP provides the opportunity for greenhouses to...

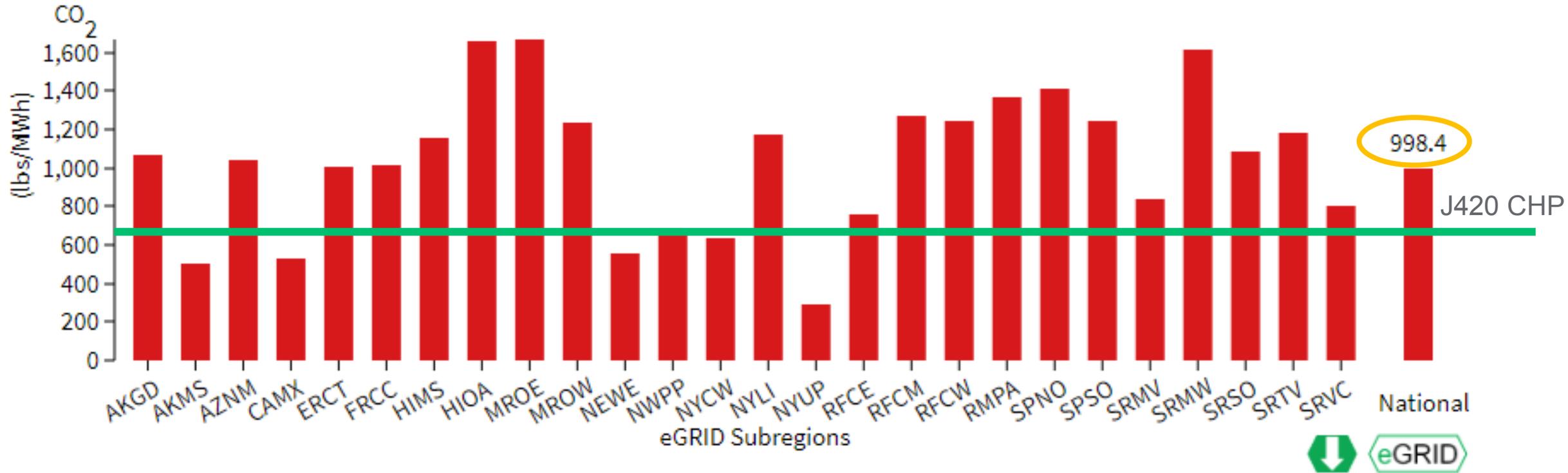
- 1 Improve GHG footprint**
 - ✓ Produce less emissions than grid power & boiler plant, reduces water requirements
- 2 Increase profitability**
 - ✓ Attractive payback on the energy side
 - ✓ Increase yields
- 3 Reliable source of peak power**
 - ✓ Can be used during peak summer loads
- 4 Overall efficiency +95%**



Many benefits that align with the community and utility

CO₂ emissions of US regions

1 Improve GHG footprint



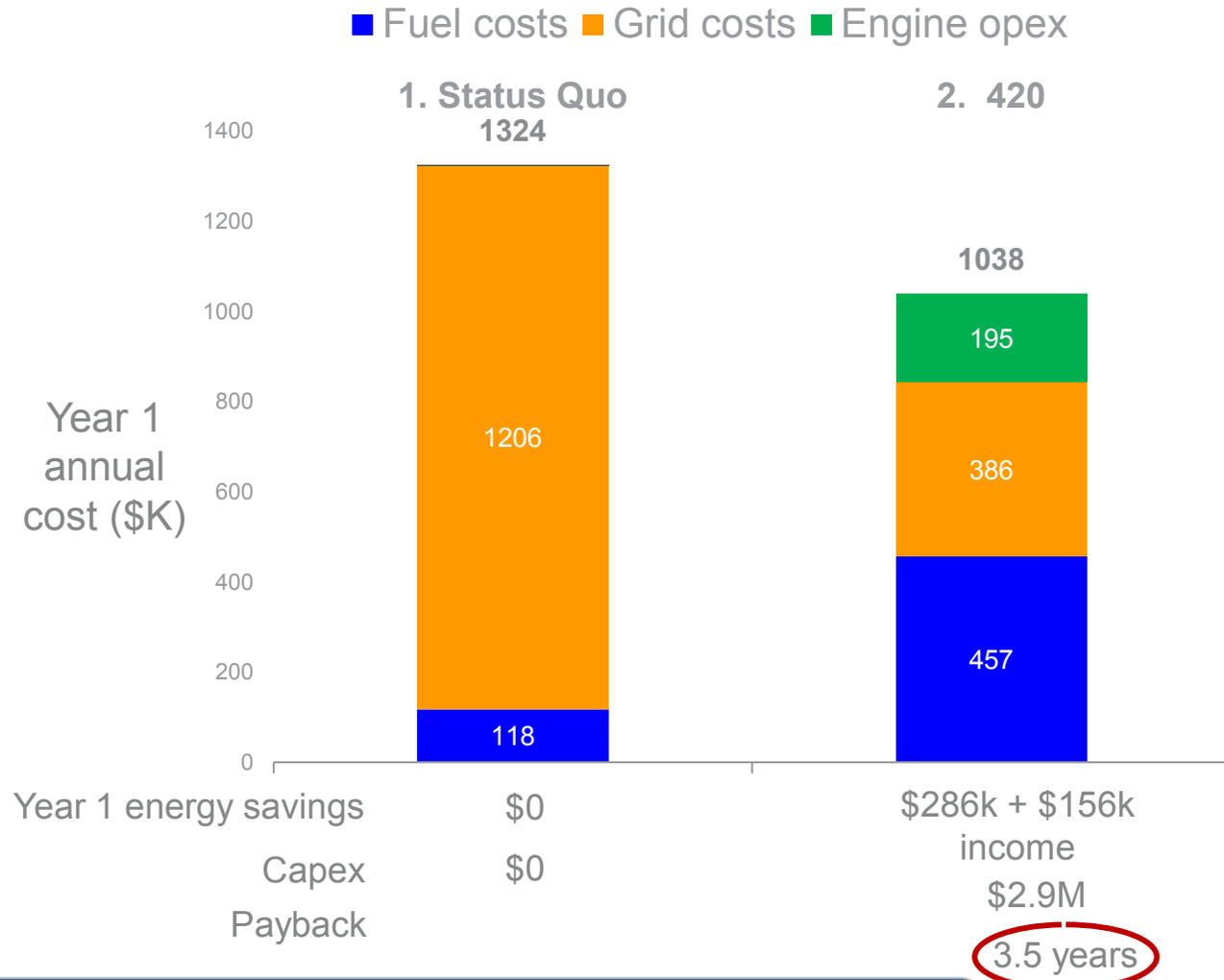
Opportunity to reduce emissions of local utilities

Example from existing greenhouse

2 Make financial sense

Assumptions:

- \$4/MMBTU
- \$0.09/kWh all-in electricity
- \$0.07/kWh avoidable electricity
- 8200 hours/year operation
- Heating = 3200 hrs (~40%)
- Chilling = 3200 hrs (~40%)
- Use tax advantages
- \$0.04 for selling electricity
- Sell excess power May-Sept

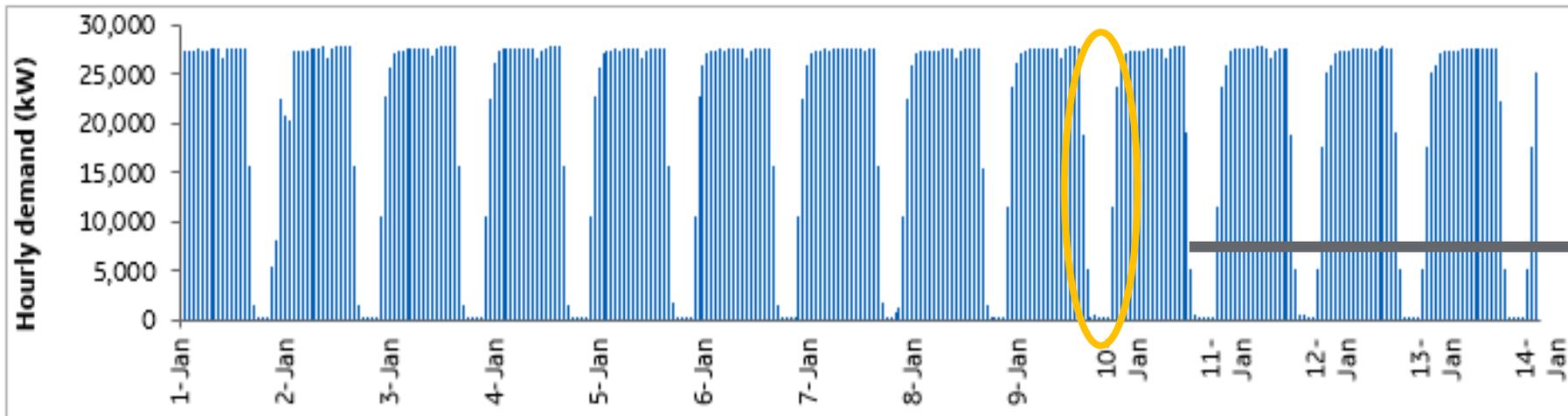
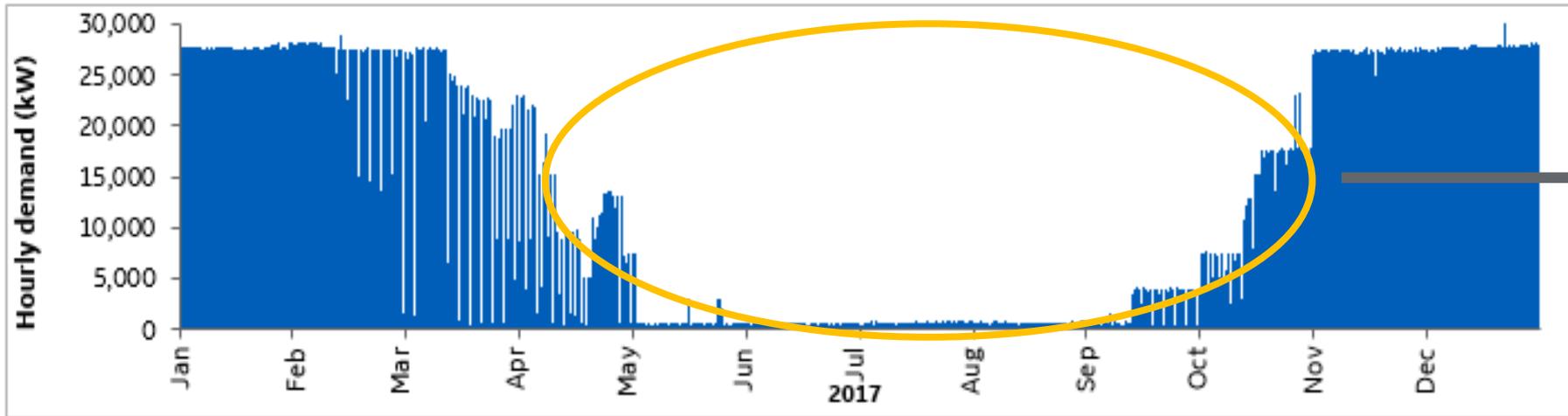


Reduce expenditures on energy and improve cash flow

An opportunity for peak power

3

Support local community

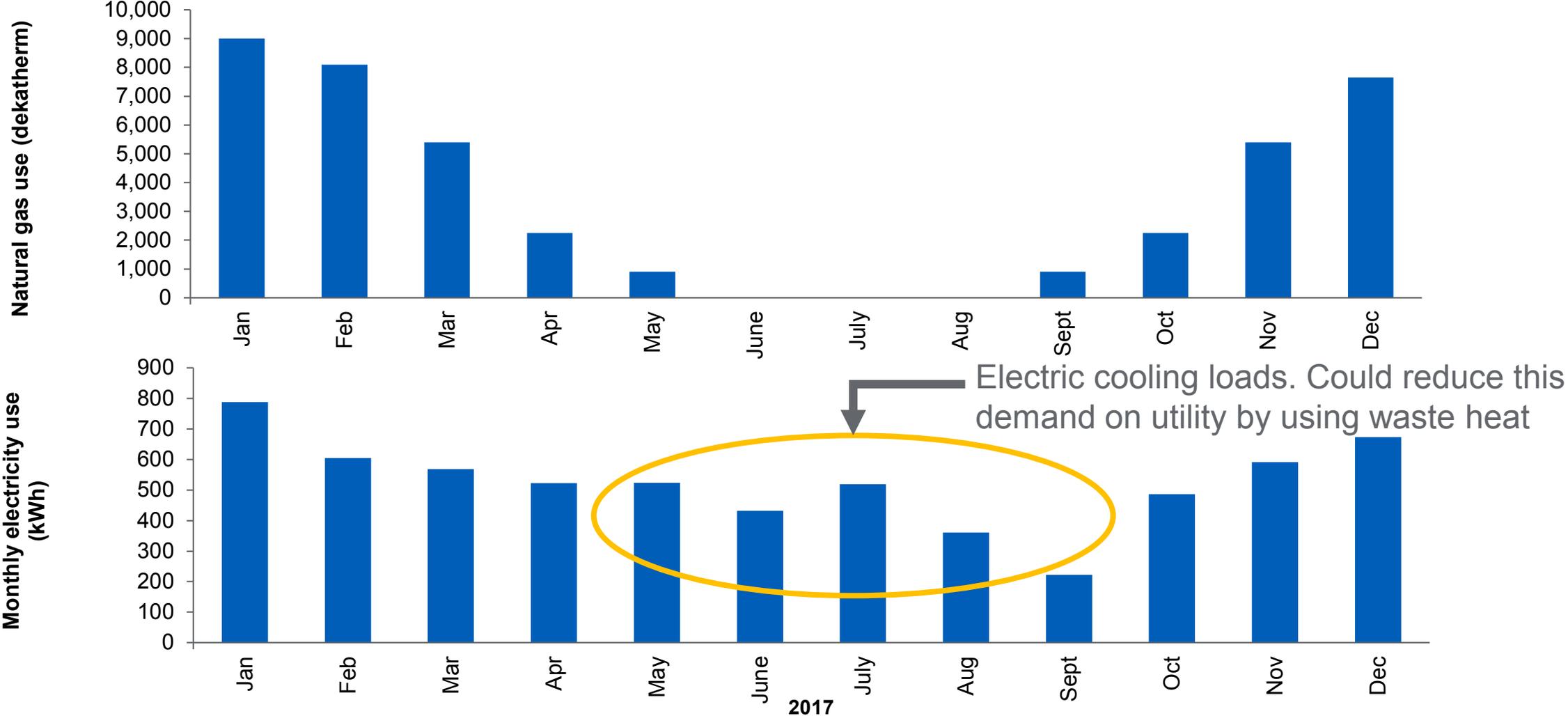


Power available for export to the grid during peak summer months, and during peak hours of the day

Save money, improve efficiency, reduce waste

A different way to meet thermal needs

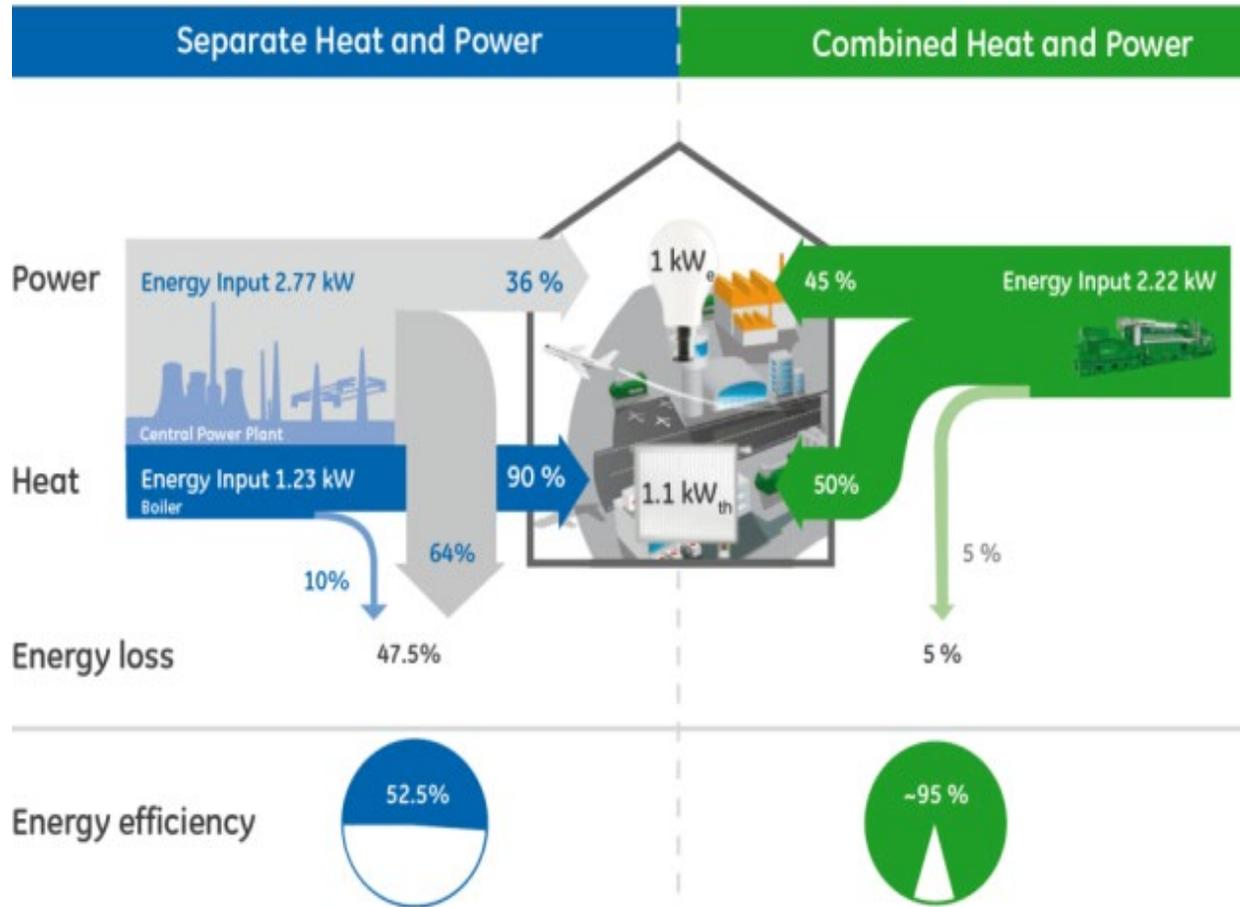
3 Support local community



Using waste heat to replace electricity... a double impact on local utility

Proven Technology

Over 6,000 MW's of greenhouse CHP installed



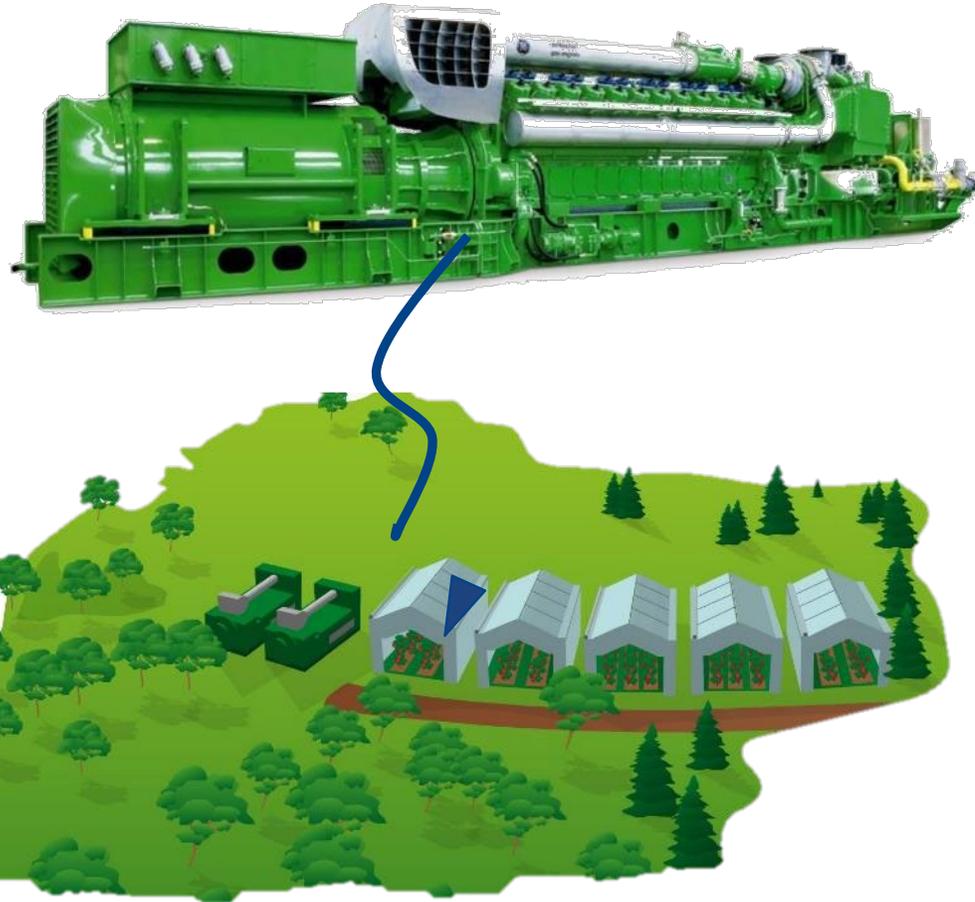
4 Higher overall efficiency

~Can exceed 95% overall efficiency

- Electric efficiency exceeds 45%
- Thermal efficiency exceeds 50%
- More energy extracted from exhaust
- Water condensed out of exhaust (used for makeup & window washing)
- CO₂ from exhaust used for fertilization not released to the atmosphere

One of the cleanest forms of generation other than some renewables

Benefits of Greenhouse Combined Heat & Power



- Resiliency
- Energy Savings
- Emission reduction
- Power availability for summer peaking
- Greenhouse operation inline with utilities summer peaking requirements
- Production of clean power
- Agriculture sustainability
- Locally grown produce year round
- Use of local labor

One of the cleanest forms of generation other than some renewables

Case study-Houweling's Tomatoes



In Review

Location	Camarillo, California
Commissioned	August 2012
Fuel	Natural Gas
System/Engine	(2) Jenbacher J624 Two-Stage Turbocharged 8.7MW Electrical Power 10.6MW Thermal Power 90% Thermal Efficiency

Technology

The Houweling's project is the first combined heat and power (CHP) greenhouse in the United States. Additional benefits include the capture of carbon dioxide (CO₂) for greenhouse plant fertilization.

- Reduces energy costs by 30% annually
- Thermal energy is recovered and stored in a 500,000 gallon thermal tank
- CO₂ recovered removes 500 trucks of liquid CO₂ from the road each year
- Summer peaking capacity equal to supplying 6,500 homes
- CHP saves an estimated 10,700 tons of CO₂ annually over purchasing power and operating boilers.
- Water condensed out of the engine exhaust saves 9,000+ gallon daily

There's work to be done

- 1 Improve awareness**
Among both growers, utilities and the ISO
- 2 Advocate for policy changes**
Electric interconnect standard agreements
Increase the natural gas supply
- 3 Improve funding resources**
USDA, local grants, low cost loans

