

Houweling's Greenhouse

CHP Case Study

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GE imagination at work



Agenda

ecomagination

- GE Gas Engines Business
- Greenhouse CHP application overview
- GE's standardized greenhouse CHP platform
- The GE's Jenbacher J624: technology for greenhouses
- The Houweling's Tomatoes Greenhouse CHP

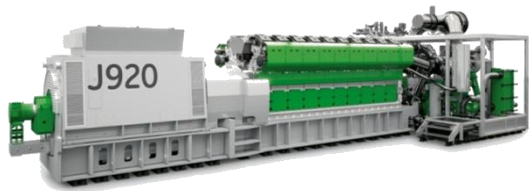


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GE's Gas Engines Business

Power Generation

Jenbacher, Waukesha



- Electrical output: 120 – 9,500 kW
- Electrical efficiency up to 48.7%, overall efficiency over 90%
- 20,500+ engines delivered, 21,800 MW power globally
- Natural gas and CHP, excellence in special gas applications (biogas, LFG, CMG, BFG), oilfield power

Gas Compression

Waukesha



- Output: 160 bhp – 4,835 bhp (119 kW – 3,605 kW)
- 12,000+ compression engines delivered, over 13.2 million bhp power globally (9,850 MW)
- Wellhead, gathering, storage/ transmission

Heat Recovery

Clean Cycle™

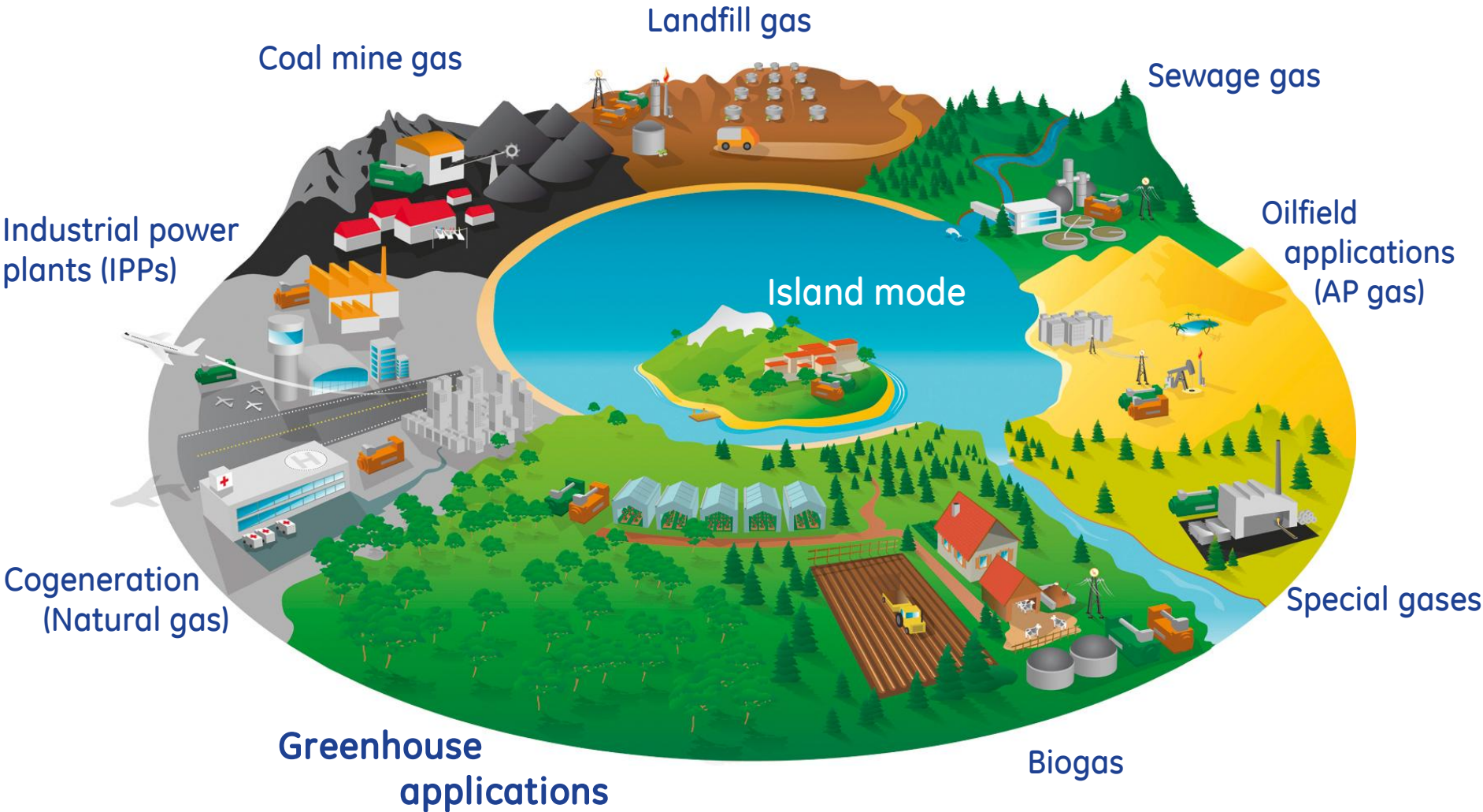


- 125 kW_e generator for waste heat-to-electricity
- For engines, biomass boilers, other heat-wasting applications as low as 121°C (250°F)
- No additional emissions in operation



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Fuel Flexibility and Tailor-Made Solutions

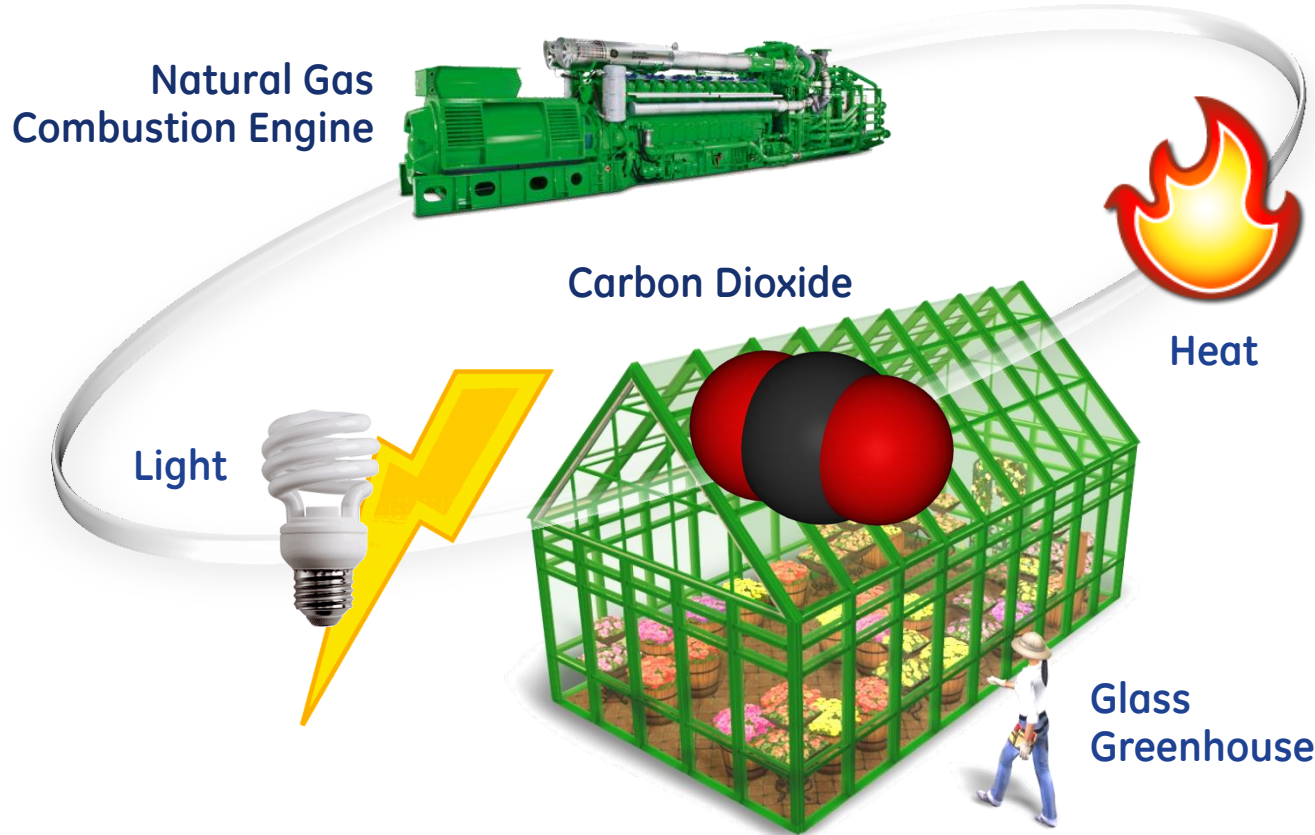


Application Overview Greenhouse CHP



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Overview of greenhouse CHP



Greenhouse CHP combines the production of heat and power to enrich the greenhouse atmosphere with CO_2 , keep the temperature on a constant level and provide dispatchable power for lighting so that harvest yield can be significantly increased.

Light: Electrical energy for illumination of greenhouses

Artificial illumination improves the quality of plants throughout the year and is suitable for:

- Vegetables (tomatoes or peppers)
- Flowers (chrysanthemums or roses)

1 lamp = 675 W (approx)

Typical demand:

- 125 lamps/ha = 80 – 90 kW/ha, 1,000 Lux

Illumination demand for:

- Roses and orchids: 10,000 – 12,000 Lux (day + night)
- Tomatoes: 10,000 – 20,000 Lux (only day)
- Chrysanthemums: 3,000 Lux



Heat: Thermal energy for heating of greenhouses

Heating enables plant growth throughout the year

Greenhouse CHP uses a greenhouse's hot water tanks to act as batteries to store thermal energy which makes power generation extremely flexible and dispatchable

Rule of thumb for heat demand sizing:

- CO₂ fertilization with heat supply:
→ 0.5 MWe per hectare (2.5 acres)
- CO₂ fertilization with heat supply and illumination:
→ 0.35 MWe per hectare (2.5 acres)
Slight reduction due to additional radiation heat of lights



CO₂: Plants grow by converting this to carbon through photosynthesis

CO₂ fertilization is suitable for nearly all plant types

- Air contains approx. 350 ppm CO₂
- Optimal CO₂ levels lie above 700 ppm, based on plant species
- Artificial lighting in greenhouses enables plants to absorb more CO₂

The combustion of natural gas produces:

- 0.2 kg of CO₂ per kWh of energy input
- CO₂ is 5 to 6% by volume

Exhaust gas is:

- Purified with special catalytic converters
- Cooled down to approximately 55°C
- Supplied to the greenhouse for CO₂ enrichment



GE's Greenhouse CHP System and Technology



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GE's greenhouse CHP application experience around the world



880 greenhouses and 1,000 engines starting in 1987

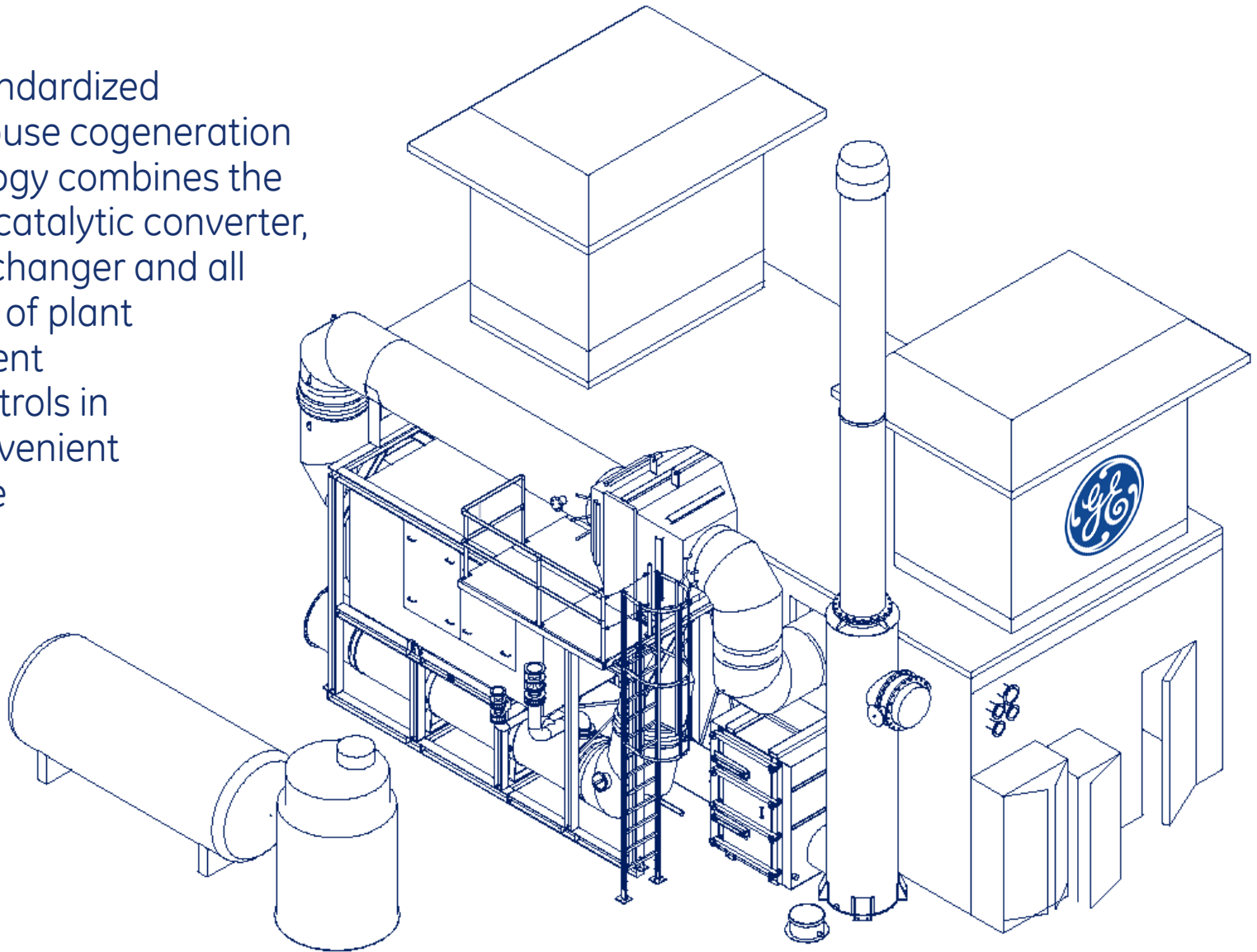
1,880 megawatts of electrical capacity

2,050 megawatts of thermal capacity



GE's standardized greenhouse CHP platform

GE's standardized greenhouse cogeneration technology combines the engine, catalytic converter, heat exchanger and all balance of plant equipment and controls in one convenient package

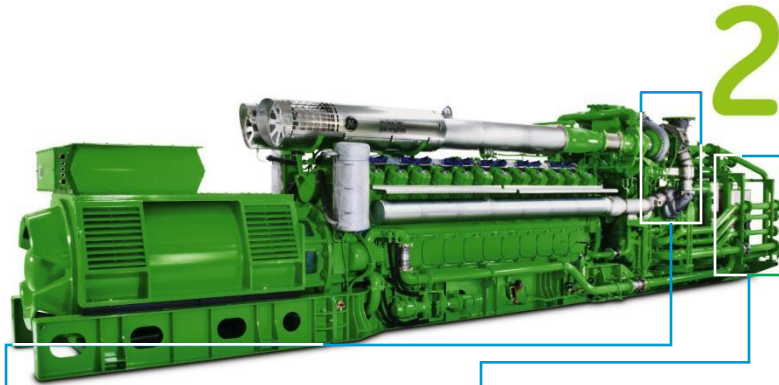


GE's standardized platform



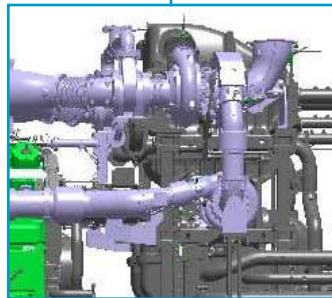
The J624 TSTC...optimized for greenhouse CHP

The J624, Jenbacher's first gas engine with a revolutionary two-stage turbocharger system enables class leading efficiency and output...**a perfect fit for greenhouse CHP**

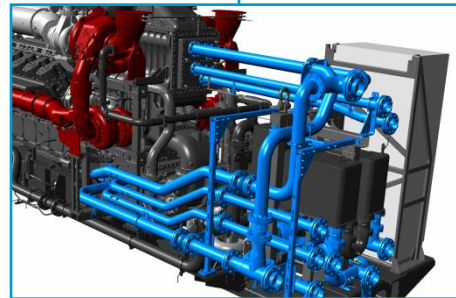


J624 Two-Stage Turbocharger (TSTC)

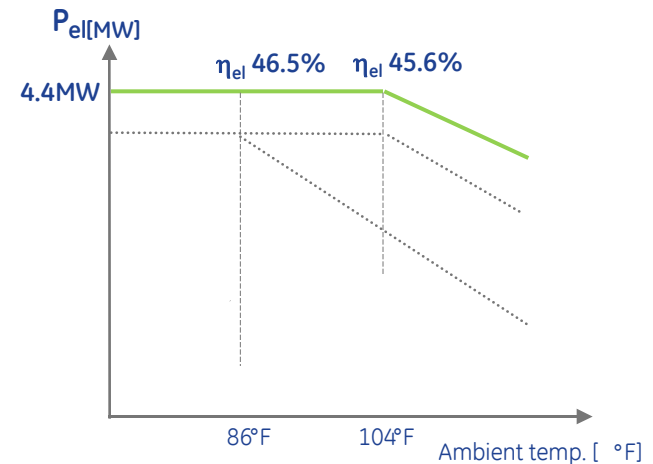
- Power Output 4.4 MWe
- Total Efficiency..... 89%
- El. Efficiency..... 46.5%
- Dimensions..... 46' x 8' x 10'



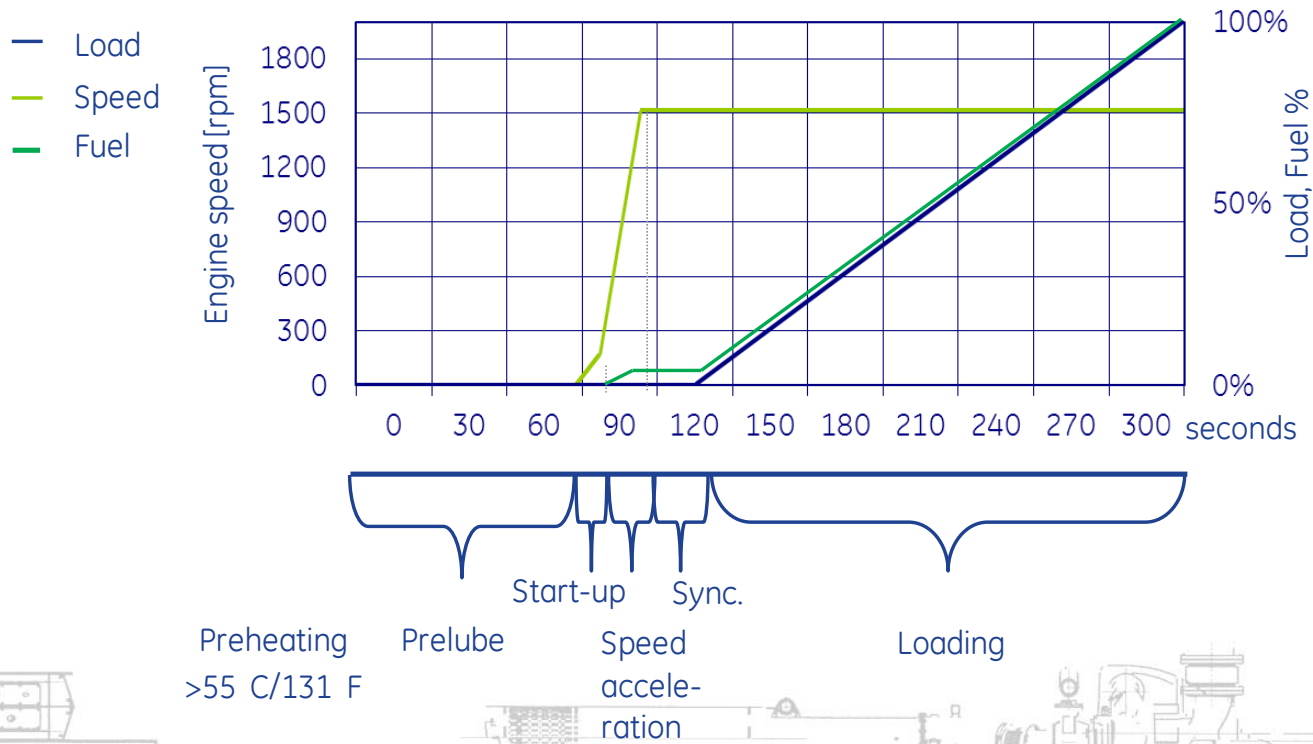
Two-stage turbochargers have a higher charging pressure enabling better heat recovery



The J624 TSTC uses all of the heat from mixture heat exchanger enabling and overall efficiency up to 90%



J624 TSTC fast start for dispatchable clean energy



5 minute start-up time with parallel start of multiple engines

GE's Greenhouse Center of Excellence

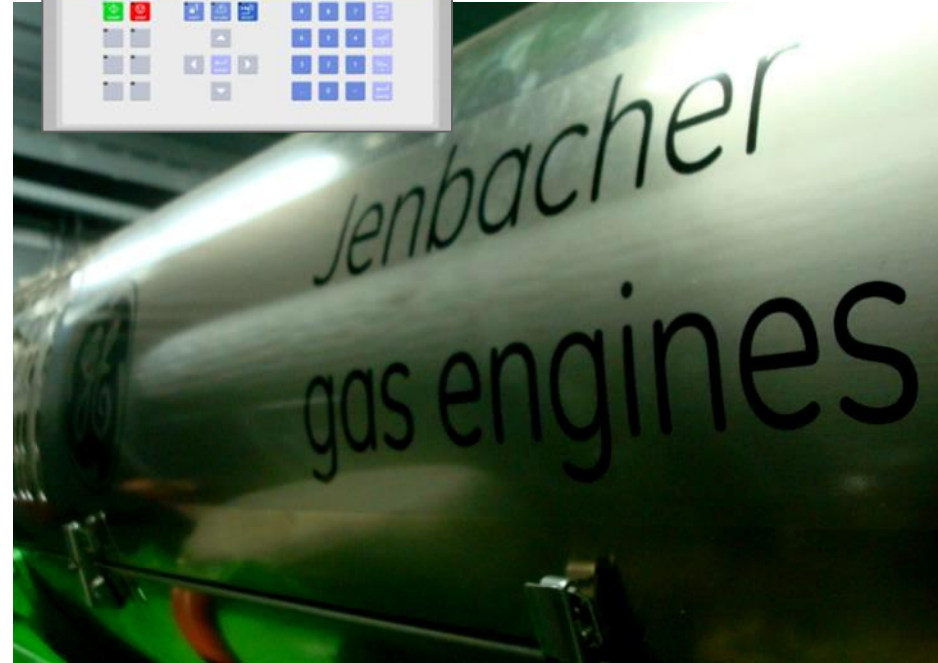
Help desk in Netherlands provides online monitoring to over 800 greenhouse cogeneration facilities around the world.

More than 100 employees.

GE's Greenhouse CHP Center of Excellence
Rotterdam, The Netherlands



The engine management system contains powerful controls that handle master and feedback controls for the engine/plant, as well as visualization.



GE imagination at work



Houweling's Tomatoes Camarillo, California



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“Mastery Under Glass”



Houweling's Tomatoes

- Second generation growers
- Established Camarillo facility in 1996 as Houweling's flagship greenhouse
- 125 acres under glass



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CHP Ribbon Cutting Ceremony August 22nd, 2012



Our emphasis has changed. When we first came here to California, we didn't worry about water use, we never really worried about energy... we didn't worry a lot about the environment.

~ Casey Houweling, Proprietor (*opening comments*)*

Growing a “Greener” Tomato

One of North America’s largest greenhouse tomato growers, Houweling’s Tomatoes, built the first combined heat and power (CHP) greenhouse project in the U.S. that captures carbon dioxide (CO₂) for use in plant fertilization.

Natural Gas



Jenbacher J624



Two GE ecomagination-qualified Jenbacher J624 gas engines

CO₂ Fertilization Process

CO₂ from the engines’ exhaust is purified and piped into the greenhouse as fertilizer, diverting 21,400 tons of CO₂ yearly, equal to **yearly CO₂ emissions of more than 4,000 cars.**

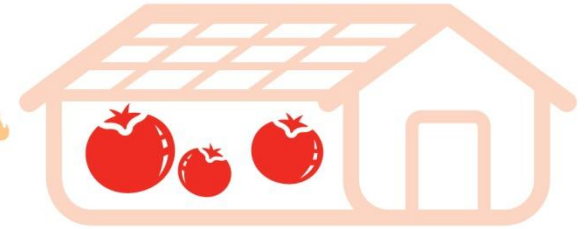


From Waste to Value

The process provides power, heat, water and CO₂ fertilization for Houweling’s Tomatoes’ 125-acres in Camarillo, CA.

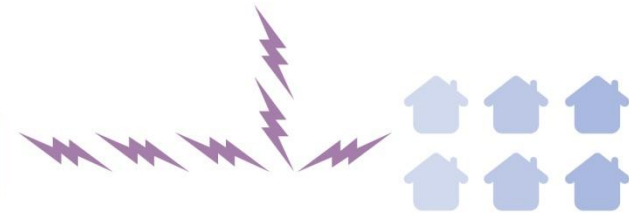
Heat

Heat produced from the engines during power generation – more than 10.6 MW of thermal power – is captured in thermal storage tanks and used to heat the greenhouses.



Power

The gas engines provide 8.7 MW of electrical power – **enough for approx. 8,800 average homes** – to meet greenhouse needs and supply energy back to the community grid.



Community Power Grid

Condensed Water

Water is condensed out of the exhaust gas system, conserving water from the Central Valley, to provide approx. **9,500 gallons of water per day** to greenhouse operations.

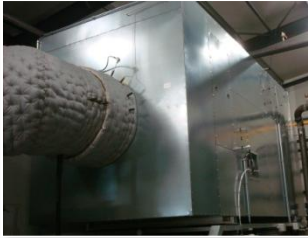


Greenhouse CHP benefits to growers



Standardized design. High efficiency of up to 95%.

Small footprint, excellent CO₂ quality, maximum operational safety and availability and reliability through engine controls



Ultra-low emissions.

NO_x, CO, C₂H₄ removed for CO₂ supply to greenhouse and minimum emissions through patented lean mixture combustion system



CO₂ fertilization.

Time-independent supply of CO₂ and heat through storage option helps increase crop productivity by 20-30%



Flexible power.

Power to grow lights and electricity to the grid





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GE's standardized greenhouse CHP platform

