Houweling’s Greenhouse
CHP Case Study

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GE Gas Engines
Agenda

- GE Distributed Power 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
GE Power & Water

Wind
Renewables
Solar
Water & Process Technologies
Nuclear

Power Gen Products
Power Gen Services
Jenbacher gas engines
Waukesha gas engines
Aeroderivative gas turbines

GE Gas Engines
Houweling's Tomatoes CHP Case Study
Aero GT for CHP applications

(HRSG only)

**Example:** 30 °C /80 % RH ambient, dry saturated steam @ 10-35 bar abs; unfired HRSG; 8 / 6 °C HRSG pinch/approach; net output after total plant aux loads

<table>
<thead>
<tr>
<th>LM2500 range</th>
<th>LM6000 range</th>
<th>Typical solutions</th>
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| - 19.5 – 27.5 MW net output | - 33 – 42.5 MW net output | - Commercial & Municipal  
✓ Airports  
✓ Hospitals  
✓ Universities  
✓ District Heating |
| - 42 – 61 tph steam production | - 53 – 73 tph steam production | - Industrial /Manufacturers  
✓ Pulp & Paper  
✓ Chemicals  
✓ Food & Beverage |
| - 34 – 35 % net LHV efficiency | - 38 – 39 % net LHV efficiency | - Oil & Gas  
✓ Petrochemicals |
| - 86 – 89 % net CHP efficiency | - 78 – 86 % net CHP efficiency | |

Proven, dependable, high performance technology
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
Fuel Flexibility and Tailor-Made Solutions

- Landfill gas
- Sewage gas
- Oilfield applications (AP gas)
- Special gases
- Greenhouse applications
- Biogas
- Coal mine gas
- Industrial power plants (IPPs)
- Cogeneration (Natural gas)

Island mode
Application Overview
Greenhouse CHP
Greenhouse CHP combines the production of heat and power to enrich the greenhouse atmosphere with CO₂, keep the temperature on a constant level and provide dispatchable power for lighting so that harvest yield can be significantly increased.
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:

- CO$_2$ fertilization with heat supply:
  \[ \rightarrow 0.5 \text{ MWe per hectare (2.5 acres)} \]

- CO$_2$ fertilization with heat supply and illumination:
  \[ \rightarrow 0.35 \text{ MWe per hectare (2.5 acres)} \]
  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
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

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 Two-Stage Turbocharger (TSTC)
- Power Output ........ 4.4 MWe
- Total Efficiency .... 89%
- El. Efficiency .......... 46.3%
- Dimensions ................ 46’ x 8’ x 10’

@ ISO3046, 60Hz; PF=1, NOx<1.1g/bhp_h, MN>80
$ 39,000 fuel savings p.a. @5.000 oph p.a., Modul; gas tarif: 7$/MMBTU-hr
Flexibility to Accommodate a Wide Range of Greenhouse Sizes

3 Hectacre → 10+ Hectare
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.

The engine management system contains powerful controls that handle master and feedback controls for the engine/plant, as well as visualization.
Houweling’s Tomatoes
Camarillo, California
Houweling’s Tomatoes

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

*http://www.houwelings.com/
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.

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.

Community Power Grid
Greenhouse CHP benefits to growers

**Standardized design.** High efficiency of up to 95%. Small footprint, excellent CO$_2$ quality, maximum operational safety and availability and reliability through engine controls.

**Ultra-low emissions.** NO$_x$, CO, C$_2$H$_4$ removed for CO$_2$ supply to greenhouse and minimum emissions through patented lean mixture combustion system.

**CO$_2$ fertilization.** Time-independent supply of CO$_2$ and heat through storage option helps increase crop productivity by 20-30%.

**Flexible power.** Power to grow lights and electricity to the grid.
GE Energy Gas Engines, North American Greenhouse Center of Excellence

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GE’s standardized greenhouse CHP platform