Energy Efficient Greenhouse Design

Tom Manning
New Jersey Agricultural Experiment Station

Principles of Energy Efficiency and Conservation
- Understand the problem (audits and monitoring)
- Use functional and efficient controls
- Size equipment and structures appropriately
- Share resources
- Maintain equipment and facilities
- Increase production
- Pick good sites
- Use efficient architecture
- Adopt efficient technologies
- Insulate

Energy savings strategies and systems
- Measure ("If you cannot measure it, you cannot improve it")
- Temperature integration (correlated with DLI)
- Integrated Light, Temp, RH and CO₂ control
- Double (triple) layer glazing
- Energy/shade curtains
- Floor heating
- Condensing boilers
- Variable speed motors and pumps
- Heat pumps with energy buffering and/or long-term storage

Both et al. 2007. Evaluating energy savings strategies using heat pumps and energy storage for greenhouses. ASABE paper 074011. ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659.

Advantages of Automated Control Systems
- Data monitoring and trending
- Alarm capability
- Maintenance scheduling
- More complex control at all times

- At least 1 foot deep (preferably 2 feet)
- At least 1 inch thick (preferably 2 inches)

- Avoid gaps
- Try to work neatly around post footings
Energy Efficient Greenhouse Design

North facing side wall insulation

Rollup fan housing curtain

Hot Air Furnace – Point Source
Cheap but inefficient

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Courtny Sion Orchids
Distributed Hot Air
More efficient and uniform

New Unit Heaters
- Direct-fired (no heat exchanger)
- 99% efficient
- Natural gas or propane
- Very low CO and NOx production
- Some have outside air-intake
- Various safety features
- CO2 enrichment

Hot Water
Even more efficient and uniform
Modulated temperature better than ON/OFF

New Boiler Technology
- Condensing boilers (95-98% efficient):
  - Made of stainless steel, allowing condensation of water vapor produced during combustion (producing more heat), and equipped with a heat exchanger to pre-heat the boiler water with heat from combustion gasses
  - Low mass (boiler components and water)
  - Operated on demand (no stand-by losses)
  - Heat delivery in minutes
  - Small foot-print
  - Low maintenance
  - Can be combined with high mass boilers
- Dual fuel boiler (natural gas & fuel oil)

Floor Heating

18 mm (0.75 inch) diameter heating pipes placed at 30.5 cm (12 inch) on center

Drain hole

Post

Drain

Spur line

21 = 15.2 cm (6 inch)

Spur line

21 = 15.2 cm (6 inch)

Sub soil

Sub soil

Header pipe

19 mm (0.75 inch) diameter heating pipe placed at 30.5 cm (12 inch) on center

Heat

Sub soil

Drain

Spur line

21 = 15.2 cm (6 inch)

Spur line

21 = 15.2 cm (6 inch)

Sub soil

Sub soil

Drain
Energy Efficient Greenhouse Design

Bench Heating

- Insulate heated and cooled spaces.
- Use strip doors & dock seals where appropriate.
- Use high efficiency boilers, furnaces and cooling equipment.
- Maintain boilers, filters, steam systems, etc.
- Run heating and cooling systems only as needed.
- Use multiple appropriately sized units (boilers, compressors, etc.)
- Install radiant heat.
- Automate greenhouse controls.

Greenhouse Ventilation

- Schedule for off-peak hours.
- Stagger lighting schedules to minimize peak loads.
- Arrange lights in accordance with manufacturer’s recommendations.
- Optimize lighting strategies
- Use efficient fixtures

Heating and Cooling

Efficient Use of Supplemental Lighting
Trading Supplemental Light for CO₂ Enrichment


Reducing Energy Costs
- Use an energy/shade curtain (20-30%)
- Consider high efficiency heaters/boilers (20-40%)
- Oil: install a flame retention burner (15-20%)*
- Consider a dual fuel system
- Use computer control and variable speed motors and pumps (5-10%)
- Use “natural” ramping (2-5%)
- Keep track of energy use
- Lower heating system temperature (5-10%)

*results in better mixing of fuel and combustion air

Greenhouse Water Use
- Recirculation systems
- Water Treatment
- Recovery of plant transpiration
  - Condensation
- Rainwater collection and use
  - Groundwater recharge concerns
- Lettuce: 2.75g of dry mass per liter of water
Reducing Energy Costs - Continued

- Use highest R-value for insulation (2-5%)
- Provide a wind barrier (don’t block light; 2-5%)
- Perform timely maintenance (5-10%)
- Check greenhouse for leaks (2-5%):
  - Caulk and weatherstrip doors, windows, etc.
  - Repair misaligned ventilation shutters
  - Seal all cracks in walls
  - Repair broken glazing
- Select the cheapest fuel supplier (2-5%)

Seawater Greenhouse

- http://www.bluethumbs.nl
- http://www.seawatergreenhouse.com
- Sundrop Farms, Port Augusta, AUS

Energy Producing Greenhouses

- ‘Closed’ Greenhouse
  - http://www.innogrow.com/
- ‘Elkas’
- Fresnel greenhouse
  - Dr. Piet Sonneveld, Wageningen University
Renewable and Alternative Energy

- Always improve efficiency first.
- Check that any new source of energy is suited for your specific location and conditions.
- Understand the performance potential of renewable and alternative technologies without incentives.

Alternative Energy Options

- Wind
- Solar (electricity and/or heat)
- Biomass
- Waste heat from industry and power stations
- Ground source or geothermal
- Reciprocating engines and (micro)turbines (CHP)
  - natural gas
  - landfill gas (gas purification required)
  - digester gas (gas purification required)
- Hydropower

- Wind

50 kW turbine
Installation cost: $5000/kW_e (2009)
Reduces energy consumption by 30-40%
Eagle Creek Wholesale Growers, Mantua, OH

http://www.greenhousegrower.com

- Land based and floating solar panels at a vineyard in Oakville, CA
$8,805/kW_e

http://www.nytimes.com
• Photovoltaic film incorporated in the glazing

Cost: €4600 per installed kW (Naples, Italy)
Manufacturer: Sun Well Solar, Taiwan

http://www.freshplaza.com

• Solar Thermal
  • 11,000 square feet of collectors for 58,000 square feet of greenhouse

• Switchgrass

5,000 kW\textsubscript{th} biomass boiler (for almost 3 ha of GH)

Installation cost: $140/kW\textsubscript{th}, including silos
Biomass

- Wood pellets for greenhouse heating

Waste Heat

Combined Heat and Power

In the Netherlands in 2010, ~12% (3 GW) of the national electricity consumption was produced by CHP units installed at greenhouse operations (operated on natural gas)
250 kW Microturbine commissioned October 2008 Installation cost: $3000/kWe

Both et al. 2011. Operating a 250 kW landfill gas fired microturbine at a 0.4 hectare research and demonstration greenhouse. Acta Horticulturae 893:397-404.

Gas Conditioning System

Anaerobic Digester

http://home.comcast.net/~hollywastewater/Process.htm

Thank You...