Sustainable Energy Systems for Indoor Growing & Greenhouses

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Gas Major Accounts
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Outline

• Who is DTE Energy?
• What do plants need to grow and thrive?
• Elements of indoor, controlled grow environment
  – Envelope, Heating, Ventilation, Cooling and Humidity
• Delivery of Nutrients: Discussion of CO2 supplementation
• Lighting and Power options
• What is CHP?
• Greenhouse case studies
  – Two tomato greenhouses with multi-MW CHP systems
  – One indoor grow-room retrofit of a warehouse for cannabis
• Indoor grow-room energy balance and model
• Cost comparisons for a Michigan Class C 1,500 plant grow
DTE Energy is a Fortune 300 company with deep Michigan roots

Our Business

- Market cap ~$18 billion
- Two fully regulated utilities serving Michigan
  - Founded in 1849, DTE Gas
  - Founded in 1886, DTE Electric
- Non-utility businesses operate in 19 states

Michigan Strength

- Top tier regulatory environment supports utility investment
- Constructive energy legislation supports transition to cleaner energy
- Strong state and local economy provides avenue for growth
New NEXUS Gas Pipeline

1.5 billion cubic feet per day
New 1,100MW Gas Plant

New NEXUS Gas Pipeline
1.5 billion cubic feet per day
DTE Energy’s natural gas plant:

- Breaks ground in 2019, creating 500 construction jobs
- Opens in 2022 in East China Township, Mich.
- Will provide 24/7 power to 850,000 homes
- Significantly reduces emissions compared with coal plant

$1B Cost
1,100 MW Combined Cycle
East China Township
Elements for Healthy Plant Growth

- Temperature, Humidity, Wind
- Solar Energy
- Carbon Dioxide
- Water and Minerals
- Nutrients
Photosynthesis – chemical reaction

\[6\text{CO}_2 + 6\text{H}_2\text{O} + \text{solar energy} \rightarrow 6\text{O}_2 + \text{glucose}\]

Glucose = C\text{}_6\text{H}_{12}\text{O}_6
Nearly all life on the planet is supported by this reaction

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{sunlight}} 6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 \]
Controlled Environment Agriculture

• Provide Light Energy
  – Solar or Artificial
• Macro Nutrients
  – CO₂ and H₂O
• Micro Nutrients: N, P, K, other Minerals
  – Soil or Hydroponics
• Suitable Environment
  – Temperature, Humidity, Wind (*ventilation*)
Elements of a Greenhouse

• Building envelope
  – Weatherization / air infiltration
  – heat insulation
  – light transmittance
• Lighting
• Heating
• Ventilation
• Cooling
• Humidity control
• Delivery of nutrients
  – CO2, water, fertilizer (N,P,K and minerals)
• Supply of energy: electric utility, natural gas, renewables, CHP
The Structure or Envelope

- **Reduce Air Leaks**
  - Weather-strip doors, vents and fan openings
  - Service louveres frequently to close tightly
  - Repair broken glass or holes in the plastic
  - Seal and weatherize foundation

- **Double Coverings**
  - Cover "inside" sidewalls and end walls inside with poly or bubble wrap
  - Install double wall polycarbonate panels to get insulation effect and reduce recovering labor.
  - Use poly with an infrared inhibitor on the inner layer for 15% savings
  - Use single or double layer of plastic over older glasshouses to reduce infiltration and heat loss

- **Energy Conserving Curtain**
  - Install a thermal curtain for 20%-50% savings. An energy curtain can significantly reduce nighttime heat loss from a greenhouse. Payback within 1 to 2 years.

- **Foundation and Sidewall Insulation**
  - 1-2" extruded polystyrene board to 18-24" below ground to reduce heat loss. This can increase the soil temperature near the sidewall as much as 10 degrees during the winter.
  - 1-2" board insulation on kneewall or sidewall up to bench height.

- **Site Location**
  - Locate greenhouses in sheltered, reduced wind areas (but not shaded)
  - Windbreaks on the north and NW exposures with rows of conifer trees or plastic snow fencing.

- **Space Utilization**
  - Optimize space utilization: movable benches, multi-level racks for low light crops, try addition of hanging baskets, and roll-out bench system can double growing space, where top level plants are moved outside during the day.
Automated Night Thermal Curtains

Photo: John Bartok, Jr., University of Connecticut
Heating Options

• Consider Thermal Storage
• Direct fired unit heaters (CO2 + heat)
• Indirect fired unit heaters
  – High efficiency condensing unit heaters (90%+)
• Natural gas boiler, natural gas
  – Radiant piping distribution
  – Radiant floor distribution
• **Combined Heat & Power (CHP), natural gas**
• Engine driven heat pumps, natural gas
• Ground source heat pumps, electric
• Renewable options
  – Solar thermal or Biomass (wood chips)
Ventilation Options

- None: sealed environment (cannabis grow room)
- Automated roof vents
- Sidewall electric fans
- Need to coordinate and control interactions with CO2 supplementation
Cooling Options

• Natural ventilation only
• Side wall evaporative cooling
• Shading
  – Shade curtains or Exterior spay on white-wash
• Ground source heat pumps, electric
• **Natural gas engine driven heat pumps**
• **Natural gas absorption cycle chillers and heat pumps**
• **Natural gas engine driven chillers (TecoChill)**
• Grow rooms best utilize natural gas heat pumps or chillers due to predominant cooling and dehumidification loads.
Gas Cooling & Heat Pumps: (tons cooling)

- Yanmar gas engine driven heat pump: (13, 16, 20, 24)
- Sierra / Aisin gas engine heat pump: (8, 15)
- Tecochill gas engine air-cooled water chiller: (25)
- Tecochill gas engine air-cooled water chiller: (50, 65)
- Tecochill gas engine water cooled chiller: (150 to 400)

- Robur gas fired, absorption heat pump: (5)
- Yazaki gas fired or HW driven, absorption chiller: (5 to 100)
- York/Johnson Controls/Hitachi absorption chillers: (30 to 4000)
- Trane HW driven absorption chillers: (112 to 465)
- Thermax (India) HW driven absorption chillers: (20 to 1150)
- Broad (China) HW driven absorption chillers: (66 to 3307)
Humidity Control

- Ventilation with outdoor air
- Active refrigeration based or chilled water dehumidification
- Desiccant dehumidification with thermal reactivation (best practice for grow-rooms)
Grow room desiccant dehumidification

- Electric or natural gas fired (lower cost)
  - Direct fired gas burner or Hot Water
- Electricity to run fan only
- Can dehumidify with lights off, with slight heating effect (no cooling)
- Best used with waste heat from CHP, or engine driven cooling systems, (essentially free dehumidification)
Delivery of Nutrients

- CO2
- N, P, K, minerals
  - Soil
  - Hydroponics
CO2 Supplementation

• Ambient CO2 ~410 ppm (April 2018)
• During daylight hours CO2 may be rapidly depleted during crop production
• Depletion may be exacerbated during winter production when there is less ventilation
• Yields can increase ~33% if CO2 doubles
CO2 Concentration vs Photosynthesis

Relative Photosynthetic Rate

CO2 Concentration, ppm

Ambient 2018
CO2 Concentration Levels

• 1,000 ppm or more have shown to increase tomato yields economically

• However, you must adjust based on plant maturity and environmental conditions
  • Bright, sunny weather 1000 ppm
  • Cloudy weather 750 ppm
  • Young plants 700 ppm
  • During moderate ventilation 350-400 ppm
  • Less needed as temperature and ventilation rates increase
CO2 Supplementation Sources

- Liquid CO$_2$ (*relatively inexpensive*)
- Combustion of natural gas or propane
  - Direct fire burners
  - ‘Conventional” Boiler exhaust
  - CHP engine or turbine exhaust

```
  natural gas  →  BOILER  →  HW, CO2, H2O

Conventional
```
```
  natural gas  →  CHP  →  Electricity, HW, CO2, H2O

Cogeneration
```
Natural Gas Combustion

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]
Natural Gas Combustion

1 MCF natural gas

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

- CH\(_4\): 53 lb
- 2O\(_2\): 159.5 lb
- CO\(_2\): 117 lb
- 2H\(_2\)O: 95.7 lb

1 MMBTU heat

11.4 gallons water
Cost of Natural Gas Derived CO2

 Approximately 1 Lb. of CO2 per hour per 1,000 sq. ft. yields 1,000 ppm's of CO2


Natural Gas CO2 Generation

<table>
<thead>
<tr>
<th>MMBTU</th>
<th>$ / lb CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.00</td>
<td>$0.034</td>
</tr>
<tr>
<td>$5.00</td>
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</tr>
<tr>
<td>$6.00</td>
<td>$0.051</td>
</tr>
<tr>
<td>$7.00</td>
<td>$0.060</td>
</tr>
<tr>
<td>$8.00</td>
<td>$0.068</td>
</tr>
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</table>
Supply of Electricity

- Utility company
- Renewables
  - Solar PV
  - Wind turbines
- Combined Heat and Power
  - Special case for greenhouse application
  - It is a heating source (boiler)
  - It is a distributed generation source
  - It is the best “Energy Efficiency” technology
  - It is also a source of CO2 and H2O
Combined Heat and Power

• Use condensing waste heat recovery (when using CO2)
• Gas treatment is required
  – Oxidizing catalyst
  – SCR urea based NOx scrubber
  – Sensors to test for NOx, ethylene, unburned HC’s
• Inherently CHP is:
  – a heating source: HW boiler
  – a source of electric power
  – the best “Energy Efficiency” technology
  – also a source of CO2 and H2O
What does CHP look like?

*Combustion Gas Turbine*
Reciprocating Engine Options

- Can produce HW or steam
- Often lower capital costs
- More flexible turndown
- Higher electrical efficiency
Thermally Driven Cooling (A/C)

Distributed Generation Technologies
- Gas-turbine
- Microturbine
- Commercial Phosphoric Acid Fuel Cell
- I.C. Engine
- Residential PEM Fuel Cell

Thermally-Activated HVAC Technologies
- Triple-Effect Absorption Chiller
- Double-Effect Absorption Water-Cooled Chiller
- Single-Effect Absorption Chiller
- Desiccant Technology

Recoverable Energy Quality (Temperature) and HVAC Technology Match
What is CHP

Combined Heat and Power (CHP), Cogeneration, also known as on-site power generation, Distributed Generation (DG) and others, is the simultaneous production of electricity and useful waste heat. Any facility that has significant thermal load requirements could be a technical fit for CHP. The economic fit will depend on the electric cost of electricity, how closely the thermal demand matches the thermal production, and the installation complexity (project first cost).

Today, energy efficiency and environmental impacts are on everyone’s mind. Understanding the real costs of the energy we consume in our buildings is also very important. CHP efficiency captures the energy content of both electricity and useful heat, it is the net electrical output plus the net useful thermal output of the CHP system divided by the fuel consumed in the production of electricity and heat.

CHP Efficiencies

Conventional Power Generation

- Power Station Fuel (103)
- Total Fuel 168
- Boiler Fuel (65)

Efficiency ~ 33%

Combined Heat & Power

- Combined Heat and Power System
- CHP Fuel 100

- Efficiency ~ 83%
- Total Efficiency 83%

Click for Video
Spark Spread - $8 Gas

$8.00 per MMBTU Natural Gas Cost

Electric Cost

1.5:1
5:1

Electric Dollars per MMBTU

Electric Dollars per kWh
Spark Spread - $6 Gas

- Electric Dollars per MMBTU
- Electric Dollars per kWh

- Electric Cost
- 7:1

- $6.00 per MMBTU Natural Gas Cost

- 2:1
Spark Spread - $4.50 Gas

Electric Dollars per MMBTU

Electric Dollars per kWh

$4.50 per MMBTU Natural Gas Cost

Electric Cost

4:1

9:1
Boiler and Liquid CO2 Supplementation

Source: GE Jenbacher
CHP System (Combined Heat and Power)

Source: GE Jenbacher
Lighting

- **Natural light**
  - Maximize use of natural light!
  - For indoor grow rooms, consider skylight tubes

- **Artificial light sources**
  - HPS (single and double ended)
  - MH (pulse start and ceramic)
  - LED
Photosynthetically Active Radiation
400nm to 700nm
Case Studies

- Howling Tomatoes – Camarillo, CA
- Great Northern (Tomatoes) – Kingsville, ONT
- Coldwater Municipal – Coldwater, MI
Houweing Tomatoes

- 125 acre greenhouse
- Camarillo, California (north of Los Angeles)
- Three reciprocating natural gas engines
  - Over 40% electrical efficiency
  - Over 90% overall efficiency
- 13 MW total with excess power exported to grid
  - condensing waste heat exchanger
- Natural Gas CHP: four products utilized
  - electricity
  - heating
  - CO2 exhaust (treated for use in greenhouse)
  - Condensed H2O (treated for use in hydroponics)
Houweling Tomatoes - California

Reciprocating Engines

Three Jenbacher ultra-low emission natural gas fueled reciprocating engines provide the electricity needed for greenhouse operations while lowering carbon dioxide emissions and saving water resources. The system generates more electricity than the greenhouse can use, allowing it to sell the excess back to the power grid.

CO₂ Fertilization Process

37,000 tons of CO₂ are diverted yearly by purifying engines exhaust into fertilizer.

Heat

Over 15.9 MW of thermal power is captured from the heat produced in the engines during the power generation.

Condensed Water

Condensed water from the exhaust gas system helps conserve 9,500 gallons of water per day.

Power

The gas engine provides 13.2 MW of electrical power. It is equivalent to over 5,000 homes’ electrical demand.

Image: Southern California Gas
• Kingsville, ONT, Canada
• 50 acres of hydroponics tomatoes
• 5 acres under HPS lighting
• 12 MW electric CHP system
  – Sells electricity to Ontario Power Authority
• Uses mainly heat and CO2 on-site
Coldwater, MI (Municipal utility)

- System was installed adjacent to large commercial greenhouse operation for CHP & CO2
- Currently operating as a peaking plant
- 13 MW electric Jenbacher CHP system
Urea Tank & Exhaust Treatment Controls
Liquid CO2 Tank
Next, the Emerging Cannabis Industry
Grow Room
Transpiration

TEMPERATURE,
HUMIDITY,
WIND

H₂O
(irrigation rate)
What is this “Vapor Pressure Deficit”?
Vapor Pressure Deficit drives the nutrient flow
Growth Cycle

• Mother plants maintained in separate room
• Clones transplant #1 into 5”x5” pots (18 Days)
• 5”x5”s transplant #2 into 3 gallon pots (3-4 weeks)
• 3 gallon Mature to ~3ft tall (3-4 weeks)
• (~10 weeks) in flowering room Harvest
  – Additional growth occurs during flowering
  – Mature watering rate ~0.5 to 1.0 gallon/day/plant

Source: John Knapp, Good Meds, Denver, CO June 2018
Good Meds: Cannabis Operation – Warehouse Retrofit

John Knapp
Executive Manager and Owner

Good Meds
Denver, CO

GOOD MEDS
Flowering Room
Estimated Indoor Cannabis Energy Consumption

Grow Room Mass and Energy Balance

- **Electrical Energy**
- **Carbon Dioxide**
- **H₂O** (irrigation rate)

**Legend**
- Energy (yellow)
- Mass (blue)

**Closed System**
- Building envelope heating or cooling (relatively small, so we will neglect)
- Evaporation = Space cooling
- Transpiration
- Temperature & Humidity Setpoints (constant)

**Cooling**
- Dehumidification / water condensation
Flowering Room, Lights ON 12 hrs/day

(qty 24) mature plants
(qty 4) 1,000 Watt HPS Fixtures

Electrical
4,320 W

H₂O (0.75 gallon/day/plant) assume 75% during lights on for 120 lb evaporation

Lighting (Heat) = 176,880 BTU
Evaporation = 116,490 BTU

Transpiration

Temperature & Humidity Setpoints (constant)

Legend

Energy

Mass

Sensible Clg: 1.2 tons
Latent Clg: 0.8 tons
TOTAL: 2.0 tons

NOTE: If a conventional DX dehumidifier is used, some reheat is needed, and this is supplied by the condenser.
Flowing Room, Lights OFF 12 hrs/day

(24) mature plants
(4) 1,000W HPS Fixtures

Night heat: 2,400 BTU

H₂O (0.75 gallon/day/plant) assume 25% during lights on for 30 lb evaporation

Legend

Energy

Mass

Closed System

Evaporation = 2,400 BTU

Low Transpiration

Temperature & Humidity Setpoints (constant)

Latent Clg: 0.2 tons

Neglect Building envelope
Four Pipe Fan Coil

HVAC engineer needs to size to your room loads: coils, fan CFM, controls, etc…
Non-Ventilated Grow Room Energy Model

### Light schedules and humidity estimates

**Indoor Grow Room Power and Cooling Model**

**Assumptions**

1. **Plant Counts**
   - **veg rooms**: 30
   - **flowing rooms**: 345

2. **Plant Class C License**
   - 1,000 lights (1 W/ft²)
   - 1 Michigan Class C cannabis license

3. **Total Connected Lighting**
   - 345 kW total

4. **Lighting Total Connected Load**
   - 300 kW total

5. **Efficiency Coefficient of Performance of Thermally Activated Chiller**
   - 3.11 MMBTU/hr

6. **Additonal Grow Room Working Space**
   - 188 gallons per plant per day for VEG RM
   - 300 gallons per plant per day for FLOWERING RM

7. **58%**
   - Increase percentage for more safety factor

### Light Fixtures and Wattage

<table>
<thead>
<tr>
<th>Plant/room</th>
<th>Max chiller tonnage that the CHP free waste heat can provide</th>
<th>Net sensible heating (lights - evap.)</th>
<th>BTU/lb per minute</th>
<th>Est. lb evaporation per plant / hour LIGHTS ON for a 12/12 schedule</th>
<th>Est. lb evaporation per plant / hour LIGHTS OFF for a 12/12 schedule</th>
<th>Estimated % evaporation during LIGHTS ON for a 12/12 schedule</th>
<th>Estimated % evaporation during LIGHTS OFF for a 12/12 schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:00</td>
<td>350.28 W / sq foot for DE HPS</td>
<td>160 kW</td>
<td>0.93</td>
<td>0.001 kW estimated for cloning / mother room</td>
<td>45 Watts total per fixture</td>
<td>3.00</td>
<td>3%</td>
</tr>
<tr>
<td>18:00</td>
<td>728,082 BTU/hr</td>
<td>362,052 BTU/hr</td>
<td>0.44</td>
<td>10 kg/mol</td>
<td>4.0</td>
<td>17.68</td>
<td>730</td>
</tr>
<tr>
<td>20:00</td>
<td>1,500</td>
<td>200 kW</td>
<td>0.30</td>
<td>12</td>
<td>20</td>
<td>188</td>
<td>150</td>
</tr>
<tr>
<td>5/16/2017</td>
<td>778,667</td>
<td>472.5</td>
<td>0.1043</td>
<td>78.8</td>
<td>31.3</td>
<td>5:00</td>
<td>218.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.3128</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Redundancy Boiler for Absorbers**

- 1 Extra redundant unit (+1)
- One additional unit for maintenance and redundancy

**Inputs:** Light fixture count, wattage, and watering rates

**Outputs:**

- Watering
- Net sensible heating (lights - evap.)
- BTU/lb per minute
- Est. lb evaporation per plant / hour
- Estimated % evaporation during LIGHTS ON for a 12/12 schedule
- Estimated % evaporation during LIGHTS OFF for a 12/12 schedule

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**Non-Ventilated Grow Room Energy Model**

**Lighting total connected load**: 300 kW total

**Lighting Power Load**: 300 kW total

**Estimated % evaporation during LIGHTS ON**: 3.00

**Estimated % evaporation during LIGHTS OFF**: 3%

**BTU/lb per minute**: 0.93

**Est. lb evaporation per plant / hour LIGHTS ON**: 10 kg/mol

**Est. lb evaporation per plant / hour LIGHTS OFF**: 4.0

**Estimated % evaporation during LIGHTS ON**: 17.68

**Estimated % evaporation during LIGHTS OFF**: 730

**BTU/lb per minute**: 0.30

**Est. lb evaporation per plant / hour LIGHTS ON**: 12

**Est. lb evaporation per plant / hour LIGHTS OFF**: 20

**Estimated % evaporation during LIGHTS ON**: 5:00

**Estimated % evaporation during LIGHTS OFF**: 218.9
Indoor Grow Room Power and Cooling Model
Jim Leidel
version 5/16/2017

Assumptions

Lighting and Space

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 sq foot per plant</td>
<td></td>
</tr>
<tr>
<td>65 W / sq foot for DE HPS</td>
<td></td>
</tr>
<tr>
<td>520 W / plant</td>
<td></td>
</tr>
<tr>
<td>1,000 W DE HPS light fixture</td>
<td></td>
</tr>
<tr>
<td>4 plants / 1,000 W DE HPS</td>
<td></td>
</tr>
</tbody>
</table>

One Michigan Class C cannabis license

<table>
<thead>
<tr>
<th>Plant Counts</th>
<th>Rooms</th>
<th>Plant/room</th>
<th>HPS/room</th>
<th>Plant total</th>
<th>HPS total</th>
</tr>
</thead>
<tbody>
<tr>
<td>cloning room</td>
<td>1</td>
<td>300</td>
<td>n/a</td>
<td>300</td>
<td>n/a</td>
</tr>
<tr>
<td>veg rooms</td>
<td>2</td>
<td>300</td>
<td>75</td>
<td>600</td>
<td>150</td>
</tr>
<tr>
<td>flower rooms</td>
<td>4</td>
<td>150</td>
<td>38</td>
<td>600</td>
<td>150</td>
</tr>
<tr>
<td>TOTALS</td>
<td>7</td>
<td>1,500</td>
<td>300</td>
<td></td>
<td></td>
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</table>

Total Connected Lighting

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 W DE HPS fixtures (or metal halide for veg rooms)</td>
<td>12,000 square feet minimum area required</td>
</tr>
<tr>
<td>1,050 Watts total per fixture</td>
<td>30 kW estimated for cloning / mother room</td>
</tr>
<tr>
<td>345 kW total connected load for lighting for circuit sizing from grid</td>
<td></td>
</tr>
</tbody>
</table>

Watering Rate (per plant in veg and flower rooms)

<table>
<thead>
<tr>
<th>Watering Rate</th>
<th>Plants per day for VEG RM</th>
<th>Plants per day for FLOWERING RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 gallons</td>
<td>4.0 pints / day</td>
<td>12.0 pints / day</td>
</tr>
<tr>
<td>1.5 gallons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.34 lb per gallon water (conversion factor)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VEG ROOMS

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% estimated % evaporation during LIGHTS ON for a 12/12 schedule</td>
<td>0.2433 est. lb evaporation per plant / hour LIGHTS ON for a 12/12 schedule</td>
</tr>
<tr>
<td>30% estimated % evaporation during LIGHTS OFF for a 12/12 schedule</td>
<td>0.1043 est. lb evaporation per plant / hour LIGHTS OFF for a 12/12 schedule</td>
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</tbody>
</table>

FLOWERING ROOMS

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>70% estimated % evaporation during LIGHTS ON for a 12/12 schedule</td>
<td>0.7298 est. lb evaporation per plant / hour LIGHTS ON for a 12/12 schedule</td>
</tr>
<tr>
<td>30% estimated % evaporation during LIGHTS OFF for a 12/12 schedule</td>
<td>0.3128 est. lb evaporation per plant / hour LIGHTS OFF for a 12/12 schedule</td>
</tr>
</tbody>
</table>
### Lighting Schedules

<table>
<thead>
<tr>
<th>Hour</th>
<th>Time</th>
<th>CloneRM kW</th>
<th>VEG1 kW</th>
<th>VEG2 kW</th>
<th>FLWR1 kW</th>
<th>FLWR2 kW</th>
<th>FLWR3 kW</th>
<th>FLWR4 kW</th>
<th>Total kW</th>
<th>Total lb H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>0:00</td>
<td>30.0</td>
<td>78.8</td>
<td>73.0</td>
<td>off</td>
<td>39.4</td>
<td>off</td>
<td>39.4</td>
<td>188</td>
<td>730</td>
</tr>
<tr>
<td>1:00</td>
<td>1:00</td>
<td>30.0</td>
<td>78.8</td>
<td>73.0</td>
<td>off</td>
<td>39.4</td>
<td>off</td>
<td>39.4</td>
<td>188</td>
<td>730</td>
</tr>
<tr>
<td>2:00</td>
<td>2:00</td>
<td>30.0</td>
<td>78.8</td>
<td>73.0</td>
<td>off</td>
<td>39.4</td>
<td>off</td>
<td>39.4</td>
<td>188</td>
<td>730</td>
</tr>
<tr>
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**Model for One Michigan Class C License of 1,500 Plants**

750.6 lb/hr avg
### Lighting Loads to Size CHP

<table>
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<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Lighting total connected load</td>
<td>345 kW</td>
</tr>
<tr>
<td>Max Lighting Power Load</td>
<td>266 kW</td>
</tr>
<tr>
<td>Add'l Power (pumps, fans, clone rm., etc...)</td>
<td>20%</td>
</tr>
<tr>
<td>Add'l Power (pumps, fans, clone rm., etc...) kW</td>
<td>53</td>
</tr>
<tr>
<td>Total Est. Power</td>
<td>320 kW</td>
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</tbody>
</table>

**Notes:**
- For electrical circuit sizing, NOT CHP sizing
- Largest value from Total kW column X from lighting schedules
- Increase percentage for more safety factor
- Total CHP load under full production, to minimum CHP capacity
- Recommend 2-3 units minimum for redundancy
- One additional unit for maintenance and redundancy

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>CHP units (sized to load)</td>
<td>2</td>
</tr>
<tr>
<td>CHP unit size each</td>
<td>160 kW</td>
</tr>
<tr>
<td>Extra redundant unit (+1)</td>
<td>160 kW</td>
</tr>
<tr>
<td>Total Number of CHP units</td>
<td>3</td>
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<tr>
<td>CHP unit size each</td>
<td>160</td>
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<tr>
<td>Total CHP plant capacity (including +1)</td>
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### CHP Plant Thermal Output Calculations

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<td>CHP unit electrical output</td>
<td>320 kW</td>
</tr>
<tr>
<td>CHP unit electrical efficiency</td>
<td>35.0%</td>
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<tr>
<td>CHP natural gas fuel input</td>
<td>913 kW</td>
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<tr>
<td>CHP natural gas input MMBTU/hr</td>
<td>3.11</td>
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<tr>
<td>CHP thermal efficiency</td>
<td>45.0%</td>
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<tr>
<td>CHP thermal output MMBTU/hr</td>
<td>1.40</td>
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<tr>
<td>typical single effect absorption chiller COP</td>
<td>0.70</td>
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<tr>
<td>max possible absorption chiller capacity MMBTU/hr</td>
<td>0.98</td>
</tr>
<tr>
<td>max possible absorption chiller capacity tons</td>
<td>82</td>
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### Lighting + Dehumidification Loads to Size Absorption Chiller

<table>
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<tbody>
<tr>
<td>Sensible heating from lighting</td>
<td>320 kW</td>
</tr>
<tr>
<td>Sensible heating from lighting BTU / hr</td>
<td>1,090,134</td>
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<tr>
<td>Avg. irrigation rate lb / hr water</td>
<td>750.6</td>
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<tr>
<td>Latent heat of evaporation BTU / lb</td>
<td>970</td>
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<tr>
<td>Evaporative cooling from water BTU / hr</td>
<td>728,082</td>
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<tr>
<td>Net sensible heating (lights - evap.) BTU / hr</td>
<td>362,052</td>
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<td>Net sensible heating (lights - evap.) tons</td>
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<tr>
<td>Dehumidification chilled water load BTU / hr</td>
<td>728,082</td>
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<td>Dehumidification chilled water load tons</td>
<td>61</td>
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<td>Total chilled water load</td>
<td>91 tons</td>
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<tr>
<td>Number of chillers sized to meet load</td>
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<tr>
<td>Chiller size each (absorption) tons</td>
<td>45</td>
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<tr>
<td>Extra redundant unit (+1)</td>
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<tr>
<td>Total Number of Chillers</td>
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<tr>
<td>Chiller size each (absorption) tons</td>
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<td>Total absorption chiller plant capacity tons</td>
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### Boiler Sizing

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<tr>
<td>Backup boiler (sized to run one absorber) BTU / hr</td>
<td>778,667</td>
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<td>Backup boiler (sized to run one absorber) MMBTU/hr</td>
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<tr>
<td>Backup boiler (sized to run one absorber) MCF/hr</td>
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<td>Redundancy boiler for absorbers MMBTU/hr</td>
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<td>Est. approx. boiler size MCF/hr</td>
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Combined Heat and Power

Combined Heat & Power

- less fuel (typically natural gas) 75-85%
- power
- heat
- less waste

Separate Production of Electricity & Heat

- coal, natural gas, & nuclear 30-40%
- power
- heat
- significant waste

combined efficiency is dramatically increased 80-90%
Conventional electric grid solution

- utility electric for lighting
- utility electric air cooled chiller cooling & dehumidification
- natural gas hot water boiler heating
Full natural gas solution with CHP

- utility electric for backup only
- natural gas Combined Heat and Power (CHP)
- waste heat absorption chiller (for cooling & dehumidification)
- waste heat, hot water heating
## Operating Energy Cost Comparisons

A: HPS on Grid with Electric A/C SEER=12  
B: HPS on CHP (35% electrical efficiency & absorption clg COP=0.7)  
C: LED on CHP (35% electrical efficiency & absorption clg COP=0.7)

| Grid Electric: | $0.12 per kWh | $120.00 per MWh |
| Natural Gas:   | $5.00 per MMBTU |

<table>
<thead>
<tr>
<th></th>
<th>Total Veg &amp; Grow</th>
<th>Total Fixture</th>
<th>Ballanced Lighting +20%</th>
<th>Lighting Energy</th>
<th>Ballanced Lighting +20%</th>
<th>Cooling</th>
<th>CHP + Boiler Gas</th>
<th>Total Electric</th>
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<th>Total Energy Cost</th>
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<th>Operating Energy Cost Comparisons</th>
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<tr>
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<td>MWh/yr</td>
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A: HPS on Grid with Electric A/C SEER=12  
B: HPS on CHP (35% electrical efficiency & absorption clg COP=0.7)  
C: LED on CHP (35% electrical efficiency & absorption clg COP=0.7)

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<tr>
<th>Grid Electric:</th>
<th>$0.12 per kWh</th>
<th>$120.00 per MWh</th>
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<tbody>
<tr>
<td>Natural Gas:</td>
<td>$5.00 per MMBTU</td>
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<th>Fixture</th>
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<td>MWh/yr MWh/yr</td>
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## Operating Energy Cost Comparisons

A: HPS on Grid with Electric A/C SEER=12  
B: HPS on CHP (35% electrical efficiency & absorption clg COP=0.7)  
C: LED on CHP (35% electrical efficiency & absorption clg COP=0.7)

| Grid Electric:  | $0.12 per kWh  | $120.00 per MWh |
| Natural Gas:    | $5.00 per MMBTU |

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## Operating Energy Cost Comparisons

### A: HPS on Grid with Electric A/C SEER=12

- **Grid Electric:** $0.12 per kWh
- **Natural Gas:** $5.00 per MMBTU
- **Total Energy Cost:** $673,920

### B: HPS on CHP (35% electrical efficiency & absorption clg COP=0.7)

- **Total Energy Cost:** $145,000

### C: LED on CHP (35% electrical efficiency & absorption clg COP=0.7)

- **Total Energy Cost:** $79,500

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Savings between A and C = $594,000 per year

Now include maintenance contracts and cost of capital to calculate a return on your CHP plant investment.
Project Development Notes for Discussion

• Construction timeline and phasing?
• Perform electric rate analysis with various lighting schedules
  – Compare to CHP, on site power generation
• Availability and capacity of sufficient 3 phase power
  – Cost to upgrade service to required capacity
• Availability, capacity and pressure of local natural gas supply
  – Cost to upgrade to required capacity
• Electric chilling vs CHP/absorption chilling cost comparison
• Look at all options, perform a 5-10 year pro-forma on various solutions to select optimal system.
Virtual Pipeline Option to Start (CNG)

- Trailers Load at Natural Gas Facility
- Empty Trailer Returns to Natural Gas Facility
- Full Trailer Departs for Customer Site
- Trailers Offload CNG at Customer Site
Conclusions

• LED tech is maturing and will be the most efficient and effective growing option for artificial light,

• Fully indoor grow environments have different load profiles and energy use requirements: cooling & dehumidification dominate,

• Supplying sufficient energy to serve your facility and operations can be done more cost effectively with Natural Gas,

• Low cost natural gas CHP can substantially lower your operating costs.
Questions?

Jim Leidel
DTE Energy
james.leidel@dteenergy.com
248.765.2027