BURNING WOOD FOR COMBINED HEAT & POWER

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Administrative Director of Facilities and Engineering
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Prior experience:

– 18 years: as Healthcare Director of Engineering
  St Francis Hospital in Hartford
  Connecticut Children’s Medical Center
  ECHN Manchester Memorial and Rockville General

– 7 years: Aerospace Design/Development Engineer as
  Hamilton Sundstrand – Boeing 747/767 Environmental Controls

– 4 years: Energy Engineer at Savage Engineering

– BSME University of Hartford
Presentation Agenda

• Cooley Dickinson Hospital Overview
• Wood Chip Plant Operation
• Implemented Energy Savings Initiatives
• Cogeneration / CHP / Plant Operations
• Financials
• Q & A
Cooley Dickinson Hospital
Northampton, Massachusetts

Vision: To Become a Model Community Hospital
Cooley Dickinson Geographic

- Rural Northampton, Massachusetts community hospital
- 125 Year Anniversary
- Currently in affiliation process with Mass General Hospital
- 600,000 square-foot main hospital
- 140 in-patient beds
- 1100 employees

Fuel consumption (approximately)
- 16,150,000 KWH in 2009 and 12,500,000 KWH in 2012 (11.5 cents)
- 100,000 therms of nat gas at $.67 per therm (back up gas boilers)
- 15,000 tons of wood chips at $26/ton ($390,000) = $.39 oil
  - Equivalent to 1,000,000 gallons of #2 oil $3,500,000 or nat gas $1,500,000
- Two micro-steam turbines produce
  - 350 KW of 2,000 KW peak load (17.5%)
  - 2,000,000 KWH per year (12.5%)
- 680 ton absorption chiller (50% of hospital cooling)
Cooley Dickinson Hospital Wood Plant

Presentation based on Cooley Dickinson’s experience

• First Wood Chip plant installed in 1984
  – Zurn – 550 HP with Wet Scrub emissions

• Second Wood Chip plant installed in 2006 with 120,000 sq ft building expansion
  – AFS – 600 HP Water/Fire Tube with Bag House emissions which removes minimum of 99.5% particulate removal

• Plant runs on one of the two boilers

• Boilers down about one month per year for maintenance

• Boilers only burn whole tree virgin wood

• Ash product can be recycled by local farmers

• Additional gas/oil boilers for backup with fuel tank
Cooley Dickinson Hospital Wood Plant

- **Wood process involves:**
  - Large amounts of space
  - Access for tractor trailers (1-2 loads per day)
  - Labor to manage plant operations (two 24/7 FTE’s)
  - Noise control
  - Well-wooded geographic location

- **Operating expenses:**
  - Service contracts on equipment (turbine/chiller)
  - Maintenance repairs – wear and tear:
    » Conveyors
    » Feeders
    » Chipper
    » Bucket loader
  - 1 month downtime in fall and 2 weeks in spring
  - Funds to refurbish every few years (approx $50,000)
Power Plant Line Diagram

Wood Chips

550 HP
Zurn Boiler

600 HP
AFS Boiler

250 lb Steam

80 lb Steam

Turbine

240 KW

Cooley Dickinson Hospital

200 KW

Turbine

15 lb Steam

200 KW

80 lb Steam

680 Ton
Absorption Chiller

490 Ton
Absorption Chiller

80 lb Steam

Chilled Water to Hospital - Air Conditioning

Back Up Electric Chillers

Chilled Water

Wet scrub emissions system

Bag house emissions system

Steam to hospital - process & heat

Winter

Summer
Overall plant buildings
Cooley Dickinson Hospital
Power Plant Photos

Overall boiler plant
Cooley Dickinson Hospital
Power Plant Photos

New chiller plant on right
Biomass / Wood

Wikipedia definition:

Biomass is any organic material which has stored sunlight in the form of chemical energy. As a fuel it may include wood, wood waste, straw, manure, sugarcane, and many other byproducts from a variety of agricultural processes.
Woodchip Specification

We only burn virgin wood:

Excerpts from Cooley Dickinson Woodchip RFP

- **WOOD CHIPS** will be provided/delivered to Cooley Dickinson Hospital Power Plant for fuel use in Boiler Room. **WOOD CHIPS Specifications** must meet: The state DEP requirement is 1.5 inch virgin whole tree chips.

- Additionally - chips shall be no less than 50% hardwood per truckload. **Wood from the waste stream, such as used pallets or construction debris, is not allowed.** Wood shall be free of sticks or brush, or foreign objects such as rocks or metal.
Woodchip Burner at Cooley Dickinson Hospital

You Tube 2007 HS student project

First Place, Documentary, MA 2007 "Imagining Tomorrow: Alternate Energy Futures" (Massachusetts Competition.)

IMAGINING TOMORROW is a creative writing and video contest about clean energy open for all high-school students in the United States. Sponsored by The Foresight Project, a non-profit corporation, top entries at state or regional levels go on to the national contest, with $10,000 committed in prizes to the national winners.

http://www.youtube.com/watch?v=fsNocaPsvfE&feature=player_detailpage or click on the fire below.
Cooley Dickinson Hospital
Wood Chip Delivery
Cooley Dickinson Hospital
Wood Chip Delivery
Cooley Dickinson Hospital
Wood Chip Delivery
Cooley Dickinson Hospital
Wood Chip Delivery
Cooley Dickinson Hospital
Wood Loading Process

Shaker and Hammer Mill to AFS Boiler
Cooley Dickinson Hospital
Wood Loading Process
Cooley Dickinson Hospital
1984 Zurn Boiler
Cooley Dickinson Hospital
1984 Zurn Boiler
Cooley Dickinson Hospital
2006 AFS Boiler

AFS Boiler
Cooley Dickinson Hospital
2006 AFS Boiler

AFS Boiler Turbine

Bag house emissions
2009 Energy Initiatives

Carrier Corporation Strategic Partnership Program to Reduce Operating Costs

First step to a Cogeneration program is to optimize energy utilization

• Central Plant Energy Efficiency Improvements:
  – Two Micro-turbine
  – One chilled water steam absorber – air condition
  – Return air modification on four existing air handlers

• Air distribution:
  – Variable frequency drives
    • One on existing 500-ton Carrier electric centrifugal chiller
    • Five on chilled water, condenser water and cooling tower pumps & motors
  – Three way valve conversions on 10 air handlers

• Control system modifications – replace older pneumatic controls

• Lighting system upgrade

• Steam distribution and blanket insulation

• Water conservation – installed wells for plant make up water systems
Summary of Proposed Savings

$3.5 million investment on energy efficiency and turbine installation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Proposed Annual</th>
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</thead>
<tbody>
<tr>
<td>CSM 1 Central Plant</td>
<td>$261,591</td>
</tr>
<tr>
<td>CSM 2 Air Distribution</td>
<td>$43,204</td>
</tr>
<tr>
<td>CSM 3 Controls</td>
<td>$11,846</td>
</tr>
<tr>
<td>CSM 4 Lighting</td>
<td>$87,273</td>
</tr>
<tr>
<td>CSM 5 Steam Distribution</td>
<td>$21,750</td>
</tr>
<tr>
<td>CSM 6 Water Conservation</td>
<td>$23,105</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$448,769</strong></td>
</tr>
</tbody>
</table>
### Summary of Incentives

<table>
<thead>
<tr>
<th>Measure</th>
<th>Rebate Estimated Original Proposal</th>
<th>Rebate and Grants Estimated as of 3/10</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSM 1 Power Plant</td>
<td>$500,000</td>
<td>$372,780</td>
<td>$(127,220)</td>
</tr>
<tr>
<td>CSM 2 Air Distribution</td>
<td>$11,800</td>
<td>$11,800 e</td>
<td>$0</td>
</tr>
<tr>
<td>CSM 3 Controls</td>
<td>$13,150</td>
<td>$13,150 e</td>
<td>$0</td>
</tr>
<tr>
<td>CSM 4 Insulation</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>CSM 5 Lighting</td>
<td>$51,000</td>
<td>$153,337</td>
<td>$102,337</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$575,950</strong></td>
<td><strong>$551,067</strong></td>
<td><strong>$(24,883)</strong></td>
</tr>
</tbody>
</table>

*Note: Does not include any renewable energy credit $*$

Hospital obtained an additional $206,250 incentive from National Grid Power Hospital in process of marketing energy credits (approximately $50,000 per yr)
Cogeneration / CHP

Wikipedia definition of Cogeneration
- also referred to as CHP - combined heat and power
- is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat
- Process puts to use the waste heat from creating electricity
- The "co" in cogeneration simply means taking advantage of all the uses of one source of energy.
- It means producing additional energy with much of the energy that would be wasted in the typical utility process.

Cooley Dickinson’s process is different by:
- Produce steam from wood
- Use steam to then drive turbine to make electricity
- Use steam to heat or cool
Cogeneration / CHP Facts

• Requires year-round consistent heat and electric load
  – Design needs to:
    • use majority of heat or electricity being generated
    • have consistent load through 4 weather seasons
  Examples:
    Can’t size for full summer electric load unless you can use heat
    Can’t size for full winter heat load unless you can use electricity

• Incentives only apply with such design
• Many hospitals are good sites, if they have large laundry or sterilization processes.
Wikipedia definition of an absorption refrigerator:

- Uses a heat source to provide the energy needed to drive the cooling system.
- Absorption refrigerators are a popular alternative where:
  - electricity is unreliable, costly, or unavailable,
  - surplus heat is available (turbine exhausts or industrial processes)
- Changes the refrigerant gas back into a liquid using heat (electric system uses pressure)
- The absorption cooling cycle can be described in three phases:
  - Evaporation: A liquid refrigerant evaporates in a low partial pressure environment, thus extracting heat from its surroundings – the refrigerator or chilled water loop.
  - Absorption: The gaseous refrigerant is absorbed – dissolved into another liquid - reducing its partial pressure in the evaporator and allowing more liquid to evaporate.
  - Regeneration: The refrigerant-laden liquid is heated, causing the refrigerant to evaporate out. It is then condensed through a heat exchanger to replenish the supply of liquid refrigerant in the evaporator.
Power Plant Line Diagram

Wood Chips → 550 HP Zurn Boiler → 600 HP AFS Boiler

- 80 lb Steam
- 250 lb Steam
- 240 KW Turbine
- 200 KW Turbine
- 15 lb Steam
- 80 lb Steam

Chilled Water to Hospital - Air Conditioning

Cooley Dickinson Hospital

- Steam to hospital - process & heat
- Summer
- Winter

Back Up Electric Chillers

- 680 Ton Absorption Chiller
- 490 Ton Absorption Chiller
- Chilled Water

Wet scrub emissions system
Bag house emissions system

80 lb Steam
Energent Micro-Steam Turbine
Chiller Turbine Output

Microsteam Power vs Flow
75 psig inlet 16 psig outlet

![Microsteam Power vs Flow Graph](image-url)
AFS Boiler / Turbine controls
### Plant / Turbine Information

#### Tables calculates cost of running plant:

<table>
<thead>
<tr>
<th>Cooley Dickinson Central Plant Information</th>
<th>HP Turbine and Boiler Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2006 Electric Rate</strong></td>
<td>2006 Pre Project Steam Pressure Produced by Boilers</td>
</tr>
<tr>
<td></td>
<td>2006 Pre Project Steam Enthalpy</td>
</tr>
<tr>
<td>$0.11 $/kWh</td>
<td>114 psig</td>
</tr>
<tr>
<td></td>
<td>1192 btu/lb</td>
</tr>
<tr>
<td><strong>2011 Electric Rate</strong></td>
<td>2011 Post Project Steam Pressure Produced by Boilers</td>
</tr>
<tr>
<td>$0.12 $/kWh</td>
<td>2011 Post Project Steam Enthalpy</td>
</tr>
<tr>
<td></td>
<td>250 psig</td>
</tr>
<tr>
<td></td>
<td>1202.2 btu/lb</td>
</tr>
<tr>
<td><strong>2006 Biomass Fuel Cost</strong></td>
<td>Feedwater Enthalpy</td>
</tr>
<tr>
<td>21.63 $/ton</td>
<td>190 Btu/ton</td>
</tr>
<tr>
<td><strong>2011 Biomass Fuel Cost</strong></td>
<td>Steam Pressure at Turbine Exit</td>
</tr>
<tr>
<td>27.5 $/ton</td>
<td>75 psig</td>
</tr>
<tr>
<td><strong>Fuel to Steam Efficiency</strong></td>
<td>Enthalpy of Steam at Exit of Turbine</td>
</tr>
<tr>
<td>80% %</td>
<td>1184.4 btu/lb</td>
</tr>
<tr>
<td><strong>Wood Fuel BTU Content</strong></td>
<td>Cost to Generate Steam at 2006 Pressure</td>
</tr>
<tr>
<td>4175 Btu/lb</td>
<td>3.24 $/klb</td>
</tr>
<tr>
<td><strong>Wood Fuel BTU Content</strong></td>
<td>Cost to Generate Steam at 2011 Pressure</td>
</tr>
<tr>
<td>8,350,000 Btu/ton</td>
<td>4.17 $/klb</td>
</tr>
<tr>
<td><strong>2006 Equivalent Steam Cost</strong></td>
<td>Turbine Steam Throughput</td>
</tr>
<tr>
<td>$3.24 $/klb</td>
<td>15000 lb/hr</td>
</tr>
<tr>
<td><strong>2011 Equivalent Steam Cost</strong></td>
<td>Turbine Steam Usage</td>
</tr>
<tr>
<td>$4.17 $/klb</td>
<td>1008 lb/hr</td>
</tr>
<tr>
<td><strong>Total Unit Throughput</strong></td>
<td>Total Unit Throughput</td>
</tr>
<tr>
<td></td>
<td>16008 lb/hr</td>
</tr>
<tr>
<td><strong>Useful Electrical Energy Output</strong></td>
<td>Useful Electrical Energy Output</td>
</tr>
<tr>
<td>243</td>
<td>241 kW</td>
</tr>
<tr>
<td><strong>Parasitic Loads for lube oil pump and fan for turbine</strong></td>
<td>Net Useful Electrical Output</td>
</tr>
<tr>
<td>2 kW</td>
<td>822,533 btu</td>
</tr>
<tr>
<td><strong>Net Useful Electrical Output</strong></td>
<td>Net Useful Thermal Output from Turbine</td>
</tr>
<tr>
<td>241 kW</td>
<td></td>
</tr>
<tr>
<td><strong>Btu Input to Turbine</strong></td>
<td>Btu Input to Turbine</td>
</tr>
<tr>
<td>24,056,022 btu</td>
<td></td>
</tr>
<tr>
<td><strong>Btu Output of Turbine</strong></td>
<td>Btu Output of Turbine</td>
</tr>
<tr>
<td>17,766,000 btu</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>Efficiency</td>
</tr>
<tr>
<td>77%</td>
<td>37</td>
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</tbody>
</table>
Cooley Dickinson Hospital

Turbine

Absorption chiller with Turbine
Cooley Dickinson Hospital

Centrifugal Electric Chiller with VFD

Double effect absorption chiller
## Chiller Run Cost Information

<table>
<thead>
<tr>
<th>Existing 500 Ton Electric Variable Speed Chiller IPLV</th>
<th>kW/Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnage on Machine</td>
<td>500 tons</td>
</tr>
<tr>
<td>Flow rate of condenser water</td>
<td>1500 gpm</td>
</tr>
<tr>
<td>HP of existing condenser water pump</td>
<td>60 hp</td>
</tr>
<tr>
<td>kW of existing condenser water pump (measured)</td>
<td>30.27 kW</td>
</tr>
<tr>
<td>Cost per ton-hr to operate chiller at 2006 rates</td>
<td>$33.52 /hr</td>
</tr>
<tr>
<td>Cost per ton-hr to operate chiller at 2011 rates</td>
<td>$39.62 /hr</td>
</tr>
</tbody>
</table>

| Existing 491 Ton Double Effect Chiller Efficiency   | lb/ton-hr |
| Steam pressure to machine                           | 114 psig |
| Enthalpy of steam at 114 psig                       | 1192 btu/lb |
| Tonnage on Machine                                  | 500 tons |
| Flow rate of condenser water                        | 2000 gpm |
| HP of existing condenser water pump                 | 100 hp |
| kW of existing condenser water pump (measured)      | 61.49 kW |
| kW of existing auxiliaries                          | 4.7 kW |
| Cost per ton-hr to operate chiller at 2006 rates    | $23.31 /hr |
| Cost per ton-hr to operate chiller at 2011 rates    | $29.19 /hr |

<table>
<thead>
<tr>
<th>CDH Chiller</th>
<th>2006 Rates</th>
<th>2011 Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Ton Const. Speed Chiller</td>
<td>$36.11</td>
<td>$42.68</td>
</tr>
<tr>
<td>500 Ton VFD Chiller</td>
<td>$33.52</td>
<td>$39.62</td>
</tr>
<tr>
<td>500 Ton DBL Effect Absorber</td>
<td>$23.31</td>
<td>$29.19</td>
</tr>
<tr>
<td>680 Ton Abs/Turbine</td>
<td>$21.56</td>
<td>$28.36</td>
</tr>
</tbody>
</table>

CDH Maintenance staff can decide chiller to run based on utility cost.
Peak Shaving

HVAC staff use real time meter data to see actual electric loads. Make decisions on most efficient equipment to run.
Cooley Dickinson Hospital

Electricity Savings Summary

Electricity usage through 1st Eight months of Fiscal Year

FY 2012 = 12,500,000 kwh
Cooley Dickinson Hospital
Wood Plant Performance

Electricity savings over past 3 FY's:

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity (kwh)</th>
<th>Cost @ .12</th>
<th>$Saved vs fy 09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fy 2009</td>
<td>16,146,000</td>
<td>$1,937,520</td>
<td>$ 149,520</td>
</tr>
<tr>
<td>Fy 2010</td>
<td>14,900,000</td>
<td>$1,788,000</td>
<td>$ 1,589,280</td>
</tr>
<tr>
<td>Fy 2011</td>
<td>13,244,000</td>
<td>$1,589,280</td>
<td>$ 348,240</td>
</tr>
</tbody>
</table>

Typical Summer Day at full production:

<table>
<thead>
<tr>
<th>Power Produced</th>
<th>kw</th>
<th>hrs/day</th>
<th>kwh</th>
<th>$/kwh</th>
<th>$/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>turbine 1</td>
<td>240</td>
<td>24</td>
<td>5,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>turbine 2</td>
<td>170</td>
<td>24</td>
<td>4,080</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Power</td>
<td>410</td>
<td></td>
<td>9,840</td>
<td>0.12</td>
<td>$ 1,181</td>
</tr>
</tbody>
</table>

Typical Summer Day:

Overhead costs:

Wood chips = $1600 (burn proportionally based on load)
Offset by $1200 of electricity savings from turbines
2 FTE Plant Operators 24/7

Output:

100% of 600,000 sf hospital heat and sterilization
680 ton absorption chiller equivalent to 600 +window air conditioners (offsets $1500 per day of electricity)
Cooley Dickinson Hospital
Sustainable Hospital Award

2011 Recipient of
VHA Leadership Award
Sustainability Excellence

Best in class program in energy management with a Cogeneration Plant.
2012 Boiler Project

$500,000 project to replace 50 year old Erie City Boiler
- Installing two 250 HP Miura Boilers
- Miura Boilers offers quick response to fluctuating changes or drop out of biomass plant
Questions and Answers