CORNELL 30 MW COMBINED HEAT AND POWER PROJECT

October 21, 2010

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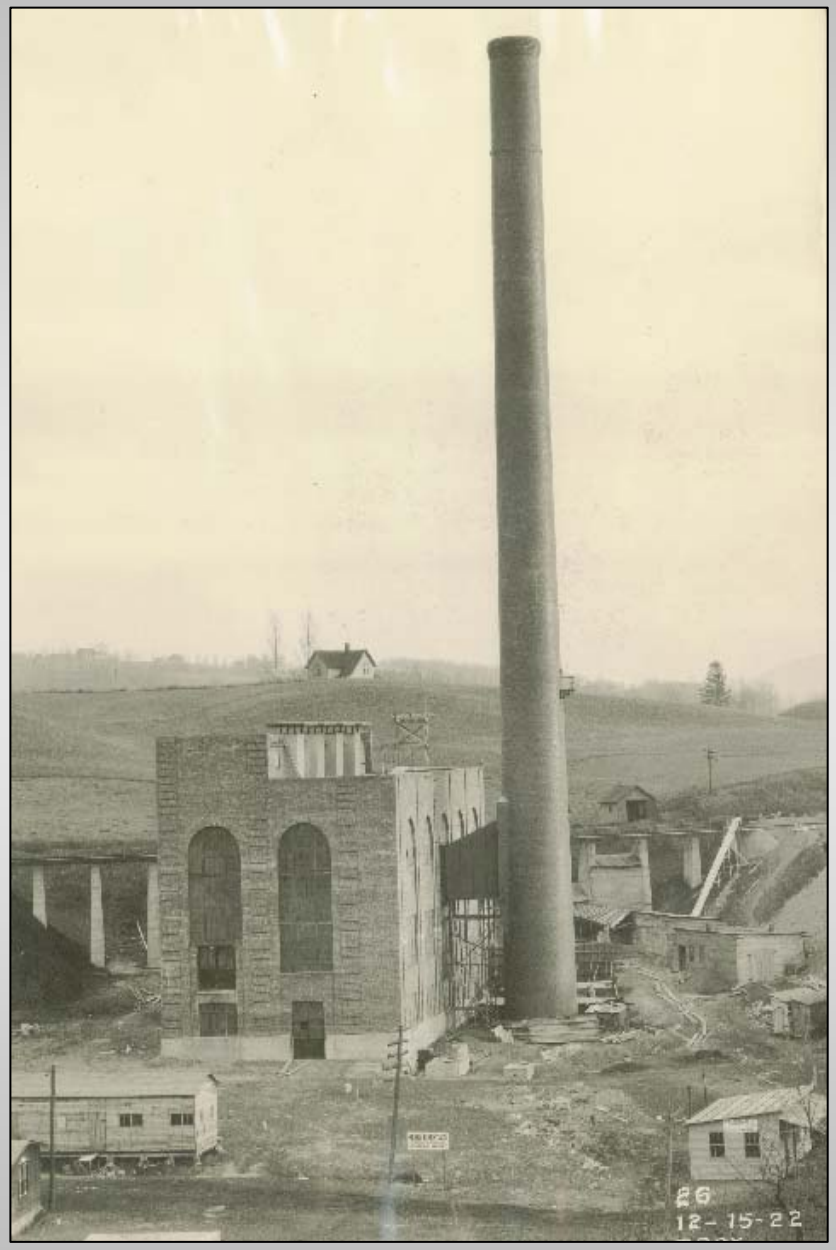
IAGT Fall 2010 Course
Hamilton Ontario

Cornell University

- Founded in 1865
- Member of Ivy League
- 1,600 Faculty
- 7,600 Staff
- 19,000 Students
- Central Utilities and Energy Management provides steam and chilled water to 300 buildings totaling 14,000,000 ft^2
  - 57% Endowed Cornell Campus
  - 40% State funded facilities
  - 3% Federal & Private Research
- Continuing to expand

Cornell University

Central Heating Plant

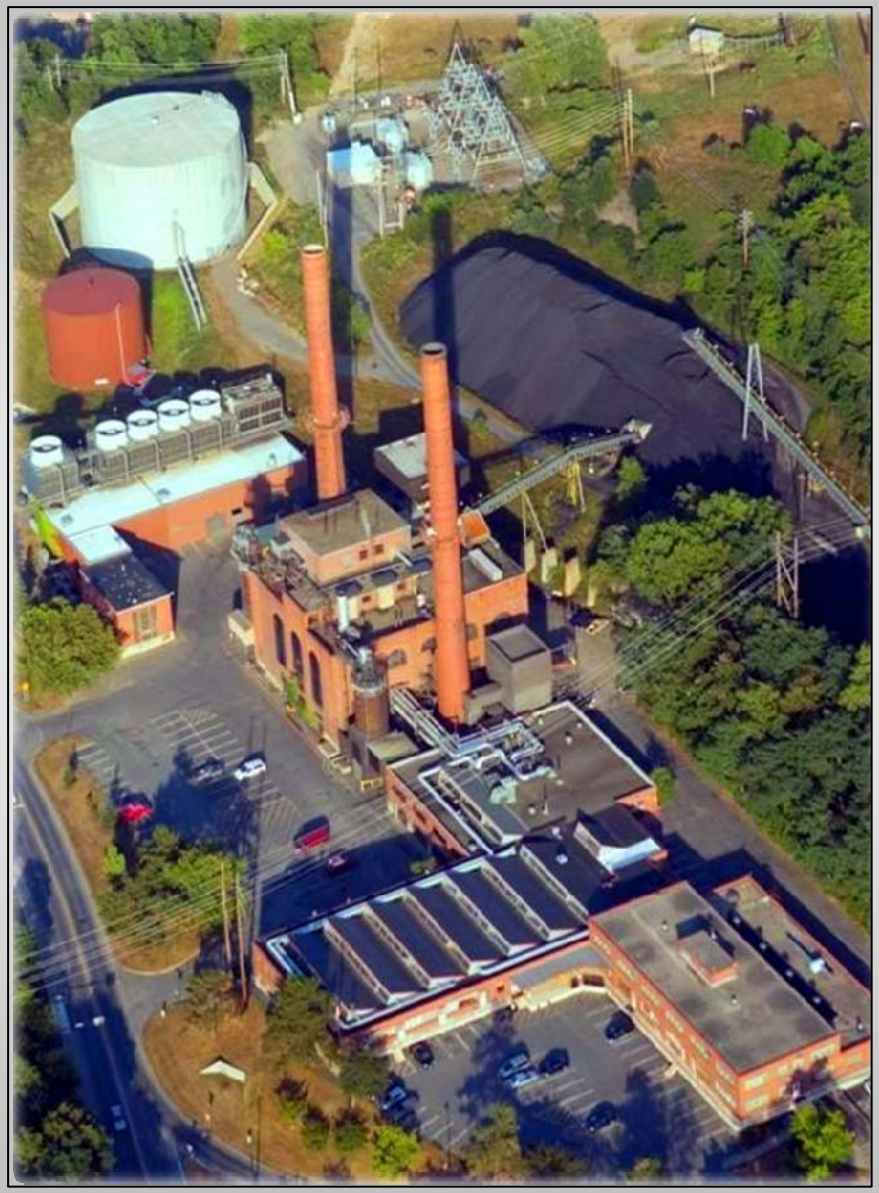


Central Heating Plant

- Six existing steam boilers

Boiler	Fuel	Pressure	Capacity
1	Coal	400 psig	75,000 lb/hr
2	#6 Fuel Oil	200 psig	70,000 lb/hr
5	Natural Gas	200 psig	100,000 lb/hr
6	Natural Gas or #6 Fuel Oil	400 psig	107,500 lb/hr 109,500 lb/hr
7	Natural Gas or #6 Fuel Oil	400 psig	107,500 lb/hr 109,500 lb/hr
8	Coal	400 psig	170,000 lb/hr

- Two existing back-pressure steam turbine generators: 1,700 kW and 5,800 kW
- Two existing hydroelectric generators: 800 kW and 1,100 kW

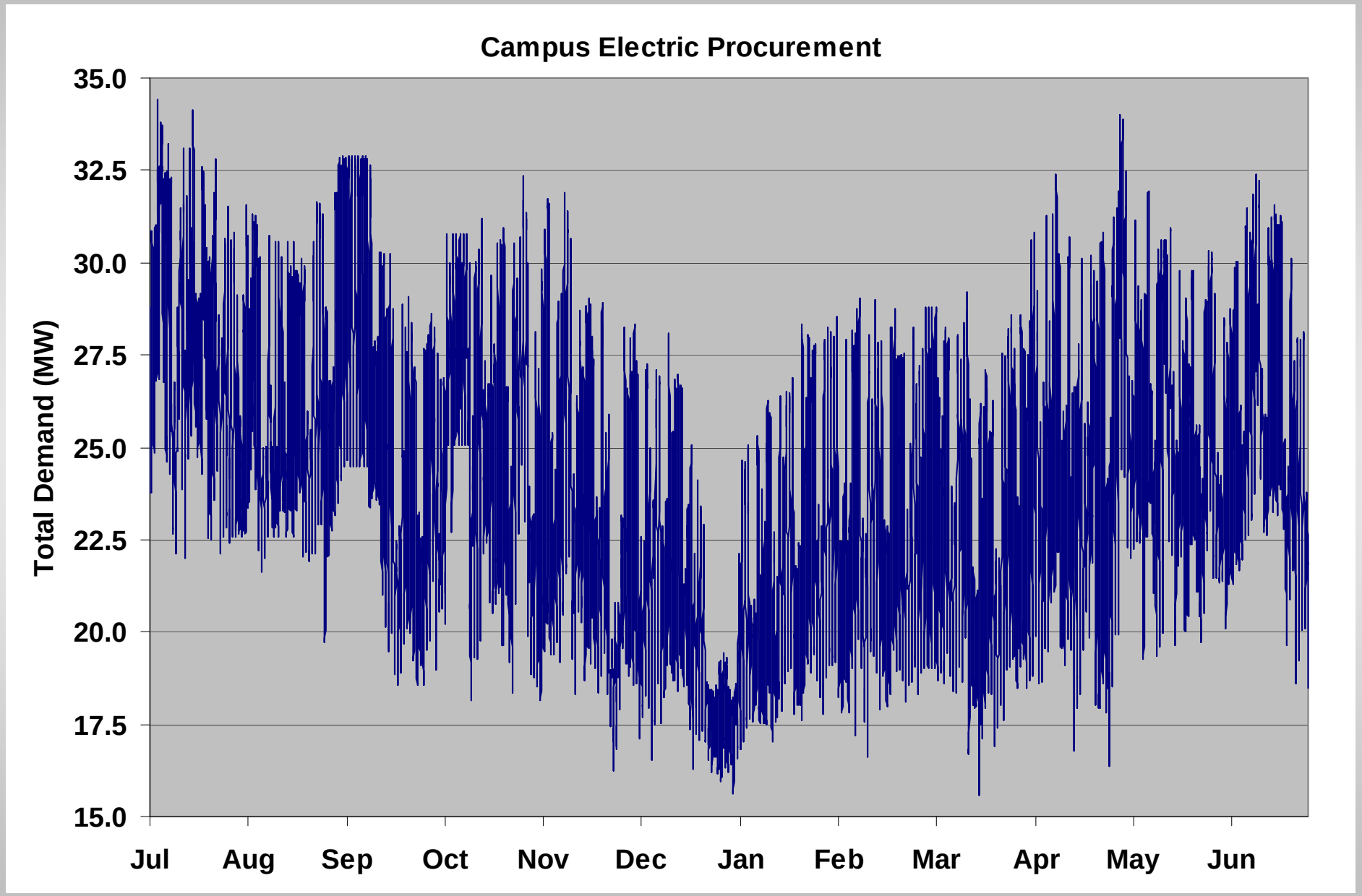


Electrical Consumption

- Total campus consumption is 250 Million kW.hr annually
- On-site generation is 32 Million kW.hr (13%)
- Peak Purchased Demand – 34,000 kW
- Minimum Demand – 16,000 kW
- Annual Average Load – 25,000 kW

- Expected 20-year Growth
  - Total Consumption – 300 Million kW.hr annually
  - Peak Purchased Demand – 41,500 kW
  - Annual Average Load – 30,600 kW

Electrical Consumption

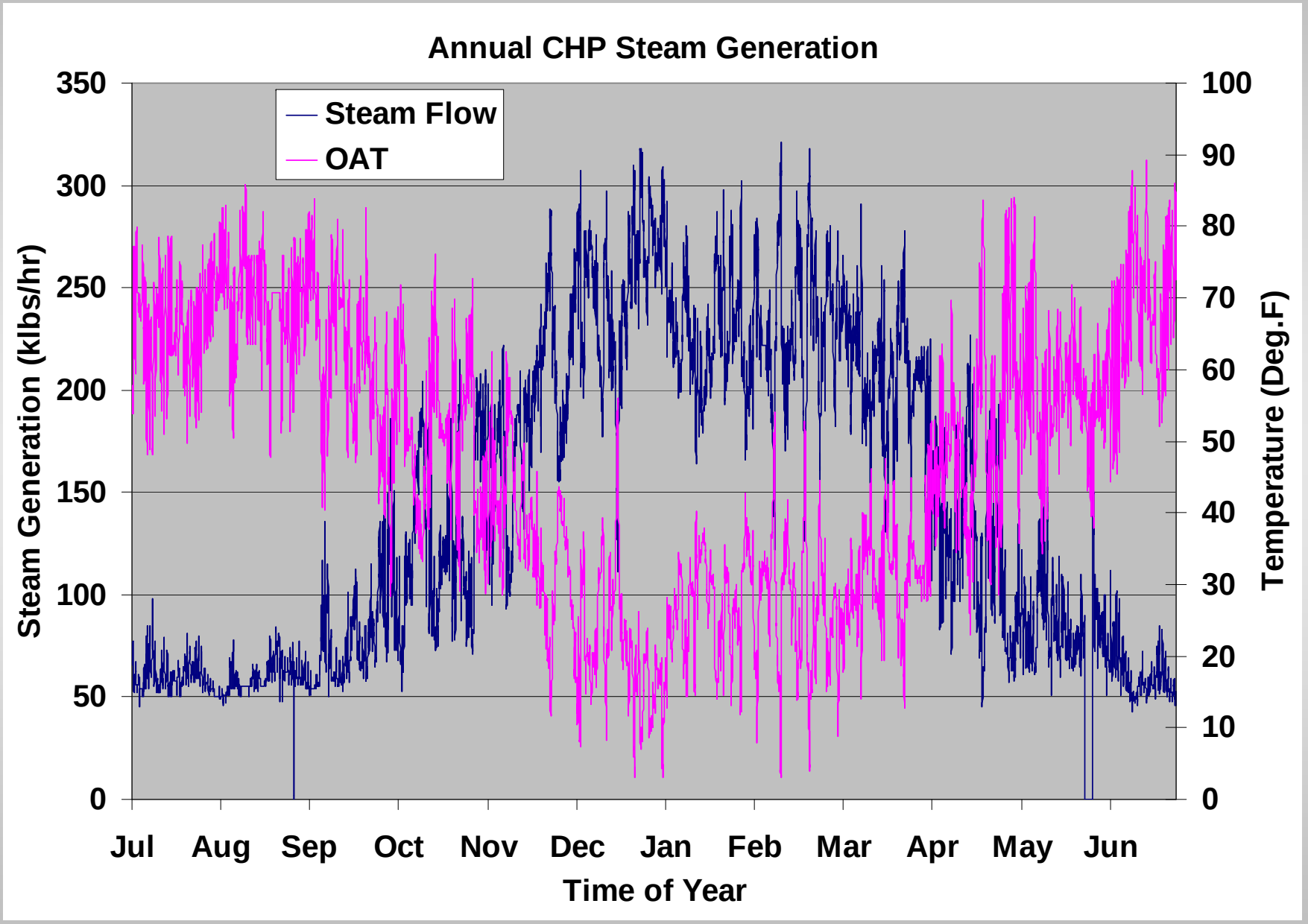


Steam Consumption

- Maximum Annual Steam Load – 360,000 lb/hr
- Minimum Annual Steam Load – 50,000 lb/hr
- Annual Average Steam Load – 143,000 lb/hr
- Steam Produced at 400 psig, 600°F
- Winter Distribution Pressure – 75 psig
- Summer Distribution Pressure – 35 psig

- Expected 20-year Growth
  - Maximum Annual Steam Load – 450,000 lb/hr
  - Annual Average Steam Load – 185,000 lb/hr

Steam Consumption



Reasons for Combined Heat and Power

- Electrical outages are very costly in terms of research and salaries
- Some critical research facilities require specific ambient conditions
- Aging existing boilers
- Continued load growth
- Wanted increased fuel flexibility to minimize operating costs

- Wanted to decrease dependence on coal
- University mandate working toward Carbon Neutral
- 2003 Northeast blackout emphasized potential vulnerability

Feasibility Study

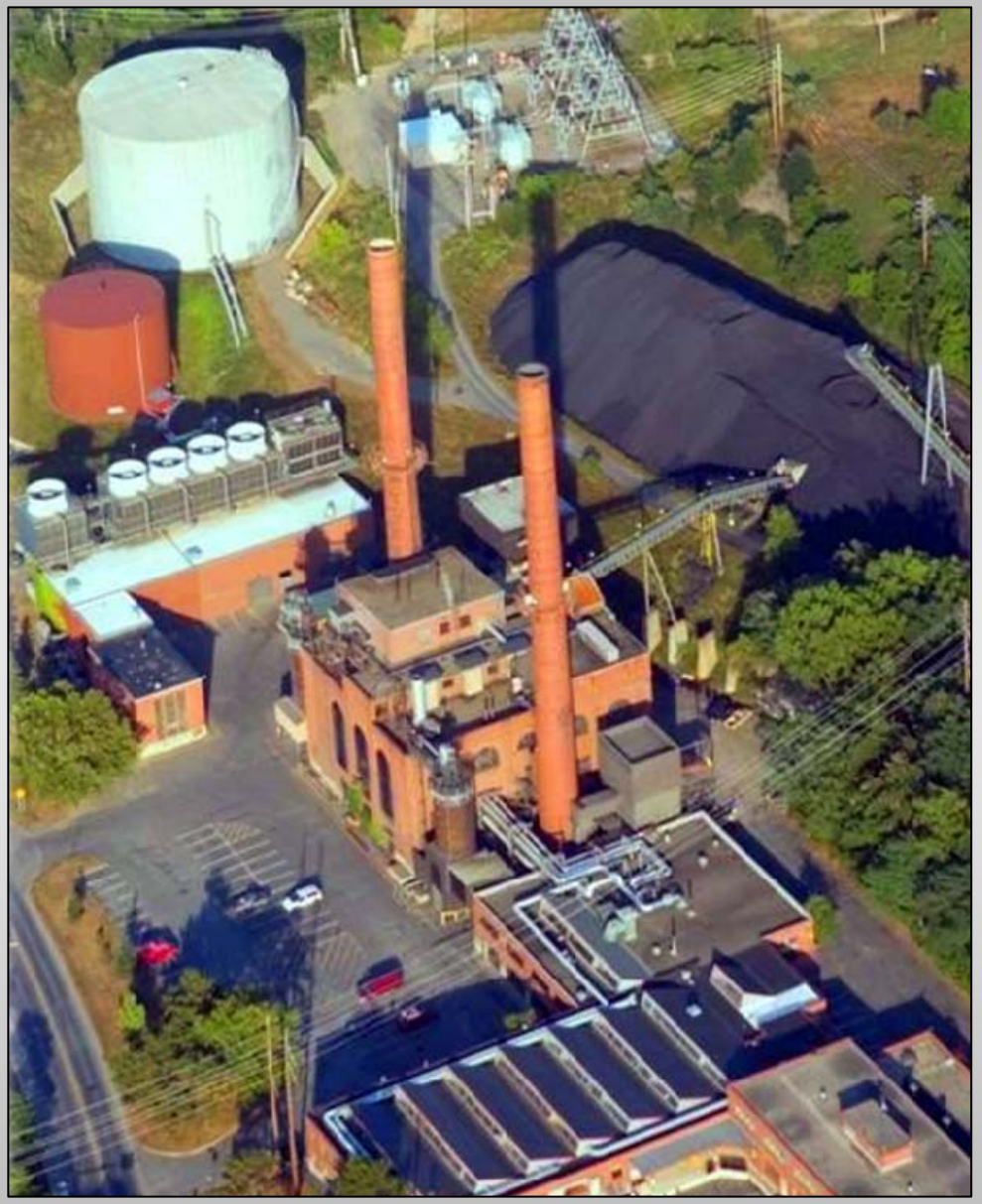
- Cogeneration plants in various sizes between 5-30 MW
- 1 vs. 2 GTG/HRSG trains
- Natural gas procurement
- Dual fuel capability
- Condensing steam turbine due to excess steam
- Other steam load modifiers
- Existing stacks vs. new stacks
- Emissions abatement req’mts
- Electrical interconnection
- Adjacent to existing heating plant or different section of campus

Feasibility Study

- Plant location:

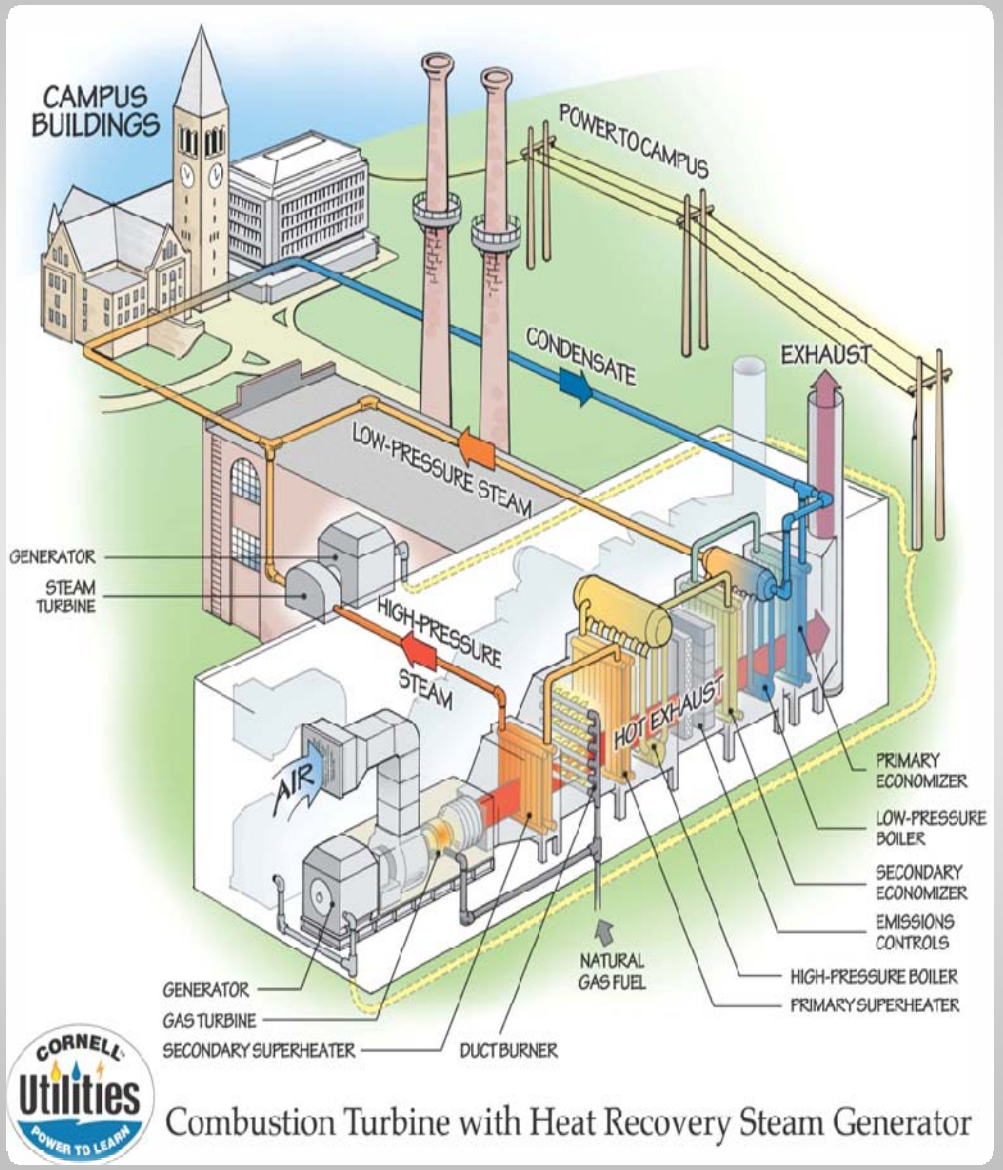
  North: buried utilities, highway, aesthetics, existing plant access

  South: virtually no visual impact, coal pile, installation of future new package boilers, hill/road
- Constructability
- Economic evaluation including all utility, operating and maintenance, debt services, compliance and labour costs
- Potential retirement of 1 or 2 existing boilers



Study Results

- 30 MW plant based on 2x15 MW units provides most flexibility and meets electric and steam needs
- HRSG equipped with duct burners for additional steam flexibility
- Natural gas to be procured through new 5.2 km high pressure line interconnecting with Dominion Transmission Inc.
- Dual fuel was determined not cost effective
- Dual fuel to be included based on risk management considerations
- Existing No.6 fuel oil system to be converted to No.2 fuel oil system



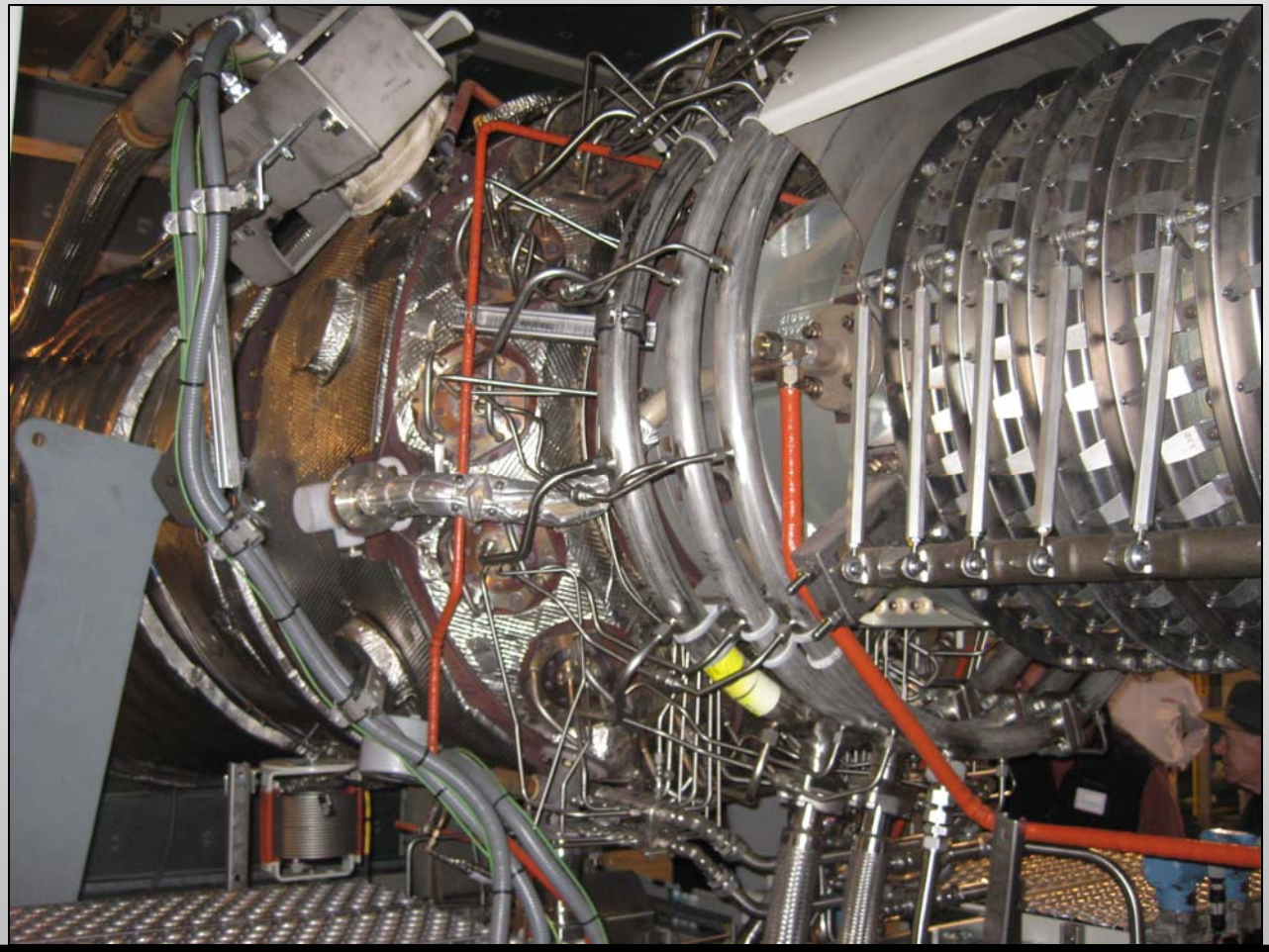
Study Results

- Condensing steam turbine not economic since not enough excess steam and significant additional equipment
- Steam condenser included to allow operation of both GTGs during summer for electrical demand reduction or sale of electricity
- New stacks included to maintain complete flexibility of operating the GTG/HRSGs and the existing boilers simultaneously
- Emissions examined included NO_x, CO, VOC, SO_2, CO_2, particulate (PM10), formaldehyde and NH_3
- Both SCR and CO catalysts required
- Renewal and upgrade of 115 to 13.2 kV substation
- Addition of third transformer
- CHP plant would be located south of the existing heating plant

Decision was made to build the Combined Heat and Power Plant

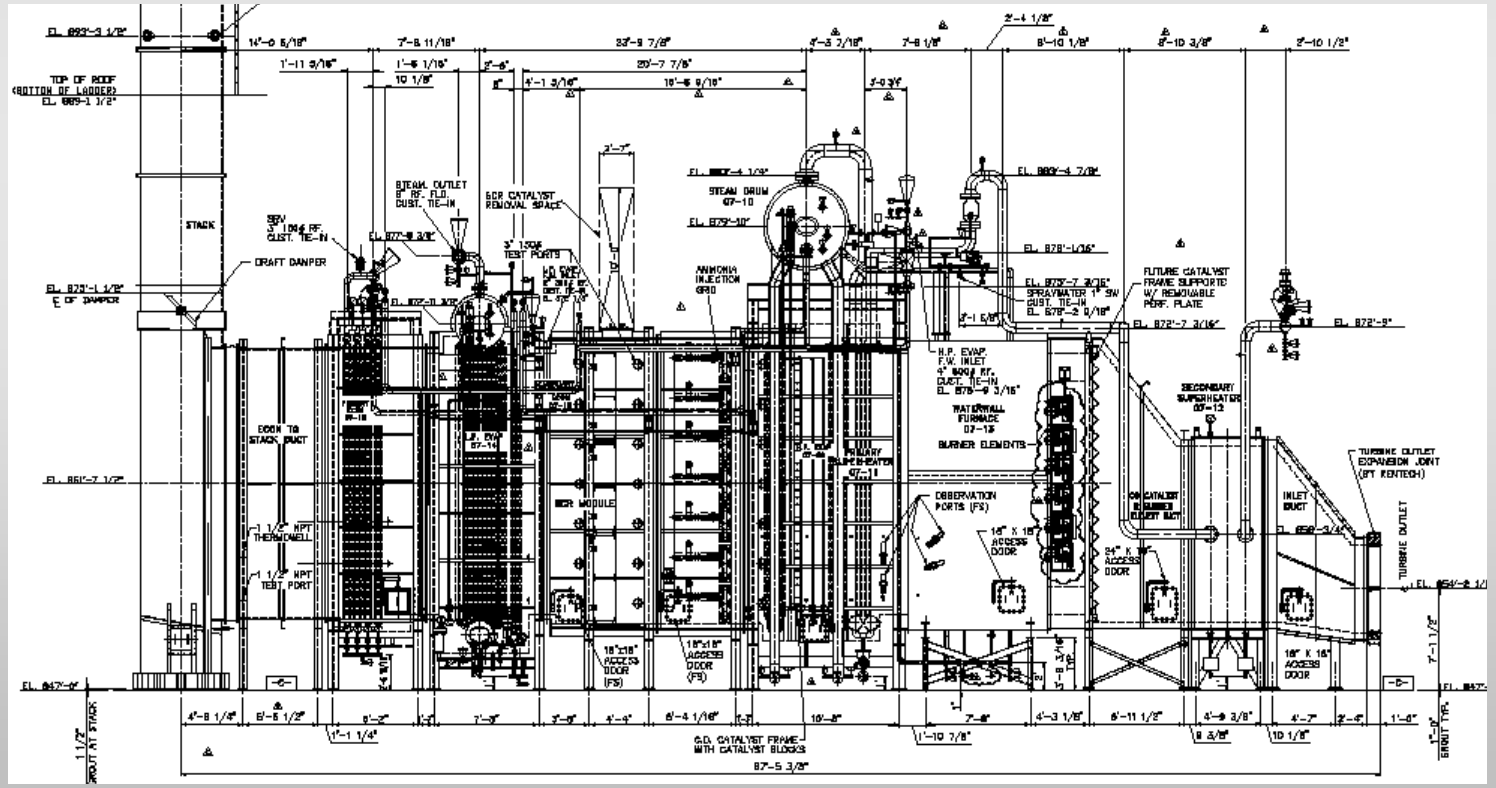
Design Implementation

- GTG and HRSG selected by competitive bid process
- 2 x Solar Titan 130 successful bid
- ISO rating: 15,000 kW, 9,695 btu/kW.hr (LHV)



Design Implementation

- SCR catalyst temperature range required a split evaporator
- HRSG changed to two pressures to avoid split evaporator and increase overall efficiency
- CO catalyst options:
  - high temperature located upstream of duct burner
  - low temperature located within evaporator



Design Implementation

- Temporary support of new enclosed conveyor

Design Implementation

- Placing the new plant deep within an existing slope
- Locating new plant beside 90 year old building/foundation
- Ensuring new plant doesn't "slide" into existing building over time
- New office building on piles to minimize additional pressure

Design Implementation

- Constrained site made setting of major equipment difficult
- Large, heavy equipment deliveries through hilly terrain and city streets req'd detailed delivery schedule and plan

- 8 "escorted" deliveries
- HRSGs alone required approximately 40 trucks

Design Implementation

- Emissions modeling and permitting accounting for GTGs, HRSG duct burners, and two 1,000 kW EDGs
- Ammonia unloading and storage system required
- Continuous Emission Monitoring system required

Design Implementation

- Replace existing two x 100% 50 MVA, 115 to 13.8 kV transformers
- Change to three x 50% 37.5 MVA, 115 to 13.8 transformers
- Maintaining electricity to campus throughout construction and commissioning

Design Implementation

- Dedicated 5.2 km high pressure 8” gas pipeline (550 psig)
- New on-site filtering, heating and regulating station (425 & 30 psig)

Construction

Construction

Construction

Overall Budget and Schedule

Budget

Construction	$43.8 Million
Engineering & Permitting	$8.0 Million
Pre-Purchased Equipment	$28.5 Million
Support	$2.0 Million
Total Project Budget	$82.3 Million

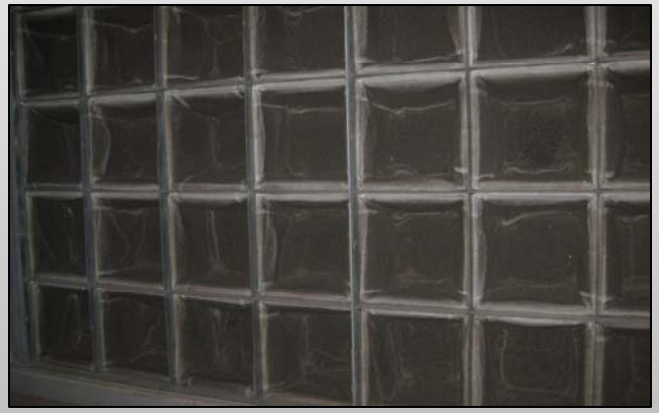
Schedule

Planning	Mar 02 – Dec 05
Engineering	Jan 06 – May 09
Permitting	Jul 07 – Jun 08
Construction	Jun 07 – Jan 10

Combined Heat and Power Plant

Combined Heat and Power Plant

Enclosed Air Plenum



"Unique" pre-filtration system for GTG inlet air, GTG enclosure ventilation and building ventilation

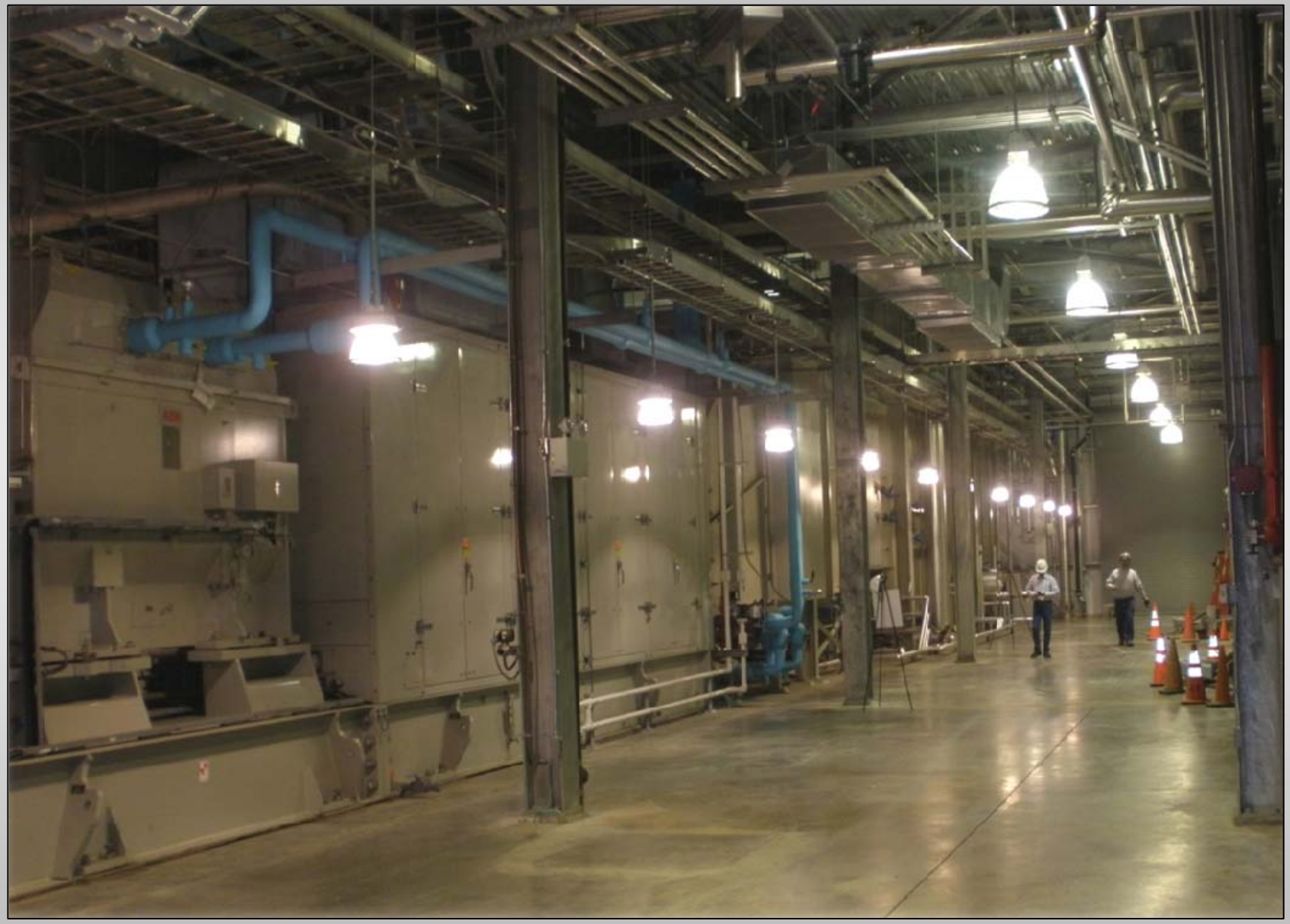
Mezzanine Level - HRSGs

Mezzanine Level – Electrical Room

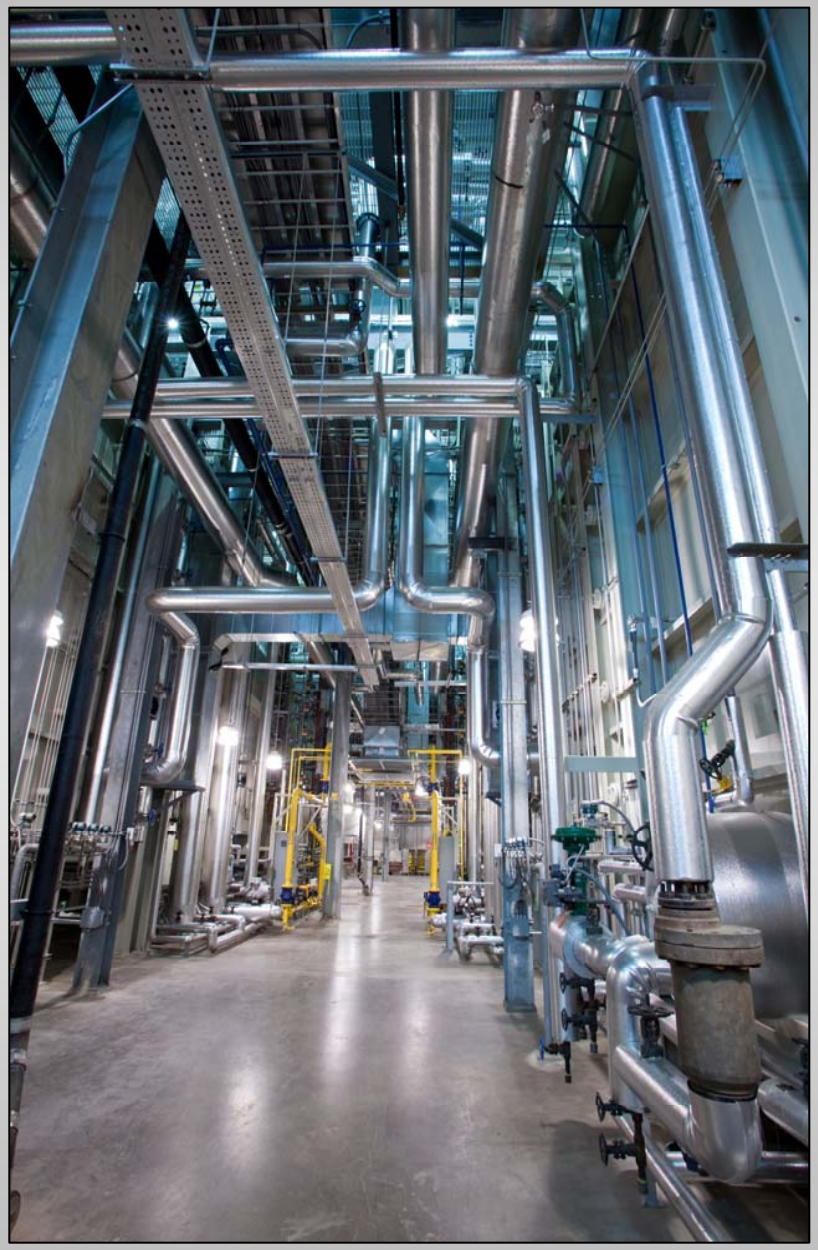
Mezzanine Level – Balance of Plant

Water cooled generator and lube oil coolers via on-campus chilled water district cooling system

Operating Floor – Access Aisle



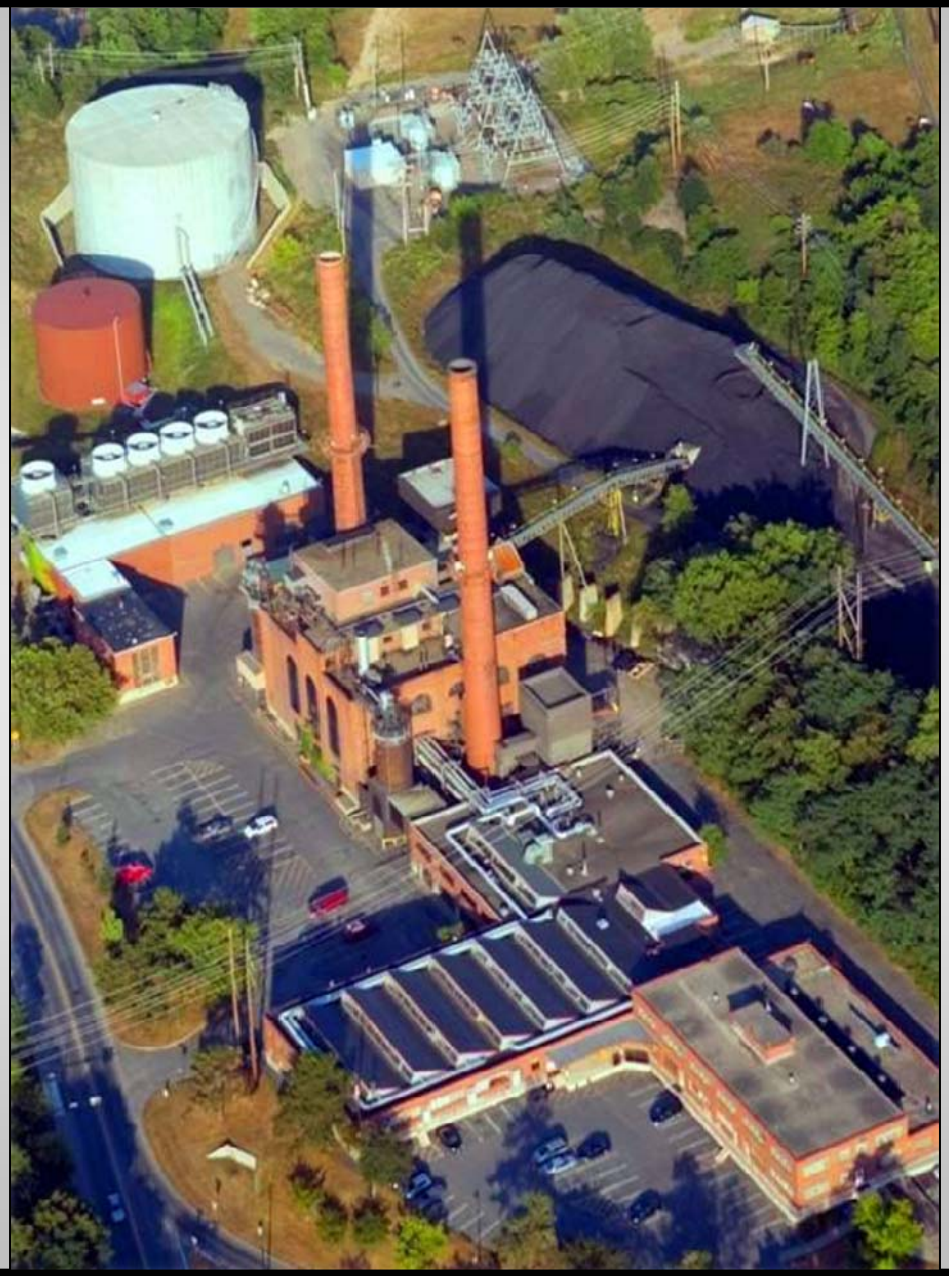
Operating Floor – Centre Aisle



New Office / Locker Room Building

Steam Condenser Building

Summer 2005



Fall 2009