INTERNATIONAL DISTRICT ENERGY ASSOCIATION
evolvingENERGY CONFERENCE
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Application of Steam Turbine Driven Chillers in CHP/DES System

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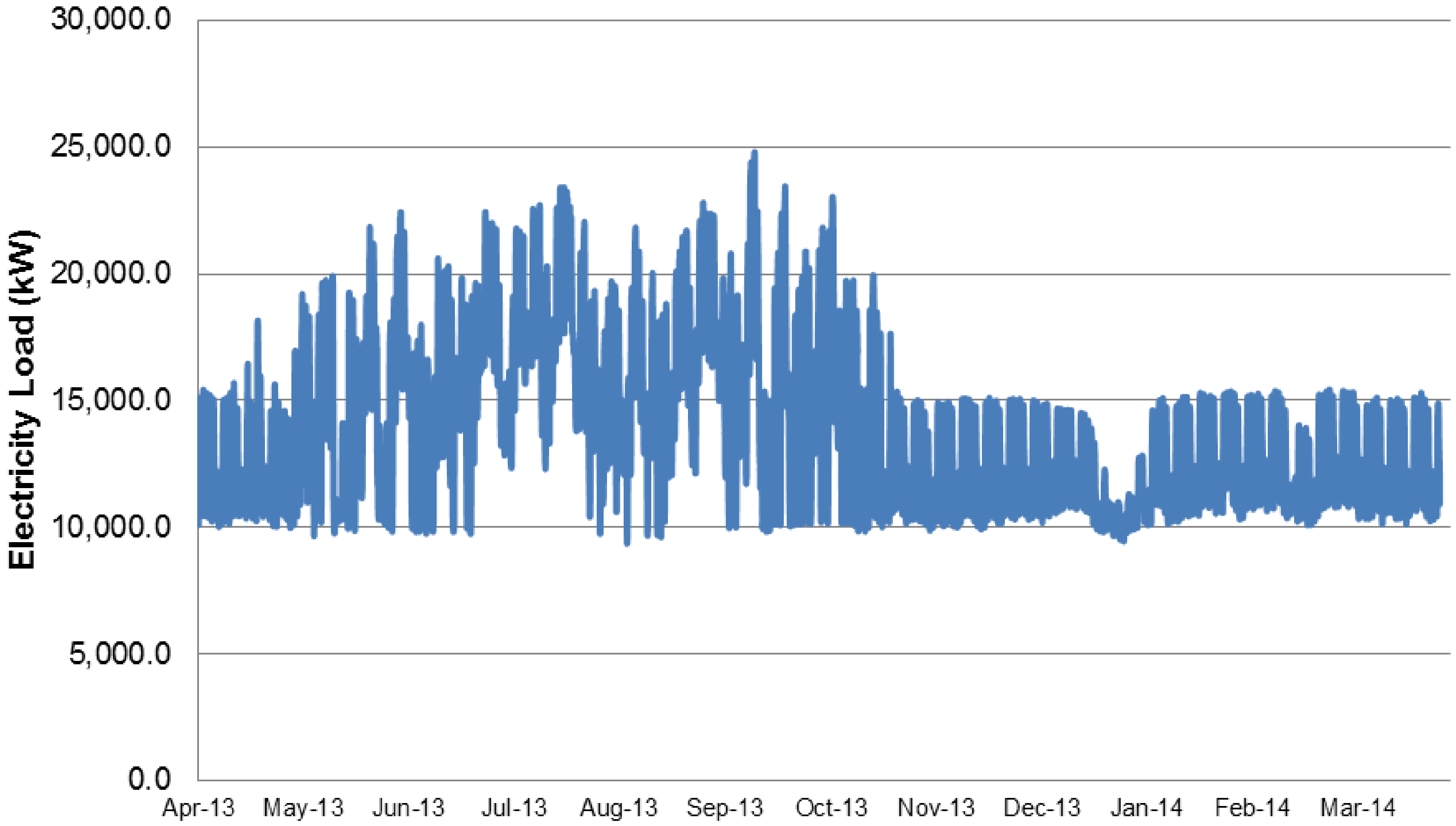
Outline

1. Typical Energy Use
2. Problem
3. Solution
4. CHP cycle to meet energy loads
5. Cost/Benefit Analysis
6. Simple payback
7. Conclusions

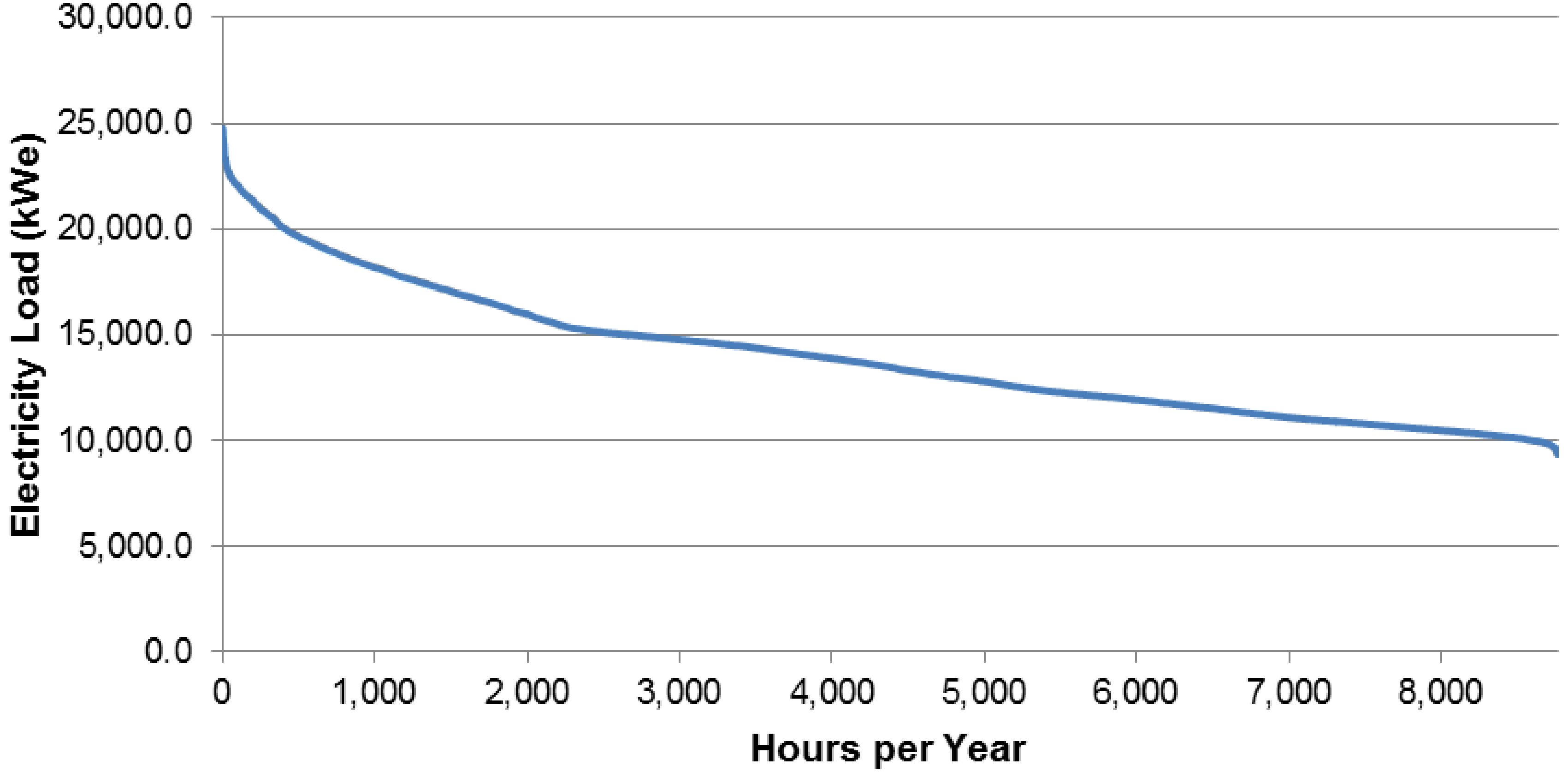
Assumptions

- Large campus-style University or Hospital
- Southern Ontario, Canada
- Electricity Rate - $0.11/kWh
- Natural Gas Rate - $5.50/mmBtu
- Operating Costs - $0.045/kWh

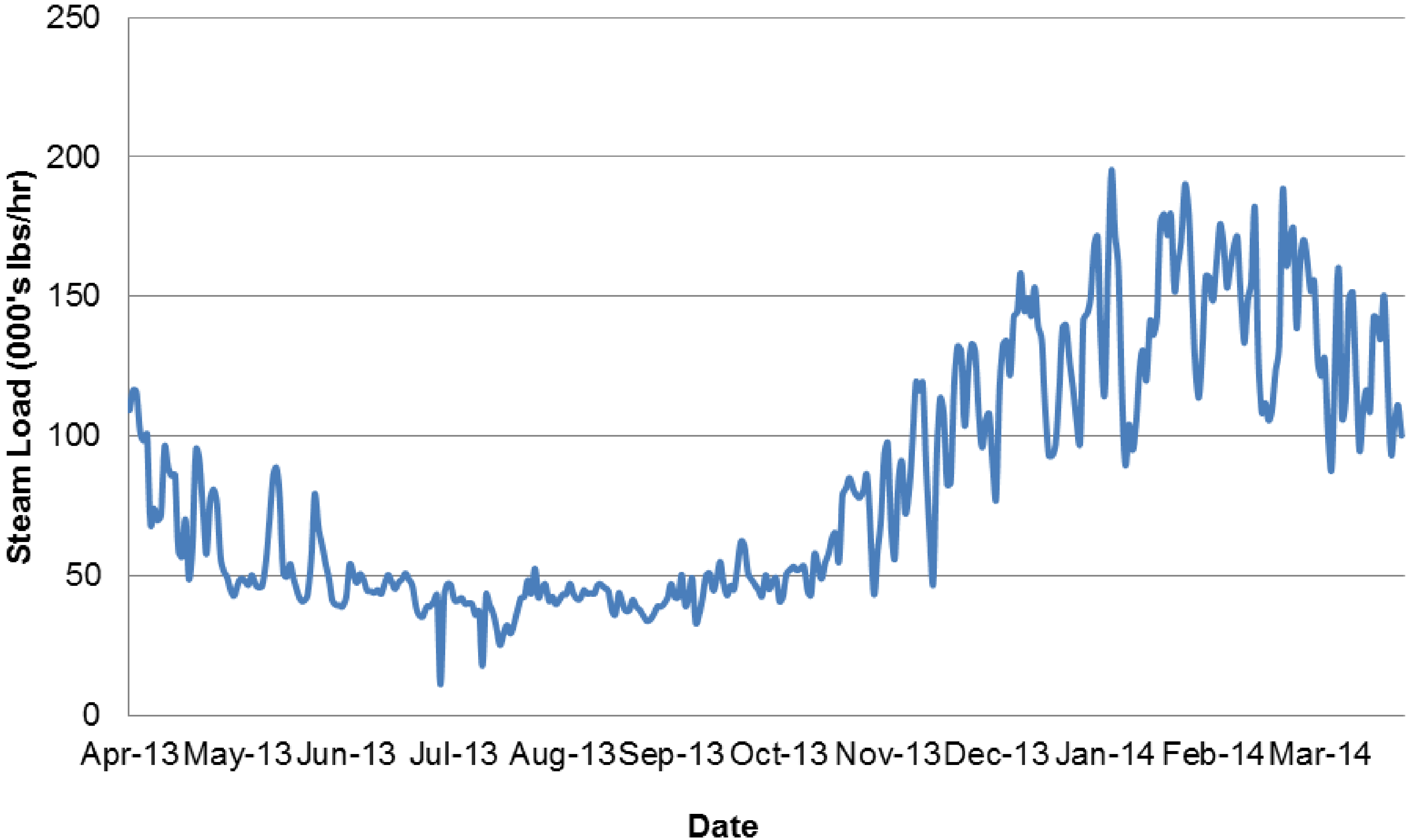
Typical Electricity Use



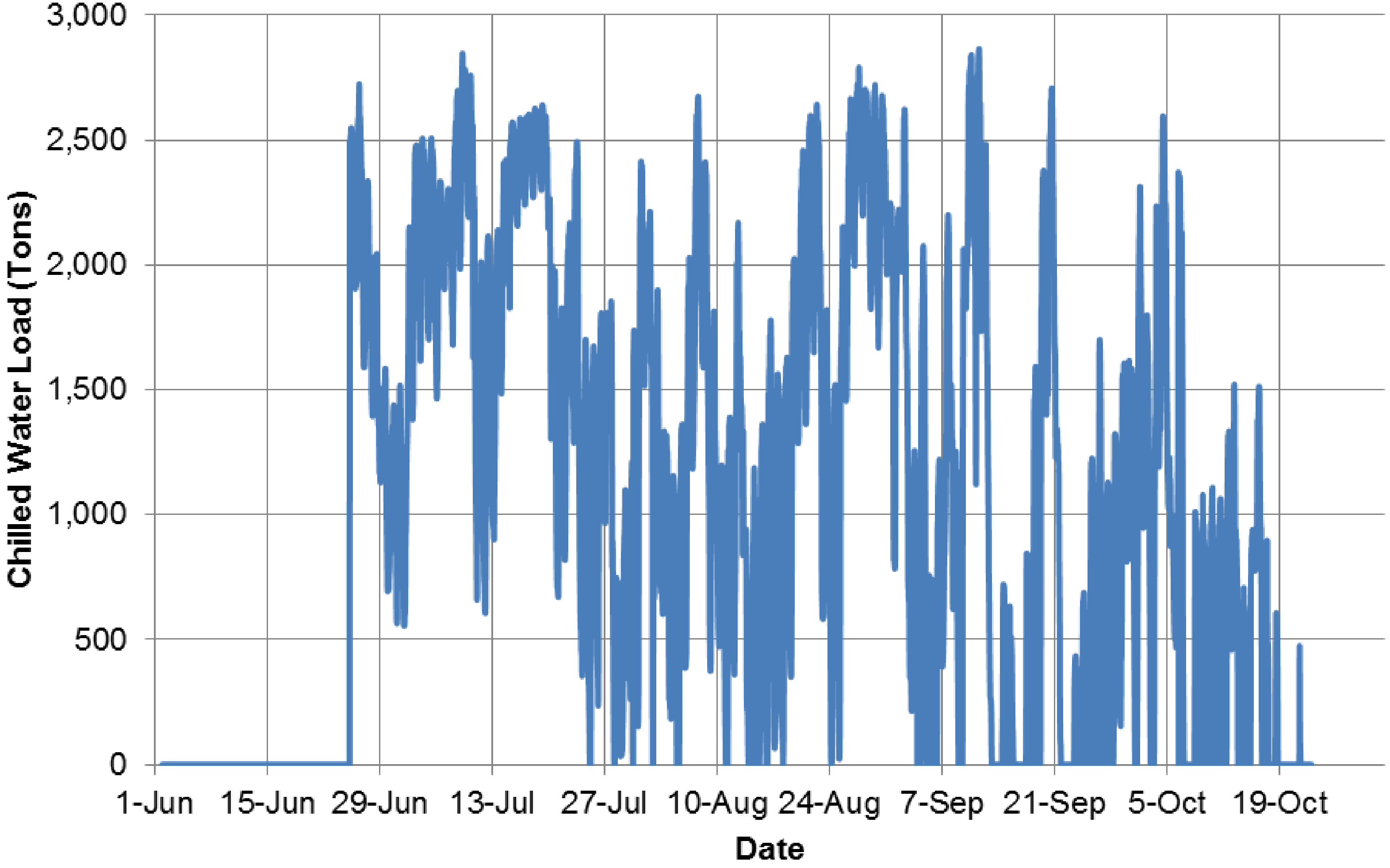
Typical Electricity Use



Typical Steam Load



Typical Building Cooling Loads



Goal

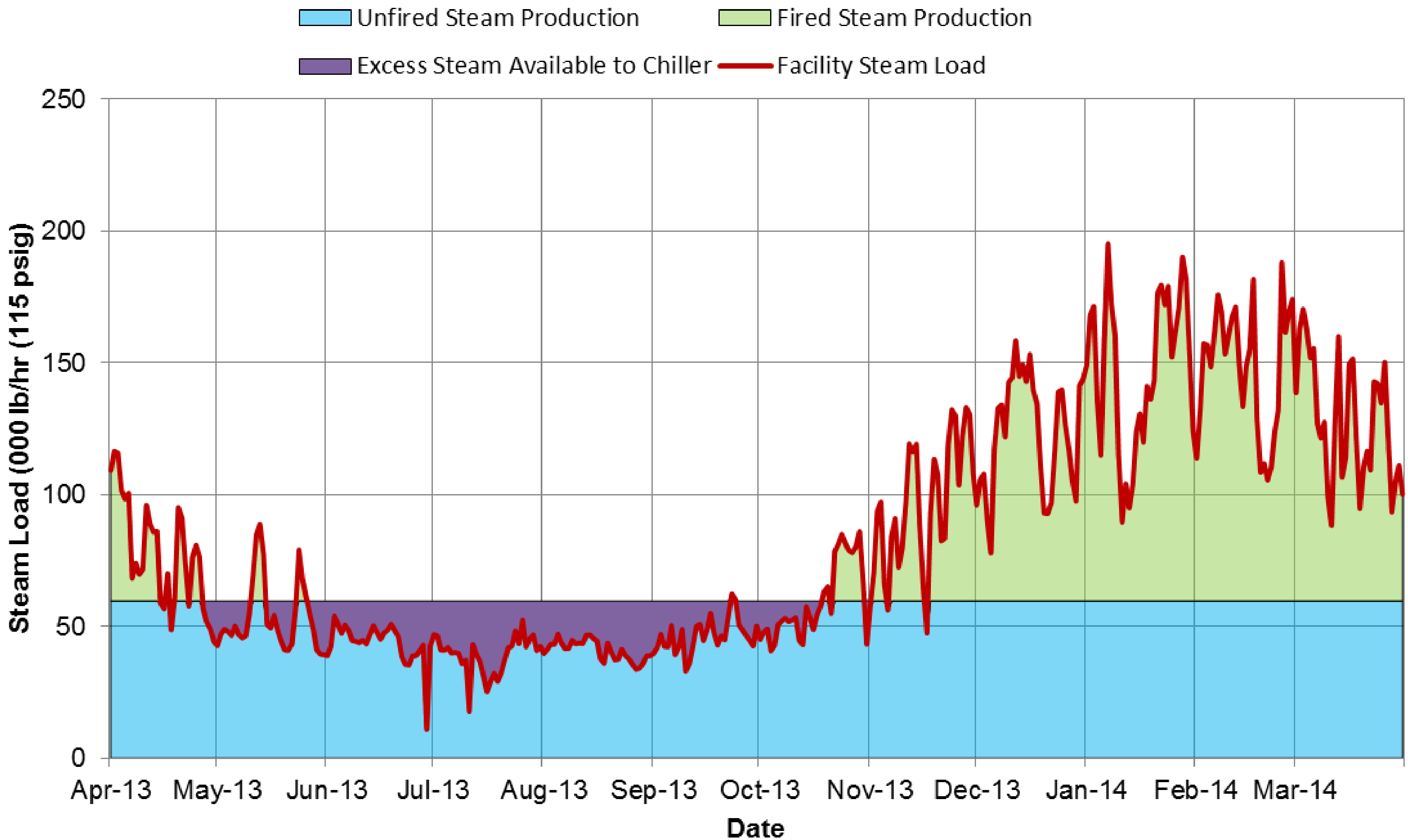
Client wants to size CHP system to displace as much purchased electricity and natural gas as possible.

Solution

- Potential CHP System:
  - Two (2) GTGs @ 5.7 MW_e (each)
  - Two (2) HRSGs @ 100,000 lb/hr (each)

- Proposed CHP system would result in roughly 20,000 lb/hr (9,090 kg/hr) of <u>surplus unfired</u> steam during summer months.

Steam Load and Steam Generation
(Based on 2 x 5.7 MW GTGs & 2 x 100 kpph HRSGs)



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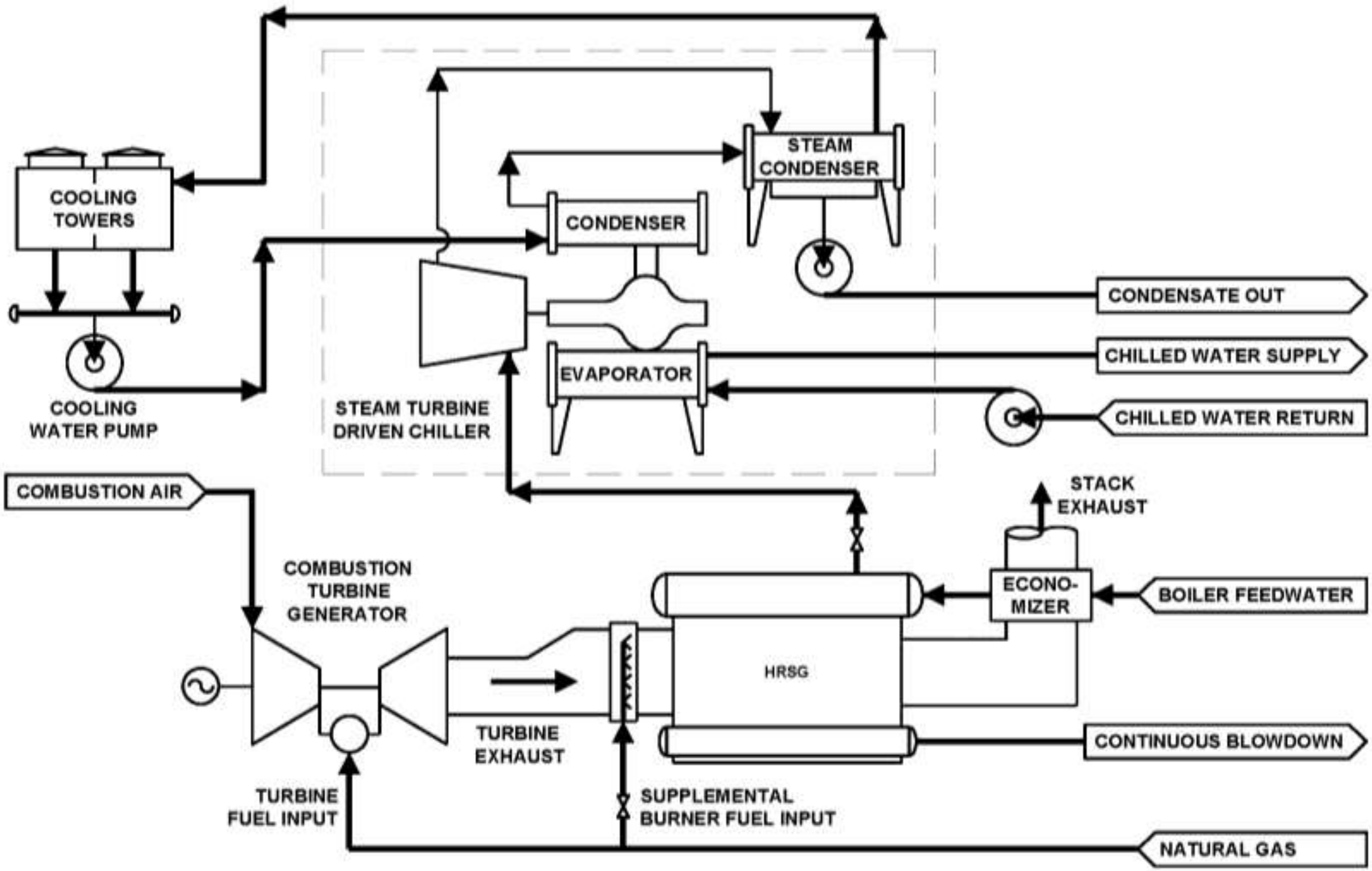
Solution – Two Options

1. Size CHP System to Eliminate Surplus Unfired Steam
   - Displacement of expensive kW_e.h is reduced/ limited
   - One (1) auxiliary boiler must be kept on low fire to meet peak steam load

2. Add to Cycle to Increase Summer Steam Loads

Optional CHP Cycle to Meet Loads



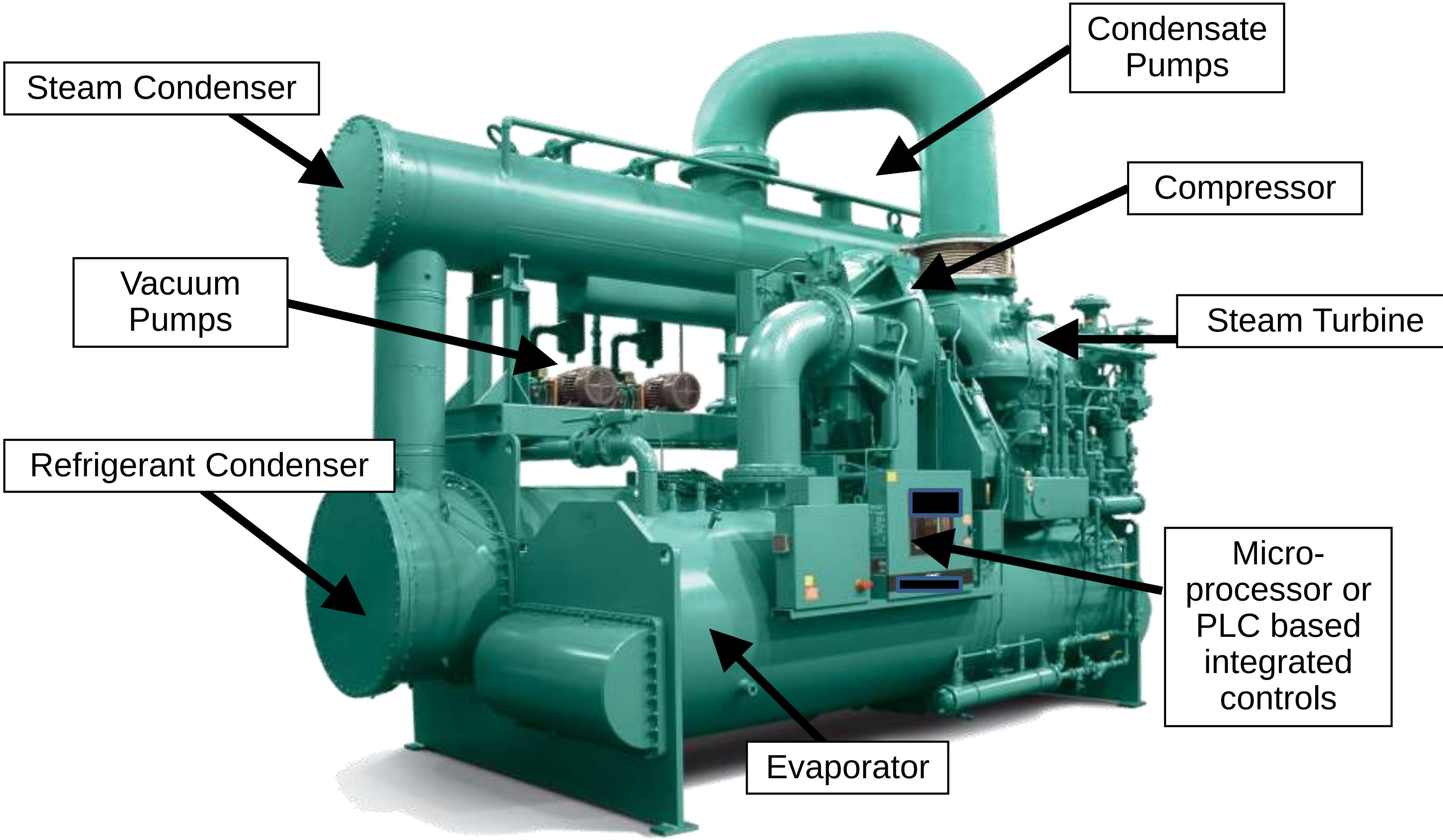
CHP Cycle to Meet Energy Loads

- Optimized CHP Cycle/Equipment:
  - Gas Turbine Generator with Heat Recovery Steam Generator (HRSG)
  - HRSG to be supplemental fired to meet peak steam demands
  - Steam Turbine Driven Centrifugal Chiller making chilled water from surplus, unfired steam in summer months
  - Steam Turbine Chiller becomes “first on/last off” chiller

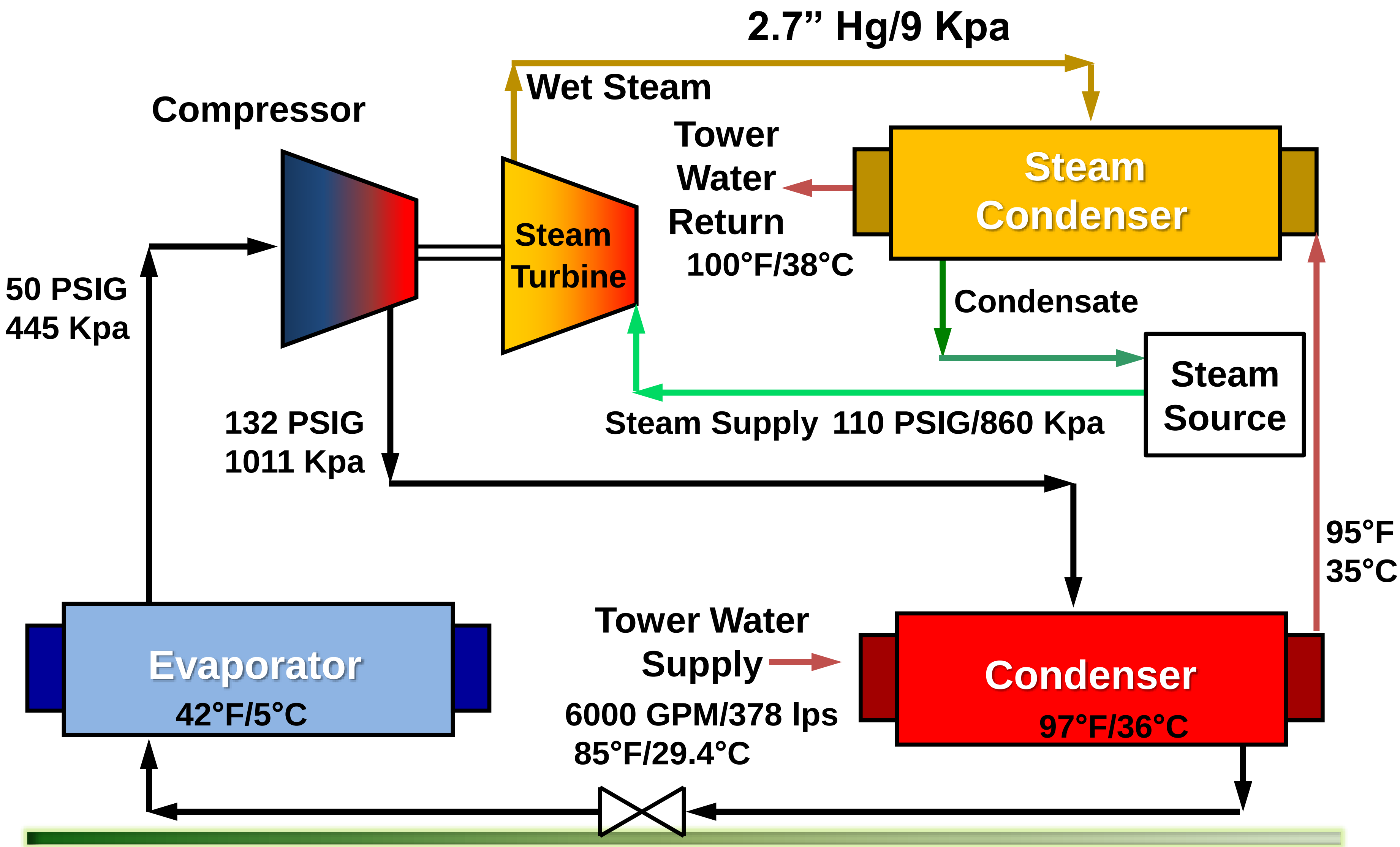
Benefits

- Steam Turbine Chiller creates additional steam load during summer months
- Higher steam load year round justifies larger CHP system
- Larger CHP system displaces more $kW_e.h$ and m^3 (NG) and may provide other benefits to host site:
  - Electrical islanding
  - Electrical blackstart
  - Improved boiler plant operation

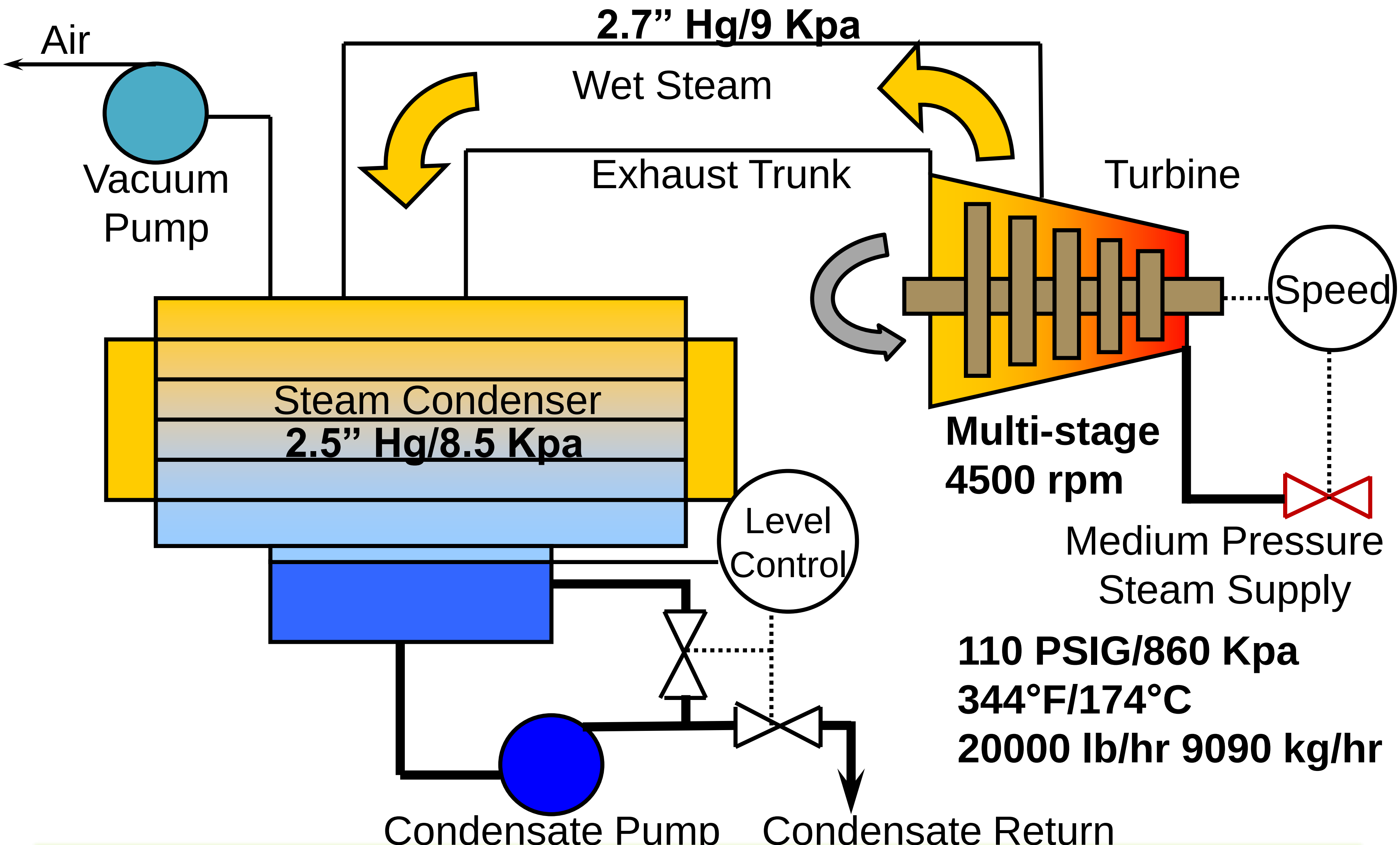
Steam Turbine Driven Chiller



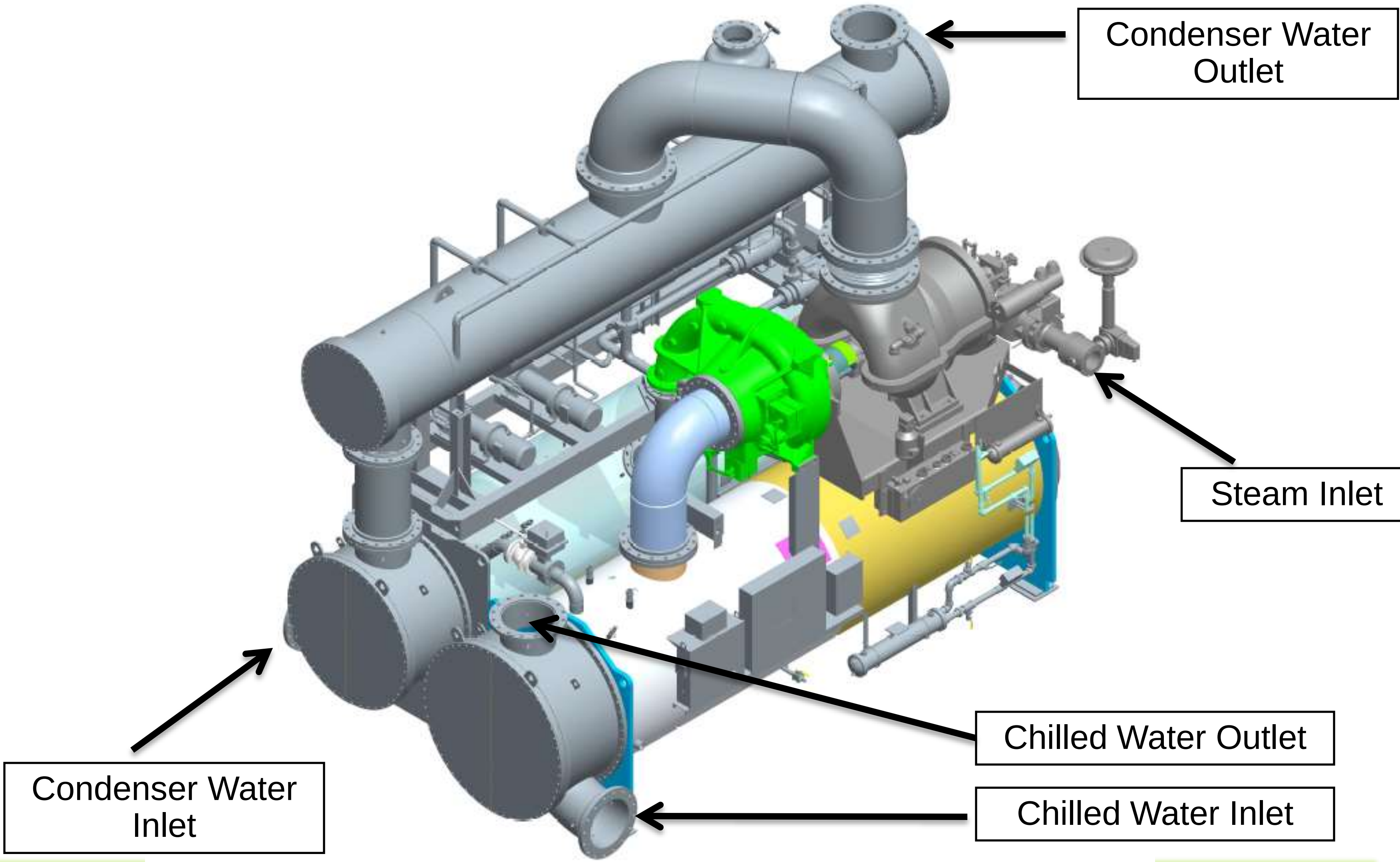
Schematic (2000 tons/7035 KW)



Steam System (for 2000 tons/7035 KW)

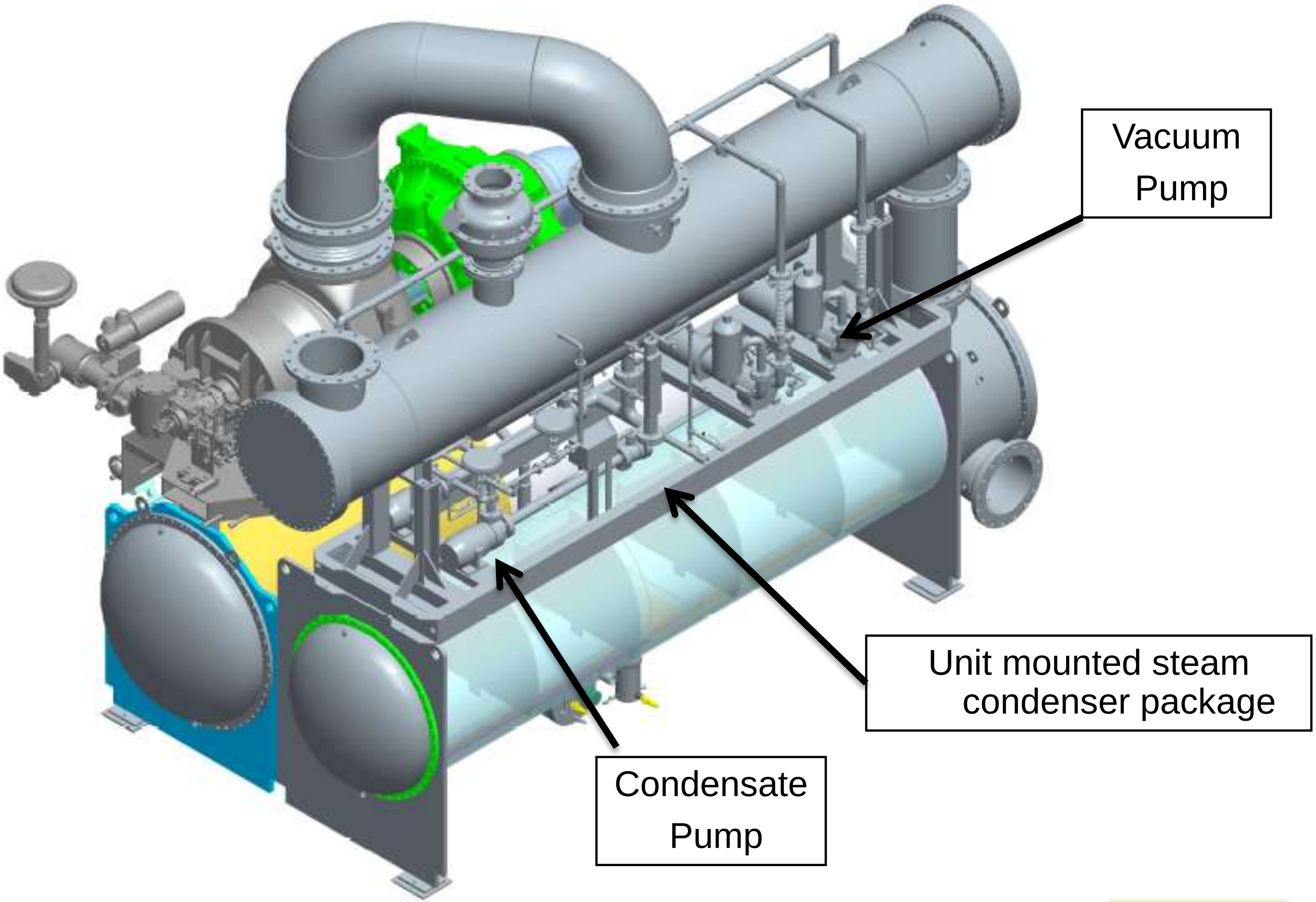


Steam Turbine Chiller Detail-Front View

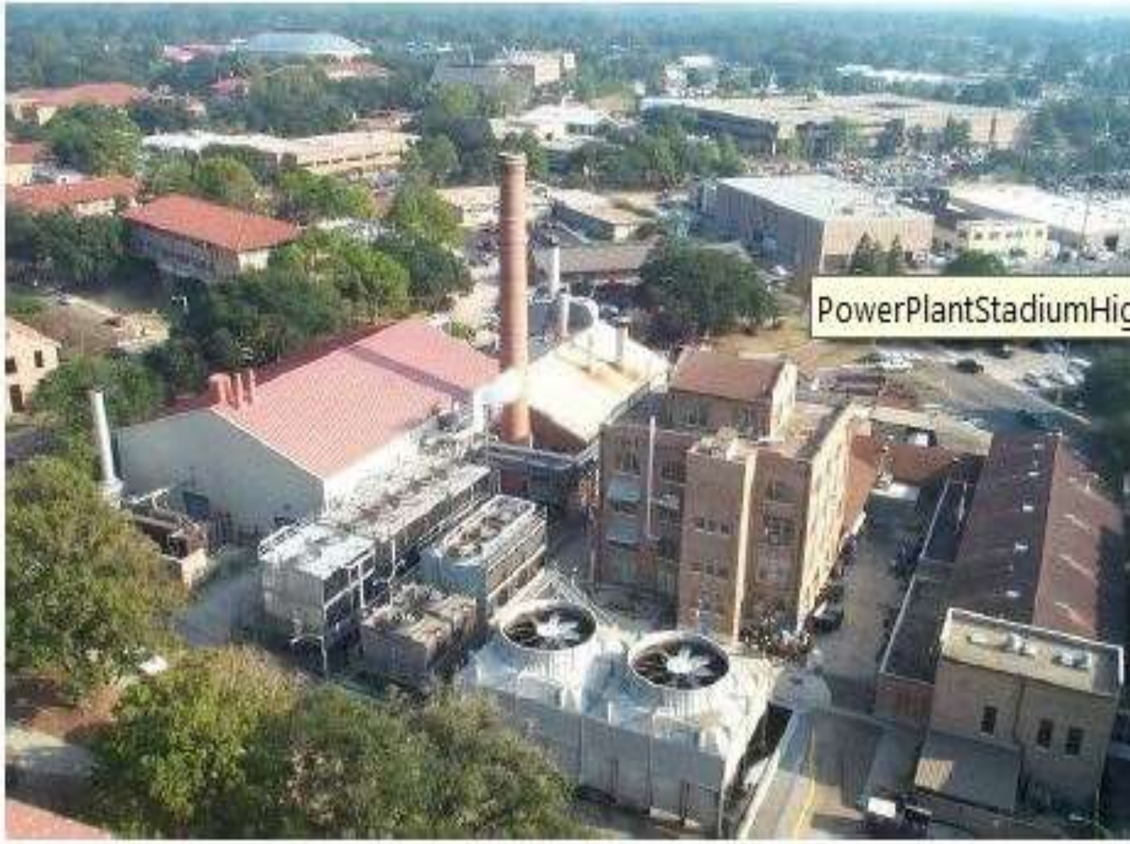


University of Missouri at Columbia – Columbia, MO

Steam Turbine Chiller Detail-Rear View



Louisiana State University – Baton Rouge, LA



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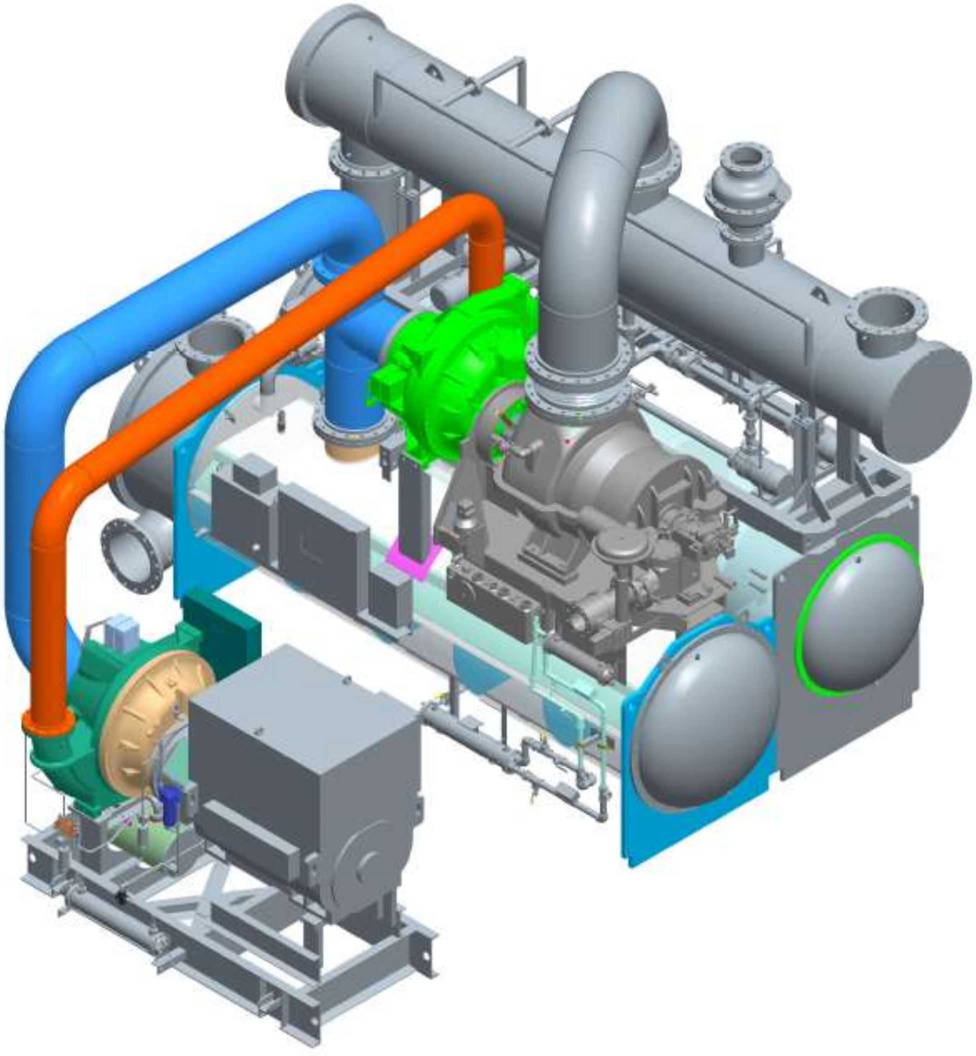
Typical Performance

- Design COP: 1.23
  – steam rate: 8.7 lb/hr/ton (3.9 kg/hr/ton)
- IPLV (as COP): 1.8
  – steam rate: 5.8 lb/hr/ton (2.6 kg/hr/ton)

Chilled water 54/44 F (12.2/6.7 C), Entering condenser water 85 F (29.4 C), Steam 120 psig (938 Kpa)

Steam with parallel electric drive line



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University of Connecticut – Storrs-Mansfield, CT

Features

- Highly reliable and proven technology
- Long life (> 30 years)
- Compact footprint
- Automatic Start – easy to operate
- Operational flexibility
  - Steam pressure 40 to 400 PSIG (275 to 2757 Kpa)
  - Entering condenser water 55°F to110°F (13°C to 43°C)
  - Leaving chilled water 36°F (2°C) or 20°F (- 6°C) with glycol

Assumptions for Cost/Benefit Analysis

- Without Steam Turbine Chiller, electrical output by Gas Turbine Generators is reduced to avoid surplus unfired steam
- Gas Turbine Generators operate at 75% of full load for 3,000 hours/year
- 2,000 ton Steam Turbine Chiller chiller costs $2 million (installed)

Cost/Benefit Analysis

- 2 x 5.7 MW_e x (1-75%) x 3,000 hrs/year
  = 8,550,000 kW.h (not produced)
- 8,550,000 kW.h x ($0.11/kW.h - $0.045/kW.h)
  = $556,000
- $2,000,000 (Steam Chiller) ÷ $556,000
  = 3.6 year simple payback

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Conclusions

- Steam Turbine Chillers are well suited to CHP Systems for Universities, Large Hospitals, and Large District Energy Systems
- Electrical loads are often quite consistent but heating loads will vary considerably throughout the year
- Adding a Steam Turbine Chiller will benefit a District Energy CHP System by:
  - Increasing electricity production by consuming surplus unfired steam
  - Producing chilled water for district energy

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