Sustainable Energy and Climate Action Planning at Cornell University

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Agenda

- Overview of Cornell energy use
- Central energy plant
- Lake Source Cooling
- Hydro electric plant
- Energy forecasting
- Energy conservation and engagement
- Climate action planning
- Questions

Cornell Energy Use

Central Energy Plant provides

Electric for about 14,100,000 GSF

Steam for 12,700,000 GSF

Cooling for 9,100,000 GSF

Cornell University District Energy

Annual Utility Budget ~ $55 million

Enterprise Units

- Electric
  - 30 MW peak
  - 200 GWh/yr
- Steam
  - 380 kpph peak
  - 900,000 klbs/yr
- Chilled Water
  - 20,000 Tons peak
  - 44,000,000 ton-hrs/yr
- Water and Sewer

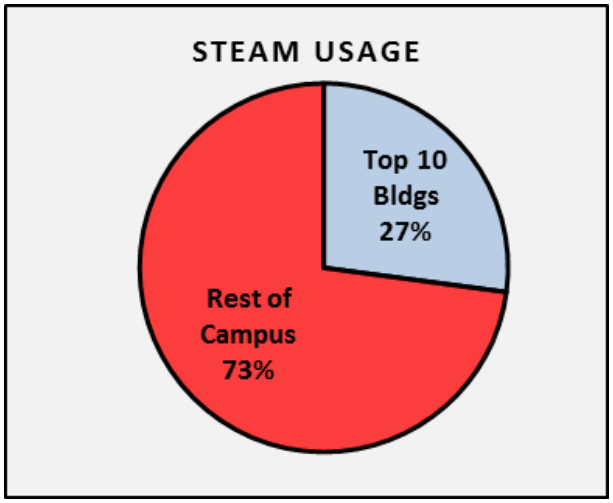
Fully Metered (>1200 meters)

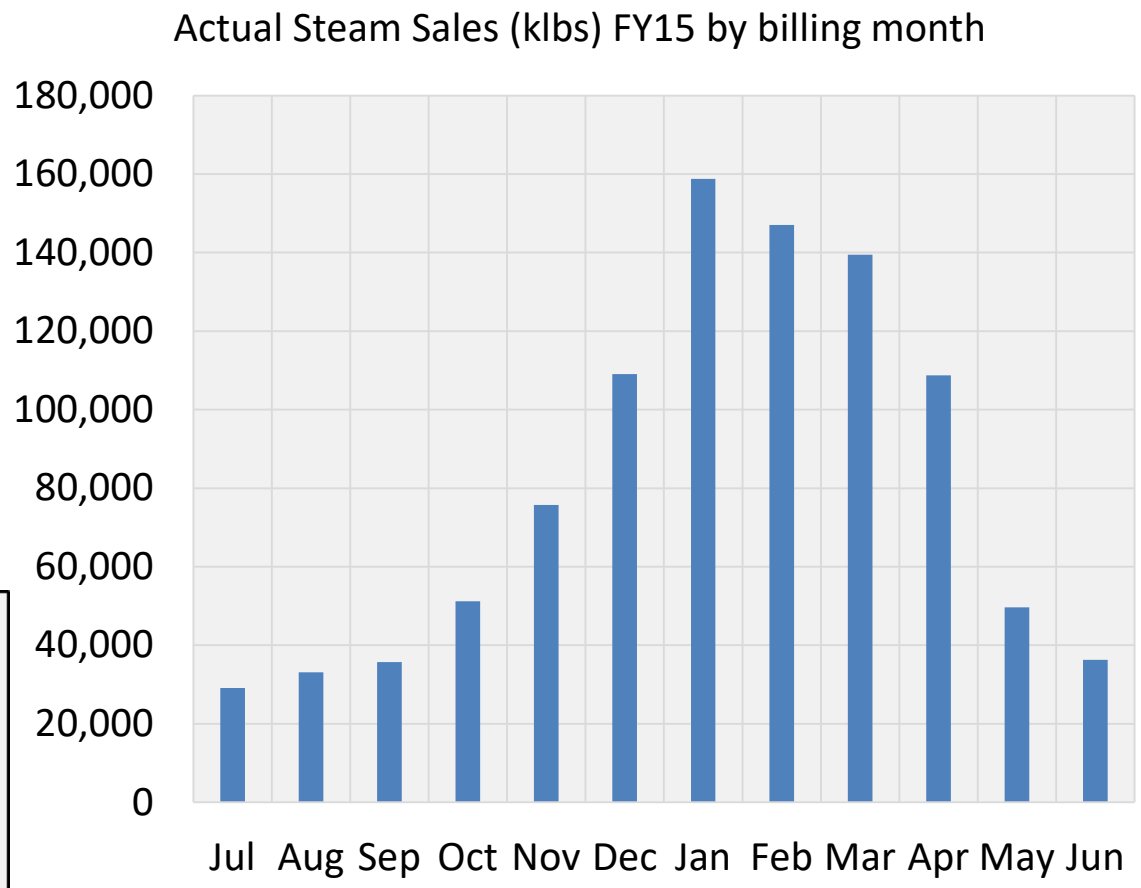
Steam Energy Use

Metered Building sales:
850,000 klbs

Steam use in summer:
Reheat; dehumidification and process loads

Peak Hourly Steam Load:
380,000 lbs. per hour
(every minute we boil 760 gallons of water)



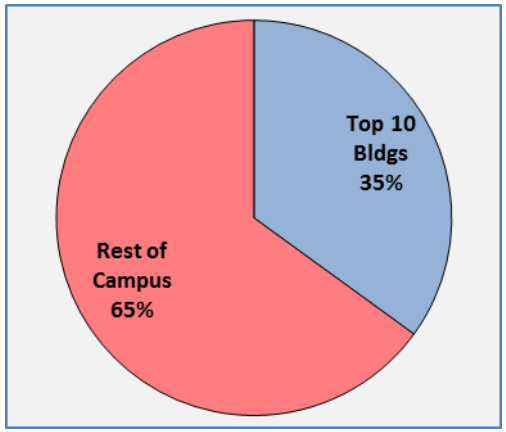


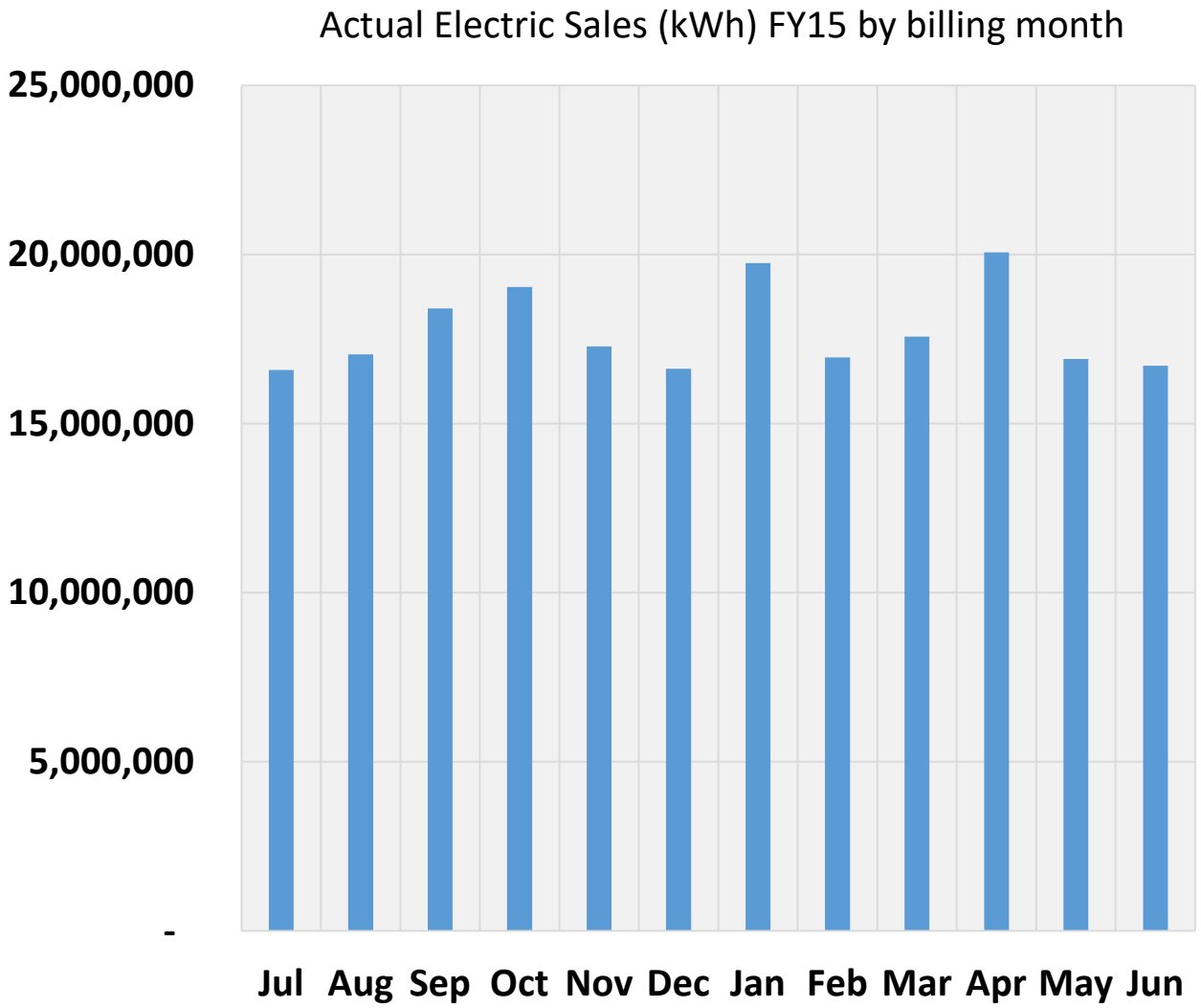
Electric Energy Use

Metered Building sales: 200 million kwh

Usage is quite flat thru out the year, average about 17 million kwh/month

Peak load is 30 MW, which is about 1/1000 of the New York State peak





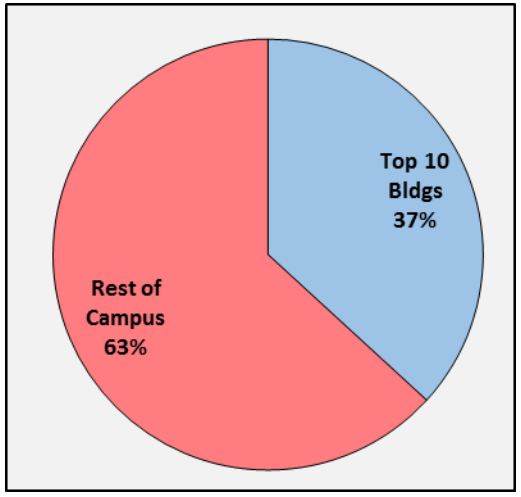
Chilled Water Use

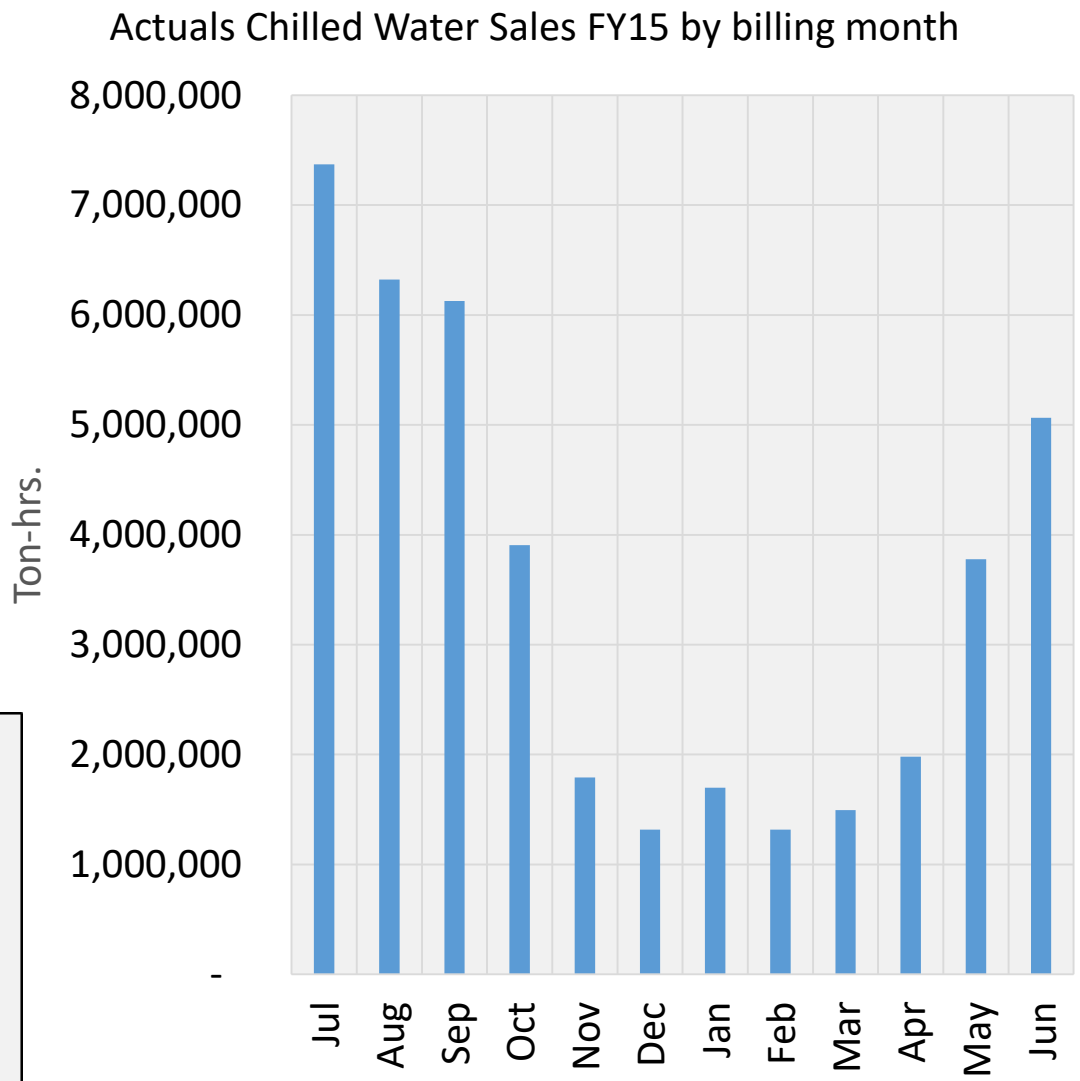
Metered Building sales:
42 million ton-hrs

About 47% of usage occurs in July/Aug/Sept

Winter usage for process cooling and some space cooling

Peak load is 25,000 tons
(1 ton is the heat rate required to melt one ton of ice in a day)





Pop Quiz Questions

- What is the peak load of Cornell University and how does it compare to the NYS peak?

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  - ~30 MW, .1% of the NYS peak of ~30,000 MW

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- Which utility load has the highest load factor (average to peak ratio) and why?

Pop Quiz Questions

- What is the peak load of Cornell University and how does it compare to the NYS peak?
  - –30 MW, .1% of the NYS peak of 30,000 MW
- Which utility load has the highest load factor (average to peak ratio) and why?
  - –Electricity
  - –Refrigeration for cooling is eliminated

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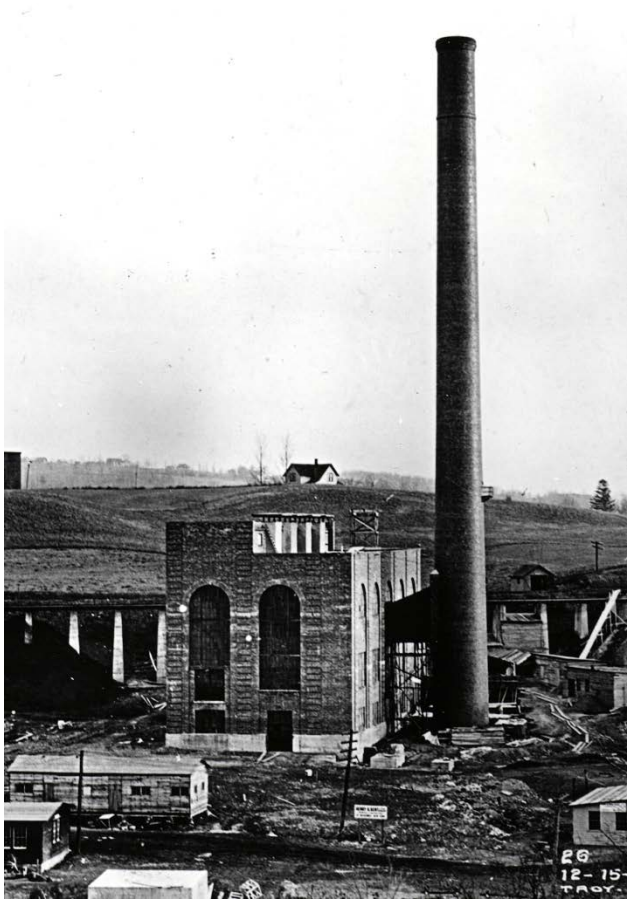
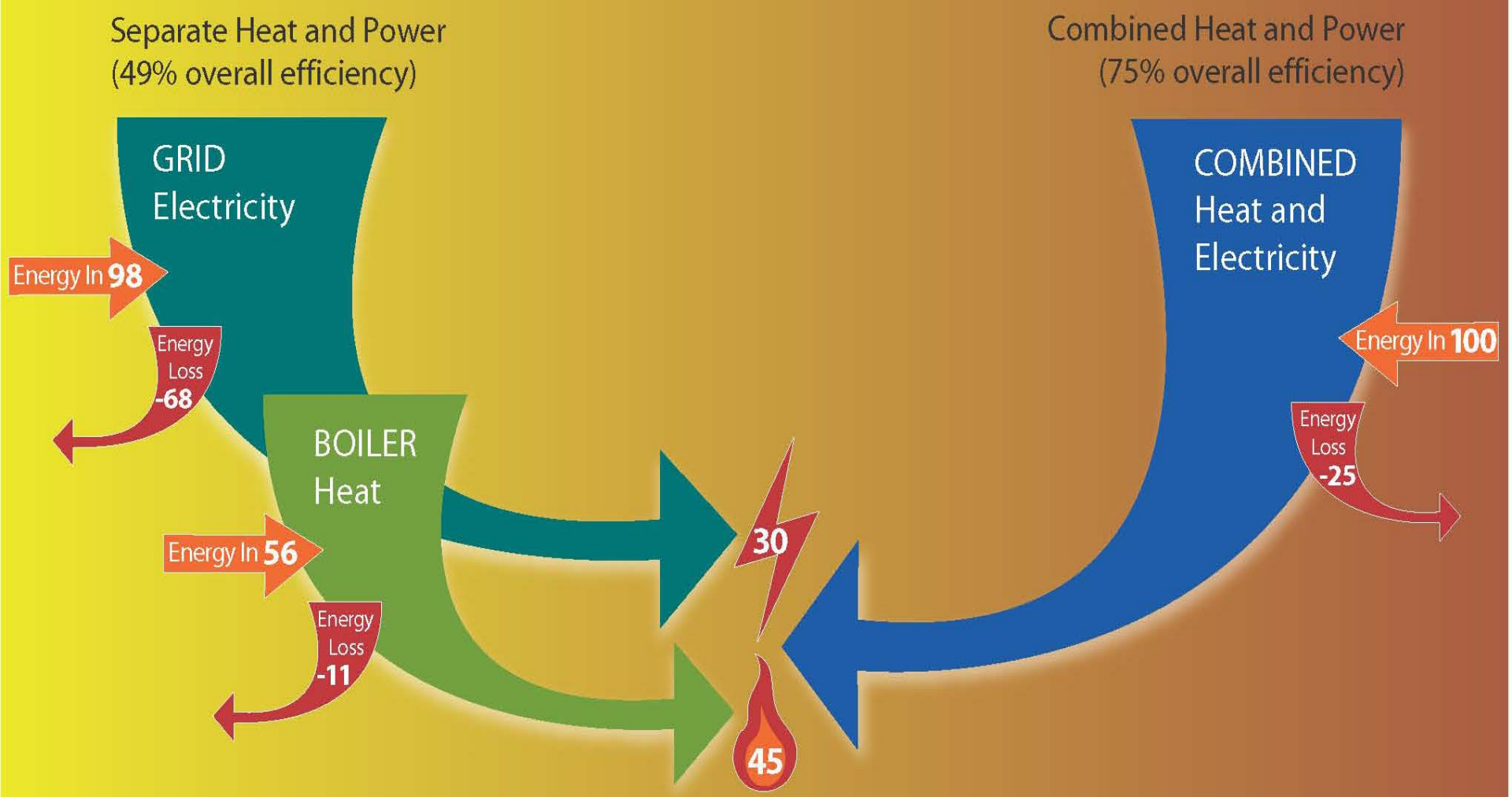
District Energy at Cornell



- Originally constructed in 1922
- Serves over 150 facilities
- Fuel input before 2010
  - 65,000 tons coal/yr
  - 150,000 DT gas/yr
  - 1.75 TBtu
- Fuel inputs today
  - 3 million DT gas/yr

- Fast Facts annual summary
  - https://energyandsustainability.fs.cornell.edu/em/fastfacts/default.cfm

Separate vs. Combined Heat and Power Production

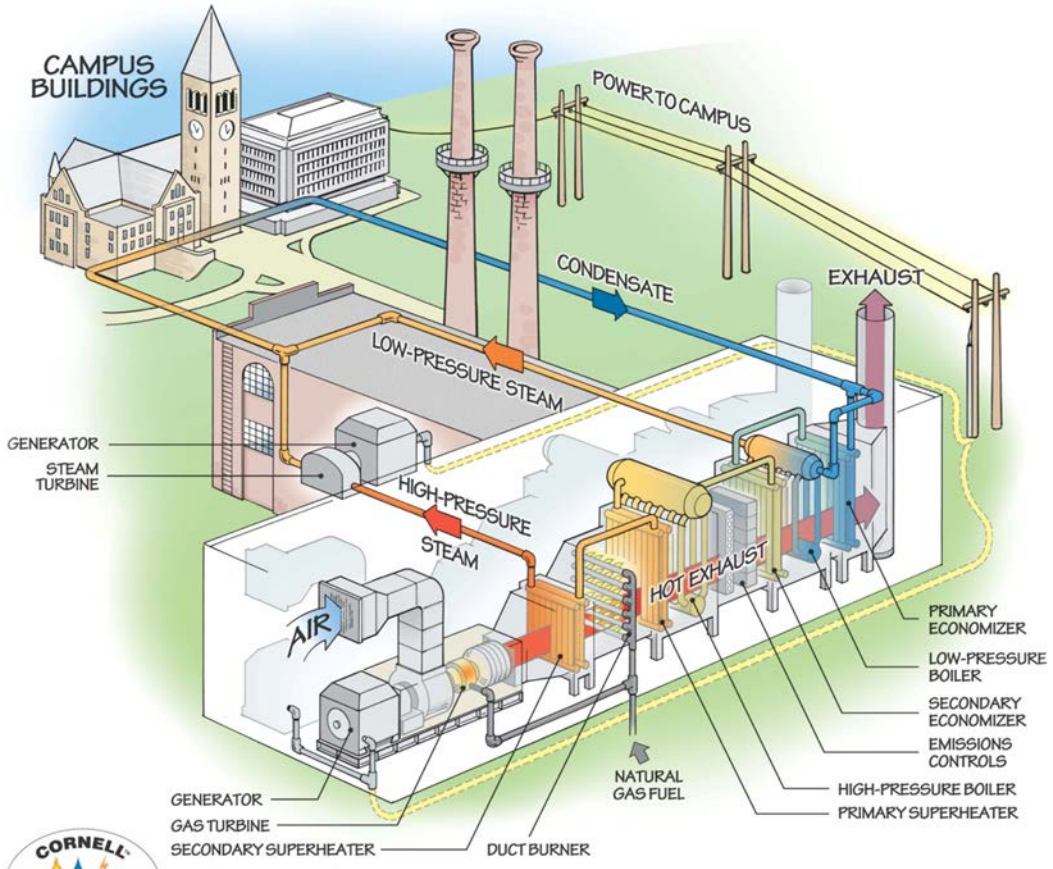


To produce 45 units of heat and 30 units of electricity, separate heat and power systems typically require 154 energy units of input. For the same output, a typical Combined Heat and Power system uses only 100 energy units, a 35% reduction.

Combined Heat & Power Project (CCHPP)

- 30 MW addition to existing (coal based) CHP plant
- 300 KPPH steaming capacity
- Renewal and upgrade to 115 x 13.2 KV substation
- 3.2 mile High pressure gas line
- Engineer of record - CHA/GIE
- $82.3 million project budget
  - $43.8 million construction
  - $8.0 million engineering & permitting
  - $28.5 million PP equipment
  - $2.0 million support & other

Combined Heat & Power Project (CCHPP)



Combustion Turbine with Heat Recovery Steam Generator

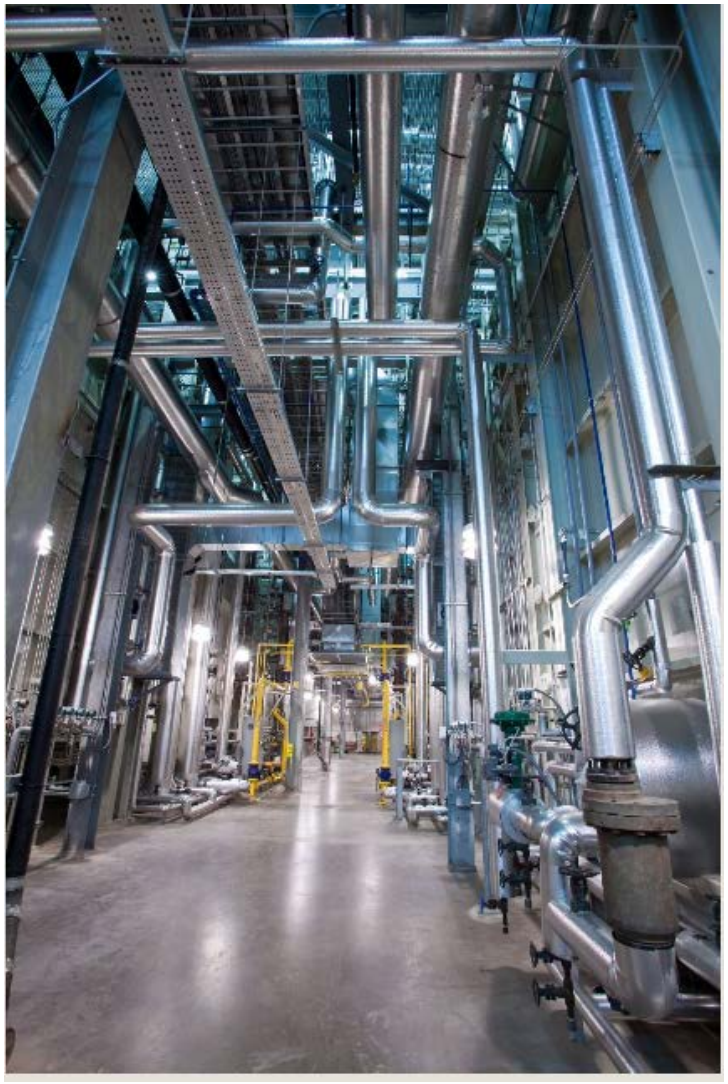
- Two Solar Titan 130s
  - Dual fuel (670 k gallons storage)
  - Inlet air chilling
  - Output direct to secondary bus at substation
- Rentech “dual pressure” HRSGs
  - 60 KPPH unfired
  - 150 KPPH fired
  - 40:1 turndown duct burner (gas only)
- SCR and CO catalyst
  - 2.5 ppm Nox
  - 5.0 ppm slip
  - 10 ppm CO

Combined Heat & Power Project (CCHPP)

- Highly efficient
  - The project is the most efficient way to generate the campus heat and electric energy needs
- Fuel flexibility
  - Cost management
  - Future bio-fuel option
- Electrical reliability
  - "Islanded' operation
- Eliminate coal usage
- Reduce CO_2 ~30%

Combined Heat & Power Project (CCHPP)

Old Versus New Plant



Central Utility Plants Controls

- History and Evolution
  - Prior to 1990- Proprietary vendor, first gen digital
  - 1991 upgrade to second gen digital
  - Ethernet and PLC's introduced in 2000
  - PLC's took off ~2010 with CCHPP project, dramatically expanding the digital infrastructure
  - 2010-2017 continuing evolution of network architecture and security

Central Utility Plants Controls

- Central Utility Plants
  - 10 Facilities
  - PLC's ~25
  - Remote I/O
    - Pressure, temperature, flow, valve position
  - Remote Devices
    - Meters
    - Transmitters w/ analog to IP conversion
  - Servers
  - ~20 Workstation screens

Pop Quiz Questions

- What is the efficiency improvement for Combined Heat and Power and what is the reason?

Pop Quiz Questions

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  - +50%
  - Making electricity alone wastes the heat (35%), CHP uses the heat increasing overall efficiency to 75-85%

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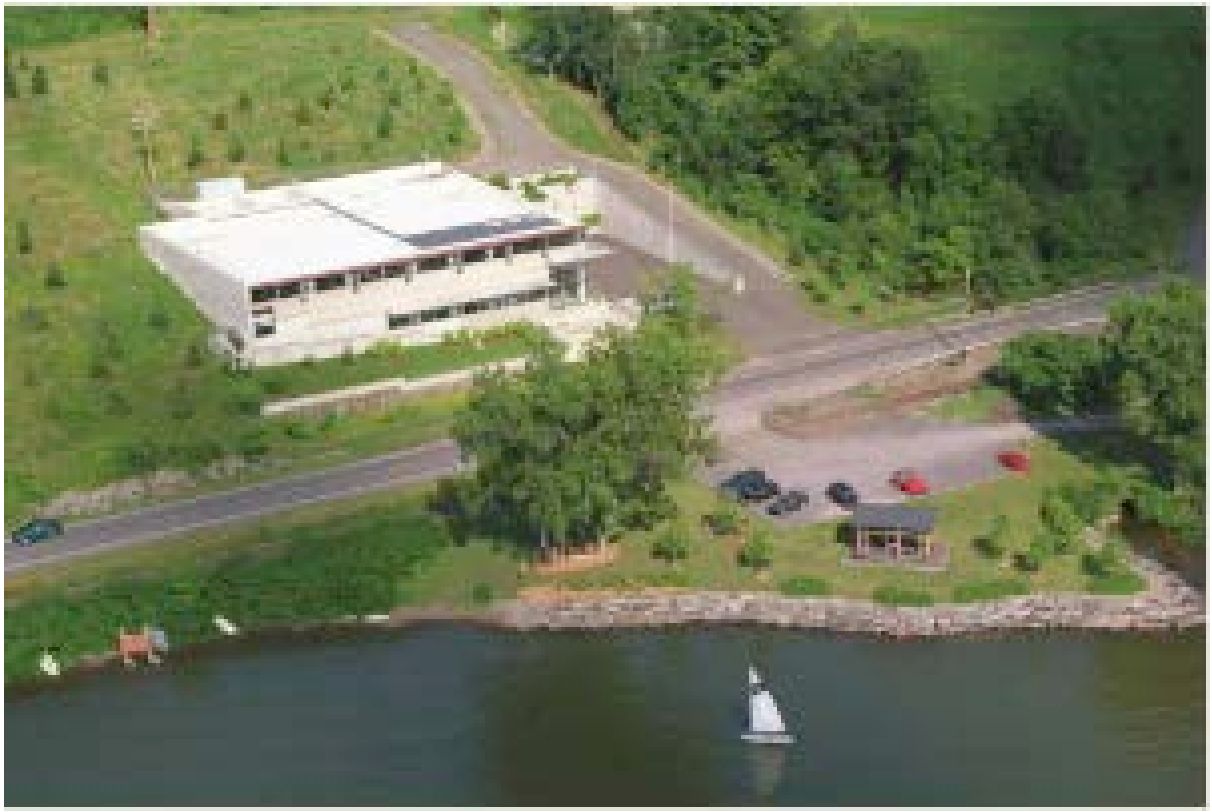
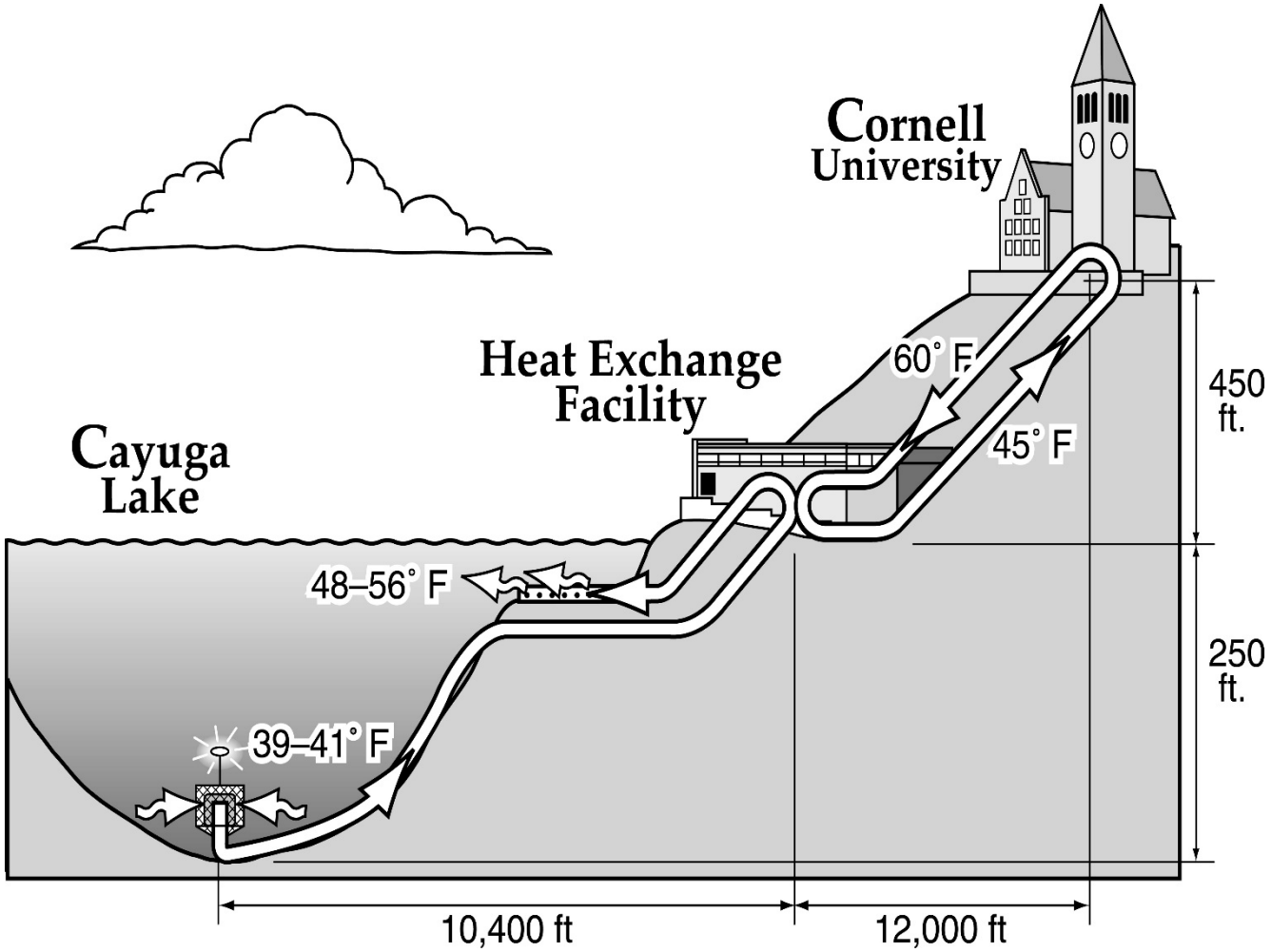
Lake Source Cooling



The Lake Source Cooling Process

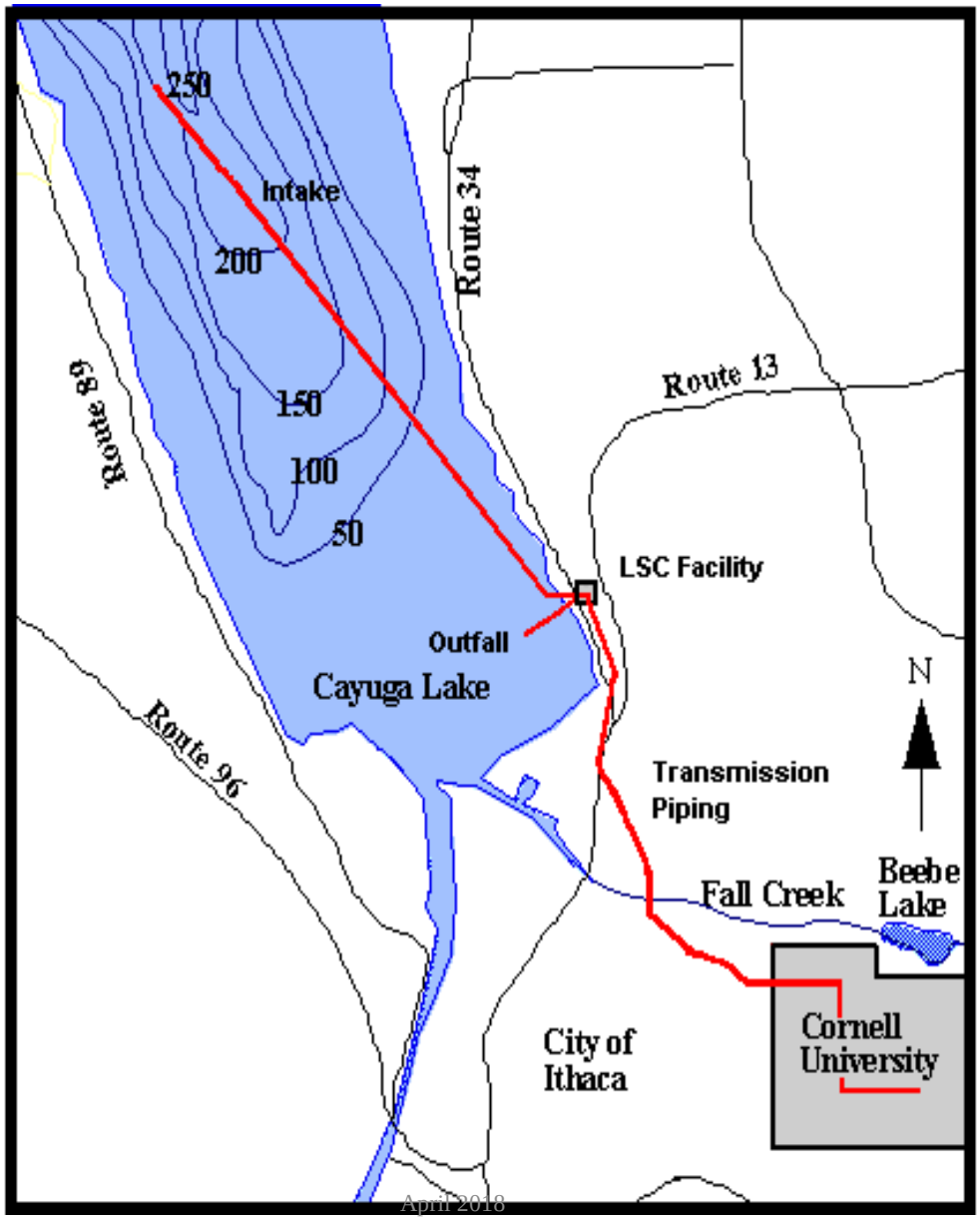


Lake Source Cooling

- Started service 2000
- Annual production at 0.1 kw/ton
- Truly “renewable” cooling

- Full automation (un-peopled)
- Carbon reduced 100,000 tons
- 25 million kwh/yr (reduction) or 10% of campus

The Lake Source Cooling Process



Positioning the Intake

Controlled Sinking

Intake ready for sinking

Chilled Water Pipe Installation

Plate and Frame Heat Exchangers

Chilled Water Pumps

Lake Water Pumps

- Vertical turbine
- single stage
- 25’ column length
- 3 x 350 HP
- variable speed driven
- 13,000 gpm @ 80 ft.

Programmable Logic Controls

- Redundant processors
- Ethernet and Modbus communications
- Over 300 I/O points
- 100% automated process

Pop Quiz Questions

- What is a typical electric use per unit of cooling and what is Lake Source Cooling?

Pop Quiz Questions

- What is a typical electric use per unit of cooling and what is Lake Source Cooling?
  - .8 to 1.0 kW/ton for chiller plants
  - .1 kW/ton for LSC, an 86% reduction on an annual basis

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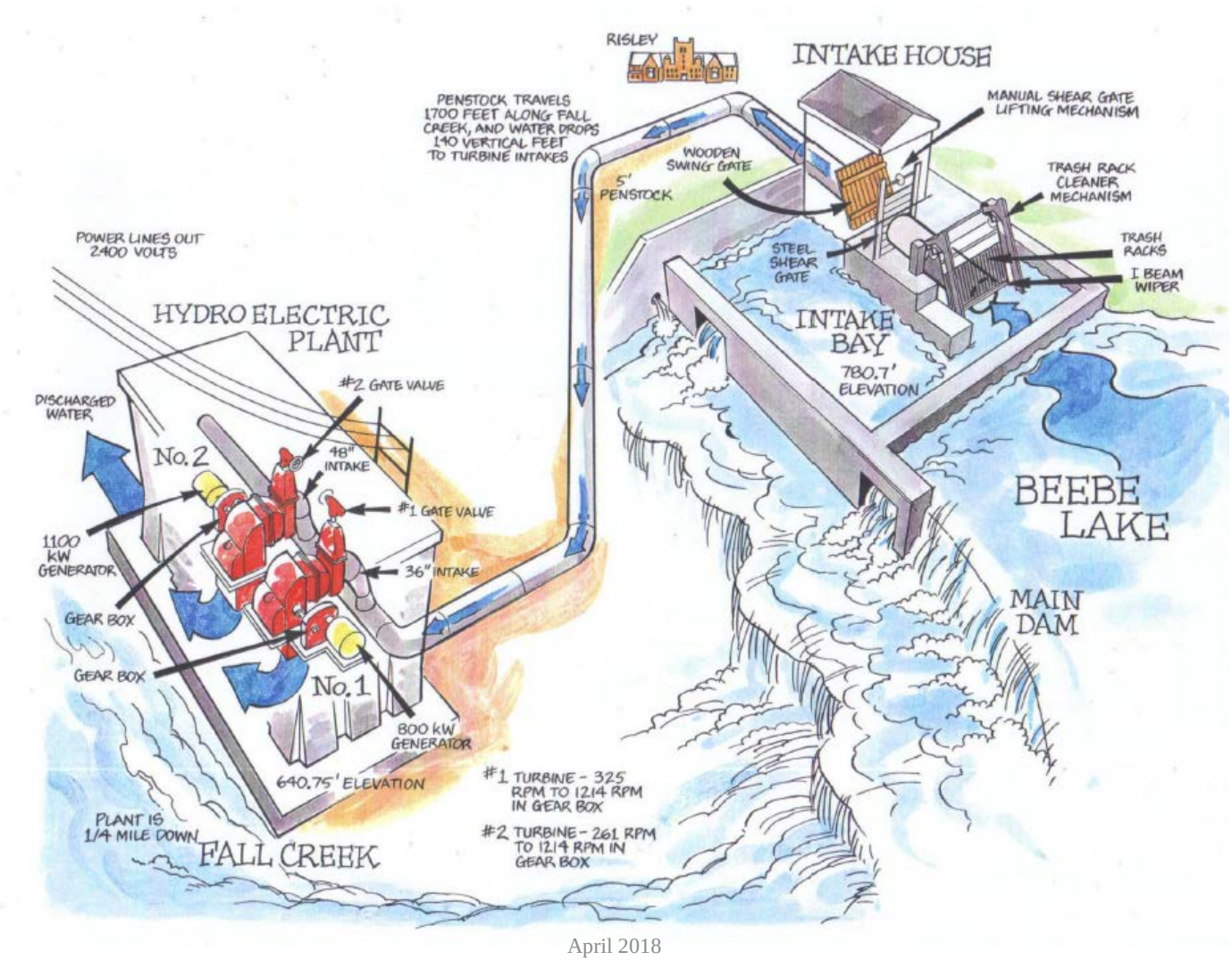
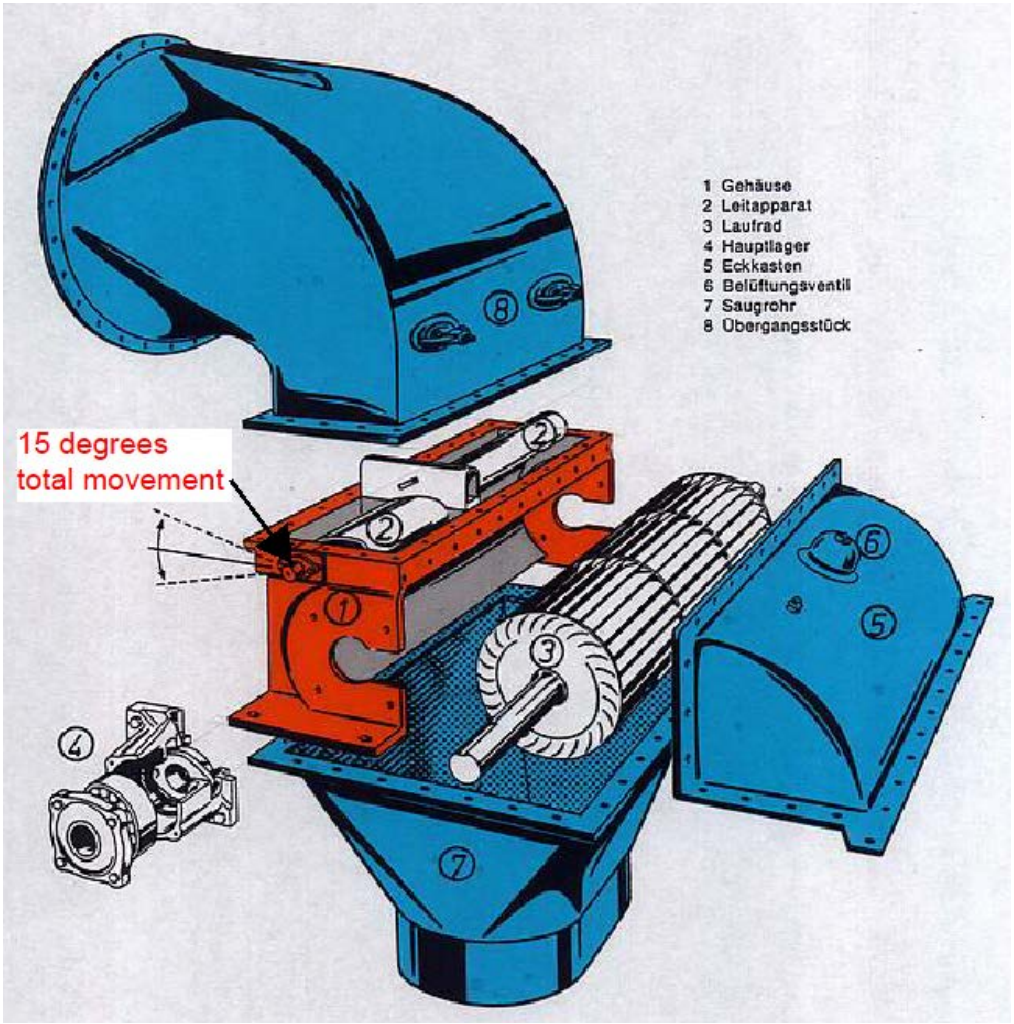
Hydroelectric Plant



Hydroelectric Plant

Hydroelectric Plant



Hydroelectric Plant

- 4-5 million kW-hr/yr or 2 % of campus
- Rebuilt 1981
- Controls and turbine upgrade in 2008/2015 increased annual production by 20%

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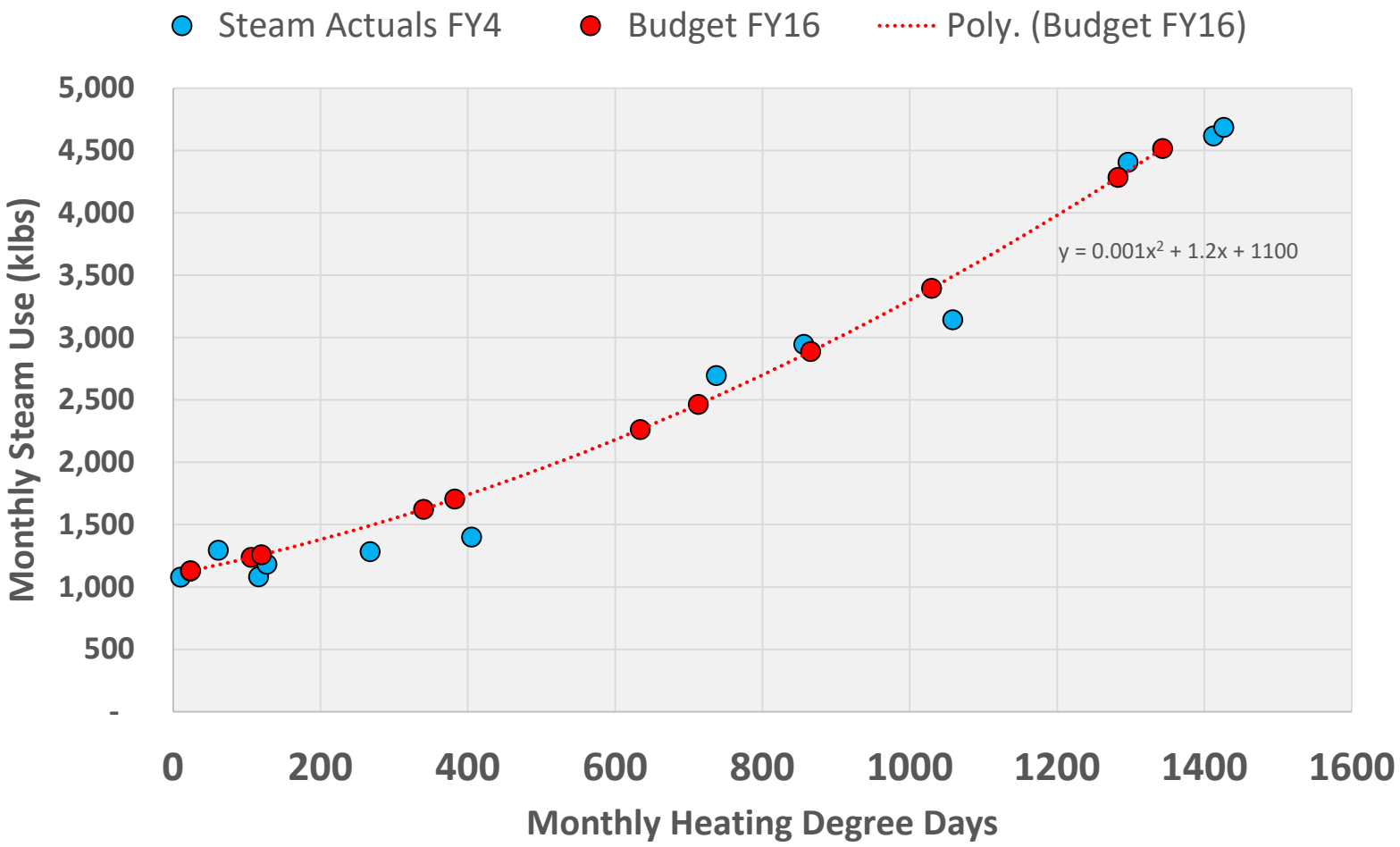
Forecasting

- Forecast is developed for each meter
  - 100 chilled water, 150 steam, 300 electric
  - Steam and chilled water require weather regression
- Reviewed / Updated each budget year based on performance.
- Track performance quarterly
- Building and Campus EUI is tracked and managed
- EUI reporting is part of online IPP metrics
- Accounts for: conservation, projects, utilization

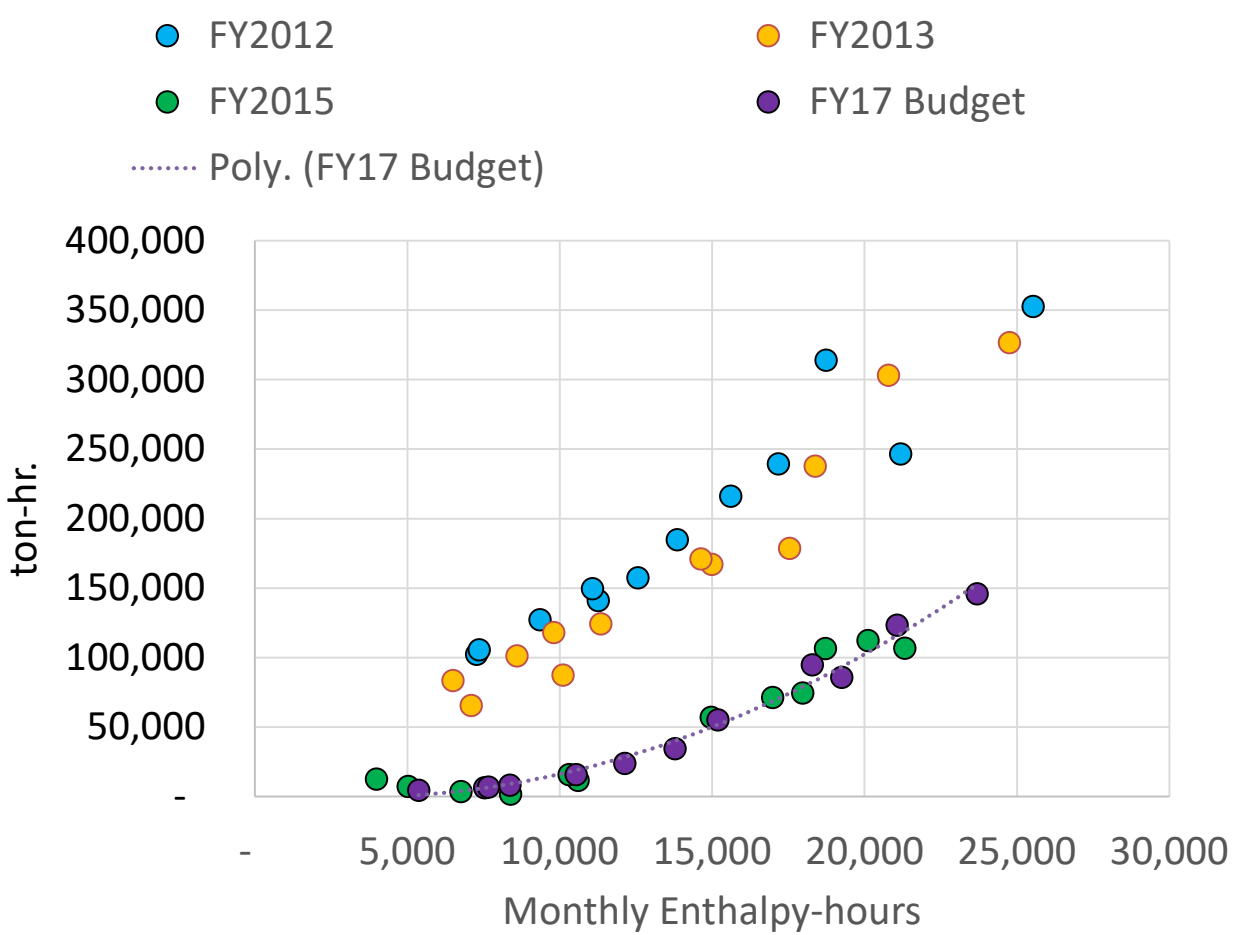
An Example: Duffield Steam forecasting
Use FY14 to develop formula to forecast FY16



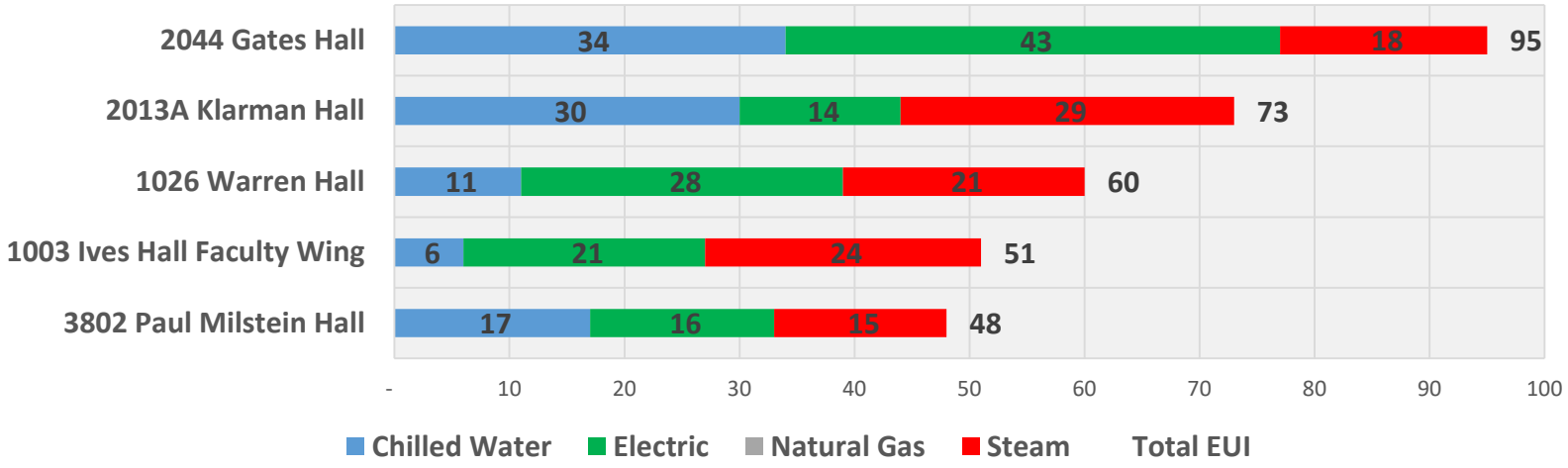
Example – Mann Library after ECI

Chilled water: Tracking the building performance for Mann Library, ECI efforts have significantly reduced overall building consumption

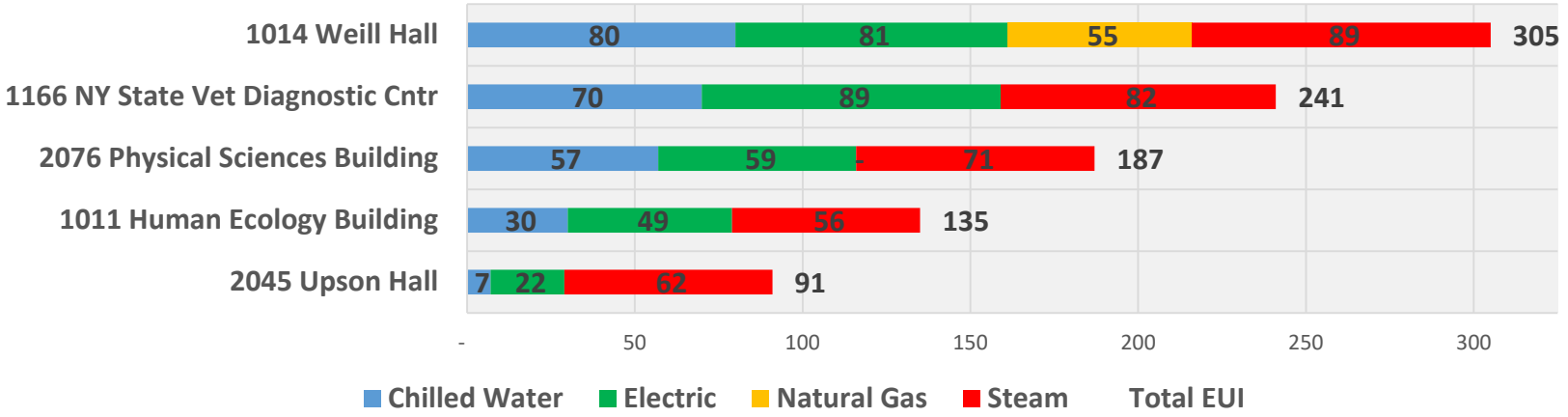
Forecasting was updated based on this new building performance, which is reflected in the FY17 budget



New Buildings/Renovations EUI (kBTU/GSF) Office-like



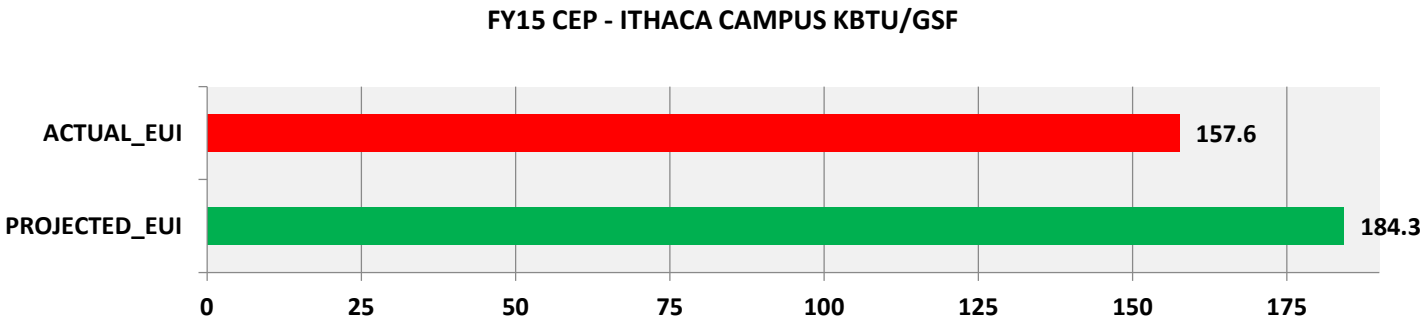
New Buildings/Renovations EUI (kBTU/GSF) Lab-like



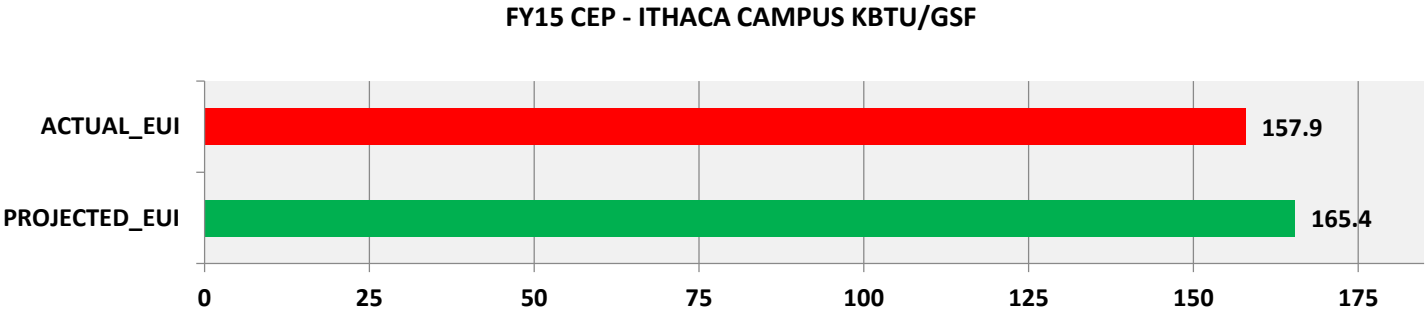
Campus EUI (kBtu/GSF)

Track performance multiple ways:

(1) pre-ECI performance versus post-ECI performance



(2) Actual performance versus Budget (weather adjusted)



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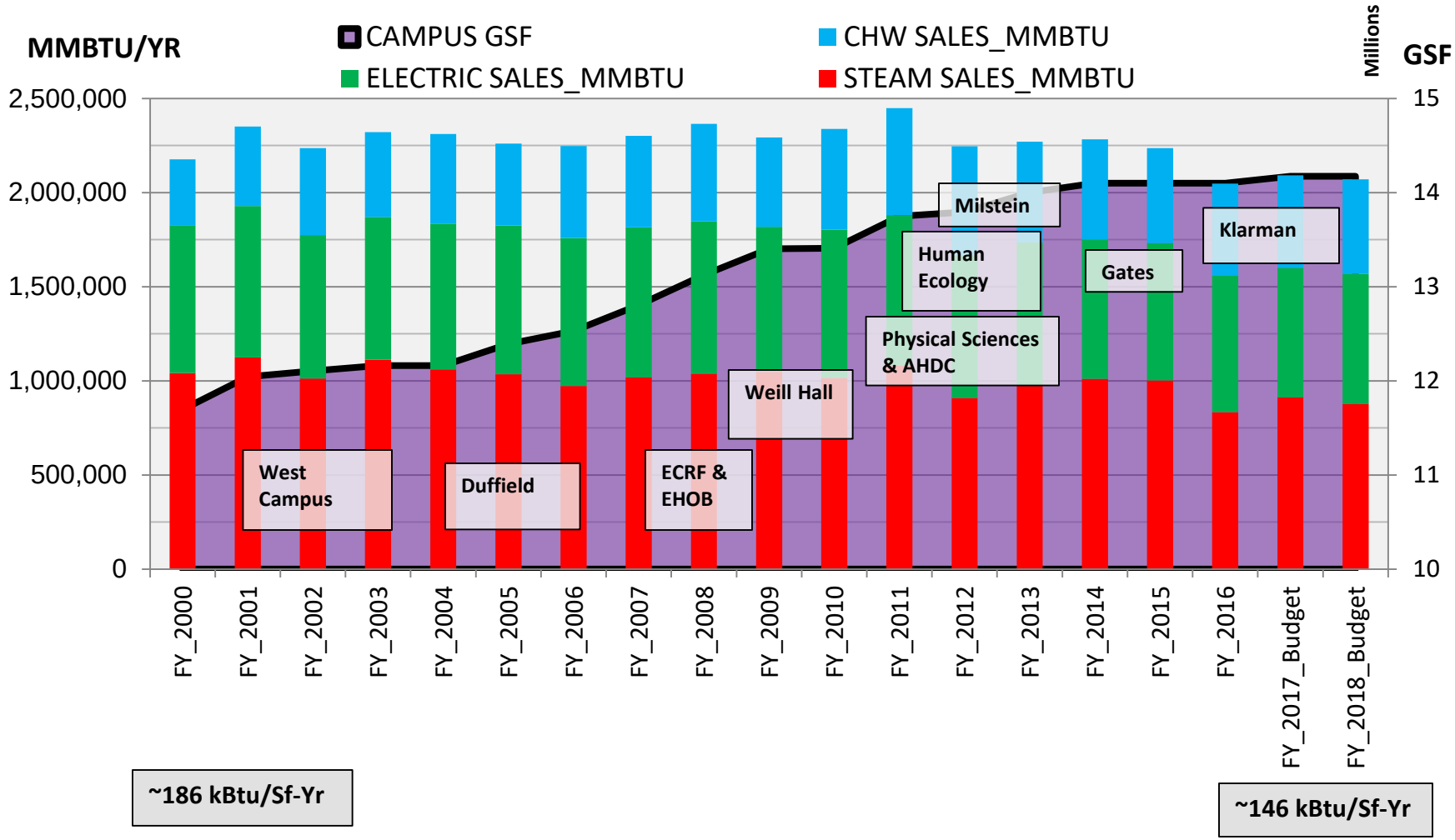
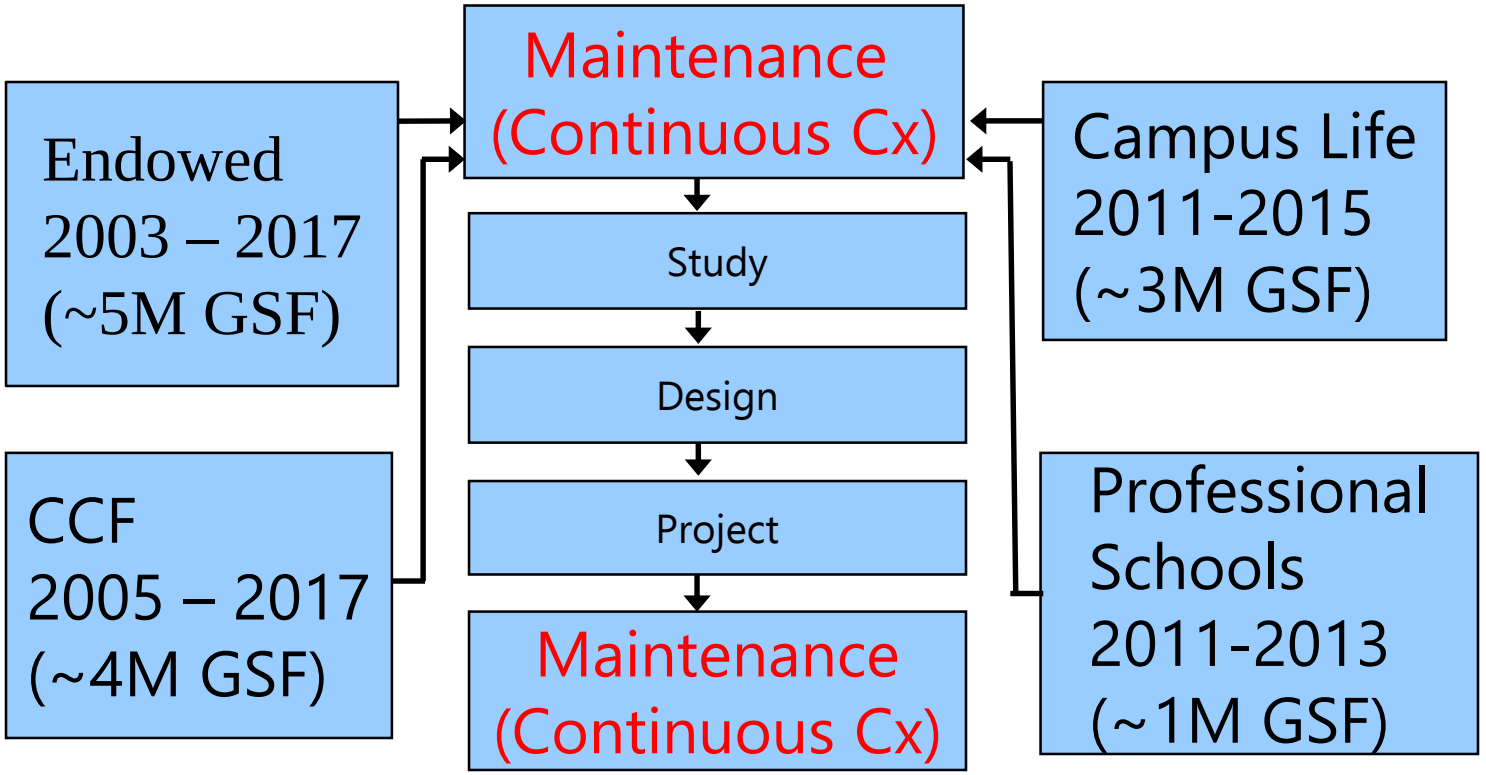
Building Energy Sales: History 2000 - 2018

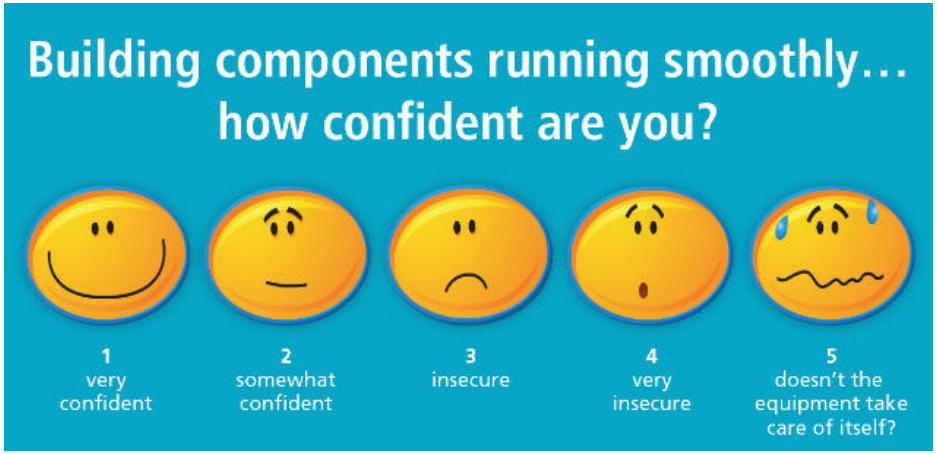


Steps of ECI


Maintenance
(Continuous Cx)
Endowed
2003 – 2017
(~5M GSF)
Campus Life
2011-2015
(~3M GSF)
Study
Design
CCF
2005 – 2017
(~4M GSF)
Project
Professional
Schools
2011-2013
(~1M GSF)
Maintenance
(Continuous Cx)

Conservation Project Elements

- Lighting – fixtures and occupancy control
- Updating of controls and control logic
- Complete Cx and Re-Cx of systems
- Humidification systems



Energy conservation in laboratories

Laboratory ventilation is responsible for approximately half of all energy use on campus ~ $25 million per year at billed rates

- Ventilation is the largest user of energy in labs.
- One fume hood = 3 households annual energy usage.
- Focus on controls to reduce outside air use
- Occupancy sensors to index room occupancy air flows, and lighting
- Relax temperatures to reduce reheat

LED Lamp Replacement Project

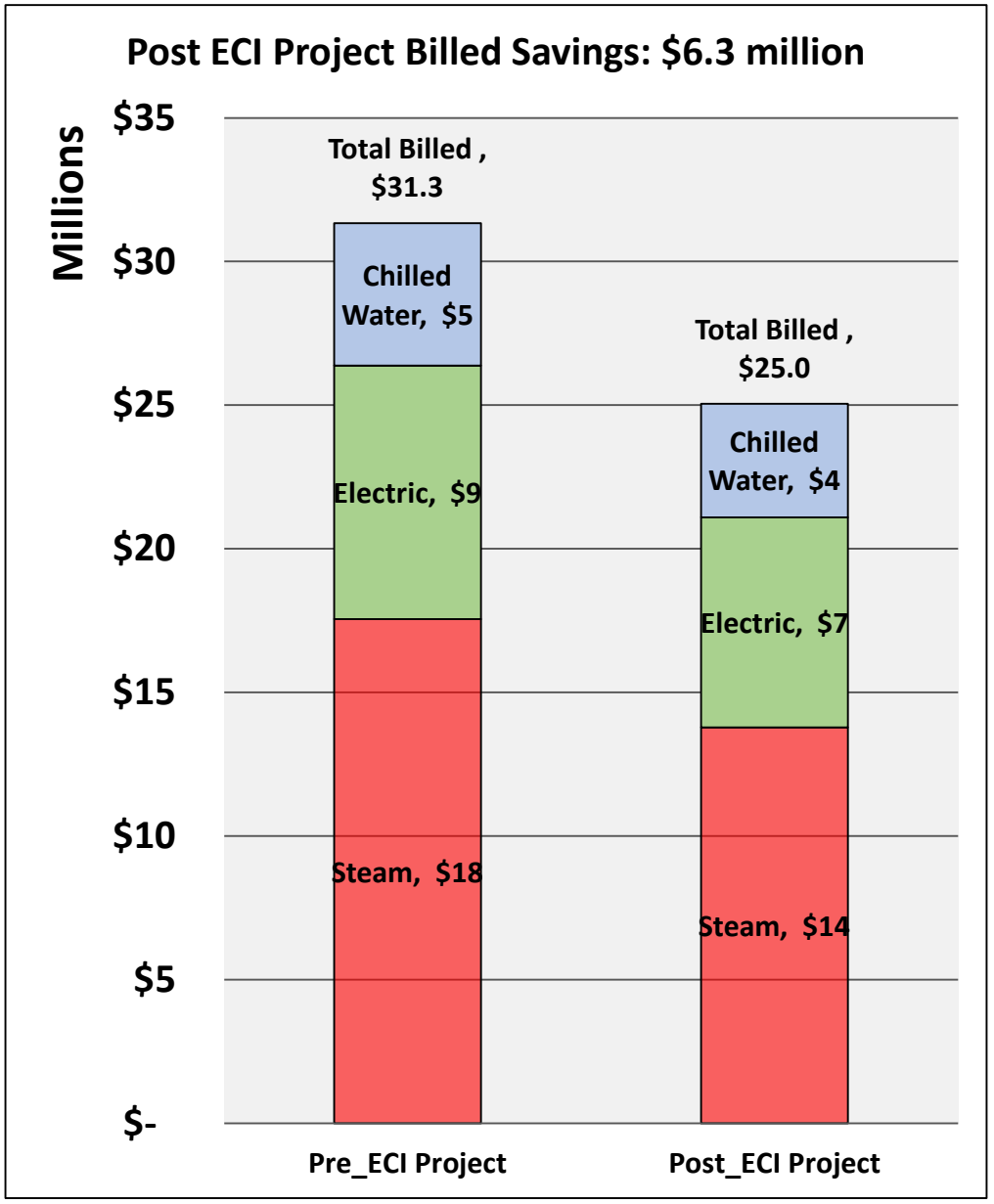
- Electrical savings to date
  - Over 60 buildings retrofitted
  - ~1400 kW reduction (peak)
  - 5,500,000 kWh/ year
  - 4.2 year simple ROI (2.1 year after incentive)
  - 155,000 lamps replaced

Insulation and Valve Upgrades

ECI Phase II Project Facts:

- Over 60 Facilities
- Over 90 projects
- Project Cost $33 million
- Project Savings: $6.3 million at billed rates with 5.3 year payback

ECI project savings	% energy savings from ECI project
Steam: 126,000 klbs	21%
Chilled Water: 5,000,000 ton-hrs	25%
Electric: 19,000,000 kwh	17%



Conservation focused preventive maintenance Energy Conservation Controls Team (ECCT)

- Retro commissioning
  - 24 month typical cycle goal central mechanical Cx
  - 36 month cycle space Cx
- Empower staff with savings metrics
- Fully involve building managers/directors
- Feedback after the work is complete
- All repairs paid for by maintenance budget

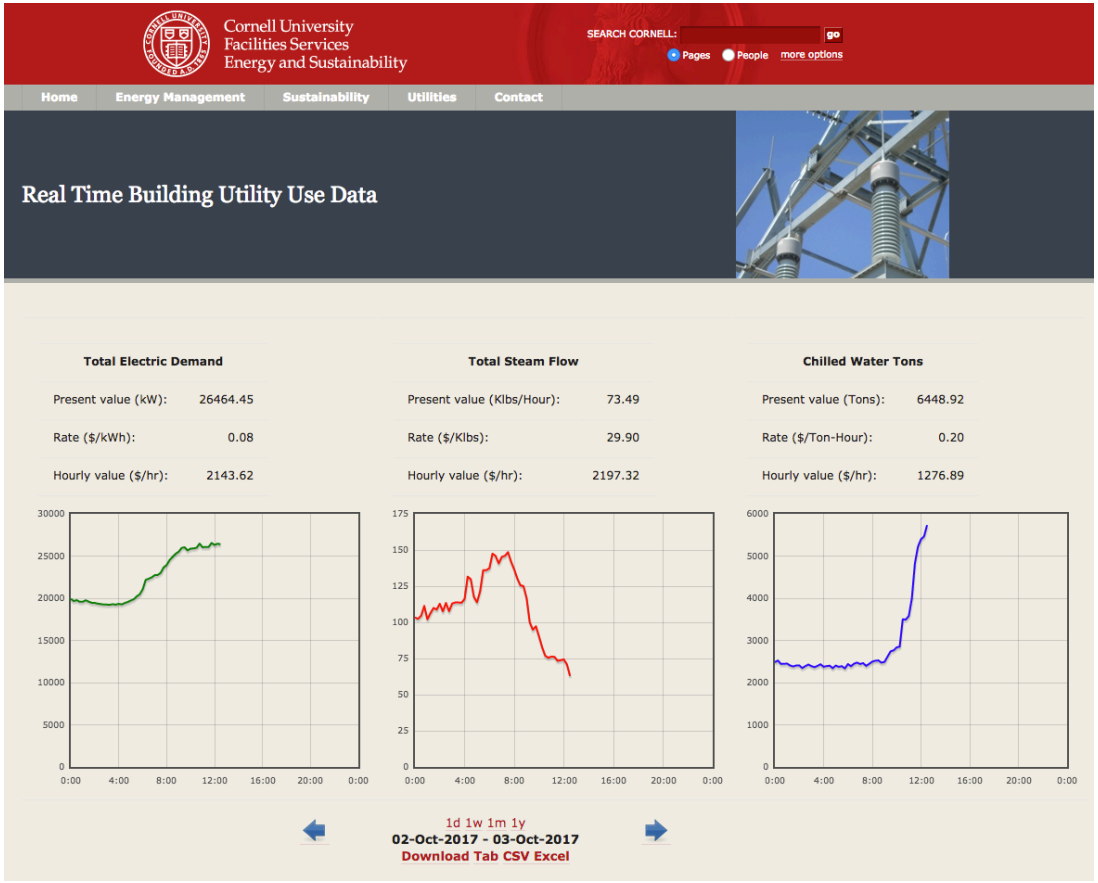
Building Dashboard

- Non-Techie, Eye Friendly
  - Easy to set up competitions
  - Quick look at building usage
  - Social media
  - Open to all
- SAS application
- Began 2011, converting to HTML5 in 2017

http://buildingdashboard.net/cornell/#/cornell
buildingdashboard.cornell.edu

Real Time Data Dashboard

- EMCS Portal
  - Techie
    - Real time energy use by facility/ Utility
    - Download to CSV/Excel
    - Cornell created
    - Includes weather data
    - Open to all



http://portal.emcs.cornell.edu/

Pop Quiz Questions

- Why does Cornell utilize continuous commissioning in its buildings?

Pop Quiz Questions

- Why does Cornell utilize continuous commissioning in its buildings?
  - To keep HVAC systems in "top tune" and continuously optimize energy systems to create 5-15% persistant savings and increase reliability/safety/comfort

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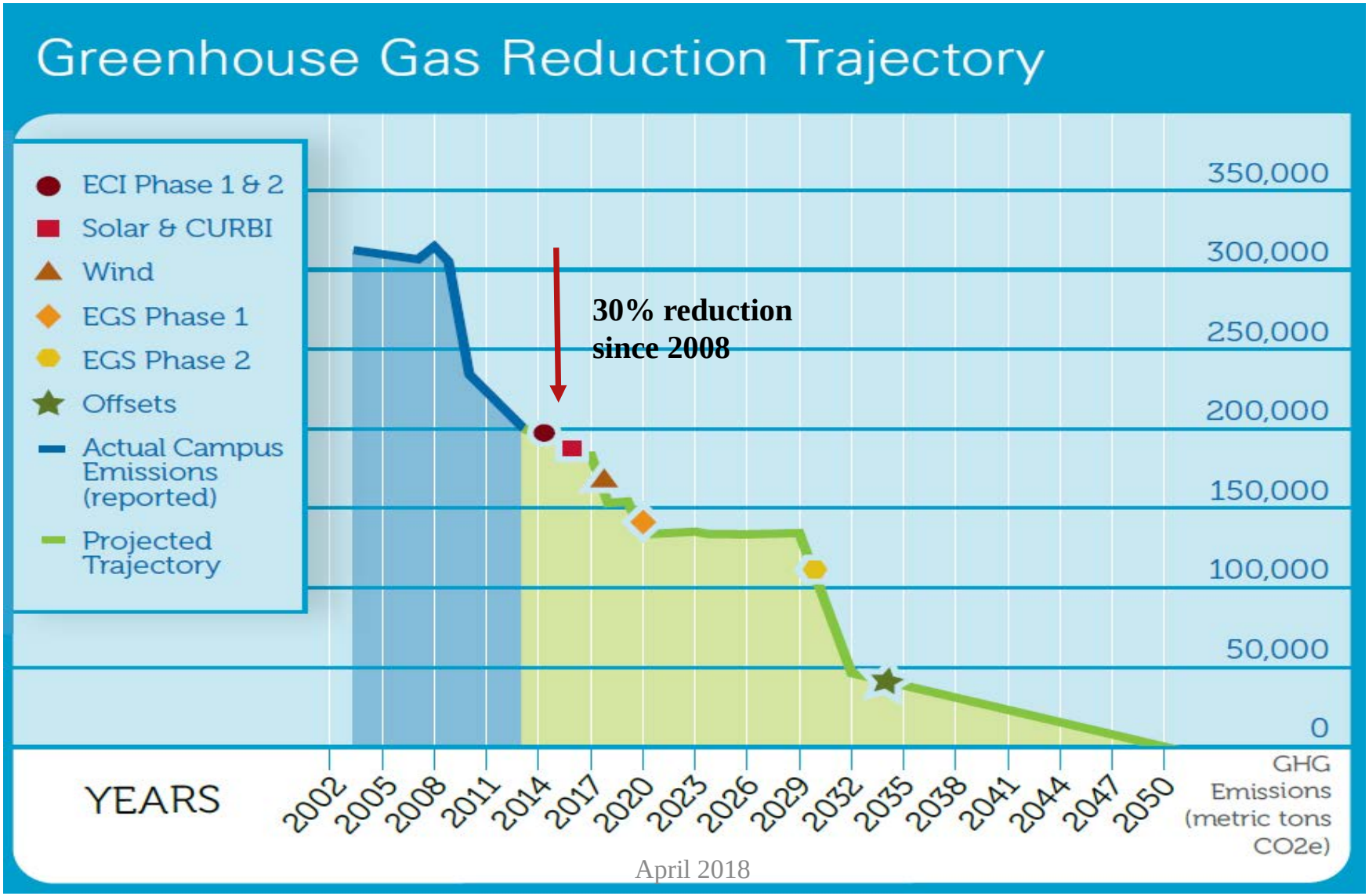
Path to Carbon Neutrality



Climate Action Plan

Making Climate Neutrality a Reality

- Actions to eliminate greenhouse gas emissions, broaden academic research, and enhance educational opportunities and outreach efforts by the year 2050.
- Cornell's Climate Action Plan (CAP) promotes the education and research needed to generate solutions for the challenges of global warming —and will demonstrate these solutions in campus operations.

Climate Action Plan

Four Tiered Strategy

1. Plan space to avoid new buildings
2. Reduce energy demand
3. Use renewable electricity and renewable heat
4. Offset business travel and commuting

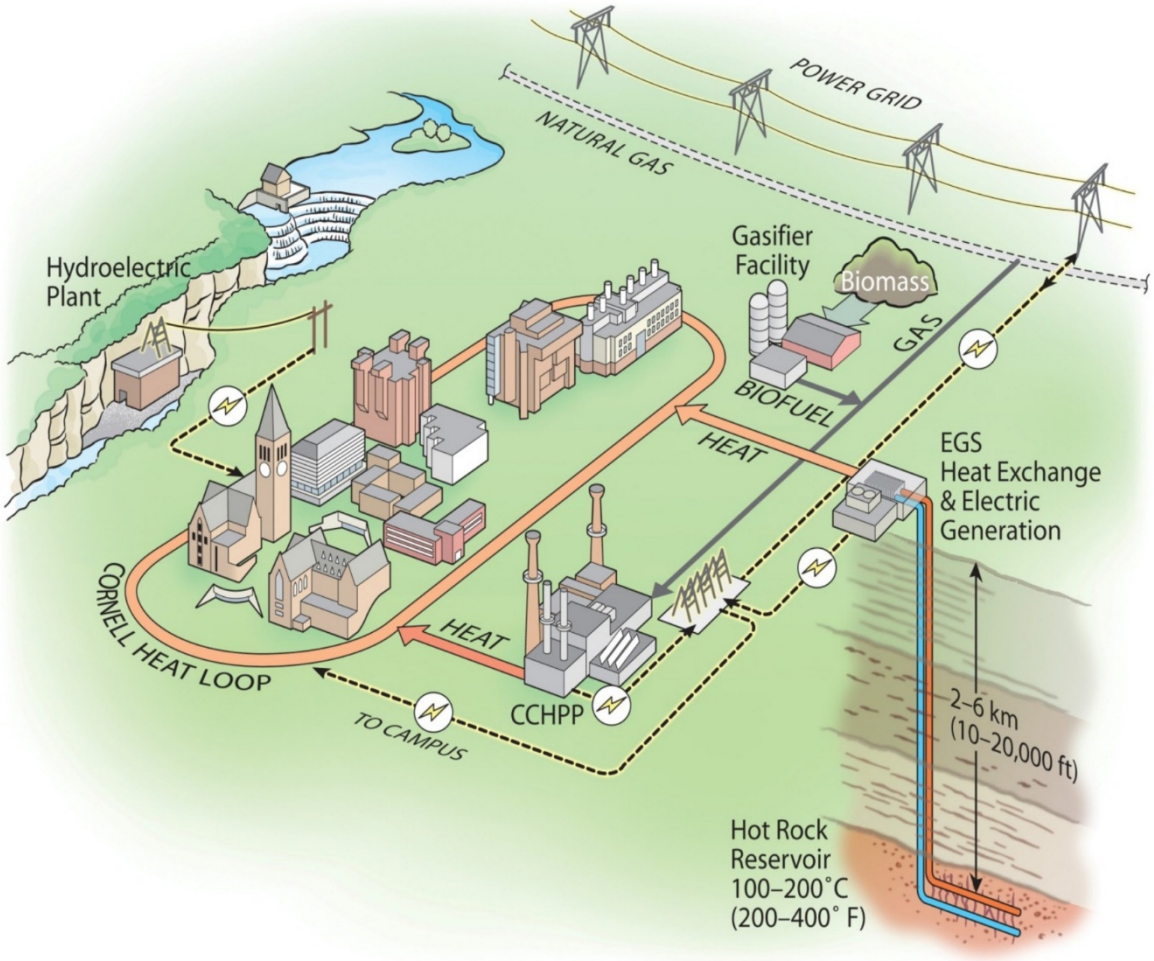
Off Campus Renewable Energy

- 2MW Cornell Snyder Road Solar Farm online in 2014
- Power Purchase Agreement
  - Remote/virtual net metered
- 1% campus electric use
- Educational array, data access, w/RECs
- $0 Cornell capital, no premium for green power, hedge effect

8MW projects complete at three other sites (4 systems) with RECs
- Very difficult utility interconnection issues, all worked out with PSC/NYSEG

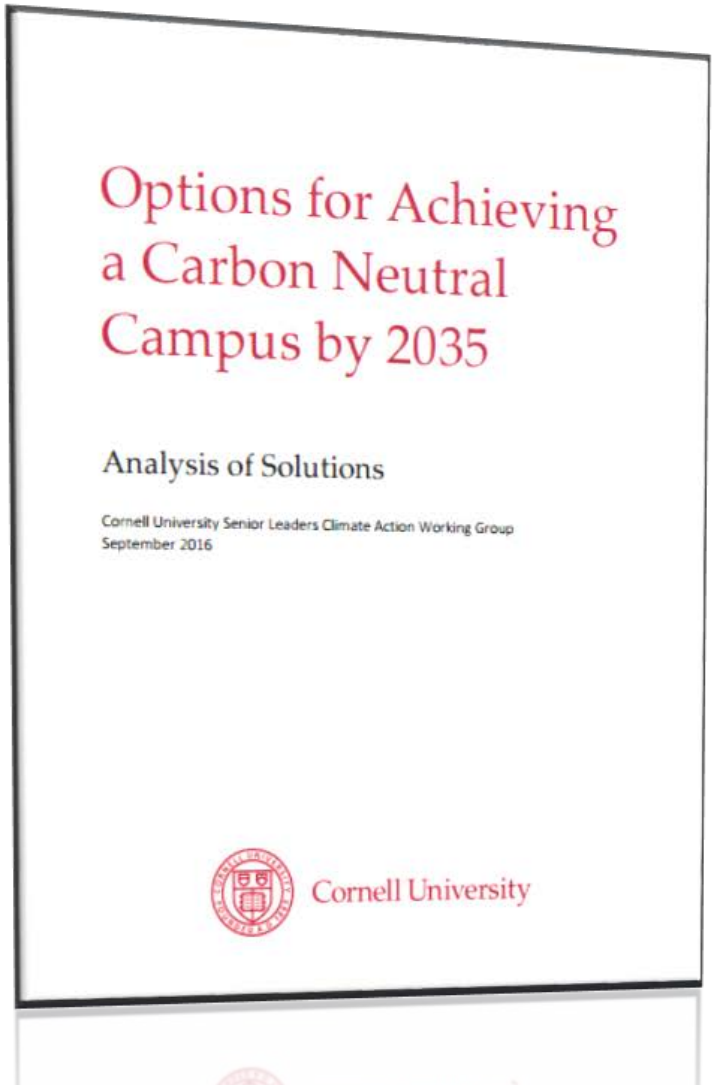
Future projects community solar (18 MW)
- All projects third party, no cost to Cornell, RECs included
- Changes to net metering, NY-Sun program, federal tax credit

Earth Source Heat and Peaking Bioenergy



Climate Action Plan

SLCAG Report



Solutions for Today:

- Conserve energy in existing buildings
- Build high-performance buildings
- Increase electric vehicle capacity
- Renewable power projects
- Campus engagement: *Think Big, Live Green* initiative
- Campus-wide climate literacy
- Utilizing campus as a living laboratory

Climate Action Plan

SLCAG Report: Solutions

2022

- Begin full ESH, if viable or alternate GSHP option
- Revise Climate Action Plan, including new energy path forward

2027

- Fully implement campus heating solution
- Advance other carbon reduction efforts

2035

- Reach carbon neutrality with full participation from the campus community

Pop Quiz Questions

- What are the large changes that have resulted in a 30% reduction in calculated total carbon equivalent emissions for Cornell?

Pop Quiz Questions

- What are the large changes that have resulted in a 30% reduction in calculated total carbon equivalent emissions for Cornell?
  - Combined heat and power
  - Elimination of coal
  - Energy conservation continuous commissioning
  - Energy conservation projects

Questions