Reducing campus emissions and energy bills through software-based HVAC optimization

Brett Pasinella, Second Nature; Kevin White, Optimum Energy; Kevin Kuretich, Optimum Energy

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About Second Nature

Second Nature works to proactively build a sustainable and positive global future through…

initiating bold commitments,

scaling successful actions,

and accelerating innovative solutions

… among leadership networks in higher education.

The Presidents' Climate Leadership Commitments

Bold commitments by leaders in the higher education sector yield positive changes at their institutions and beyond.

The Climate Commitment: integrates carbon neutrality with climate resilience. Provides systems approach to addressing climate.

The Carbon Commitment: focused on reducing Greenhouse Gas emissions and achieving carbon neutrality as soon as possible.

The Resilience Commitment: focused on climate adaptation and community capacity-building to deal with a changing climate and resulting extremes.

Reducing Campus Emissions and Energy Bills Through Software-based Optimization

Kevin White, Director of Business Development
Kevin Kuretich, Director, Optimization Services

April 19, 2017

Optimum Energy

The world's leading provider of scalable HVAC energy efficiency programs for enterprise organizations

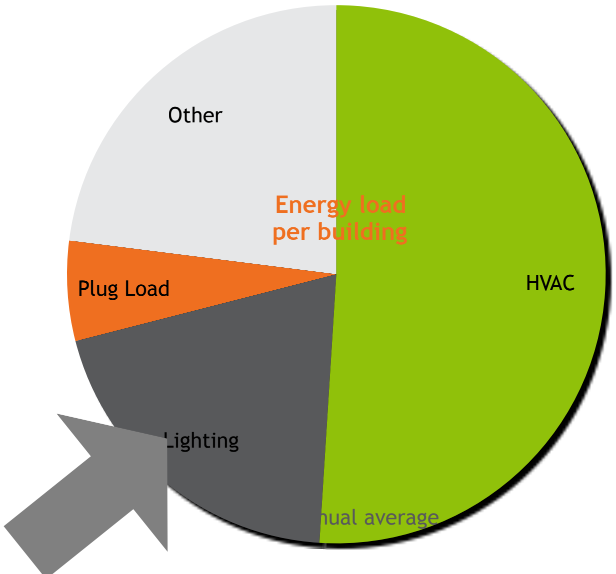
By the Numbers

- Up to **50% energy savings** on HVAC across a portfolio
- **200+ installations**
- **120,000,000+ ft2** under optimization management
- 1.5 billion optimization calculations conducted annually
- 500+ Gigawatt hours of energy saved

Differentiators

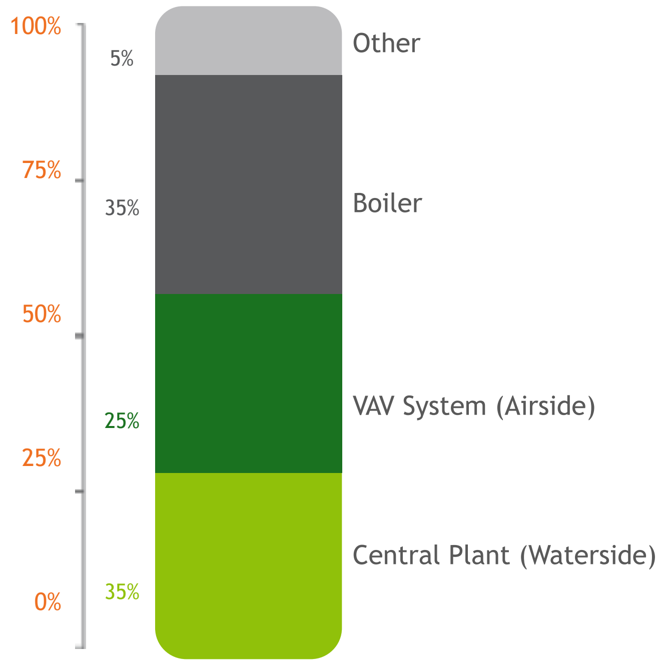
- We maintain **more chiller plant tonnage under optimization than all other providers**
- We deliver **large-scale sustainability programs for major colleges & universities and the fortune 500**
- We provide **consistent results** in a **wide variety** of industries, verified by **automated M&V**

Lighting Is Big, But HVAC Is Bigger



Low-hanging fruit
getting picked over

HVAC system detail



Sources: IDC and the EIA Commercial Building Consumption Survey

Electricity Consumption in Higher Ed

$14 Billion

44% of electricity and 77% of gas

→ $6+ Billion

20% → $1.2 Billion

What is Optimization?

- Merriam-Webster – “an act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible”
- More than just using less energy
- For HVAC, optimization is making the whole system as efficient as possible

The Three Laws of Optimization

You cannot optimize what you cannot **measure**

Optimize **systems** not just components

Optimization must be **continuous**, **dynamic**, and **self-actuating**

What is Optimization?

Approach to System Optimization

Design

- System Infrastructure
- Selection of Components

Operate

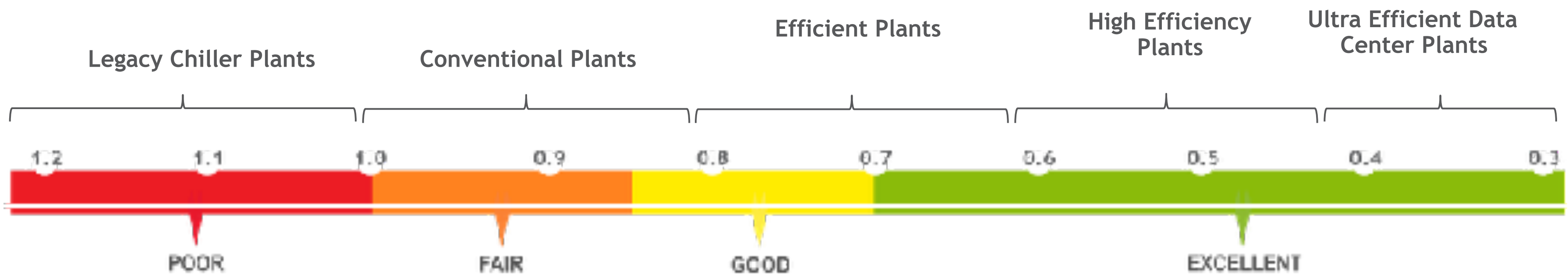
- Plant Automation
- Component Application
- Networked Optimization Software

Maintain

- Enhanced Visibility
- Measurement & Verification
- Persistent Maintenance

Chiller Plant Efficiency Scale

Just like miles per gallon, the kW/ton figure reflects the efficiency of the chiller plant regardless of the amount of cooling produced



Average annual chilled water plant efficiency in kW/ton.
Input includes: chillers, tower fans, condenser pumps, and chilled water pumping.

Annual average kW per ton

Chiller Plant + Airside Optimization

Chiller Plant

Normal Building Load

Distance 100 miles

Chiller Optimization

Chiller Plant Optimization
improves the efficiency of the Chiller Plant
Saving energy by improving kW/ton.

Building Load

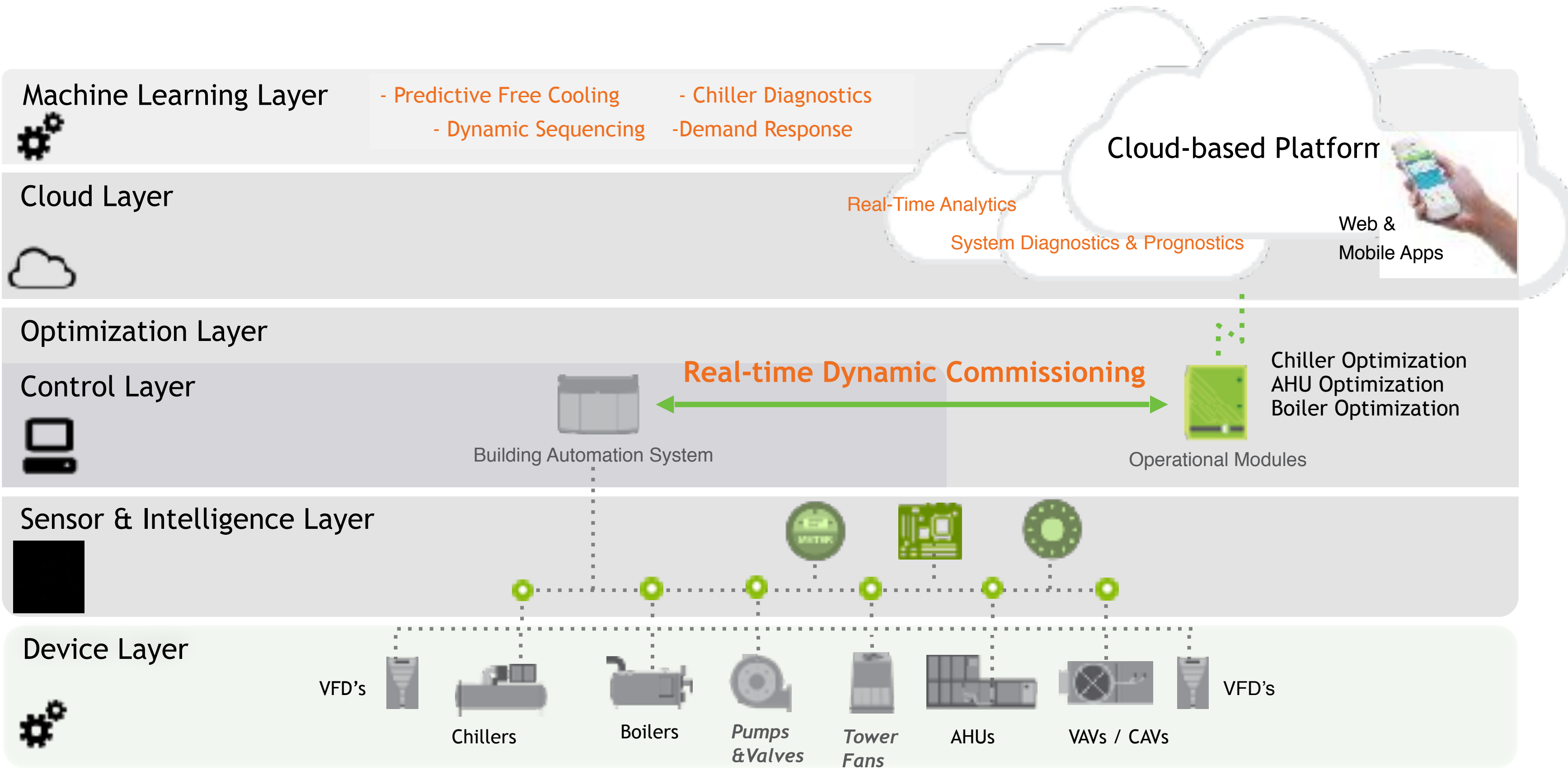
Building Load with Airside Optimization

Airside Optimization

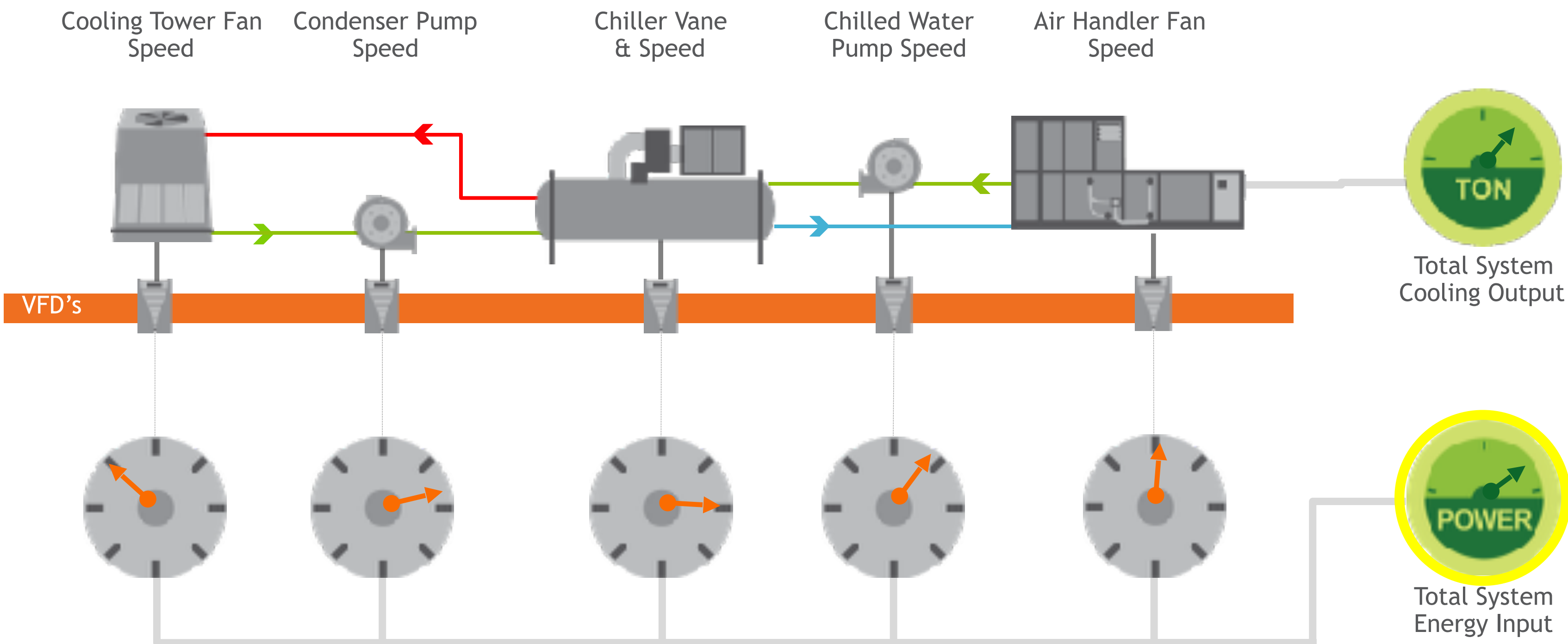
Distance 60 miles

Airside Optimization improves the efficiency and operation of the Air Handlers reducing the load on both the Chiller Plant and Heating System of the building.

Software-based Optimization: Typical Architecture

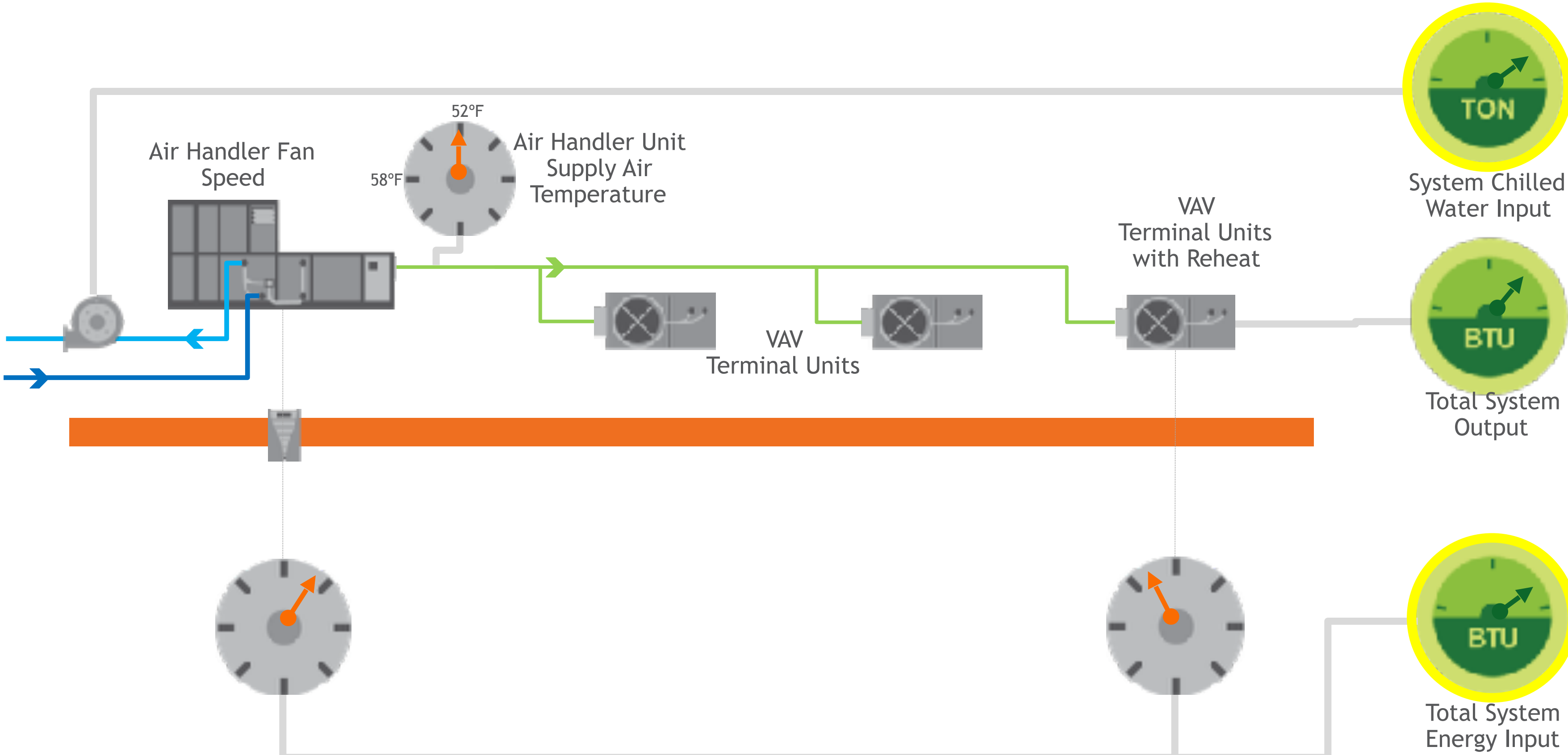


Chilled water plant and HVAC optimization



Total System Schematic

Air Handling System Optimization



Total System Schematic

What are the Benefits of Optimization?

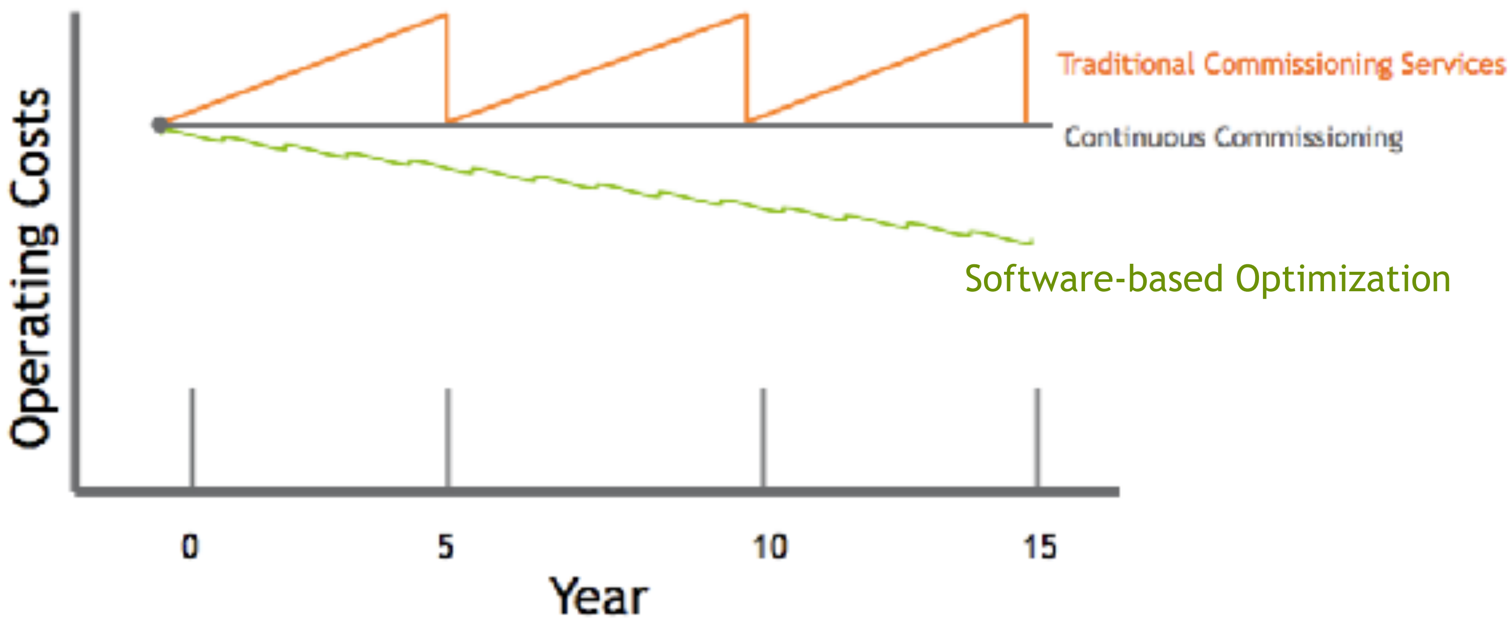
- Saves energy and money
  - Typical ROI is 2 – 5 years
- Reduces carbon emissions
- Saves water
- Mitigates performance drift
- Improves your operations through improved visibility
- Allows your facility staff to focus on other things

What should you look for?

- Experience - references and case studies
- Modular/Scalable solution
- Fully automated Measurement & Verification
- BAS and HVAC equipment vendor-agnostic
- Comprehensive (Chilled water + airside)
- Detailed baseline
- Engineering and Technical support
- Persistent, long-term savings

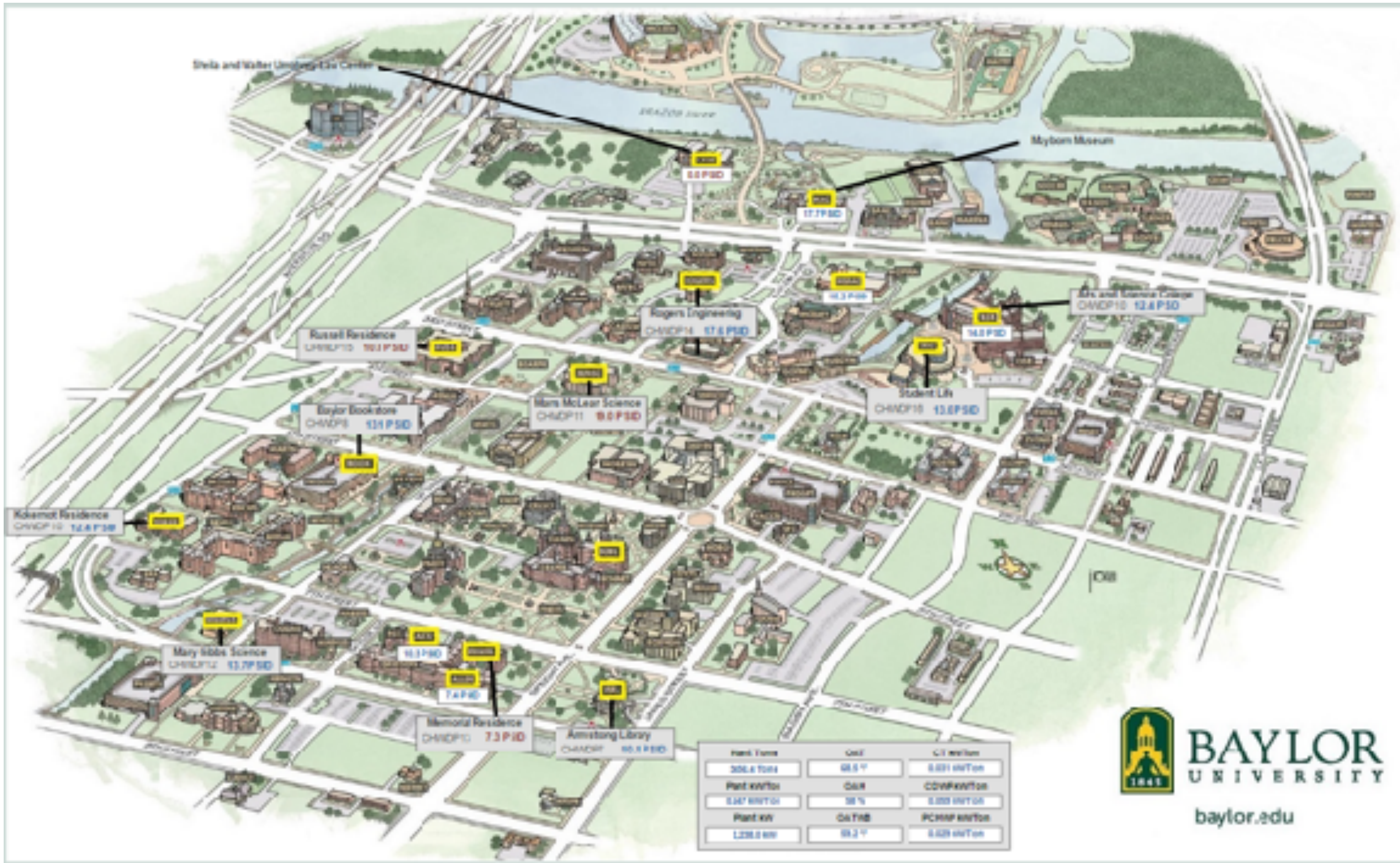
Why Software-based Optimization?

- Building performance degrades over time
- Typical traditional commissioning insufficient
- Even continuous commissioning keeps you on target, at best
- Software-based Optimization can actually help you reduce your operation costs over time



Software-based Optimization Case Studies

Baylor University



Case Study

Baylor University

Overview

- Baylor University, located in Waco, Texas implemented an energy reduction goal of $1 million by the end of a 10 year contract
- Campus environment requires 24/7/365 cooling, with concern for occupant comfort
- Total of 7 chillers on a variable primary system, all different sizes and different mfg, 6 constant speed (2 dual compressor) and two small variable speed
- New 2,700 Ton variable speed chiller installed in Oct 2016 and integrated into Optimization system

Results

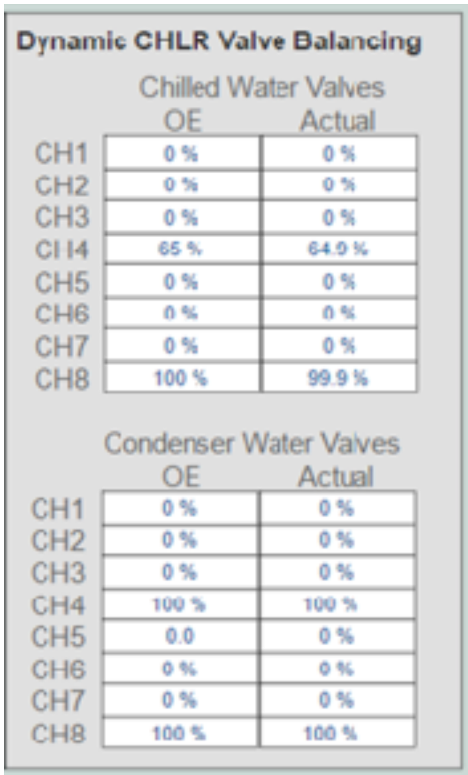
- Chiller efficiency rating: 0.75 kW/ton—a 17% improvement
- Achieved 4,788,001 kWh savings in 2016
- Carbon emissions saved: 7,087,679 lbs of CO_2 in 2016
- New chiller has increased savings by 651,000 kWh since Oct 11, 2016
- Avg plant performance since Oct 2016 - .58 kW/Ton

Baylor University: 17% Improvement in Plant Efficiency

Savings Summary by Month								
	Baseline Usage Estimate			Projected Performance		Actual Performance		
Month	Plant Ton-Hours	Plant kWh	Plant kW/ton	Plant kWh	Plant kW/ton	Plant Ton-Hours	Plant kWh	Plant kW/ton
January	1,165,199	1,037,111	0.890	444,747	0.382	1,242,582	669,231	0.539
February	1,411,889	1,239,735	0.878	695,981	0.493	1,663,467	921,870	0.554
March	1,937,195	1,695,857	0.875	1,059,459	0.547	2,253,036	1,578,280	0.701
April	2,801,017	2,466,113	0.880	1,906,426	0.681	2,978,893	1,983,557	0.666
May	3,582,345	3,181,601	0.888	2,666,224	0.744	3,641,959	2,590,937	0.711
June	4,577,392	4,143,880	0.905	3,770,378	0.824	4,731,381	3,938,940	0.833
July	4,825,485	4,376,579	0.907	4,011,903	0.831	5,145,549	4,356,001	0.847
August	5,121,930	4,700,174	0.918	4,362,018	0.852	4,990,792	4,055,284	0.813
Septembe	4,281,205	3,881,704	0.907	3,467,200	0.810	4,438,293	3,450,094	0.777
October	2,615,021	2,303,407	0.881	1,702,983	0.651	3,142,529	2,301,423	0.732
November	1,783,953	1,566,984	0.878	958,336	0.537	1,850,188	1,340,994	0.725
December	1,284,719	1,141,067	0.888	567,507	0.442	1,571,320	994,164	0.633
Total	35,387,350	31,734,212	0.897	25,613,162	0.724	37,649,988	28,180,775	0.748

17 % Efficiency Improvement

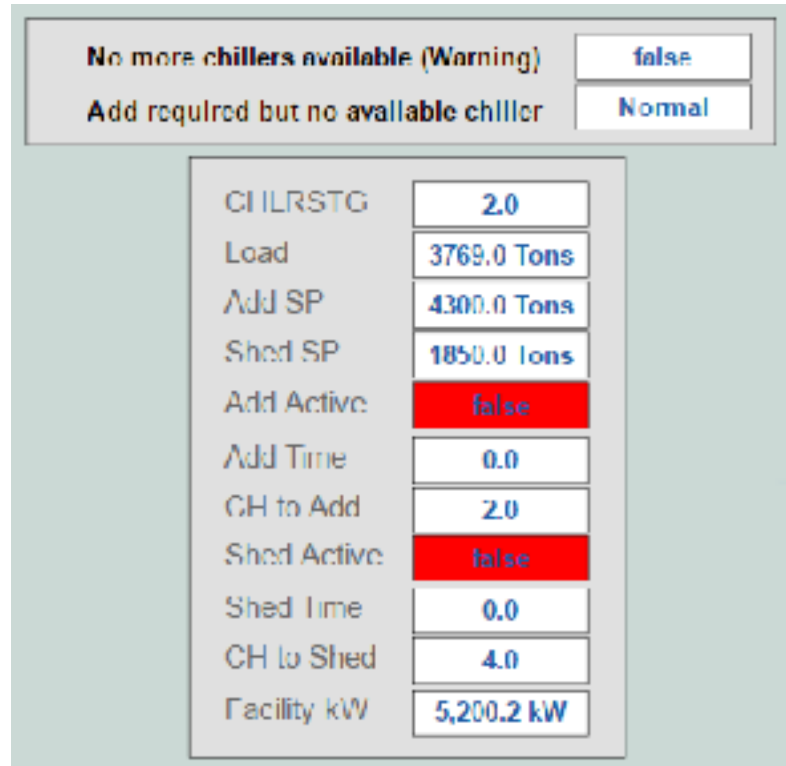
Baylor University: Screen for Operations



Dynamic CHLR Valve Balancing

Chilled Water Valves	OE	Actual
CH1	0 %	0 %
CH2	0 %	0 %
CH3	0 %	0 %
CH4	65 %	64.9 %
CH5	0 %	0 %
CH6	0 %	0 %
CH7	0 %	0 %
CH8	100 %	99.9 %

Condenser Water Valves	OE	Actual
CH1	0 %	0 %
CH2	0 %	0 %
CH3	0 %	0 %
CH4	100 %	100 %
CH5	0.0	0 %
CH6	0 %	0 %
CH7	0 %	0 %
CH8	100 %	100 %



No more chillers available (Warning)	false
Add required but no available chiller	Normal

CHLRSTG	2.0
Load	3769.0 Tons
Add SP	4300.0 Tons
Shed SP	1850.0 Tons
Add Active	false
Add Time	0.0
CH to Add	2.0
Shed Active	false
Shed Time	0.0
CH to Shed	4.0
Facility kW	5,200.2 kW

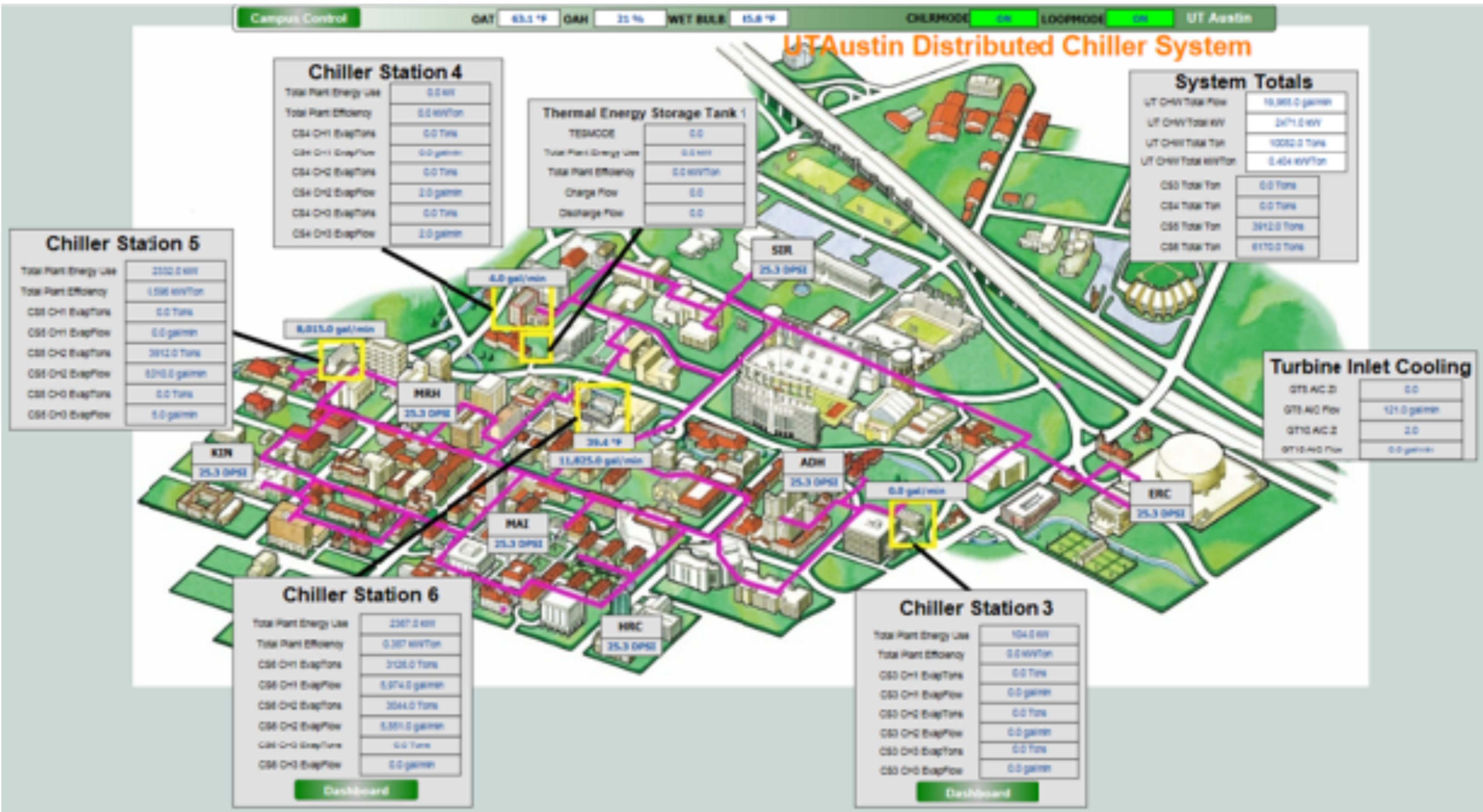
Case Study

Baylor University

Summary/ Challenges

- Siemens Apogee BAS using Modbus RTU to communicate to OE controller
- Old BAS network infrastructure causing chilled water DP values to go stale
- Multiple types of chillers on common header all with different pressure drops across evaporator and condenser required dynamic valve balancing
- Discovered which locations were the drivers for DP control. University installed new building pumps for these buildings
- Data from OE's OptiCx web platform was used by engineers for the design of the new chiller
- Plant operators use main OptiCx overview screen 24/7 in control room to view chiller staging status and dynamic valve balancing

UT Austin Distributed Chiller System



Case Study

University of Texas, Austin

Overview

- One of the largest public universities in the U.S.: 350-acre main campus supports 21,000 faculty and staff, 17 colleges and schools and more than 50,000 students.
- Four (4) chilled water plants (45,000 tons) on a common loop with 4 million gallon TES
- OE total optimization of new 15,000 ton plant (3 - VSD 5,000 ton chillers)
- Control of chiller staging for all four (4) chiller plants, DP control and flow control, and TES charge and discharge

Results

- Total savings of 21,000,000 kWh/yr in total campus electrical energy, 200,000 mmbtu steam usage, and 4,000 kgal water usage
- Annual total chiller plant kW/ton improved from 0.77 kW/Ton to 0.63 kW/Ton
- Peak summer kW of chiller plants reduced by nearly 5 MW
- Performance of new 15,000 ton plant ranges from 0.35 kW/Ton to 0.65 kW/Ton
- Improved control of chilled water DP significantly reduced pumping kW as well as steam use

OE Optimization Projects at UT-Austin

2008	Chilling Station 6 (CS6) constructed as design build project
2009	Installed OptimumLoop on CS6
2011	Installed "Sweet Spot" Optimization on Chilling Station 3 (CS3)
2013	TES added into total campus chiller dispatch
2013	Installed OptimumLoop on 3,250 Ton Chiller plant for HPCF
2017	Chilling Station 5 (CS5) added into total campus chiller dispatch

Case Study

University of Texas, Austin

Chilling Station 6 Summary

- OE worked with Owner to design chiller plant "Optimization Ready"
  - All systems on common header, any chiller could be served by any chilled water pump, condenser water pump and cooling tower
  - Only one (1) modulating control valve, only line size butterfly valves (modulating valve on one tower cell to equalize flow
  - Three (3) identical chillers, chilled water pumps, condenser water pumps and cooling towers
  - Commissioned Optimization system July of 2009
  - Tuned Optimization system October of 2009
  - First four (4) months of fall/winter operation in Optimization Mode achieved full payback for the system

Case Study

University of Texas, Austin

Flow and DP Control for CS6, CS3 and TES

- Project labeled "Sweet Spot" Control
- Concept:
  - Use variable speed chilled water pumps at CS6 to control campus chilled water loop differential pressure (Based on seven (7) remote DP's)
  - Use variable speed chilled water pumps at CS3 to control flow such that chillers at CS6 would be loaded to approx. 75% (Hence the term Sweet Spot) No other plants had variable speed drives on pumps
  - Once concept proven added in TES charge and discharge. Control discharge to keep additional chillers at stations other than CS6 and charge at night to keep CS6 chillers loaded to the 75% load point
  - University now installing variable speed drives on CS5 chilled water pumps so that the plant can be added to the overall campus staging and flow control

Case Study

University of Texas, Austin

Summary/ Challenges

- Allen Bradley PLC Balance of Plant (BOP) control system using Modbus TCP to communicate
- Attempt to communicate to OE controllers with a single OPC server was not successful
- Open loop control for chiller and pump staging an ongoing issue, not recommended
- Once CS5 added to total dispatch logic, CS5 will be used to control DP when a chiller there is running. Location and size of piping out of this plant is better for DP control
- Campus able to run off of CS6 and TES for approximately 4 months annually at very low kW/Ton
- Controlling chilled water DP significantly reduced the differential pressure throughout the system increasing Delta T and lowering steam use (simultaneous heating and cooling due to very high DP's on chilled water side)

Case Study

Columbia University

Powerhouse Chillers

	C.O.P.	Tons	kW	Steam Flow
URIS				
CH1	0.00 COP	0.0 Tons	0.0 kW	
CH2	0.00 COP	0.0 Tons		0.0 Lbs/hr
CH3	0.00 COP	0.0 Tons		0.0 Lbs/hr
FAIR				
CH4	0.00 COP	0.0 Tons		0.0 Lbs/hr
CH5	19.72 COP	987.0 Tons	176.0 kW	
CH6	0.00 COP	0.0 Tons		0.0 Lbs/hr
CH7	0.00 COP	0.0 Tons	0.0 kW	

	Rated COP	Rated Ton	Rated kW	Rated Steam Flow
CH1	5.06	1500	1042	
CH2	1.30	2000		10.48 lb/Ton
CH3	1.31	1600		10.41 lb/Ton
CH4	1.46	2800		26153 lb/hr
CH5	5.97	2800	1647	
CH6	1.45	2800		26220 lb/hr
CH7	5.55	2800	1773	

OAT	40.0 °F
OAH	77 %
OA TWB	37.2 °F
LOOPMODE	ON

Campus

Total Tons	969.4 Tons
Total COP	11.45 COP

OPII Plant Overview

Powerhouse DP Control

	#CHWPR	SPD Requested	Chiller Flow	Loop Flow
URIS	0		0.0 gal/min	1,781.0
FAIR	2	43 %	4,300.0 gal/min	2,956.0

CU	10.2 PSI
NWC	10.0 PSI

Control DP Setpoint

OA Wet Bulb Based

Case Study

Columbia University

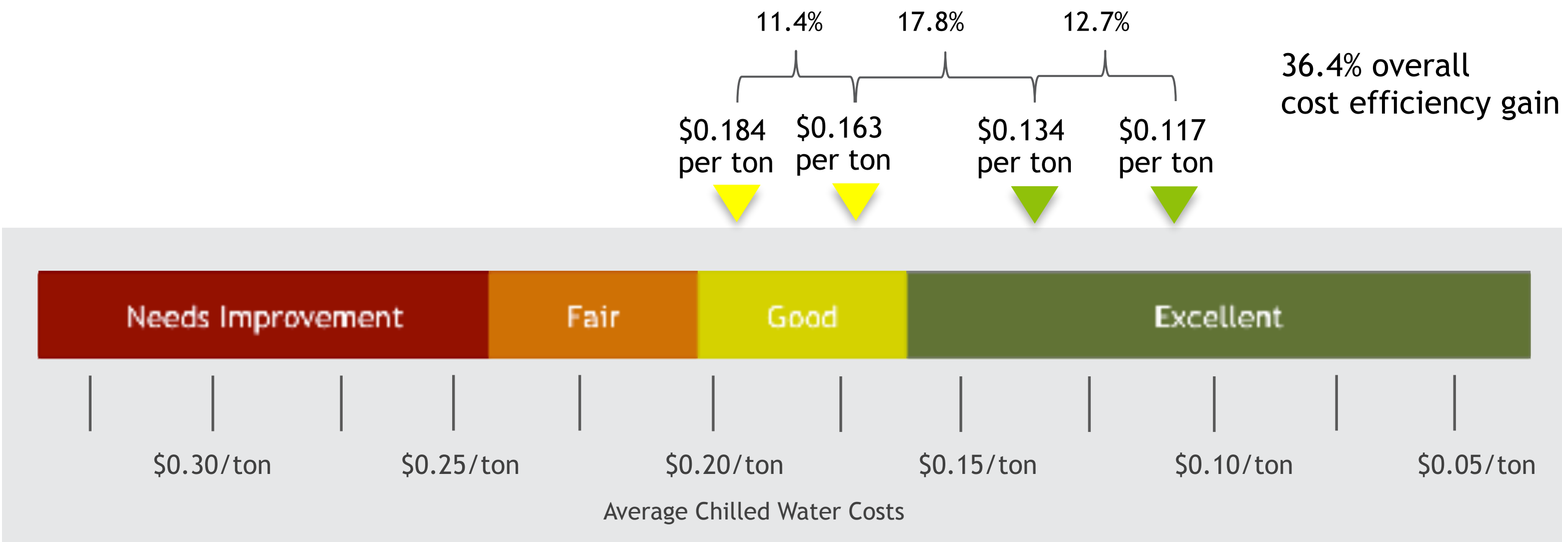
Overview

- Large, complex system: 14,000-ton peak load
- Mix of old and new equipment, mixed-fuel site, steam and electric chillers
- Mix of chiller sizes and manufacturers
- Multi-phase optimization approach
  - Phase 1: Install controller, monitor plant and collect data
  - Phase 2: Begin with open loop control
  - Phase 3: Move to "Modified" closed loop control

Results

- Total of $1,100,000 / yr in savings
- Phase 2: Over 3,300,000 in kWh savings and 15,000 Mlbs of Steam
- Phase 3: Over 2,100,000 in kWh savings and 19,700 Mlbs of Steam
- 75% reduction in total plant power consumption at base loads
- Cut plant base load in half

Columbia University: Chilled Water Efficiency Scale

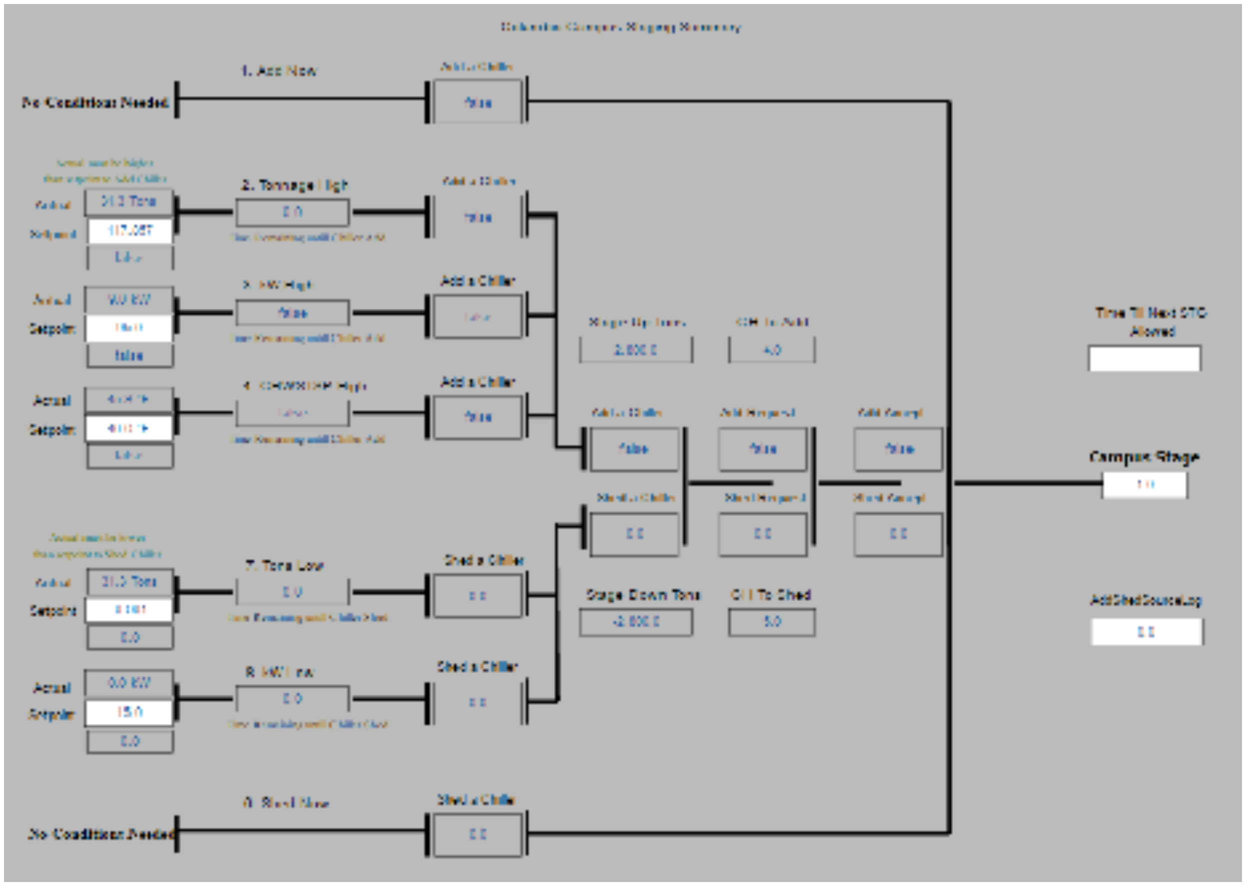


Campus Chilled Water Cost Efficiency Scale

Campus chilled water plant cost efficiency in $/ton.
Input includes: steam and electric chiller energy (gas and electric), all tower fan energy, all condenser pump energy, and all chilled water pumping energy.

Modified Closed Loop Control

Columbia University



Case Study

Columbia University

Summary/ Challenges

- Allen Bradley PLC control system with Modbus TCP communication
- Mix fuel required different performance metrics
- Modified closed loop control of chillers was challenging
- Monthly reports generated by OE web application OptiCx used by Columbia to determine chilled water pricing to campus departments
- Over pressurizing the chilled water system was major problem in beginning but correcting this led to significant results
  - Reduced base load of plant by 50%, pumping 50% less chilled water
  - As with UTA, reduced steam consumption caused by having to reheat air that had been over cooled
  - Decreased chilled water flow low enough in winter that one chiller could support load

Thank you.

Engineered. Deployed. Proven.

Questions?

RESILIENCE COMMITMENT
CLIMATE LEADERSHIP

CLIMATE COMMITMENT
CLIMATE LEADERSHIP

CARBON COMMITMENT
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