PHASED APPROACH TO CAMPUS CHILLED WATER SYSTEM OPTIMIZATION

TONY PUTNAM, PE, CEFP – CLEMSON UNIVERSITY
MATTHEW HOLBROOKS – CLEMSON UNIVERSITY
ERIC TOBACK, PE, LEED AP – OPTIMUM ENERGY

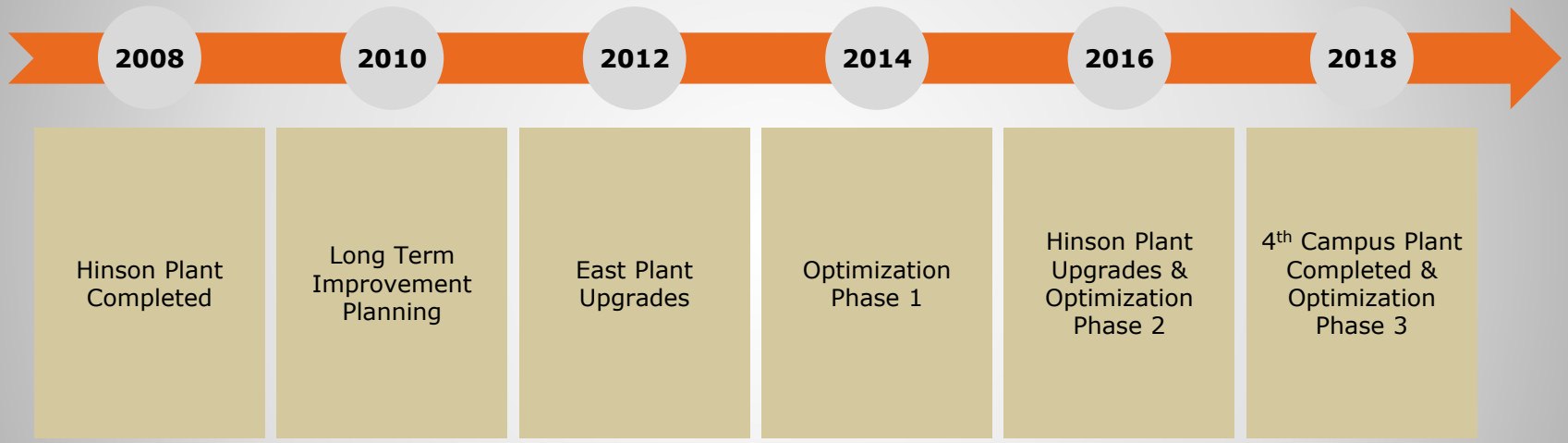
February 2019

OPTIMUMENERGY

CLEMSON UNIVERSITY

PHASED APPROACH

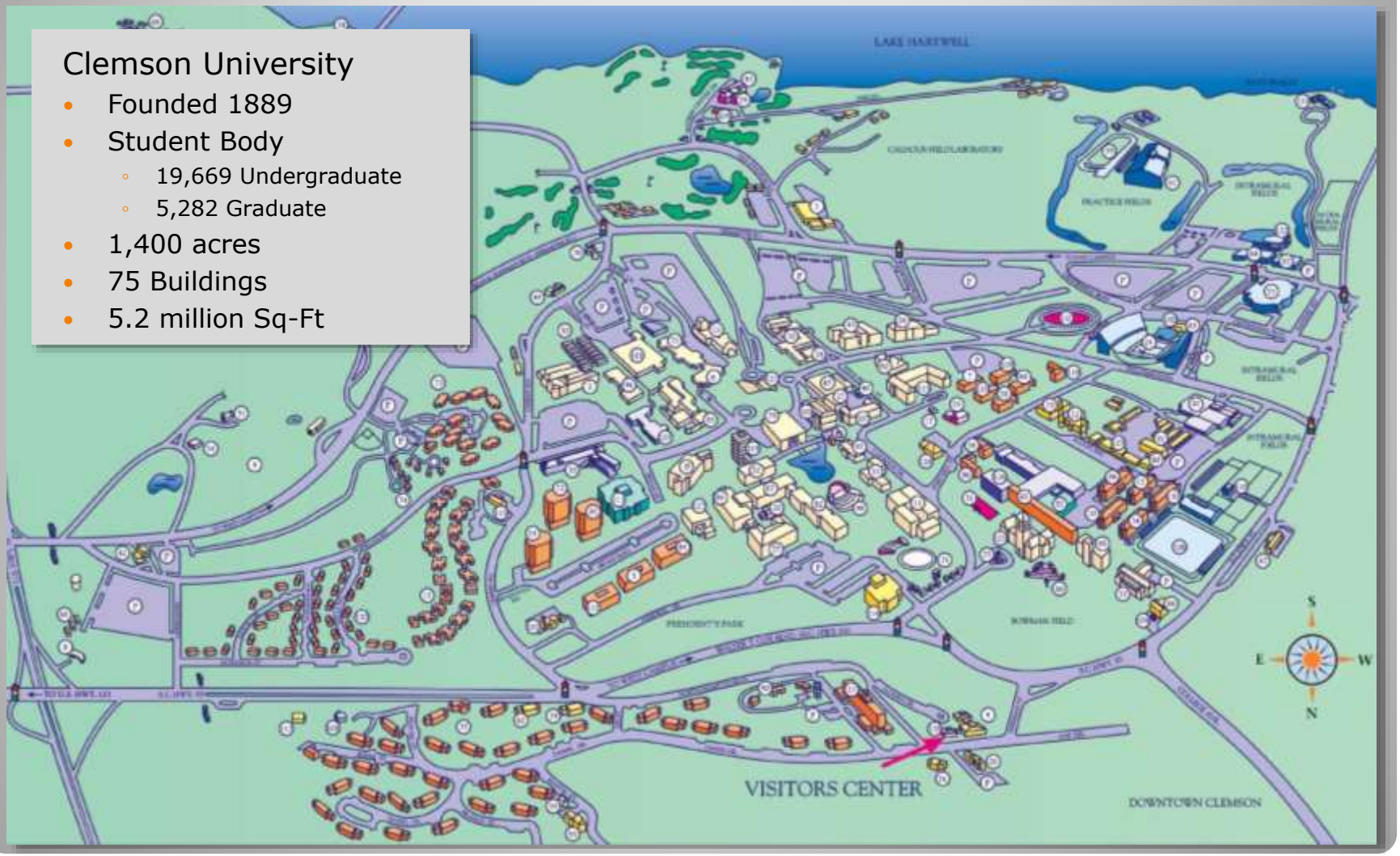
Campus Optimization Timeline



CAMPUS BACKGROUND

Clemson University

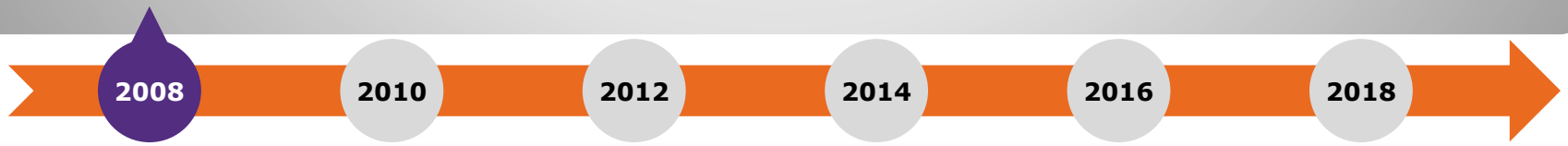
- Founded 1889
- Student Body
  - 19,669 Undergraduate
  - 5,282 Graduate
- 1,400 acres
- 75 Buildings
- 5.2 million Sq-Ft



SYSTEM DESCRIPTION

2008 – Hinson Plant Completed

- Two (2) existing central chiller plants
  - Central Energy Facility
  - East Plant
- Previous campus CHW delta T improvements achieved
  - Building decouplers
  - Flow limiting controls at buildings
  - Variable speed distribution pumping at central plants & buildings
- Completed construction of 3rd campus chiller plant
  - South Hinson Plant



SYSTEM DESCRIPTION

Campus Chilled Water System – 2008

- Three (3) interconnected central chilled water plants totaling 11,400 tons of capacity

Central Energy Facility
- Built 1999
- 5,400 tons

South Hinson Plant
- Built 2008
- 3,600 tons

East Plant
- Built 1985
- 2,400 tons

2008 2010 2012 2014 2016 2018

SYSTEM DESCRIPTION

2008 – Campus Chiller Plant Summary

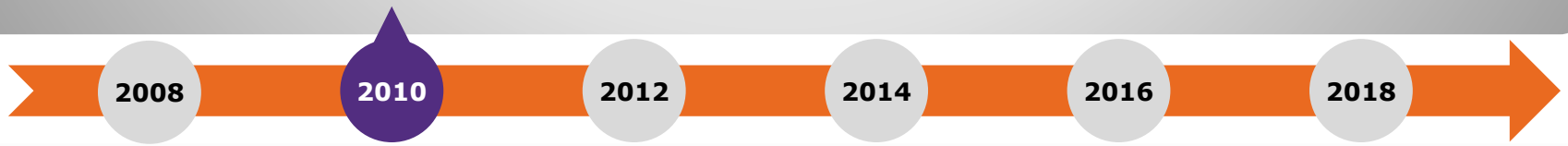
	Central Energy Facility	South Hinson Plant	East Plant
Chillers	3x 1,800-ton	3x 1,200-ton	2x 1,200-ton
	Constant Speed	Constant Speed	Constant Speed
Primary CHW Pumps	3x 60 HP	3x 40 HP	2x 75 HP
	Constant Speed	Constant Speed	Constant Speed
Secondary CHW Pumps	2x 100 HP; 2x 60 HP	2x 200 HP	2x 125 HP
	Variable Speed	Variable Speed	Variable Speed
Condenser Water Pumps	2x 250HP	3x 100 HP	2x 100 HP
	Constant Speed	Constant Speed	Variable Speed
Cooling Towers	Lake Hartwell	3x 50 HP	2x 50 HP
	N/A	Variable Speed	1 Variable / 1 2-speed
Free Cooling HX	No	Yes / 40 ^{0}F	Yes / 40 ^{0}F
CHW Supply Temp	40 ^{o}F	40 ^{o}F	40 ^{o}F
Condenser Supply Temp	80 ^{o}F	85 ^{o}F	85 ^{o}F
Distribution System	Decoupled Tertiary Building Pumping		
BAS	Johnson Controls Metasys		

2008 2010 2012 2014 2016 2018

DEFINE

2010 – Defining the Issues & Challenges

- Struggled with best control strategy to achieve BOTH:
  - Peak efficiency
  - System demand and condition requirements
- Chiller & pump sequencing of all 3 plants proved challenging
  - Stage next chiller, pump, tower at 90-95% load
  - Avoid degradation of CHW supply & return temps
- Plant Staging Order – 1) Hinson → 2) CEF → 3) East
- CHW return bottlenecks during low loads
  - Return water reversed direction
  - Required excessive pumping to get water back to Hinson plant



Measure & Analyze

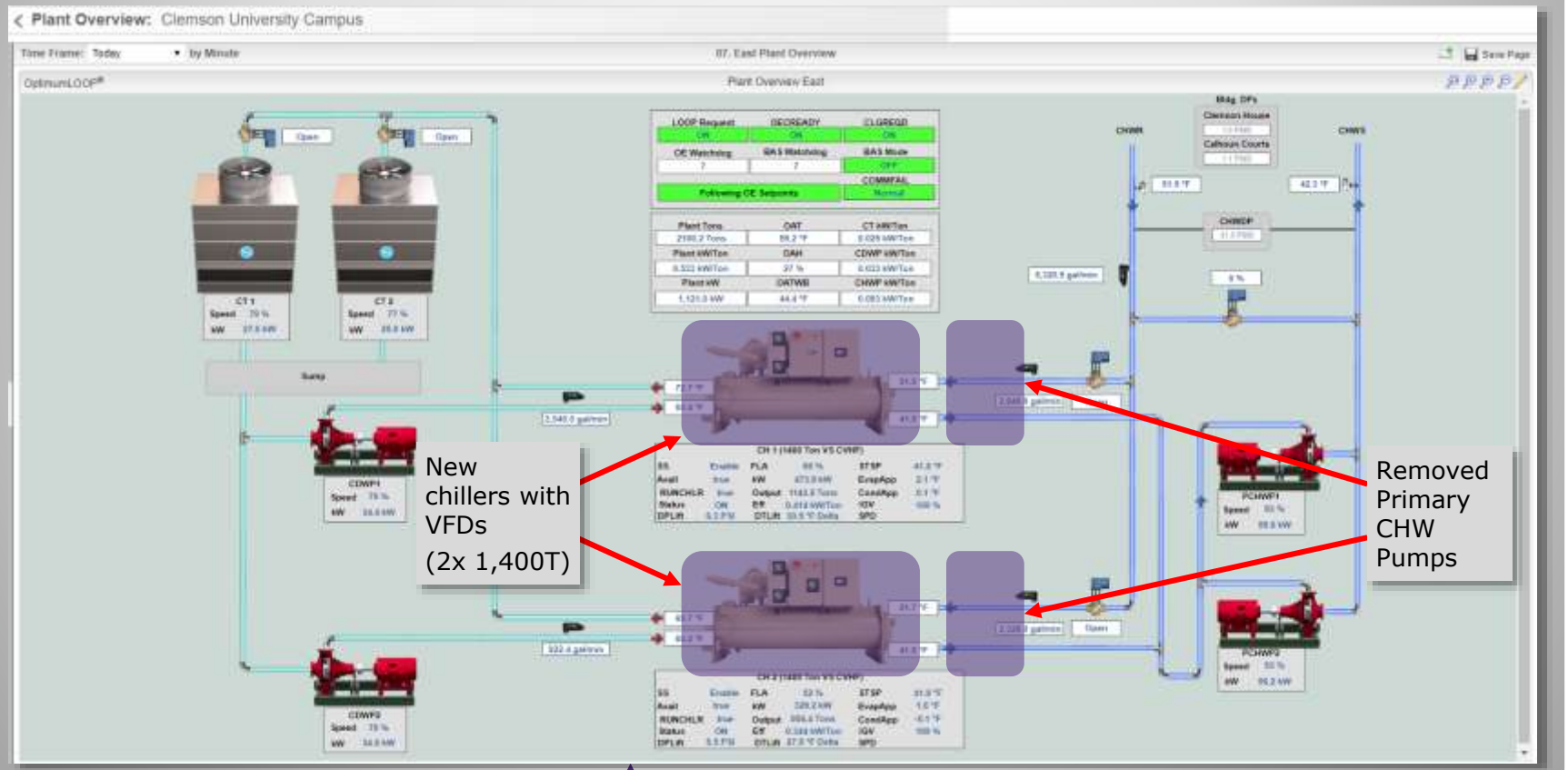
2010 – Long Term Improvement Planning

- Read article about new approaches for cooling system efficiency
  - "How High Can You Go?" by Ben Erpelding, Optimum Energy - District Energy Magazine Q4 2009
- Detailed field assessment and analysis performed by Optimum Energy determined significant opportunity for energy savings
- Substantial scope necessary to maximize benefits
- Multi-year phased approach put in place for capital project and operational budgeting

2008 | 2010 | 2012 | 2014 | 2016 | 2018

2012 – East Plant Upgrades

- East Chiller Plant Upgrades & Replacements



2008 | 2010 | **2012** | 2014 | 2016 | 2018

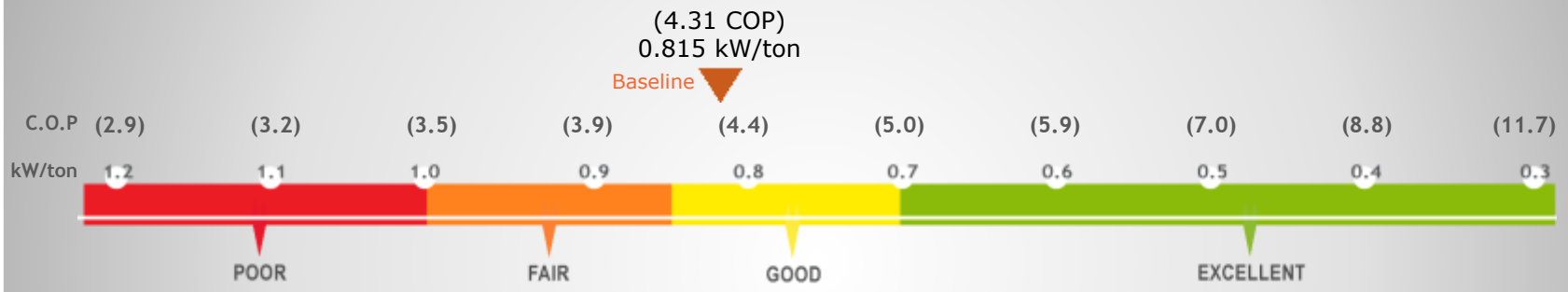
Control

2014 – Optimization Phase 1

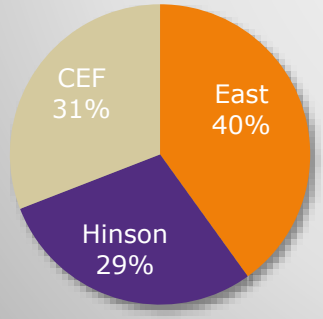
- Optimum Energy / Johnson Controls team awarded RFP for campus wide chilled water optimization project
- East Plant chosen as initial optimization project
- All-variable speed configuration
- Quickest path to achieving savings

2008 | 2010 | 2012 | **2014** | 2016 | 2018

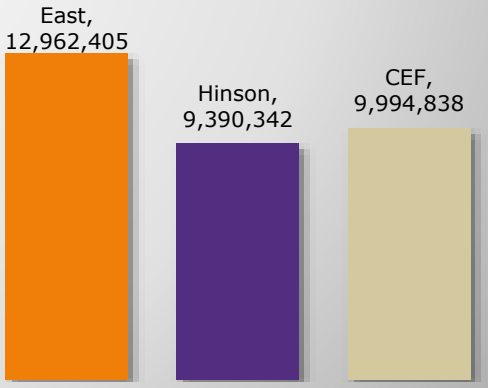
2014 – Existing Campus Chilled Water System Efficiency



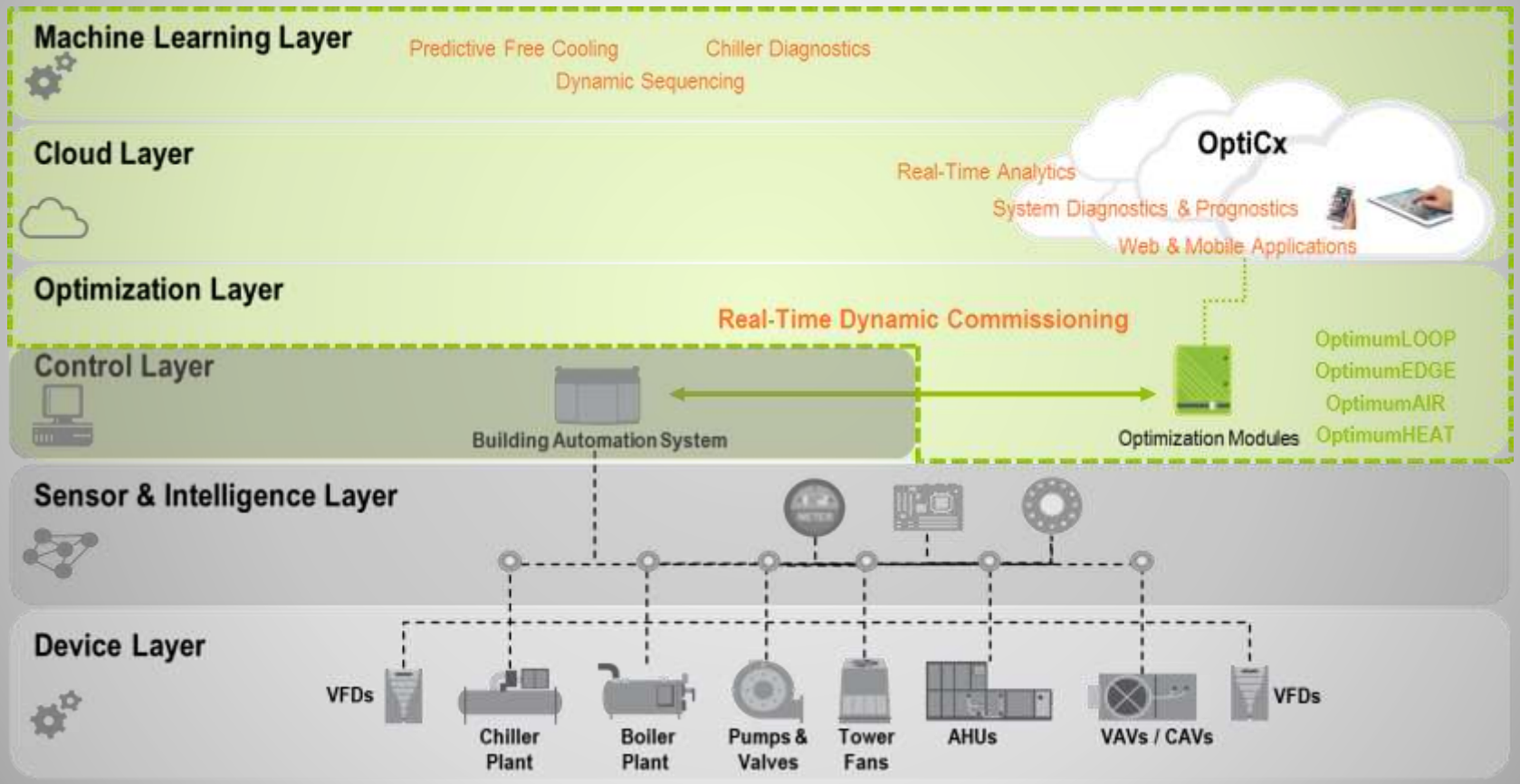
Average annual chilled water plant efficiency in kW/ton.
Input includes: chillers, tower fans, condenser pumps, and chilled water pumping.



Campus Load Distribution
(Pre-Optimization)



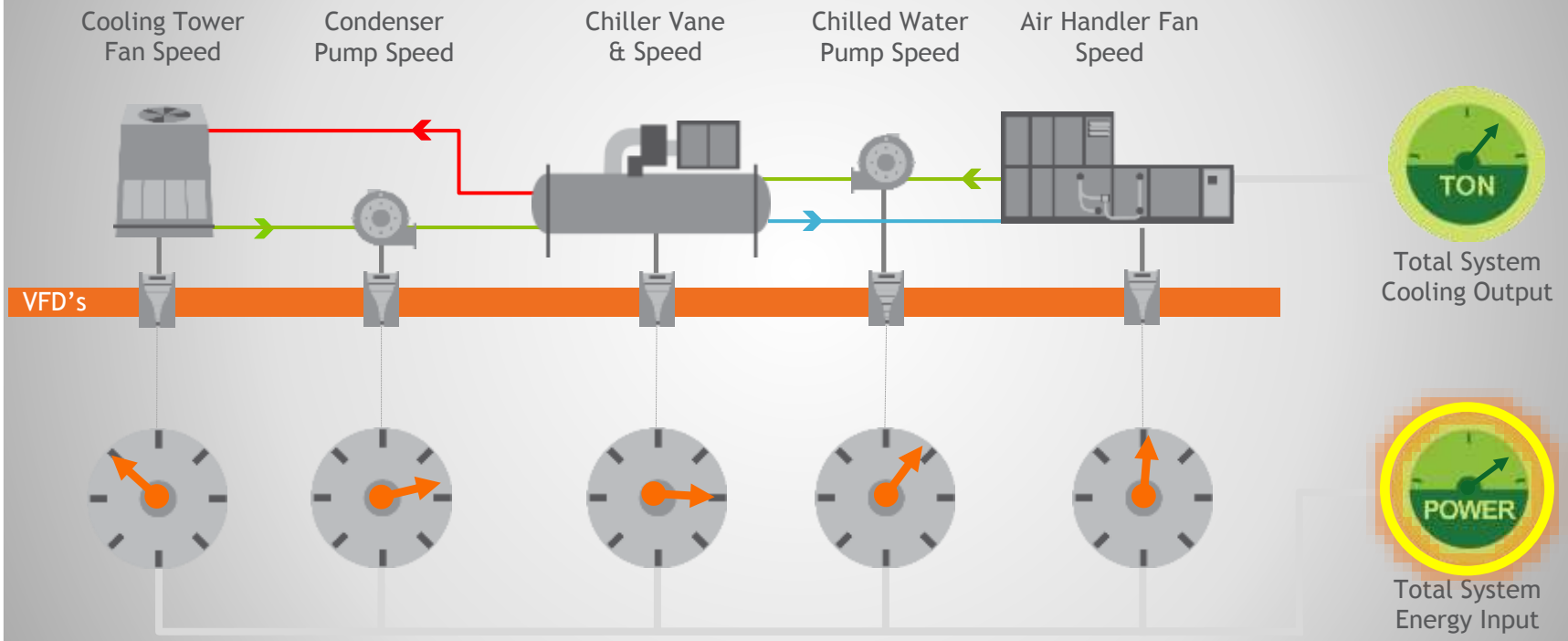
2014 – Optimization System Architecture



2008 | 2010 | 2012 | **2014** | 2016 | 2018

Control

2014 – Relational Based Control Optimization

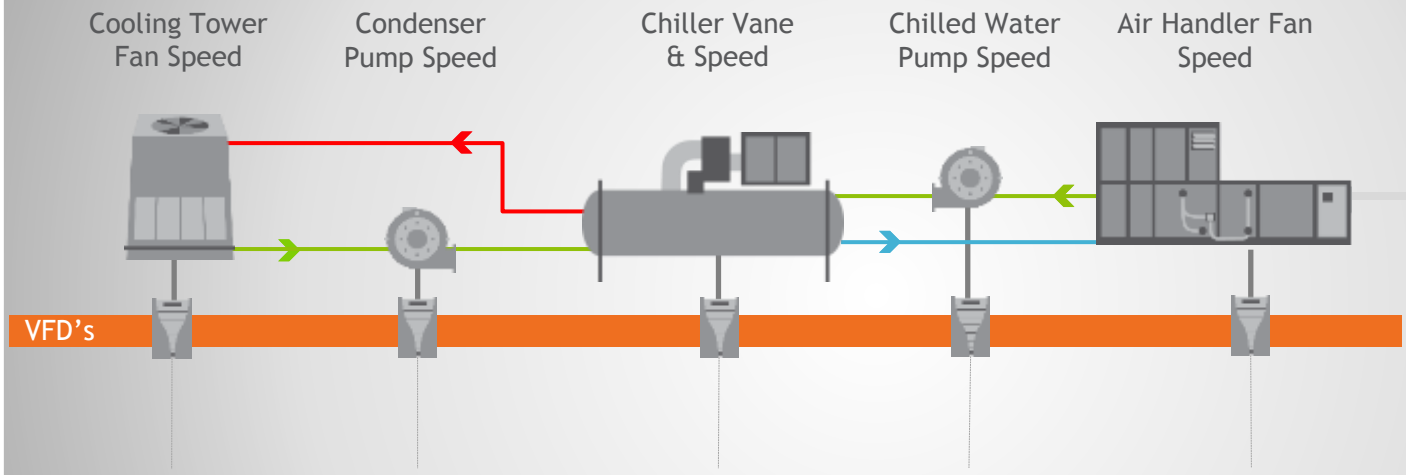


Total System Schematic

2008 | 2010 | 2012 | **2014** | 2016 | 2018

Control

2014 – Relational Based Control Optimization (East Plant)



Fixed temp	Fixed flow	Fixed Temp Full Load Staging	Variable Flow Fixed Plant DP	Original Control
Variable Temp Relational Control	Variable Flow Relational Control	Variable Temp Natural Curve	Variable Flow Variable Remote DP	Optimum Control

Total System Cooling Output

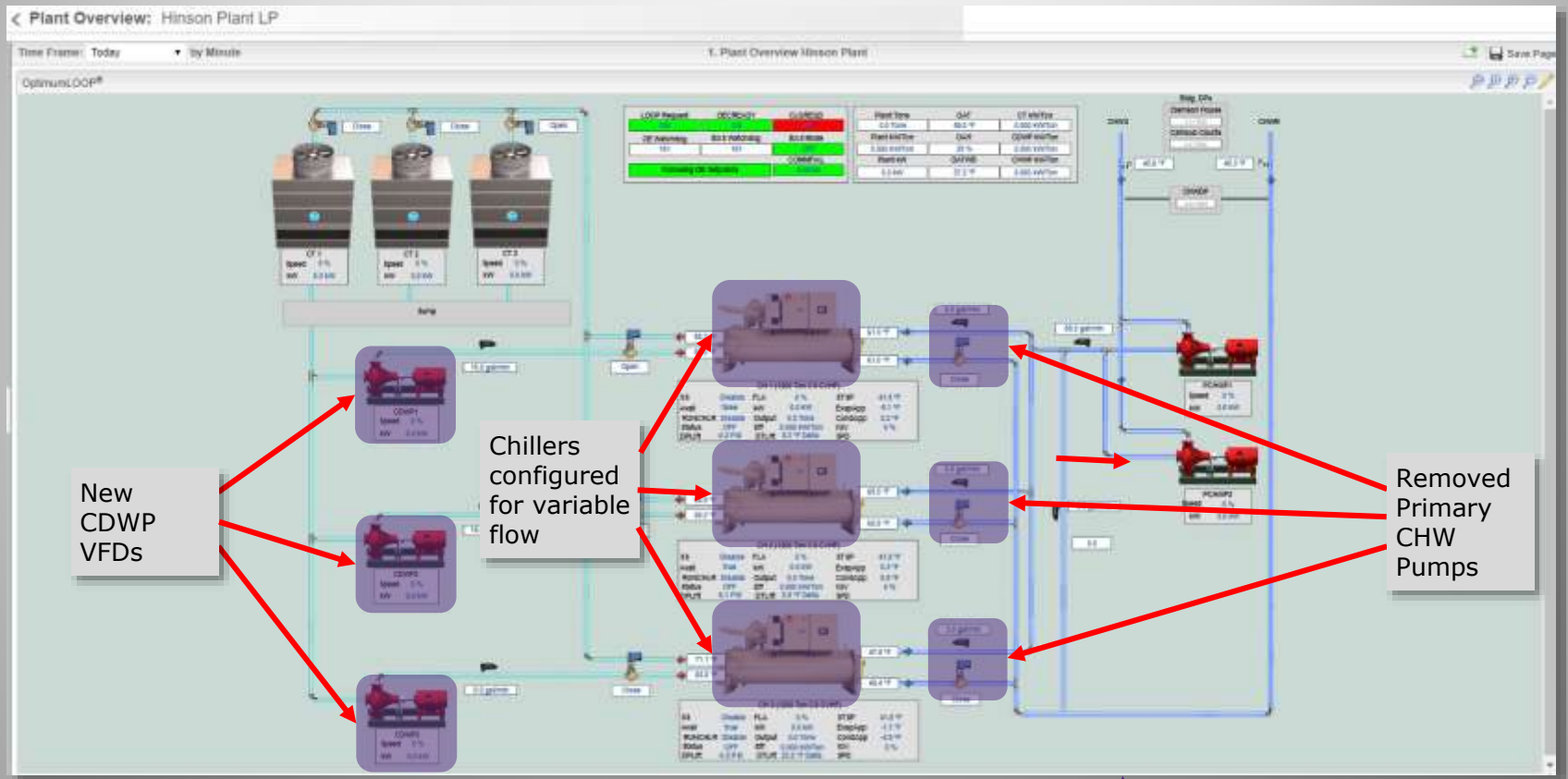
Total System Energy Input

Total System Schematic

2008 2010 2012 **2014** 2016 2018

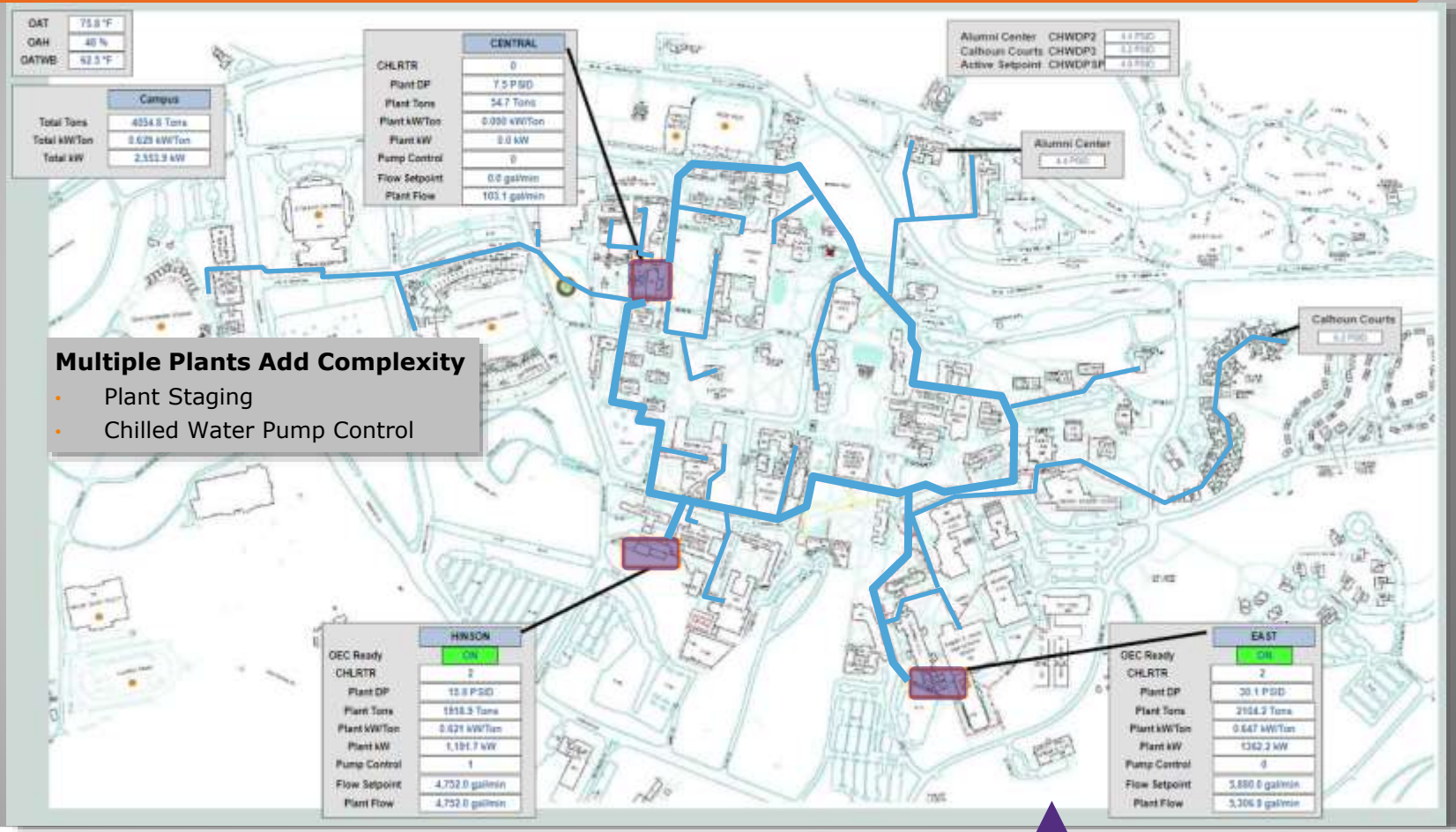
2016 – Hinson Plant Upgrades & Optimization Phase 2

- South Hinson Chiller Plant Upgrades



2008 | 2010 | 2012 | 2014 | **2016** | 2018

2016 – Campus Control

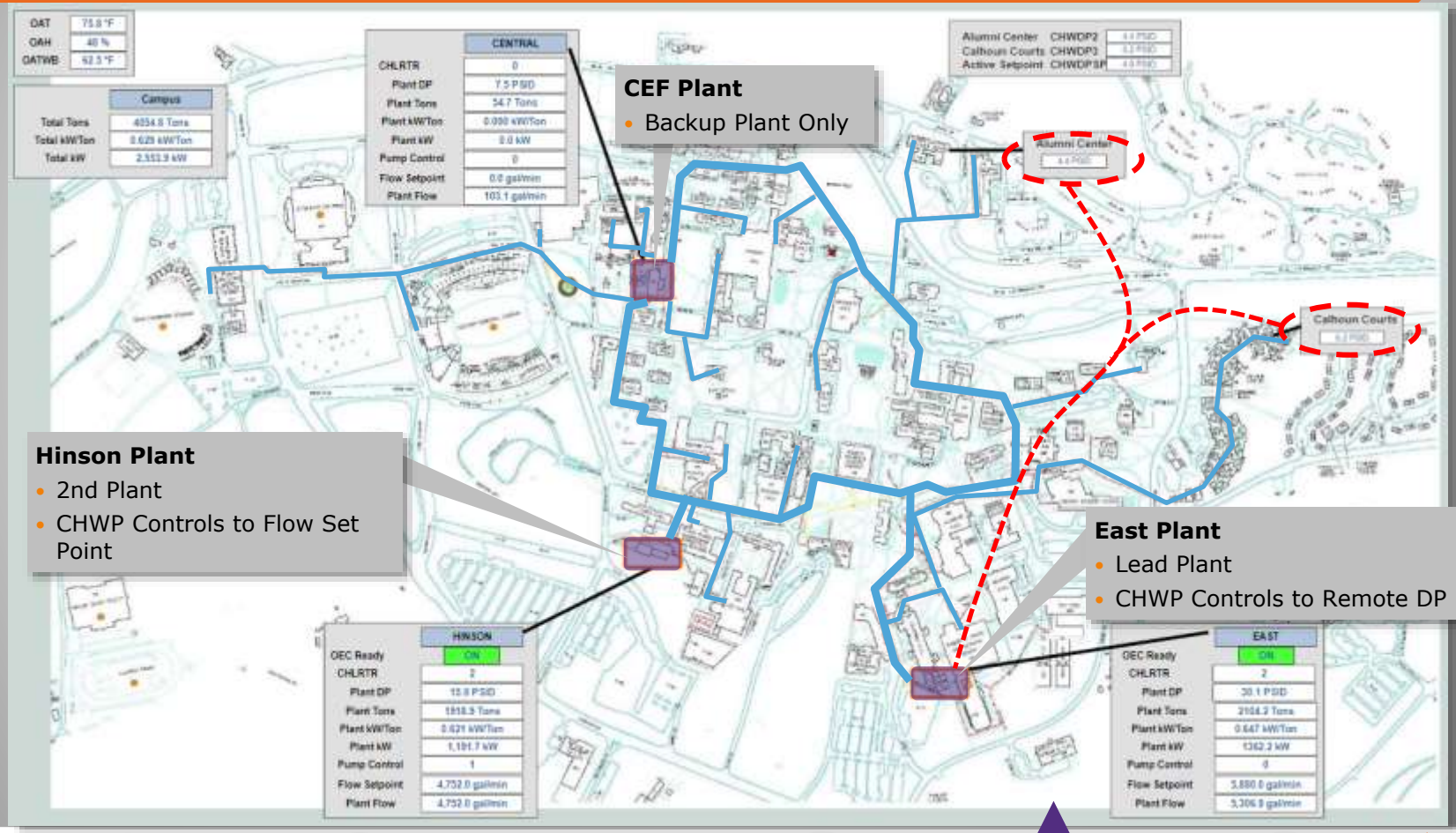


Multiple Plants Add Complexity

- Plant Staging
- Chilled Water Pump Control

2008 | 2010 | 2012 | 2014 | **2016** | 2018

2016 – Campus Control

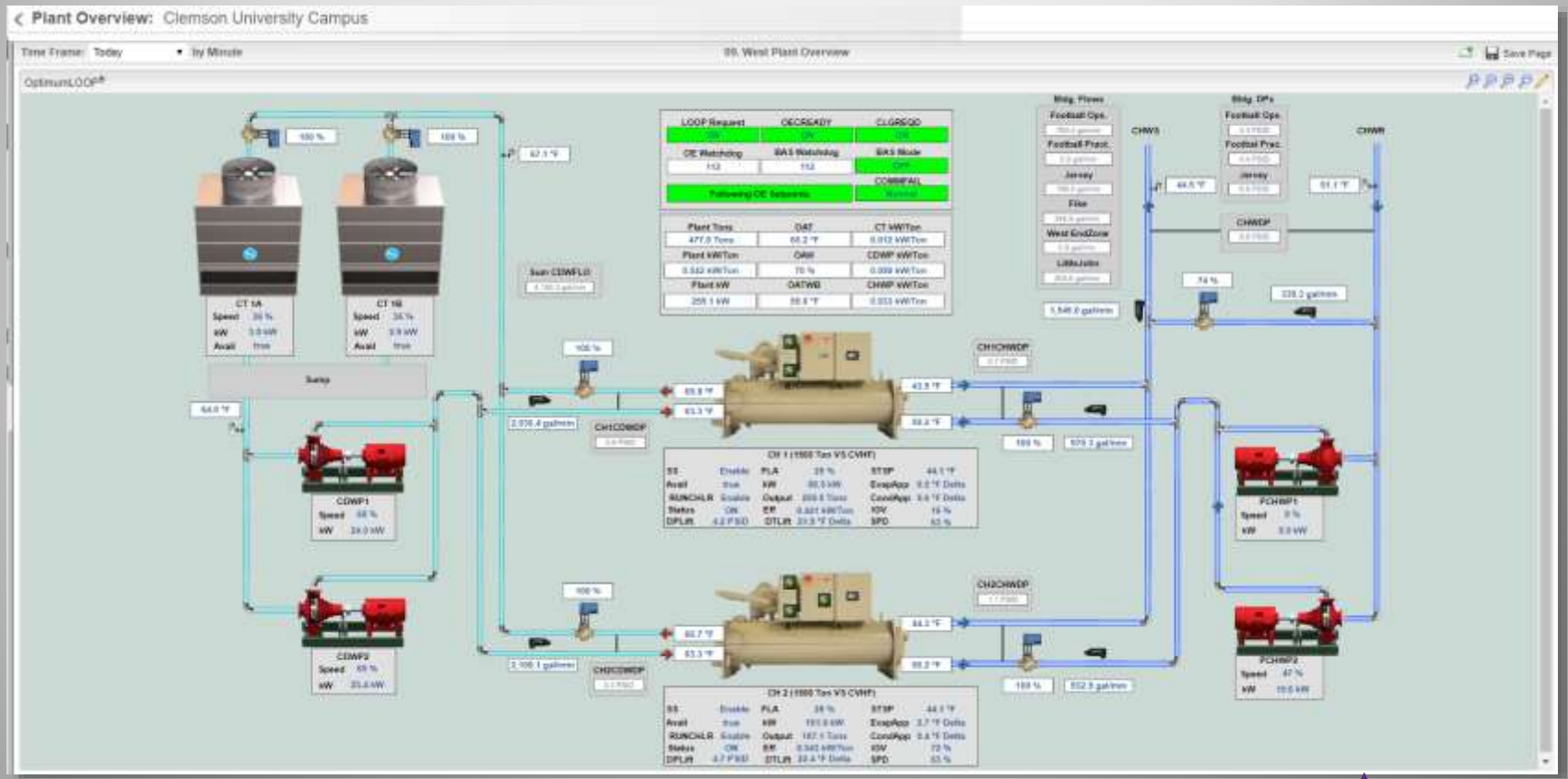


2008 | 2010 | 2012 | 2014 | **2016** | 2018

Improve & Control

2018 – 4th Campus Plant Completed & Optimization Phase 3

- West Plant Completed & Optimized – 3,000 ton All-Variable Speed

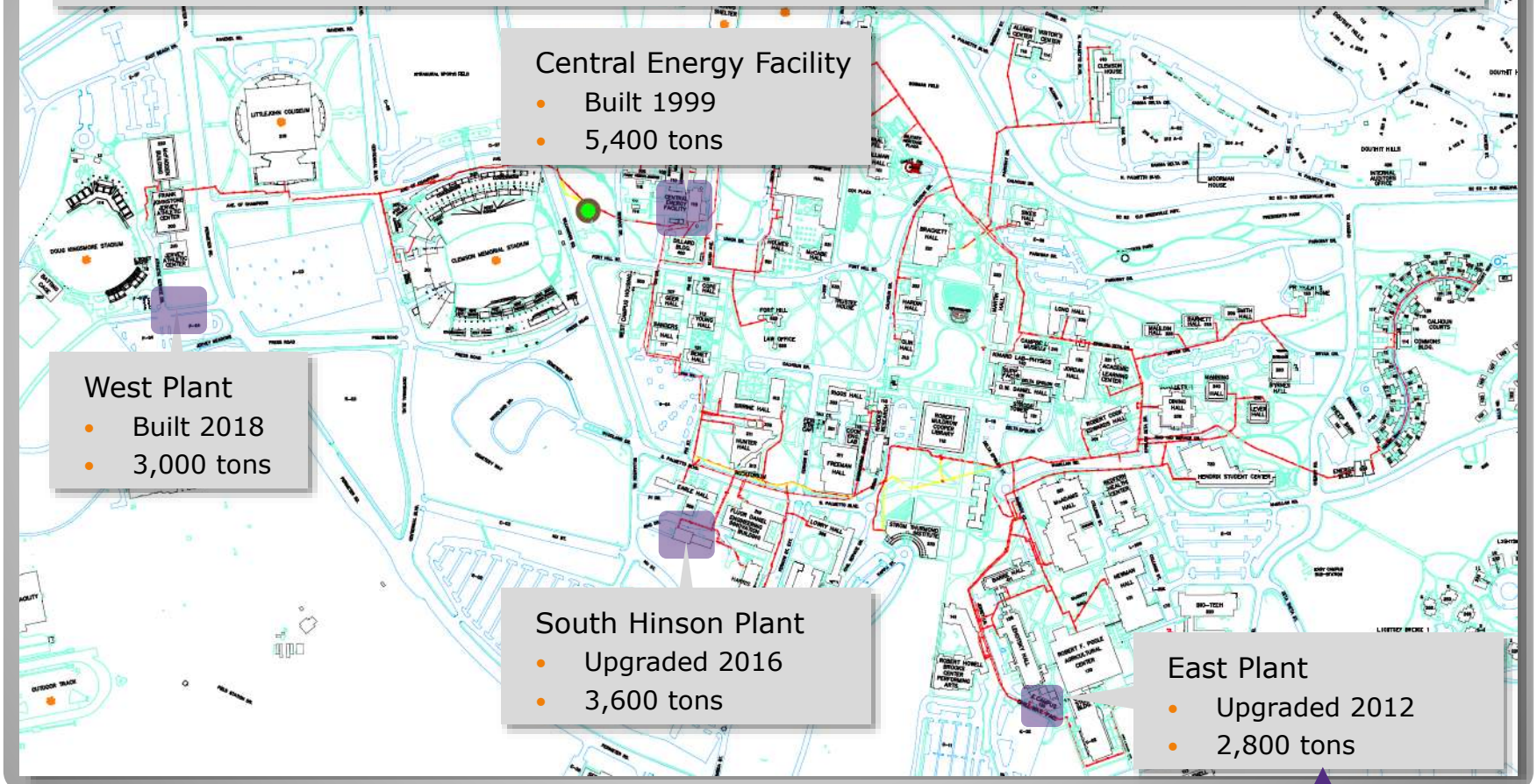


2008 | 2010 | 2012 | 2014 | 2016 | 2018

SYSTEM DESCRIPTION – 10 Yrs LATER

Campus Chilled Water System – 2018

- Four (4) interconnected central chilled water plants totaling 14,800 tons of capacity



Central Energy Facility
- Built 1999
- 5,400 tons

West Plant
- Built 2018
- 3,000 tons

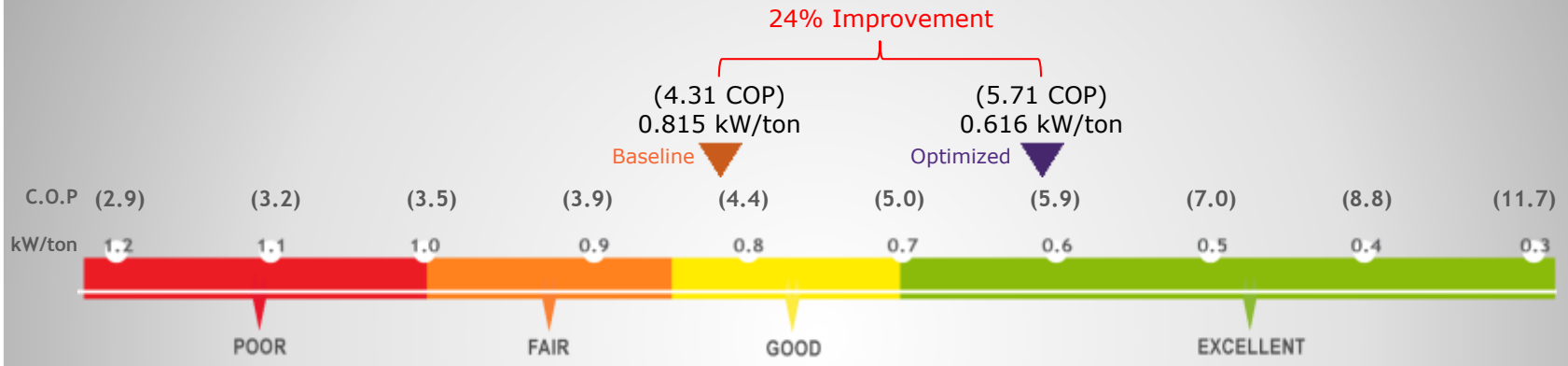
South Hinson Plant
- Upgraded 2016
- 3,600 tons

East Plant
- Upgraded 2012
- 2,800 tons

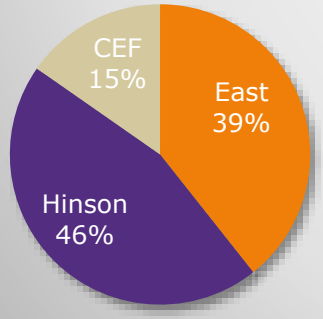
2008 | 2010 | 2012 | 2014 | 2016 | **2018**

RESULTS

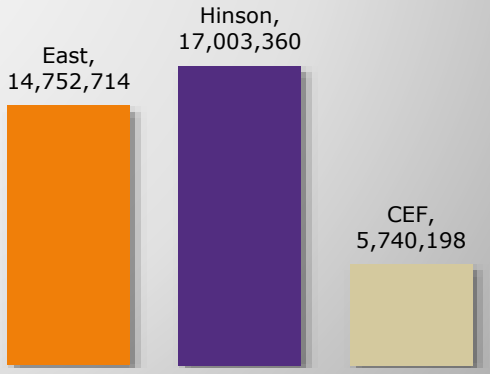
2018 – Chiller Plant Optimization Results



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



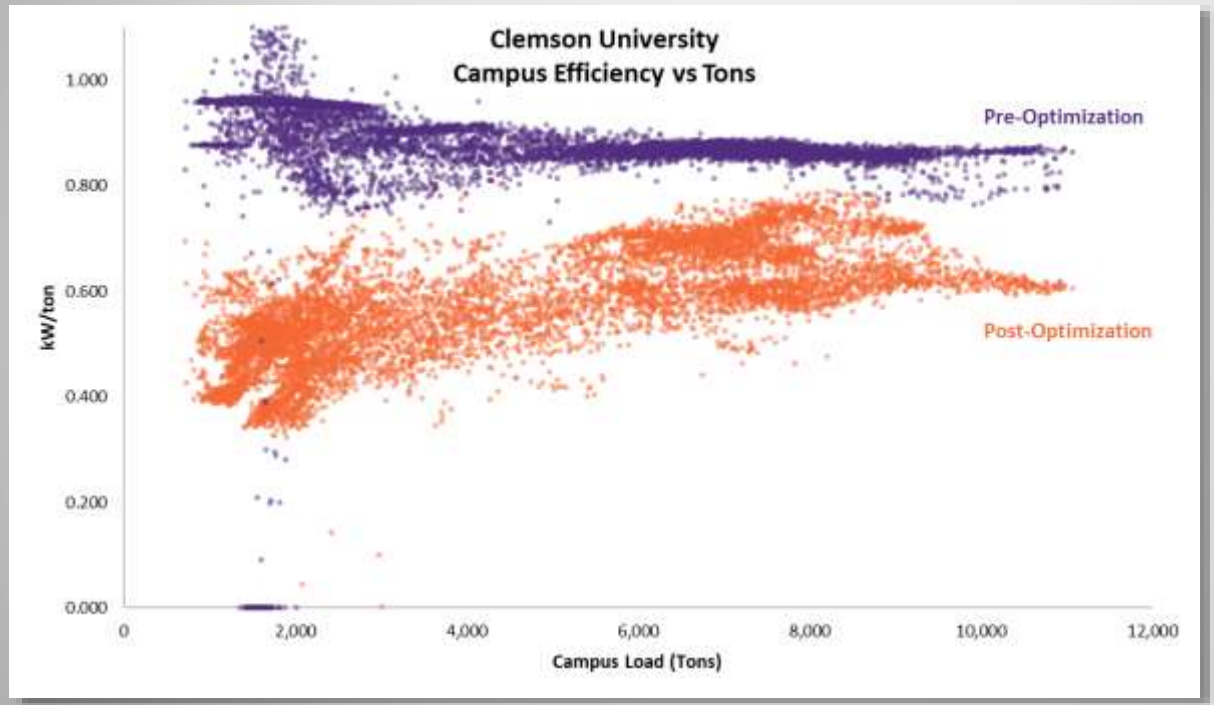
Campus Load Distribution
(Post-Optimization)



2008 2010 2012 2014 2016 2018

RESULTS

2018 – Chiller Plant Optimization Results



Optimization Savings (2014 Baseline)

- **8,406,000 kWh**
- **15,520,000 lbs of CO_2**
- **2,593,000 gallons H_20**
- **USD $475,000**

2008 2010 2012 2014 2016 2018

CONCLUSIONS

2008–2018: Phased Approach to Campus Chilled Water System Optimization

- Optimization does not have to be an "All-or-Nothing" approach
- When splitting into short term phases, always remain focused on the long term goals
- Partner with experienced experts that can help guide your path
- Ongoing maintenance & support is critical for long term success

QUESTIONS?