# Data Driven Non-Proprietary Plant Optimization

# DEFINITIONS

1. **Data Driven**
   - Data drives the solution and not engineering rules of thumb
2. **Non-proprietary**
   - Code that is fully open, non-encrypted, modifiable by any programmer, and the end-user has full ownership
3. **Plant**
   - Group of energy consuming equipment arranged in a process: Power plant, chiller plant, steam plant, water treatment plant, etc.
4. **Optimization**
   - Webster's - An act, process, or methodology of making something as fully perfect, functional, or effective as possible
   - The combination of capital expenditures that results in the highest possible NPV

# PRESENTATION OUTLINE

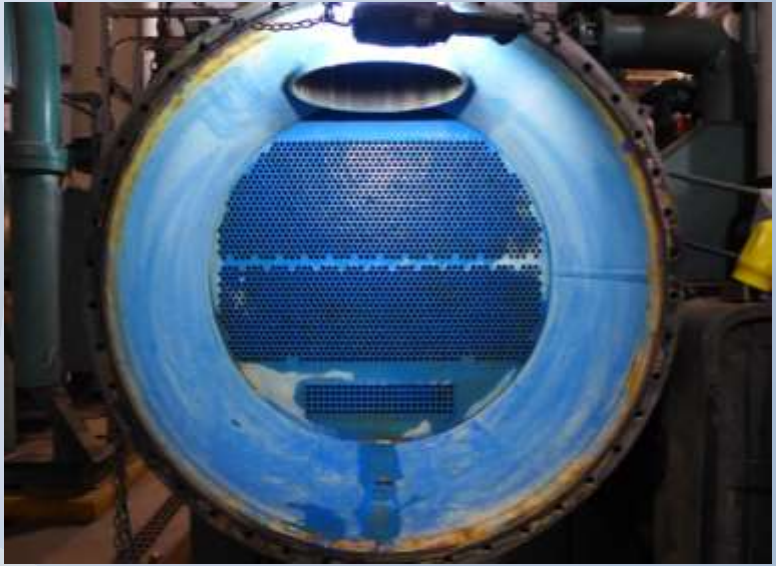
1. **Optimization process**
   A. Optimization Prerequisites
   B. Baseline the plant's energy use
   C. Complete understand of utility rate structure
   D. Proper Evaluation
   E. Understand the optimization contract
   F. Adhere to site standards
   G. M&V

2. **Real world examples with results**
   A. Merck Pharmaceutical – West Point, PA
   B. Large Financial Institution – Pittsburg, PA
   C. LEED Gold Data Center (Princeton University) – Princeton, NJ

# OPTIMIZATION PRE-REQ – MAINTENANCE

**Energy savings from routine maintenance:**

1. Punch chiller cond/evap tubes
2. Combustion analyses/tuning
3. Check chiller refrigerant levels
4. Clean strainers
5. Open balancing valves on VFD driven pumps
6. Unclog tower nozzles
7. Repair CW supply temperature reset
8. Utilize existing free cooling HX
9. Repair steam traps
10. Etc.



**Do this before the plant baseline is established**

# OPTIMIZATION PRE-REQ – INSTRUMENTATION, CALIBRATION, AND HISTORICAL TRENDING

1. **Does the plant have adequate instrumentation?**
   A. Meters, PTs, TTs, etc.

2. **Is the instrumentation calibrated?**
   A. Meters, valves, TTs, PTs, etc.
   B. ABC (Always Be Calibrating)

3. **Is the data trended?**
   A. Required to establish an energy baseline and used for rebates
   B. One year or two years of trend data is optimal
      - If no existing data: establish trends or use operator hand logs



SMITH ENGINEERING

# Optimization Process

SURVEY EXISTING PLANT PIPING, VALVING, AND EQUIPMENT ARRANGEMENT

DEVELOP SYSTEM ONE-LINE DIAGRAM

DEVELOP SYSTEM HYDRAULIC MODEL

SURVEY EXISTING PLANT, COLLECT TREND DATA, AND COLLECT ENERGY RATE STRUCTURE

CREATE OPERATIONAL BASELINE

BUILD EQUIPMENT EFFICIENCY MAPS

MODEL PLANT SEQUENCE MODIFICATIONS IN PERFORMANCE MODEL TO DETERMINE SAVINGS

APPLY FOR REBATES, AND DETERMINE ROI

IMPLEMENT SEQUENCE

COMMISSIONING

MEASUREMENT AND VERIFICATION

# BASELINE – COLLECT TREND DATA AND PERFORM RATE STRUCTURE ANALYSIS

1. **Collect Trend Data**
   - A. Chiller, tower fan, CW pump, CHW pump, and fan power data
   - B. CW and CHW flow data
   - C. CHW and CW temperatures
   - D. Start/stops on constant speed motors, if no power data
   - E. Weather data

2. **The largest driver of energy costs and potential energy savings is the rate structure**

A. Be very wary of blended rates

B. Modeled savings for large financial client using blend rates resulted in $100,000 per year

C. Modeled savings for large commercial client using actual rate structure was $55,000 per year



SMITH ENGINEERING

# BASELINE DATA COLLECTION

**Chiller Plant Operational Data** Measure: Base

Date: 5/9/2013 | Client: Bank of NY Mellon
Project: CHW Plant Optimization

Calculation Method: Baseline - Thermosystems Data | Basis: ✓ Installed ☐ Conceptual ☐ Manufacturer Dynamic

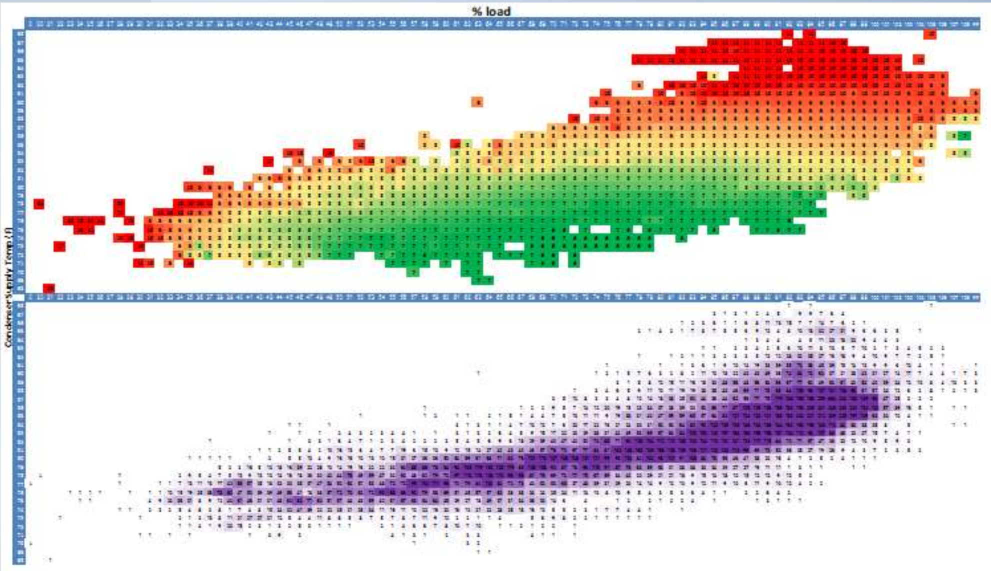
| Tag | CH-1 | | | CH-2 | | | CH-3 | | | CH-4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Design** | | | | | | | | | | | | |
| Equip | Chiller | | | Chiller | | | Chiller | | | Chiller | | |
| Make/Model | Trane/CVHF770 | | | Trane/CVHF770 | | | Trane/CVHF770 | | | Trane/CVHF770 | | |
| Capacity/Hp | 700/ | | | 700/ | | | 700/ | | | 700/ | | |
| CHW | 1,400 | | | 1,400 | | | 1,400 | | | 1,400 | | |
| CW | 2,100 | | | 2,100 | | | 2,100 | | | 2,100 | | |
| **Existing Operation** | Hours | kTon-hrs | kWh | Hours | kTon-hrs | kWh | Hours | kTon-hrs | kWh | Hours | kTon-hrs | kWh |
| Jan | 228 | 42 | 0 | 4 | 1 | 0 | 162 | 48 | 14,638 | 371 | 94 | 46,398 |
| Feb | 535 | 91 | 53,455 | 2 | 0 | 70 | 138 | 43 | 13,449 | 0 | 0 | 0 |
| Mar | 519 | 164 | 74,702 | 221 | 75 | 32,901 | 81 | 30 | 12,355 | 0 | 0 | 0 |
| Apr | 720 | 163 | 79,799 | 19 | 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| May | 83 | 32 | 13,891 | 458 | 234 | 94,401 | 306 | 144 | 60,854 | 120 | 38 | 18,968 |
| Jun | 21 | 8 | 3,536 | 116 | 56 | 23,202 | 218 | 67 | 33,403 | 612 | 314 | 117,008 |
| July | 728 | 334 | 152,402 | 198 | 99 | 61,973 | 227 | 106 | 46,628 | 6 | 3 | 1,298 |
| Aug | 735 | 330 | 139,080 | 267 | 128 | 53,107 | 70 | 32 | 13,868 | 12 | 5 | 1,878 |
| Sep | 720 | 307 | 119,847 | 0 | 0 | 0 | 142 | 68 | 28,918 | 0 | 0 | 0 |
| Oct | 69 | 20 | 9,117 | 3 | 1 | 360 | 78 | 32 | 12,958 | 670 | 231 | 94,823 |
| Nov | 0 | 0 | 0 | 29 | 6 | 2,551 | 5 | 1 | 481 | 608 | 166 | 52,772 |
| Dec | 0 | 0 | 0 | 1 | 0 | 0 | 53 | 18 | 6,973 | 234 | 58 | 21,157 |
| Total | 4,358 | 1,492 | 645,829 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Total Cost | $ | | 33,583 | $ | | 13,094 | $ | | 12,798 | $ | | 17,901 |

| Utility Rate Data | | | |
|---|---|---|---|
| Utility | Blend Rate | | |
| Elec | $ | 0.052 | $/kWh |
| Demand | $ | 8.61 | $/kW |
| Gas | | | $/Therm |
| Swr | | | $/hcf |
| Wtr | | | $/hcf |

| | Sum kh | Sum kWh | Sum Cost |
|---|---|---|---|
| Jan | | 61,056 | $ 3,175 |
| Feb | | 66,973 | $ 3,483 |
| Mar | | 120,018 | $ 6,241 |
| Apr | | 84,377 | $ 4,388 |
| May | | 188,209 | $ 9,787 |
| Jun | | 177,239 | $ 9,216 |
| July | | 242,242 | $ 12,597 |
| Aug | | 207,993 | $ 10,813 |
| Sep | | 148,765 | $ 7,736 |
| Oct | | 107,258 | $ 5,577 |
| Nov | | 55,804 | $ 2,902 |
| Dec | | 28,129 | $ 1,463 |
| Total | [illegible] | [illegible] | |
| Total Cost | $ - | $ 77,376 | $ 77,376 |

# OPTIMIZATION ENERGY ANALYSIS – EQUIPMENT AND SYSTEM PERFORMANCE

**Steam Chiller Efficiency Map**



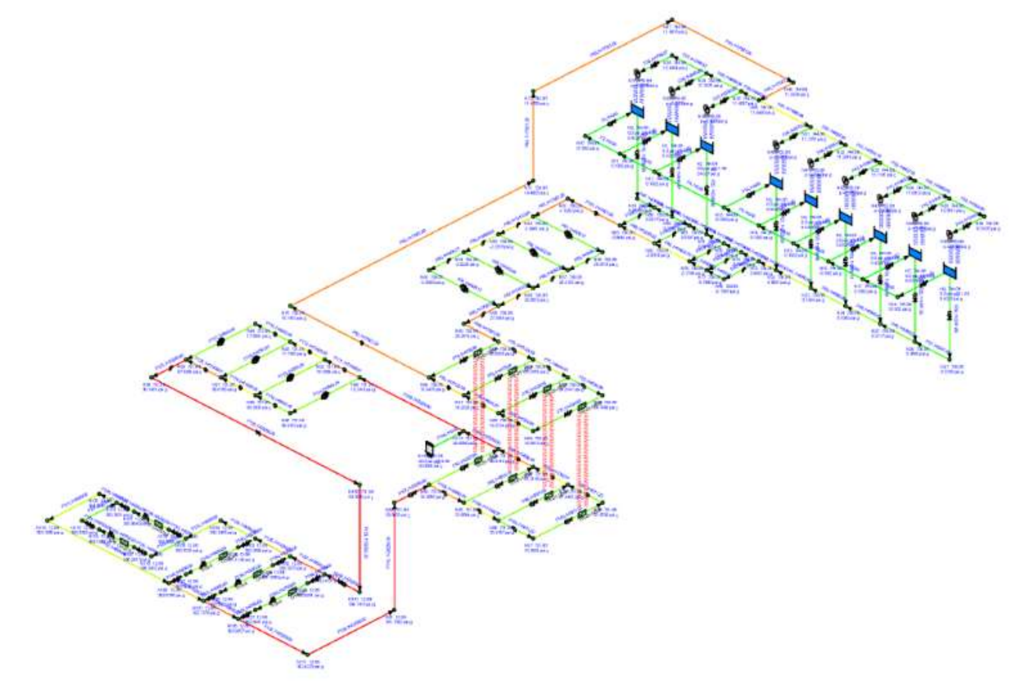

1. **Use real data, no models, no IPLV**
   A. Develop Efficiency Maps for:
      - Chillers
      - Pumps
      - Towers
      - Boilers
      - CTGs
      - STGs
      - Compressors

2. **Model Actual Proposed Sequence**
   A. Sequences are code, use the actual code to model the plant improvements

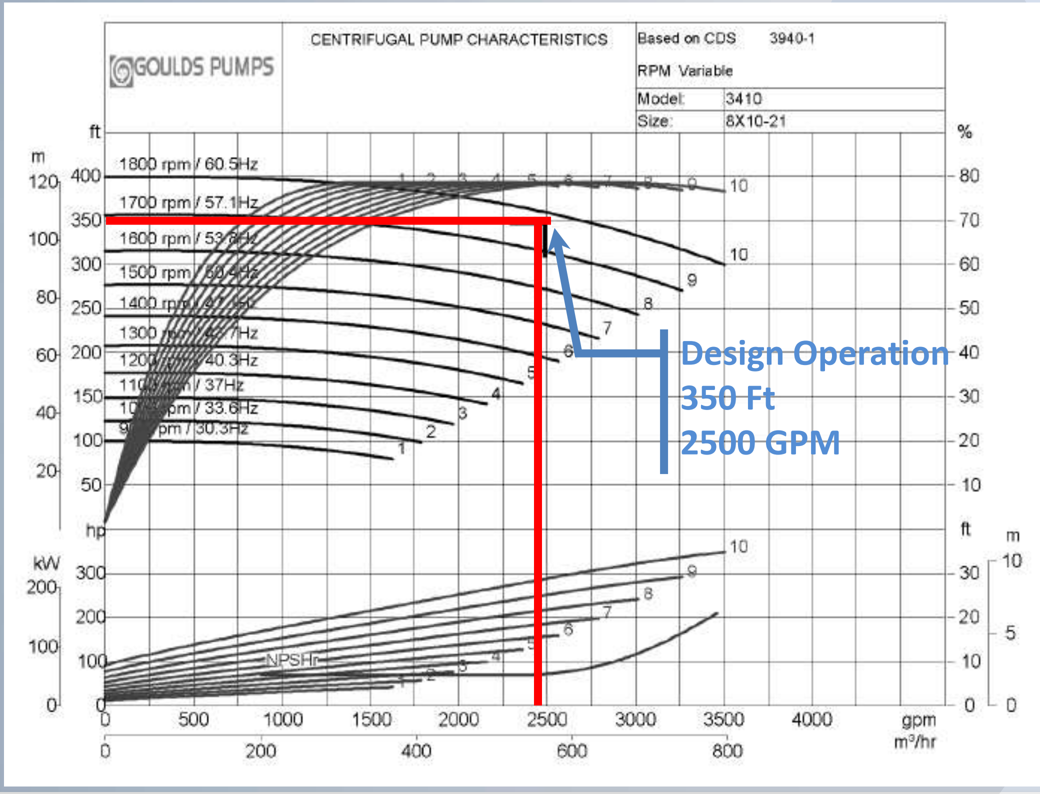
# HYDRAULIC MODELING

1. Compressible and Non-Compressible
   - A. Pipe Flo
   - B. Fathom
   - C. Termis

2. Requires extreme detail, otherwise don't spend the money
   - A. All valves, strainer, elevations, coil dp
   - B. Calibrate with actual test data



# OPTIMIZATION




## LARGE CAMPUS CHILLED WATER PUMP

$$HP = \frac{Flow\ x\ Head}{3960\ x\ \eta}$$

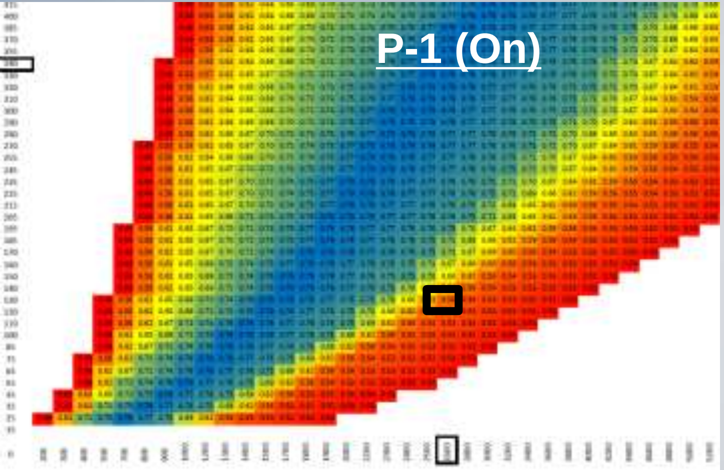
1. Flow: Campus dictates ΔT and thus flow
2. Head: Too many valves to poll to perform DP reset; therefore hydraulically remote DPT determines pump head
3. η can never be greater than pump+motor+VFD **BEP** ~80%



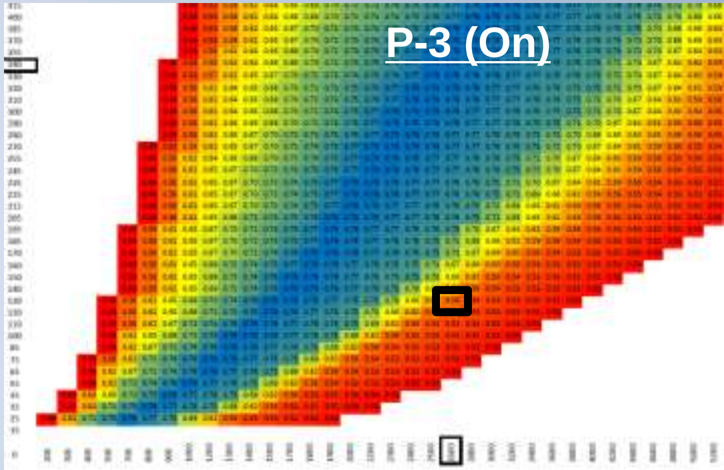
SMITH ENGINEERING

# 3 CHW Pumps

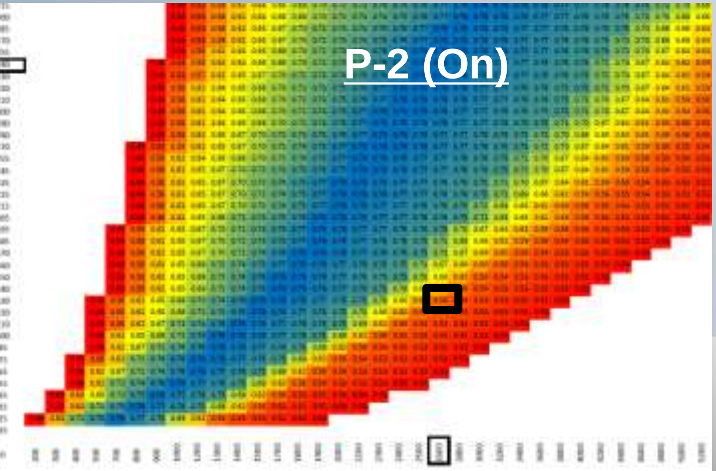
TDH: 135’ FLOW: 2621 GPM η : 56%



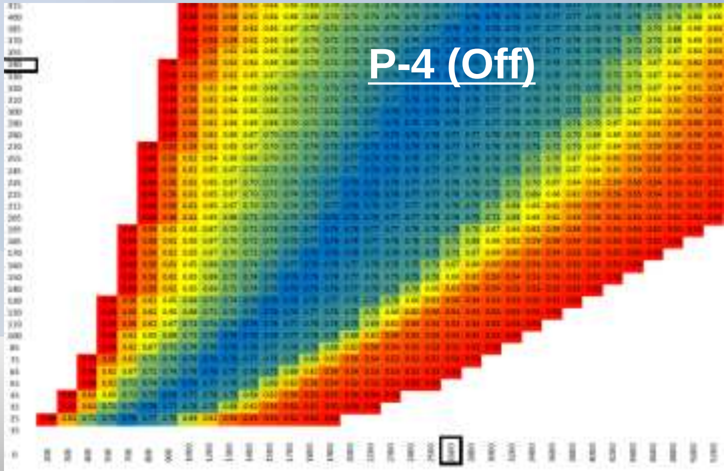

TDH: 135’ FLOW: 2621 GPM η : 56%




TDH: 135’ FLOW: 2621 GPM η : 56%




TDH: 0’ FLOW: 0 GPM η : 0%




**TDH:**

**135’**

**Total FLOW:**

**7,863 GPM**

**η:**

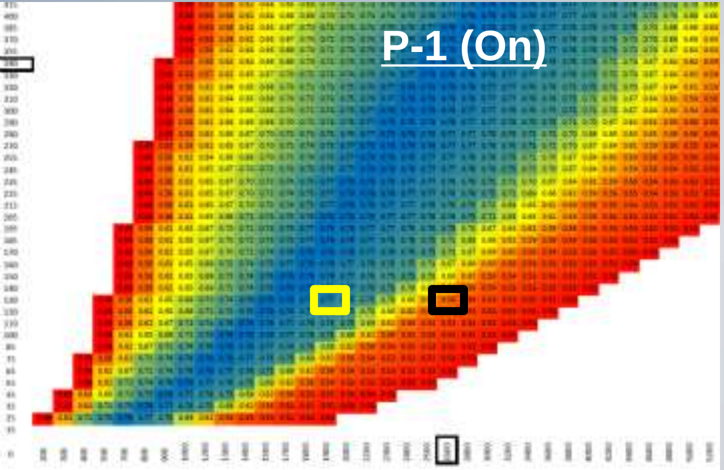
**56%**

**Total kW:**

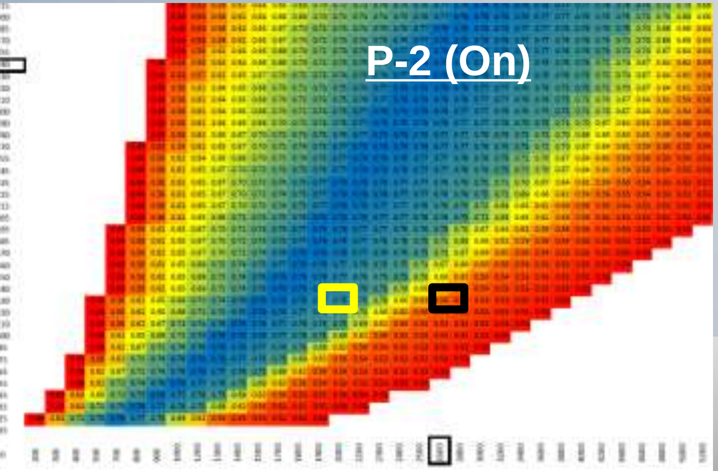
**375**

# 4 CHW Pumps

**TDH: 133’ FLOW: 1965 GPM η : 76%**




**TDH: 133’ FLOW: 1965 GPM η : 76%**




**TDH:**

**133’**

**Total FLOW:**

**7,863 GPM**

**η:**

**76%**

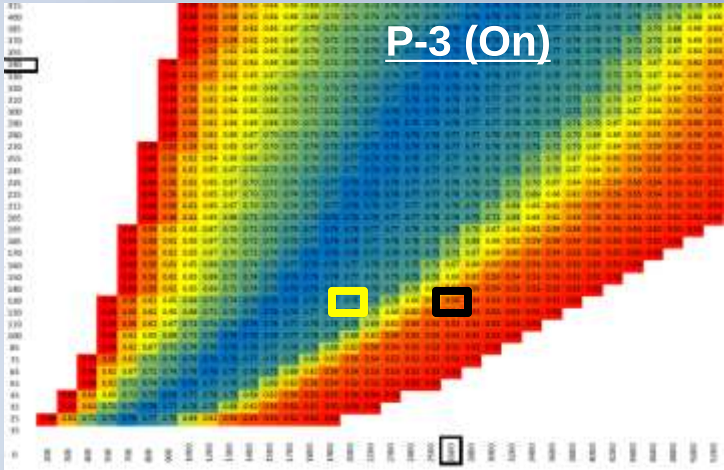
**Total kW:**

**259**

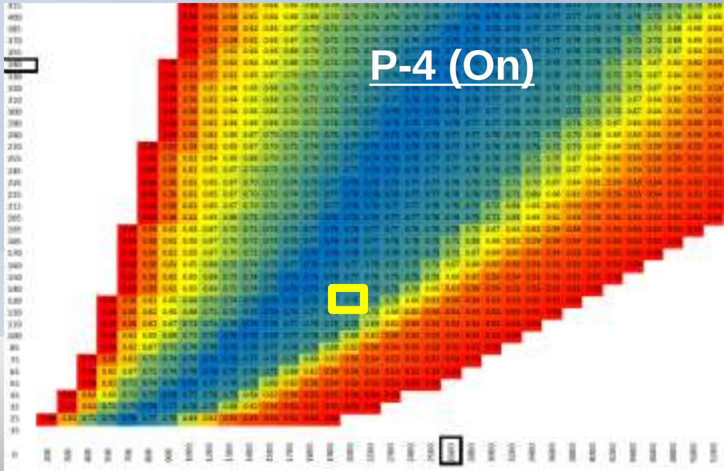
**kW Reduction:**

**115**

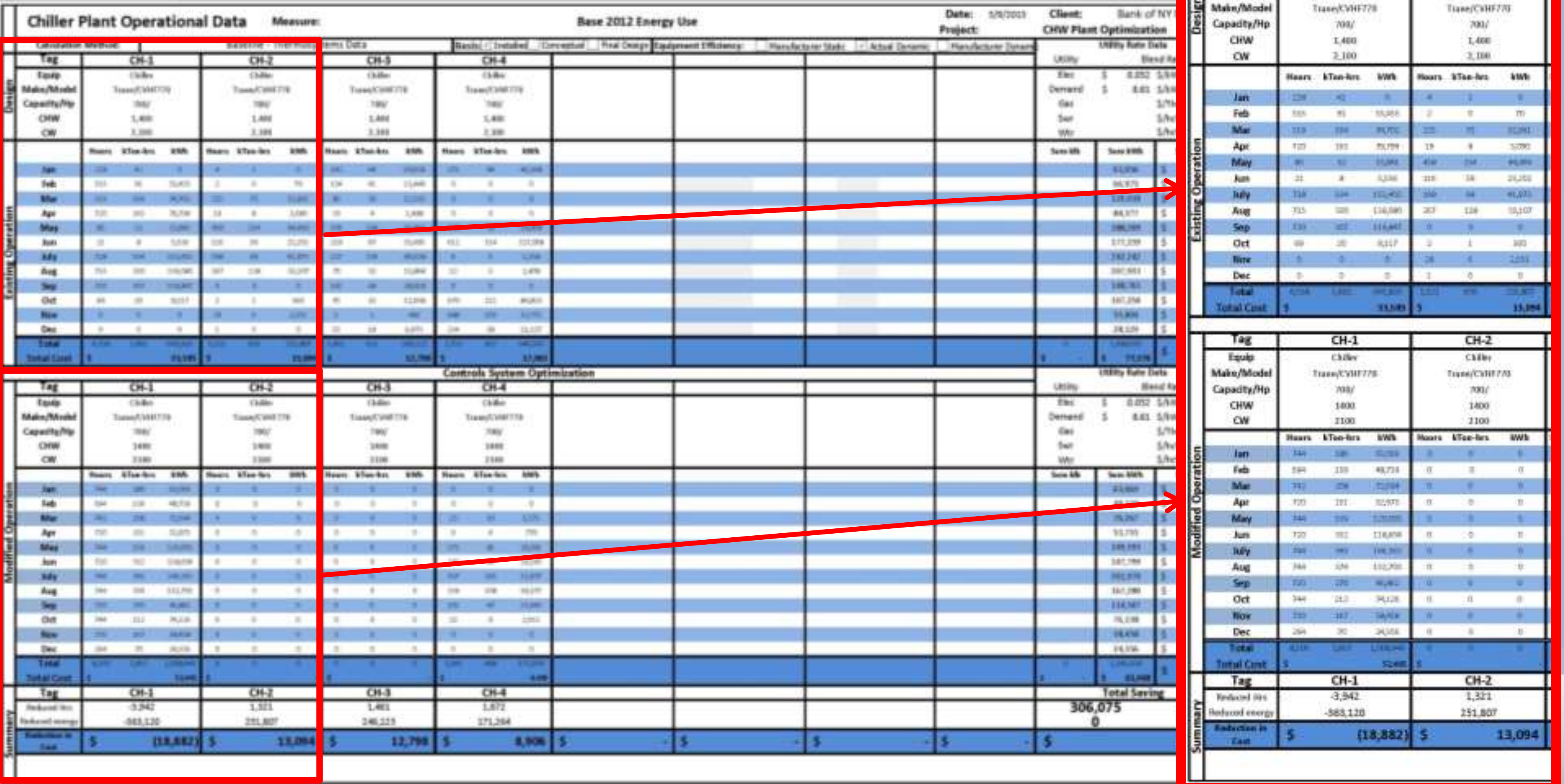
**TDH: 133’ FLOW: 1965 GPM η : 76%**




**TDH: 133’ FLOW: 1965 GPM η : 76%**



# ENERGY ANALYSIS



# OPTIMIZATION - FINANCIAL ANALYSIS

1. **First Cost**
   A. Use contractor GMP quotes, do not use engineering estimates
   B. Include all ongoing contract costs
   C. Include all maintenance costs

2. **Useful Life**
   A. Project VFDs and BAS controllers may be obsolete in 5-10 years

3. **Separate equipment from controls optimization**
   A. ECM-1 – Controls optimization
   B. ECM-2 – Free cooling heat exchanger
      - ECM-2 should use ECM-1 as a base

# OPTIMIZATION - IMPLEMENTATION

1. **Service Provider**
   A. Ask for **relevant** project and client references for the project manager that will be on your project, the brand is less important

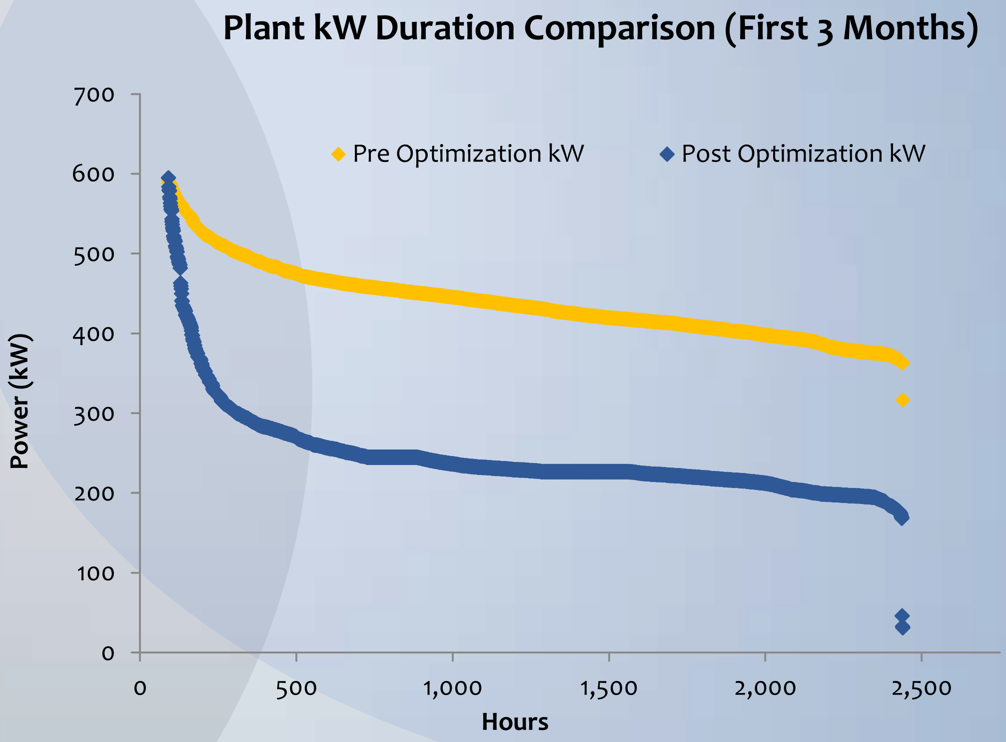
2. **Site Standards**
   A. Packaged bundles must adhere to site quality standards
   B. Examples:
      - VFD – IEEE-519
      - Chillers – marine water box
      - Meters – magnetic, ultrasonic, etc.
      - TT & PT – Rosemount, etc.

# Case Study:
# Merck Pharmaceutical
## West Point, PA

1. **Plant – 6,250 Tons (Total Site 80,000 Tons)**
   - (3) 1,250 Ton Trane CVHE Chillers, (2) 1,250 Ton Trane CVHF Chillers
   - Variable Volume Primary
2. **Rates**
   - $0.065 per kwh
3. **Controls System**
   - Allen Bradley PLCs

# OPTIMIZATION RESULTS

- Plant average reduction in kW
  - **43%**
- Chiller average reduction in kW
  - **28%**
- CW pump average reduction in kW
  - **76%**
- CHW pump average reduction in kW
  - **73%**
- Tower average reduction in kW
  - **42%**
- Average reduction in CW flow
  - **63%**
- Average reduction in CHW flow
  - **60%**



# OPTIMIZATION RESULTS

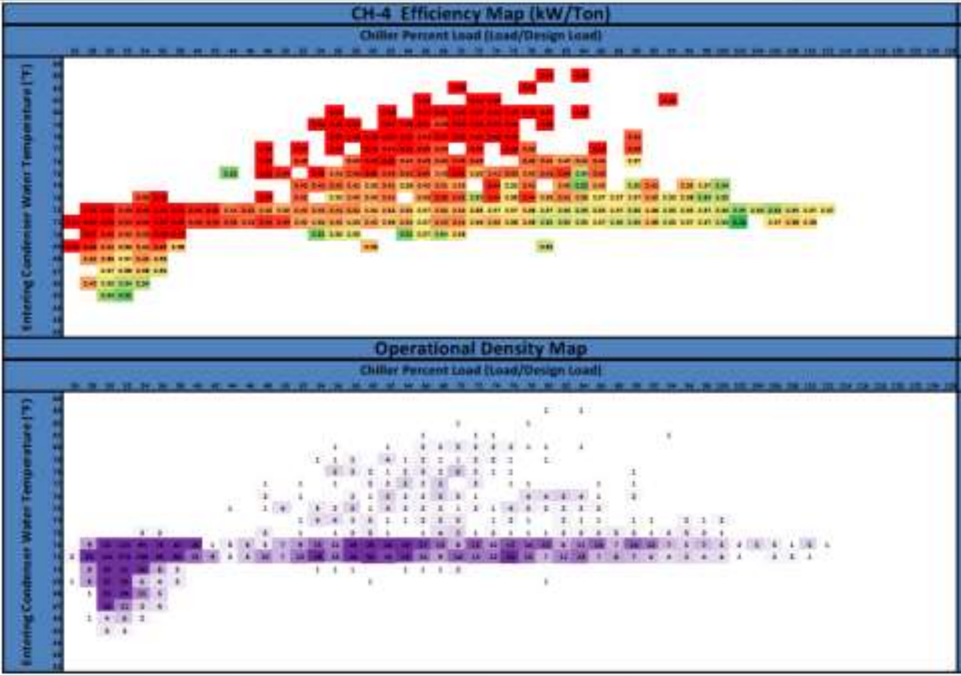
| | Controls Optimization |
|---|---|
| All in First Cost ($) | $548,000 |
| Rebate ($) | $213,296 |
| Net CapEx ($) | $334,704 |
| Energy Savings ($) | $173,303 |
| Simple Payback | 1.93 Years |

# Case Study:
# Large Financial Institution CHW Plant
## Pittsburgh, PA

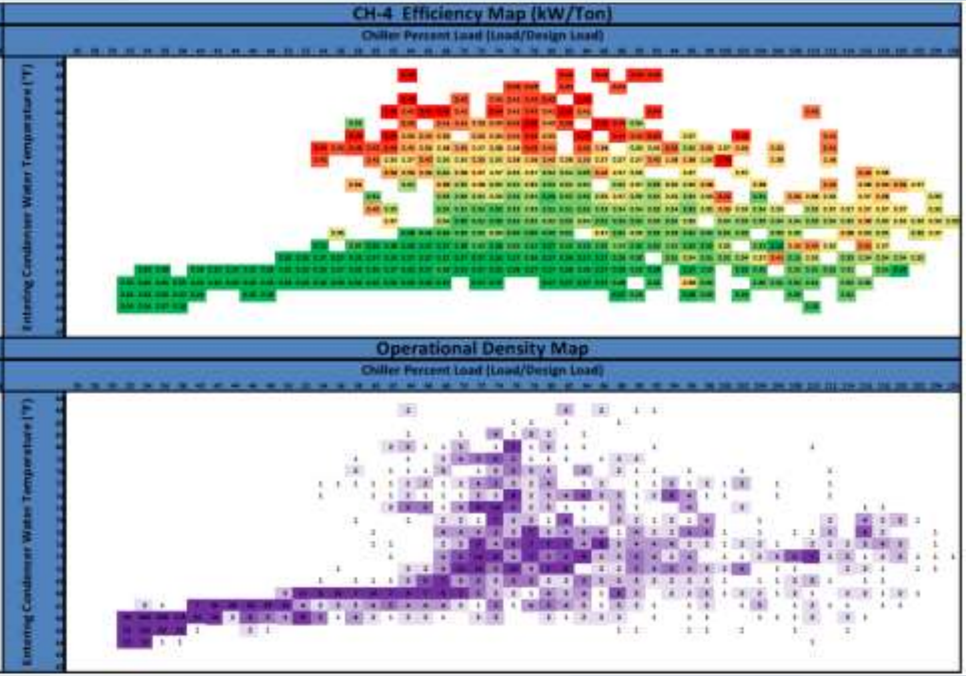
1. **Plant**
   - (4) 700 Ton Trane CVHF Chillers
   - Primary secondary system
   - Data Center
2. **Rates**
   - $0.052 per kwh and $8.61 per kw
3. **Controls System**
   - Allen Bradley PLCs

# OPTIMIZATION - CHILLER EFFICIENCY MAPPING

## Pre-Optimization



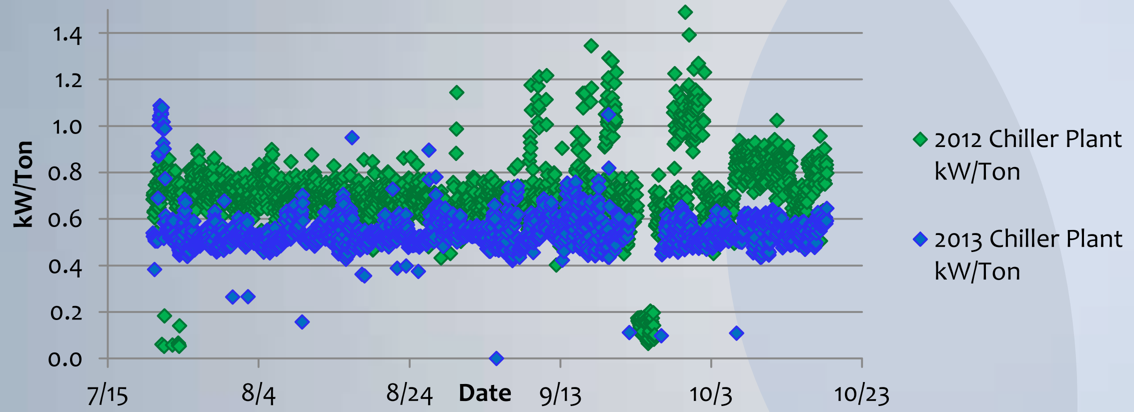

## Post-Optimization

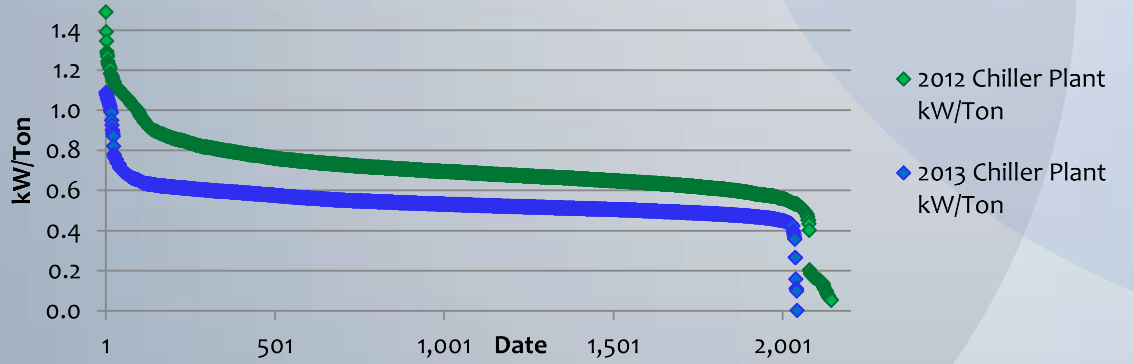





SMITH ENGINEERING

# OPTIMIZATION RESULTS – M&V




| kWh Savings | 879,547 |
|---|---|
| $ Savings | $55,035 |
| Rebate | $52,772 |
| Simple Payback | Less Than 1.5 Years |


Payable To: Mellon Bank NA
Attention To: First Name: Dan
Address 525 WILLIAM PENN PL STE 2500
City: PITTSBURGH
Incentive Payment: $55,312.32

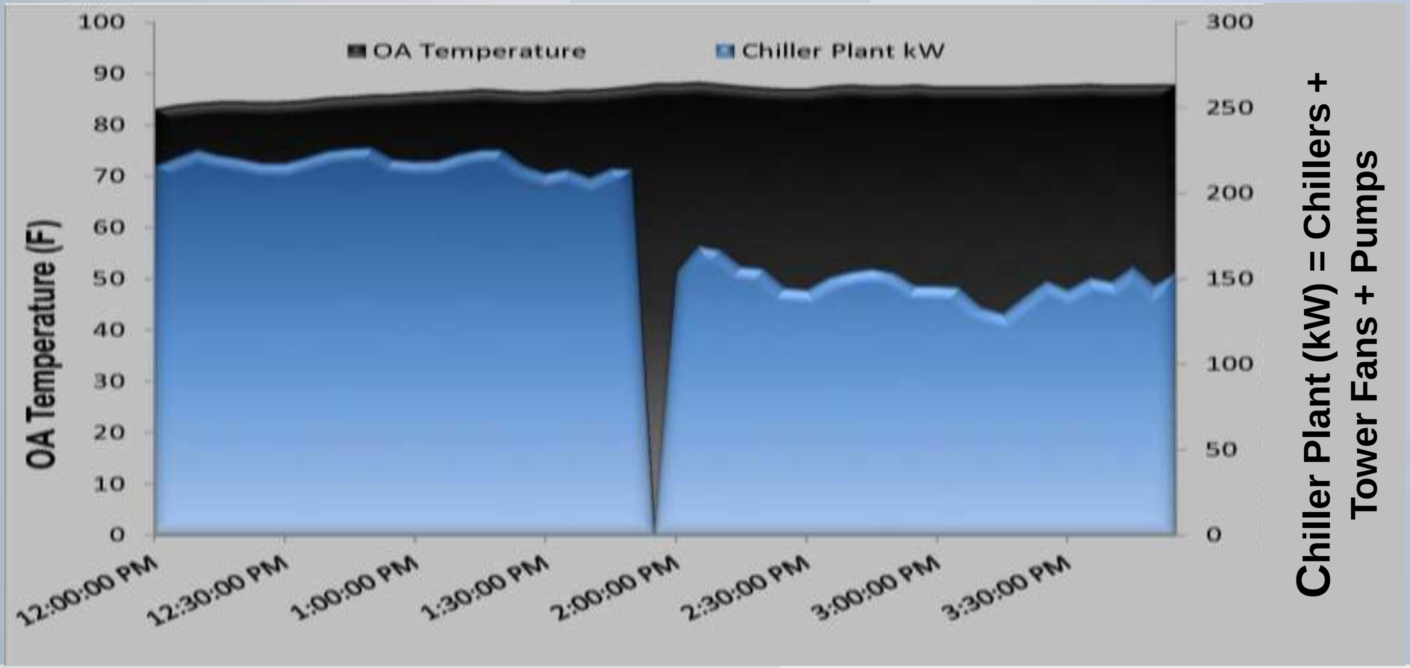
SMITH ENGINEERING

# Case Study:
# LEED Gold Data Center
## Princeton, NJ

1. **Plant**
   - (3) 500 Ton Trane CVHF chillers
   - Primary-secondary system
   - Data center

# LEED GOLD DATA CENTER.

**Plant energy demand pre and post enhanced control logic (zero demand spike is from bringing the controller down to install the new logic)**



# CLOSING

- Plant efficiency improvement decisions should be based on product agnostic, data-driven, rigorous analysis. A full understanding of the complete system, utility rates, component efficiencies, feasibility, and implementation cost is required.

- Optimization is not a "magic pill" – it requires an investment in the time of highly qualified people.  The more complex the plant and process, the more time and "hands-on" attention required.

- The terms of the contract may be more important than the level of optimization.