Pharmaceutical Plant

Software-based cooling-system optimization case study

A pharmaceutical manufacturing facility improved average chilled-water plant operating efficiency from 0.74 to 0.65 kW/ton after deploying ClimaMind software-based supervisory optimization on condenser-water pumps and cooling-tower fans.

12.11%	37 days	0 retrofit
Measured kW/ton improvement	Software-optimized window	No BMS replacement

The result is reported as plant-level operating efficiency within the measured control boundary. The optimized period was warmer and more humid than the baseline period, so the comparison is conservative with respect to weather context.

The case uses the same technical figure set prepared for the AEE/IJEM publication submission: the ClimaMind DDQN workflow, daily kW/ton versus weather plots, and representative cooling-tower frequency trends for baseline and software-optimized operation.

The facility remains anonymized. No customer name, geography, site identifier, or project-party attribution is included in this public case study.

Facility And Control Boundary

The site operates a secondary-pump variable-flow chilled-water system serving pharmaceutical manufacturing and process-support loads. The central plant includes four chillers in a three-duty, one-standby arrangement; four chilled-water pumps; four condenser-water pumps; three air-side chilled-water pumps; and four process-side chilled-water pumps.

The software layer was added above the existing BMS. The BMS remained the system of record for execution, protection logic, alarms, local loops, manual override, and operator visibility. ClimaMind selected supervisory frequency commands only inside approved operating envelopes.

Equipment	Typical installed unit	I-P specification	Role
Centrifugal chiller	Trane	650 tons cooling; 539 hp input	Cooling production
Chilled-water pump	Grundfos	66 ft head; 40 hp; 1,541 gpm	Primary flow
Condenser-water pump	Xylem	72 ft head; 60 hp; 837 gpm	Optimization scope
Cooling tower	BAC	2,201 gpm; 30 hp	Optimization scope

Approved software-control scope

Control item	Approved boundary
Condenser-water pump frequency	42 Hz to 50 Hz, constrained by low-flow protection
Cooling-tower fan frequency	22 Hz to 50 Hz, constrained by tower operation and plant response
Current measured scope	Condenser-water pumps and cooling towers
Reserved interfaces	Chilled-water supply temperature and chilled-water pump frequency
Data inputs	BMS trends, equipment status, daily system kW/ton, outdoor dry-bulb, outdoor wet-bulb

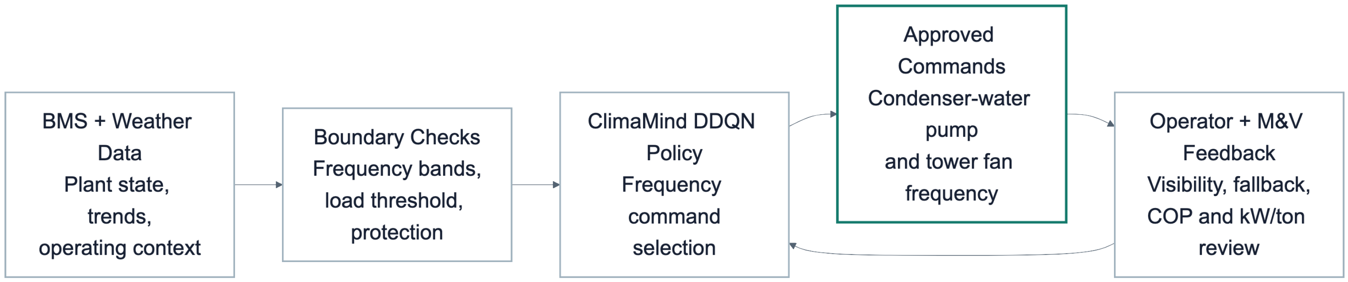
Software Optimization Method

The controller is a software-based supervisory layer, not a replacement for the installed BMS. It uses reinforcement learning, specifically a ClimaMind DDQN policy, to select condenser-side frequency commands from the current plant state, equipment limits, weather context, and measured feedback.

Boundary checks are explicit and separate from policy selection. Frequency bands, low-flow protections, load thresholds, and operator-approved operating modes are evaluated before a command is issued through the BMS-compatible interface.

The reward targets plant energy performance and process-relevant response. This differs from a static reset rule because the policy can move pumps and tower fans dynamically as weather, load, and equipment interactions change.

Figure 1. Software-based optimization workflow



The workflow separates BMS and weather inputs, boundary checks, DDQN policy selection, approved command execution, and operator plus M&V feedback.

Measurement And Verification

The measurement boundary covers the optimized condenser-side equipment and reports plant operating efficiency in kW/ton. Lower kW/ton indicates less electric input per ton of cooling delivered.

Baseline operation used 27 valid daily records from Jun 1 to Jul 7 after excluding days with missing power data. Software-optimized operation used 37 daily records from Sep 1 to Oct 7.

The optimized period was hotter and more humid on average: 78.2 F dry-bulb and 72.4 F wet-bulb, compared with 72.8 F dry-bulb and 66.8 F wet-bulb during the baseline period.

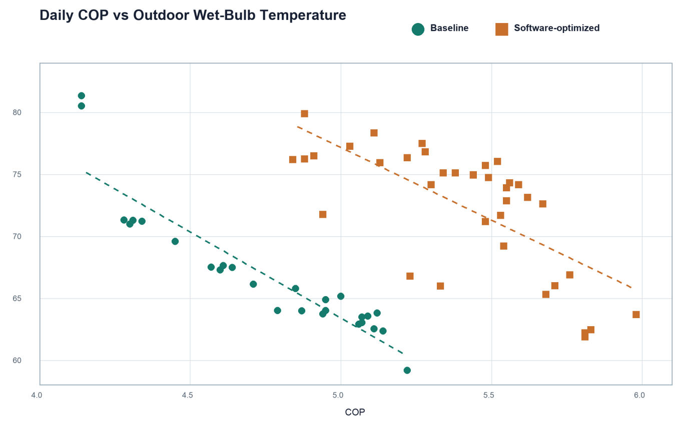
Metric	Baseline operation	Software-optimized operation
Valid daily records	27	37
Operating period	Jun 1 to Jul 7	Sep 1 to Oct 7
Average COP	4.75	5.41
Average plant efficiency	0.74 kW/ton	0.65 kW/ton
Average dry-bulb	72.8 F	78.2 F
Average wet-bulb	66.8 F	72.4 F

Improvement = (0.74 - 0.65) / 0.74 x 100% = 12.11%. Total kWh and inferred dollar savings are intentionally not published in this public file because the available public dataset supports operating-efficiency comparison, not a full utility-bill claim.

Weather-Normalized Operating Evidence

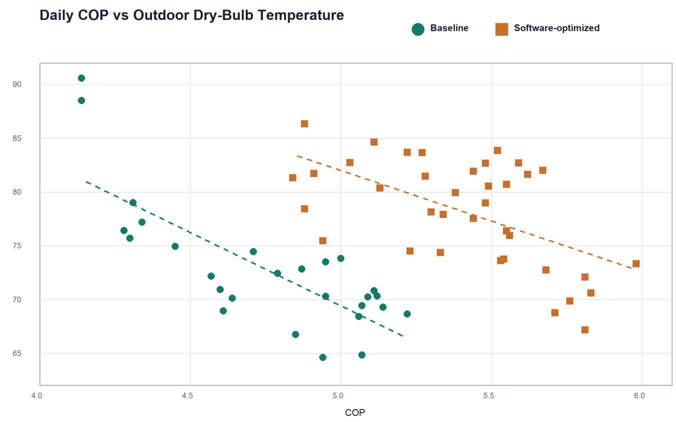
Daily operating points were reviewed against outdoor wet-bulb and dry-bulb temperature. The optimized period retained lower average kW/ton even though the measured weather conditions were less favorable than the baseline period.

Figure 2. Daily plant efficiency versus outdoor wet-bulb temperature



The software-optimized records cluster at lower kW/ton while operating at higher wet-bulb conditions than the baseline records.

Figure 3. Daily plant efficiency versus outdoor dry-bulb temperature

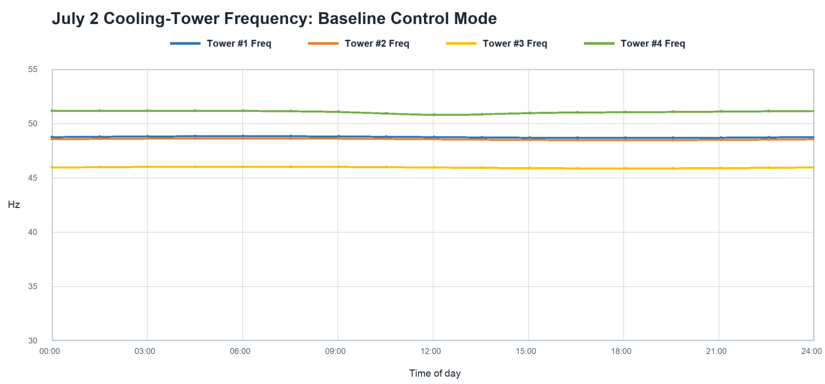


Dry-bulb comparison shows the same directional result: lower average kW/ton during the optimized period under warmer ambient conditions.

Cooling-Tower Frequency Evidence

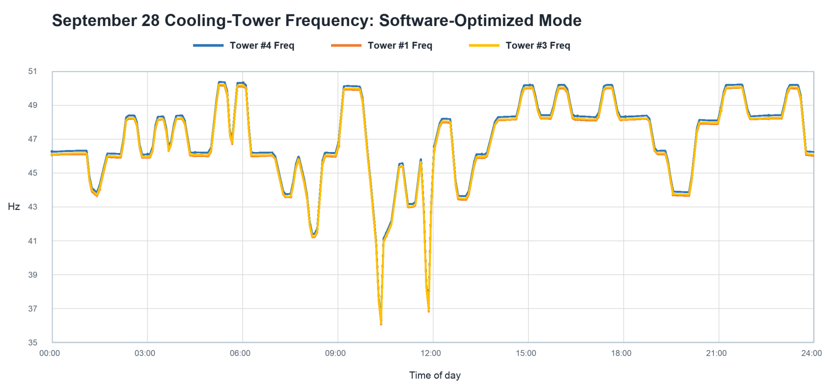
Representative cooling-tower frequency trends show the operating difference between baseline control and software-optimized control. Baseline operation stayed near fixed frequency. Under software optimization, the tower commands moved dynamically within the approved envelope in response to plant state and weather.

Figure 4. July 2 cooling-tower frequency under baseline control mode



A brief single-sample transient around 08:30 was excluded because it did not represent sustained cooling-tower frequency operation.

Figure 5. September 28 cooling-tower frequency under software-optimized mode



The optimized trend shows dynamic tower-frequency modulation over the day, rather than fixed-frequency operation.

Technical Interpretation

The measured result is not explained by a simple reduction in cooling demand. The optimized period had higher outdoor dry-bulb and wet-bulb averages, yet the measured average plant efficiency improved from 0.74 to 0.65 kW/ton.

The control behavior also changed in a physically meaningful way. Baseline tower operation stayed close to fixed frequency for most of the representative day, while the optimized day shows bounded modulation. This indicates that the software layer was actively coordinating condenser-side operation instead of merely reporting analytics after the fact.

The deployment preserved established industrial control responsibilities. The BMS executed approved commands and maintained equipment protection. ClimaMind supplied a supervisory optimization policy, command screening, operator visibility, and an M&V feedback path.

Cooling-tower running energy was reduced by about 30% within the comparison window while the plant remained inside approved operating boundaries. The public case reports this equipment-scope operating result rather than extrapolating to a whole-facility energy bill.

Deployment evidence operators can audit

Evidence item	What it shows
BMS trend history	Commands were issued through existing plant interfaces
Frequency envelopes	Optimization stayed inside approved Hz ranges
Weather plots	Lower kW/ton was observed despite warmer, more humid optimized operation
Daily kW/ton records	The result is tied to measured plant performance, not only model simulation
Operator feedback loop	Manual visibility and M&V; review remain part of the control cycle

Summary

This case study shows a software-first path for improving industrial chilled-water plant operation. The deployment did not require replacing the BMS or retrofitting major plant hardware.

Within the measured control boundary, average plant operating efficiency improved from 0.74 to 0.65 kW/ton, a 12.11% improvement, across a 37-day software-optimized operating window.

The technical evidence is consistent across the M&V table, weather plots, and representative frequency trends. The software layer changed the control behavior, operated within explicit bounds, and delivered lower measured kW/ton under warmer and more humid average conditions.

Publication-aligned figure set

Figure	Public case-study role
Figure 1	ClimaMind DDQN control workflow and feedback boundary
Figures 2 and 3	Daily kW/ton comparison against wet-bulb and dry-bulb weather context
Figures 4 and 5	Cooling-tower frequency evidence for baseline and software-optimized operation

Prepared by ClimaMind. The facility is intentionally anonymized for public distribution.