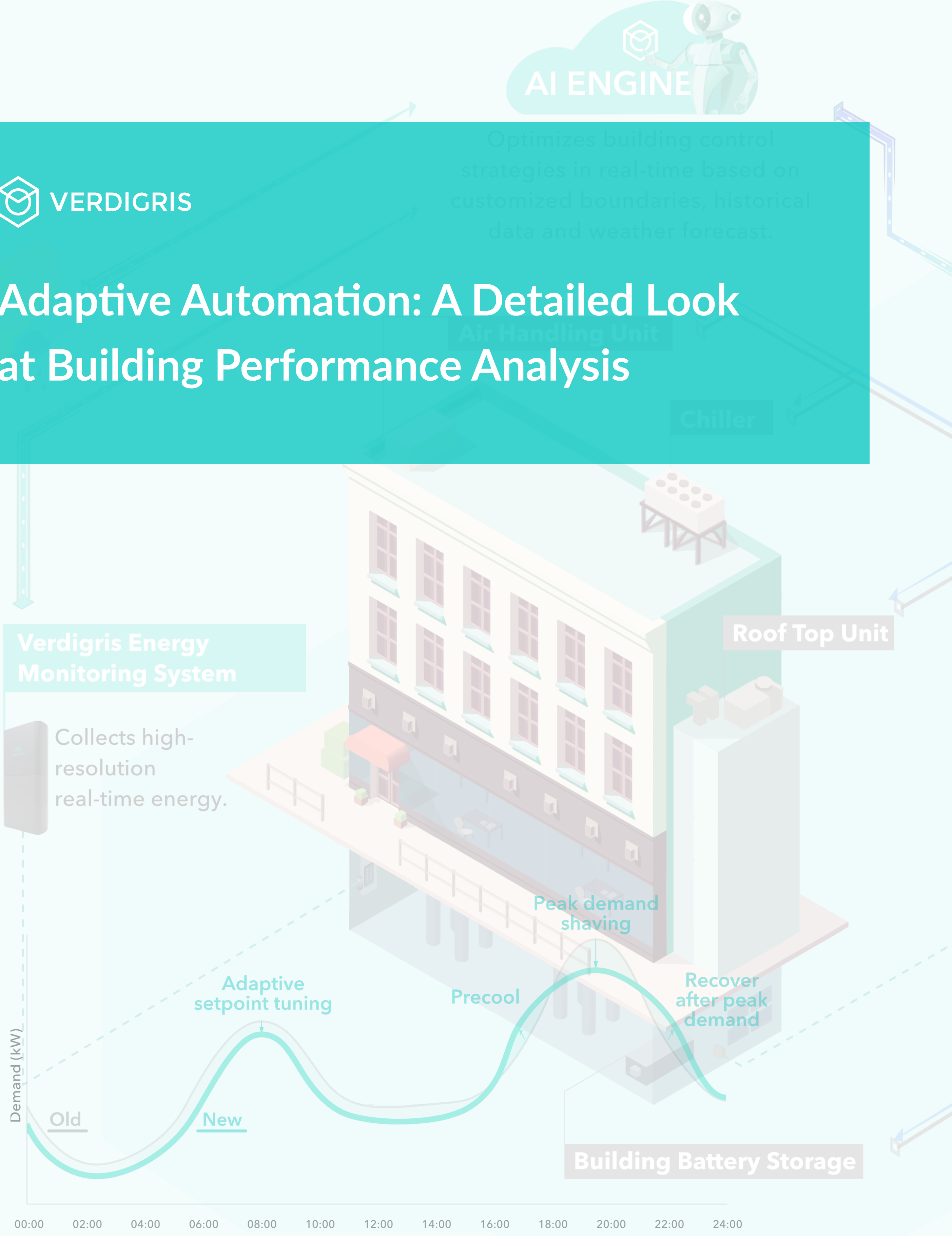
VERDIGRIS

Adaptive Automation: A Detailed Look at Building Performance Analysis



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Executive Overview

Verdigris Adaptive Automation™ helps reduce energy consumption and save money effortlessly, using AI to continuously and automatically optimize HVAC system operations.

First, our AI learns your building's patterns, combining real-time, high-frequency meter data with local weather, utility pricing, and building management system (BMS) data to develop forecasts.

Then, we continuously optimize the energy efficiency of equipment that operates 24/7, and automate demand management and response to shed and shift loads without compromising tenant or guest comfort.

Verdigris customers have seen savings of $0.10-$0.30 per square foot using Adaptive Automation, with no additional effort from onsite staff required.

In this white paper, we take an in-depth look at where Adaptive Automation begins, with building performance analysis. You'll learn how Adaptive Automation:

- Identifies the optimization opportunity
- Dynamically adjusts the setpoints to meet building needs while reducing energy usage
- Ensures building occupant comfort with a secondary control loop

Identifying the Optimization Opportunity

The goal of Adaptive Automation is to make the cooling supply more responsive to the demand in the building. To do that, we start by identifying the opportunity available for optimization.

Let's explore two examples: one for a building with a chiller, and one for a building with rooftop units (RTUs). These represent two types of HVAC equipment that Adaptive Automation can optimize.

Example #1: Chiller

Figure 1 shows a building with a chiller, with cooling supply on the X-axis and chiller power on the Y-axis. Cooling supply is a combination of the chilled water flow rate and the difference between the chilled water return and supply temperatures. In this example, there is a relationship between the two, but there are also areas where more chiller power is being used, even if the cooling supply is lower (areas above the yellow trend line). Our AI engine's objective is to learn the relationship between setpoints and energy in order to find a chiller setpoint that minimizes energy usage while achieving the same cooling supply.

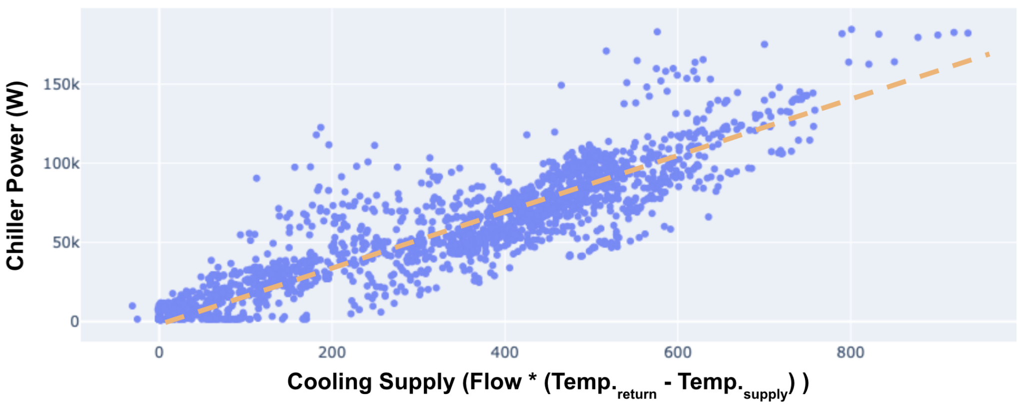


Figure 1. Cooling supply vs. chiller power.

Identifying the Optimization Opportunity *(continued)*

Example #2: Rooftop Unit (RTU)

Figure 2 shows a building with RTUs, with cooling supply on the X-axis and RTU power on the Y-axis. Cooling supply is the flow rate times the delta between the discharge and return air temperatures. The variation in power used by the RTUs indicates significant room to optimize. Adaptive Automation will optimize supply fan speeds and discharged air temperature to meet the same demand but at a lower base power, while maintaining a suitable return air temperature for building comfort.

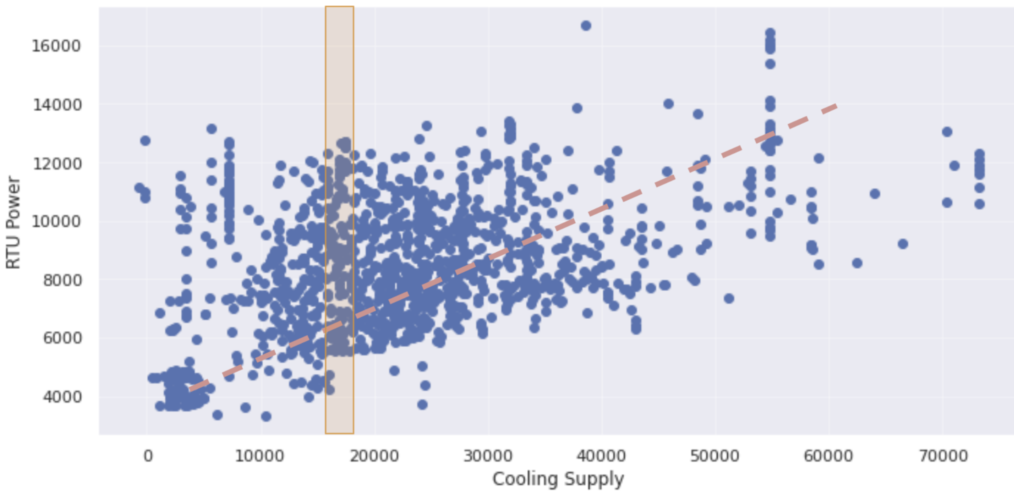


Figure 2. Variation in power used by the RTUs indicates significant room to optimize.

With the optimization opportunity identified, it's time to train the model.

Data Enrichment & Model Training

Verdigris IoT energy meters capture highly-granular energy data down to the circuit level, sampled at 8 kHz.

Next, we combine the Verdigris energy data with data pulled from the building management system (BMS). We pull and store values from the BMS on a 5 minutely basis. You can view this data and our controls on the Verdigris analytics dashboard.

We also combine the above data with additional third party sources. This additional data can include weather variables including temperature, humidity, pressure, and wet bulb; chiller water supply and return temperatures; discharge and return air temperatures; supply fan output; and more.

Verdigris IoT energy meters capture energy data at 8 kHz — **8,000 times a second**

Verdigris Energy Data + **BMS & 3rd Party Data**

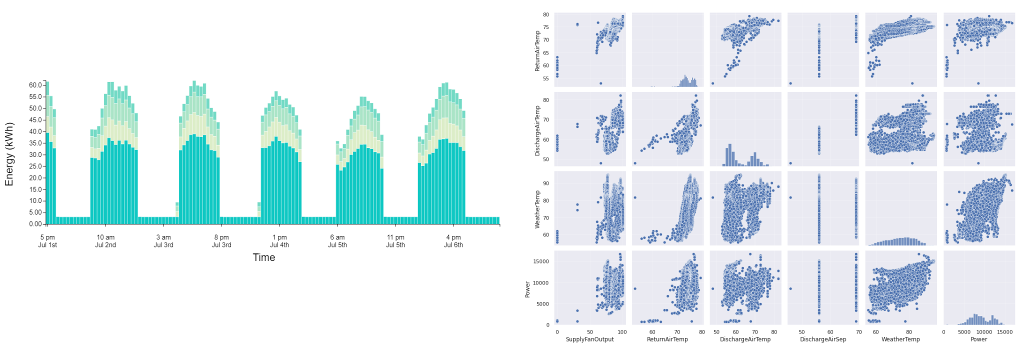


Figure 3. The data set is enriched by combining Verdigris energy data with BMS and 3rd party data.

Verdigris' AI then uses this ingested data to train the model to accurately predict the behavior of the HVAC equipment on a 15-minute interval. If the model accuracy R2 is greater than 0.78, it is able to explain most of the variation in the data and it can start to be trusted. Recent implementations have seen model accuracy R2 ranging from 0.87 to 0.93.

Once the desired model accuracy is achieved, it's time for optimization.

Optimization: Adjusting Supply to Meet Demand

With Adaptive Automation, we build an energy model that can correctly forecast and predict what will happen with a building's energy usage, and when it will happen. A 24-hour forecast is generated on a 15-minute interval, and our model uses that to determine the controls to adjust. There is a feedback loop every 5 minutes to make sure everything stays within certain bounds, so we protect the equipment and don't compromise the comfort of building occupants.

Let's look at four examples of optimization during the building performance analysis phase of implementation:

- Chiller
- Cooling tower
- Cooling tower and chiller
- Rooftop unit (RTU)

Example #1: Chiller

First we'll look at a building with a chiller. In this example, the data shows two potential improvement opportunities:

- **Reduce overnight chiller and pump usage and cooling:** The equipment seems to be using a decent amount of energy overnight.
- **Relax supply temperatures slightly during the day:** There is an opportunity to allow the supply temperature to rise slightly, without impacting occupant comfort.

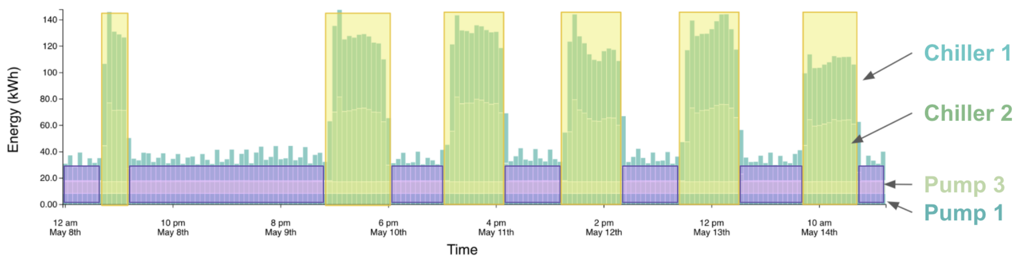
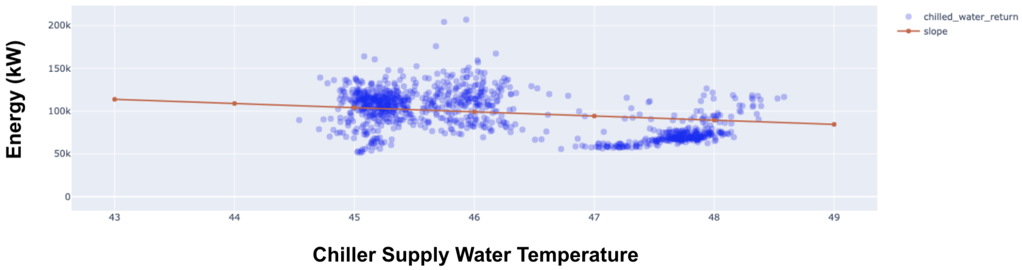


Figure 4. Looking for improvement opportunities by examining the building's energy usage patterns.

Optimization: Adjusting Supply to Meet Demand

We then build a model to figure out chiller energy based on chiller supply temperature, weather variables such as temperature and wet bulb, and time of day.



$$Chiller_{Energy} \propto (Chiller\ Supply\ Temperature)(Weather_{e.g.Temperature})(Time_{e.g.Hour\ of\ Day})$$

Figure 5. Modeling chiller energy based on chiller supply temperature.

Next, we separate the data set into working hours and overnight hours. In both groupings, the chiller is cooling the water more than is necessary.

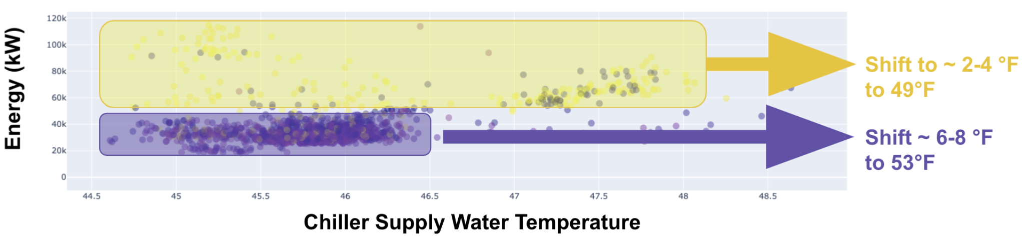


Figure 6. Identifying patterns and optimization opportunities for working hours and overnight hours.

In this example:

- For overnight hours, highlighted in purple, there is an opportunity to move the supply temperature up 6-8 °F to 53 °F. At the lower bound, shifting the temperature 6 °F for the ten hour period translates to an energy savings of 292,725 kWh per day.
- For working hours, highlighted in yellow, there is an opportunity to move the supply temperature up 2-4 °F to 49 °F. The smaller shift reflects a desire to be more conservative and ensure the comfort of building occupants is not compromised. At the lower bound, shifting the temperature 2 °F for the fourteen hour period translates to an energy savings of 136,605 kWh per day.

These adjustments saved the customer $1,100 in the first month, with projected annual savings of $8-12k (depending on assumptions, e.g. impact of seasonality). Additional savings can be achieved with more aggressive temperature adjustments, after ensuring safe and comfortable operations at the lower bound.

Optimization: Adjusting Supply to Meet Demand *(continued)*

Example #2: Cooling Tower

Many cooling towers currently operate with a constant setpoint for condenser water temperature while performance varies by season and hour of day; in Figure 7 this is represented by the red dotted line. By constantly adjusting that setpoint throughout the day, shown as the blue dotted line and range in Figure 7, Verdigris Adaptive Automation is able to achieve significant savings—for this example building, nearly $8,000/year.

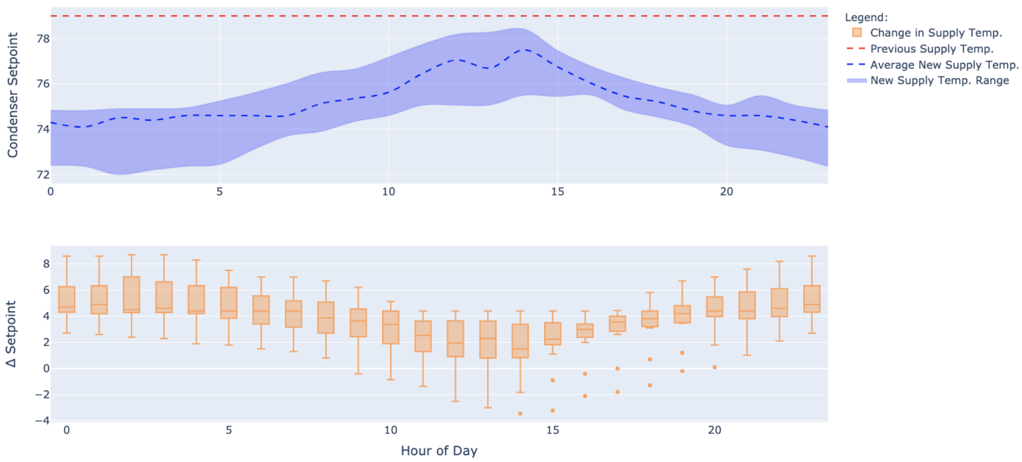


Figure 7. Continuously adjusting the condenser water temperature setpoint throughout the day (blue line) achieves significant energy savings compared to a static setpoint (red line).

Example #3: Cooling Tower and Chiller

Here we'll look at an example of two separate pieces of equipment: a cooling tower and a chiller. Typically these are set individually with optimized programming loops for each one, but they don't necessarily collaborate well. Adaptive Automation is able to bridge that gap and identify opportunities to realize energy savings.

Figure 8 shows how Adaptive Automation algorithm found that running the cooling tower a little bit harder would be more than offset by an outsized savings in the chiller, gaining efficiency for the entirety of the building; in this example, a savings of almost $10,000/year.

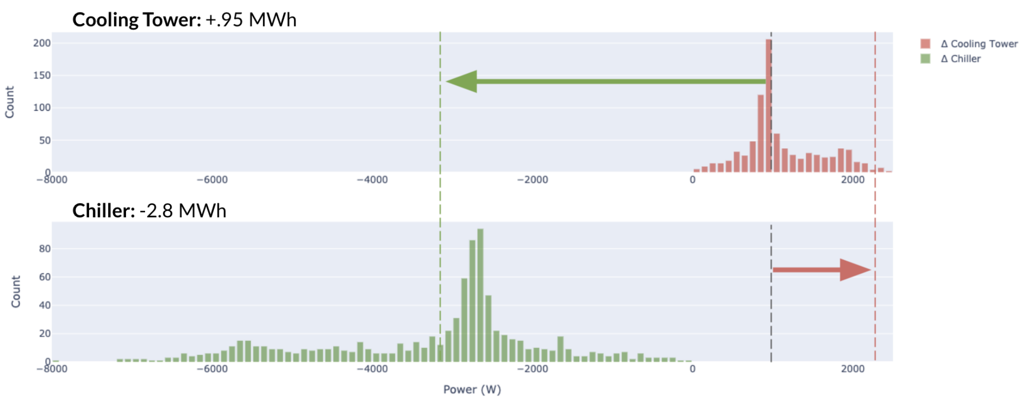


Figure 8. Running the cooling tower slightly out of efficiency is more than offset by savings in chiller energy usage.

Optimization: Adjusting Supply to Meet Demand *(continued)*

Example #4: Rooftop Units (RTUs)

For buildings with RTUs, Adaptive Automation will optimize supply fan speeds and discharged air temperature, while maintaining a suitable return air temperature to make sure that building comfort is not compromised.

To optimize supply to meet demand, Adaptive Automation will adjust the discharge air temperature and the supply fan speed, moving both towards optimal setpoints as determined by Verdigris' AI engine. In the example shown in Figure 9, optimized discharge air temperature is around 60 degrees (determined by discussions with the building and historical data), and optimized supply fan speed is 80 RPM.

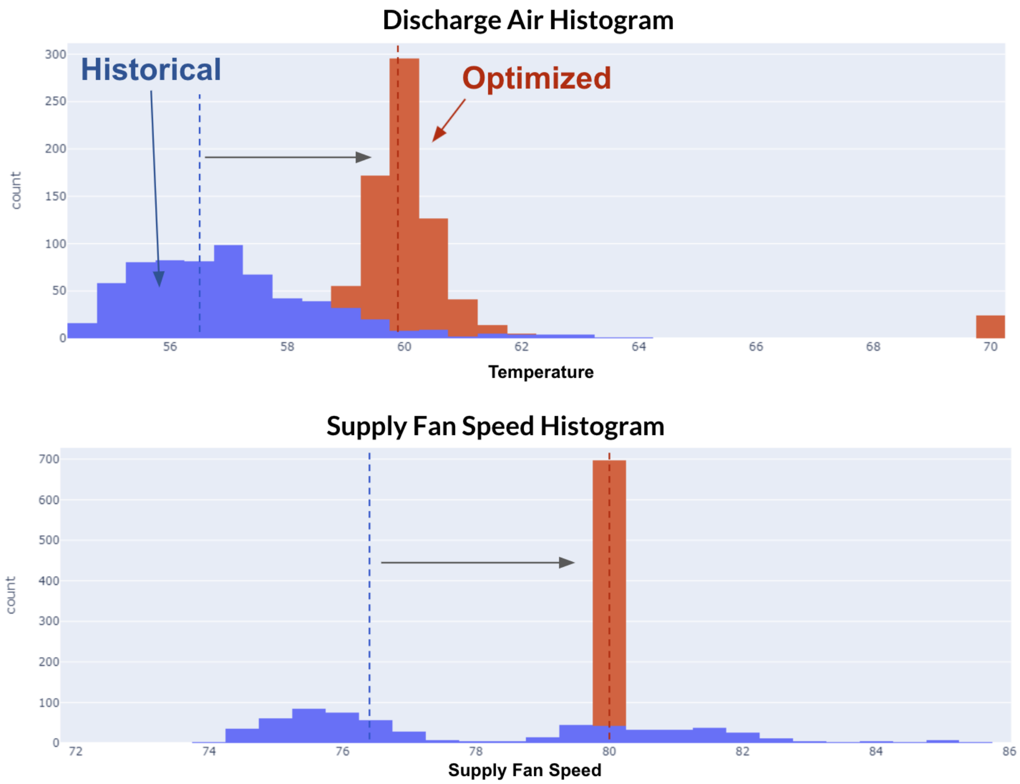


Figure 9. Historical vs. optimized discharge air temperature and supply fan speed.

By increasing discharge air temperature as well as supply fan speed, while maintaining the return temperature, Adaptive Automation better matches cooling supply to cooling demand while saving energy.

Optimization: Adjusting Supply to Meet Demand *(continued)*

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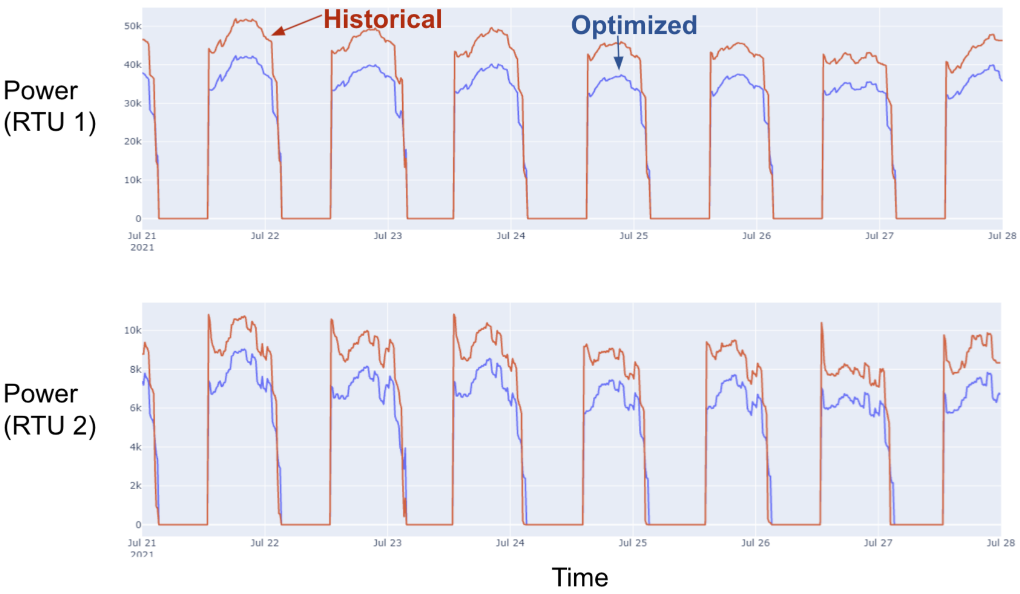

Figure 10. Historical vs. optimized power usage for two of the example building's four RTUs.

In this customer example, implementing Adaptive Automation for a building with four RTUs achieved a 17% reduction in RTU energy usage.

Implementing Adaptive Automation for a building with four RTUs achieved a **17% reduction in RTU energy usage**

Optimization: Demand Savings

In addition to the baseline savings, Adaptive Automation contributes demand savings.

Adaptive Automation is set up to look at the max of any 15 minute interval by hour of day, to most closely match utility rate schedules. Figure 11 shows the red off-peak period and the green peak period.

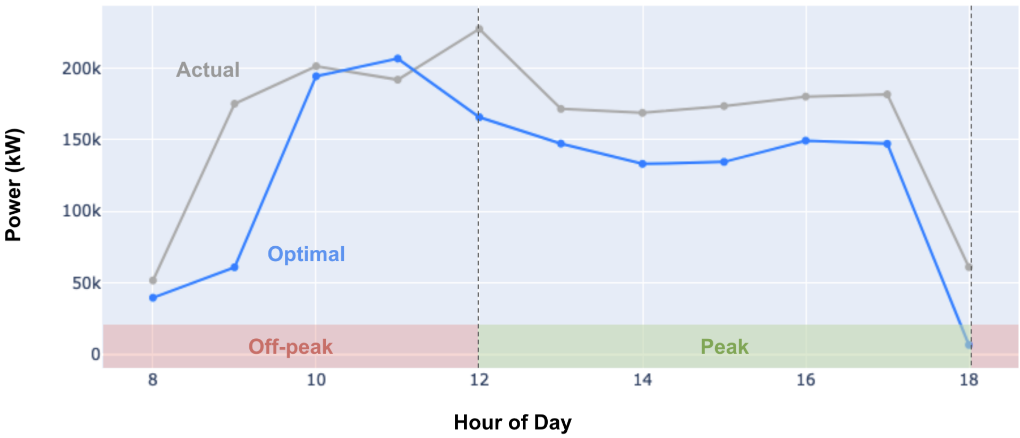

Figure 11. Shedding and shifting loads for demand savings.

By shifting a little energy usage from the peak period to the off-peak period, and carrying the optimization through the remainder of the peak period, we help customers achieve significant demand savings in addition to the baseline savings.

Comfort & Safety

While Adaptive Automation is optimizing HVAC system performance, with new predictions and setpoints every 15 minutes, it is critical that the adjustments do not impact the comfort of building occupants. There are several ways we ensure that we operate safely.

First, we have strict rules set up in Adaptive Automation, with a 5-minute control loop running on the Energy Data Gateway, checking to make sure that temperatures are not getting too high, or that we're not asking for controls adjustments that would fall outside of the desired range.

An example for a chiller is shown below. The safety control loop checks every five minutes and adjusts chiller supply based on the chiller return temperature to ensure cooling demand is met.

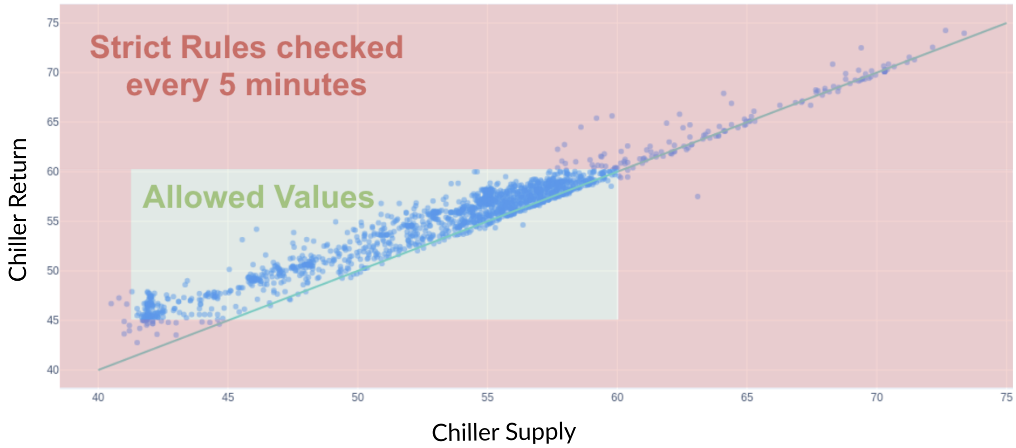

Figure 12. Red area shows where strict rules will be applied.

For a second layer of safety, we also set up the BMS register to reject any instructions that fall outside of the min/max range setup after discussions with the building.

In addition, to protect against a potential loss of connection, every hour Adaptive Automation stores an updated set of predictions and controls for the next six hours.

An example of Adaptive Automation's impact on building humidity is shown in Figure 13. The red dotted line of humidity with Verdigris controls in place tracks very closely to the blue dotted line without Adaptive Automation, indicating no negative impact on building occupant comfort.

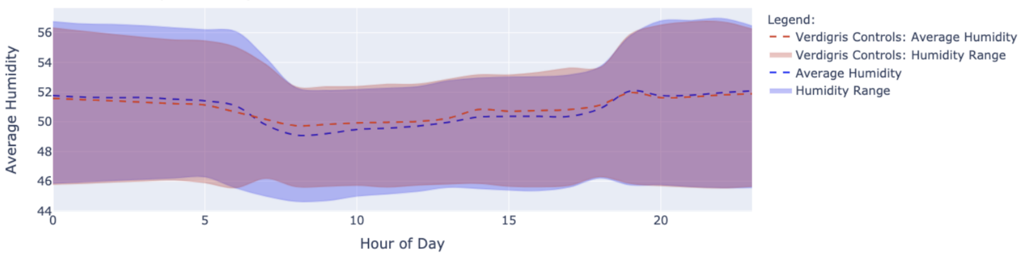

Figure 13. Red shows building humidity with Verdigris controls; blue shows previous humidity.

Summary

Automation is the key to efficient HVAC system operations, enabling building managers to move from a model of static setpoints and occasional human intervention, to one with 24/7 continuous optimization.

Verdigris Adaptive Automation helps customers reduce energy consumption and save money, without compromising the comfort of building occupants. By providing transparency into the data behind the savings, the results are quantifiable, auditable, and trustworthy.

Contact us today if you are ready to put your energy savings on autopilot.

Automation is the key to efficient HVAC system operations, moving from static setpoints to 24/7 continuous optimization

Appendix A: Standard BMS Integration Points

Adaptive Automation requires points of control within a building. Latency to read / write should ideally be minutely.

Integration Point	HVAC Configuration	Verdigris Permissions
Chiller On/Off Status	Chiller Only; Chiller and Cooling Tower	Read
Chiller Setpoint Temperature	Chiller Only; Chiller and Cooling Tower	Read
Chiller Water Flow Rate	Chiller Only; Chiller and Cooling Tower	Read
Chiller Water Return Temperature	Chiller Only; Chiller and Cooling Tower	Read
Chiller Water Supply Temperature	Chiller Only; Chiller and Cooling Tower	Read
Condenser On/Off Status	Chiller and Cooling Tower	Read
Condenser Water Flow Rate	Chiller and Cooling Tower	Read
Condenser Water Return Temperature	Chiller and Cooling Tower	Read
Condenser Water Setpoint Temperature	Chiller and Cooling Tower	Read
Condenser Water Supply Temperature	Chiller and Cooling Tower	Read
Verdigris Chiller Cloud Enable*	Chiller Only; Chiller and Cooling Tower	Read, Write
Verdigris Chiller Setpoint Temperature*	Chiller Only; Chiller and Cooling Tower	Read, Write
Verdigris Condenser Cloud Enable*	Chiller and Cooling Tower	Read, Write
Verdigris Condenser Setpoint Temperature*	Chiller and Cooling Tower	Read, Write
Site Enable	Chiller Only; Chiller and Cooling Tower; RTU	Customer Only
Discharge Air Setpoint Temperature	RTU	Read
Discharge Air Temperature	RTU	Read
Mixed Air Temperature	RTU	Read
Return Air Temperature	RTU	Read
Static Pressure Setpoint	RTU	Read
Supply Air Flow	RTU	Read
Supply Fan On/Off Status	RTU	Read
Supply Fan Output (percentage)	RTU	Read
Verdigris Discharge Air Setpoint Temperature*	RTU	Read, Write
Verdigris Supply Fan Output (percentage)*	RTU	Read, Write

** Separate setpoints denoted by the Verdigris prefix are created on the BMS for use by Adaptive Automation. Existing customer BMS setpoints should not be overwritten.*

Get started with automation that can help you tackle your energy challenges today.

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