22 expo acaire 2023

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Cartagena

| 27, 28 y 29 de septiembre |

AI Applied to Chiller Plant Control

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Sept 28, 2023

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Frases como/Phrases like:

"Hable bien, como un varón" ("You should talk like a man")

"Si fueras más femenina te iría mejor en la vida" ("You should act more feminine.")

Son microagresiones (are microaggresions)

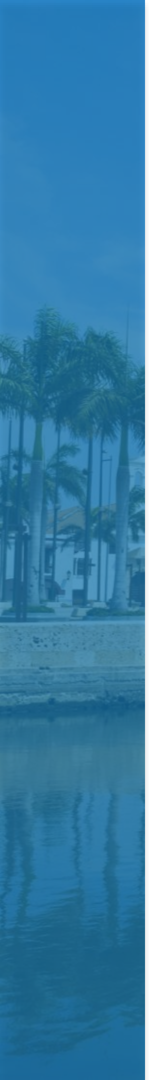
#DTenColombia
#LaIgualdadDeGéneroEsConmigo

*"Limiting CO2 emissions-driven global warming is one the **biggest challenges of our time**"*

- Individual Pieces of Equipment are efficient in their own rights
- Variable Speed Drives (VSD) have been introduced to improve the part-load efficiency of chillers, pumps, and cooling towers

However

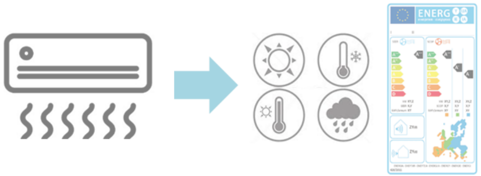
A ‘conductor’ is needed to carefully consider each aspect of the system and how tweaking or adjusting one variable will affect the building operation as a whole



Paradigm shift how we design, build, operate & maintain buildings and their relationship on the wider community

2000 — Today — Vision 2050

Equipment



COP → SEER

- Individual product assessment
- Energy efficiency measured at rated points

Building

nZEB Building → Smart Building

- Consider environmental impact of complete solution, with real operating conditions
- Connectivity and interoperability between building systems

Community

Smart City → Carbon Neutral Society

- Integrated communication platforms
- Asset management to guarantee a seamless and efficient operation

Where does the chiller plant sit within the operation?

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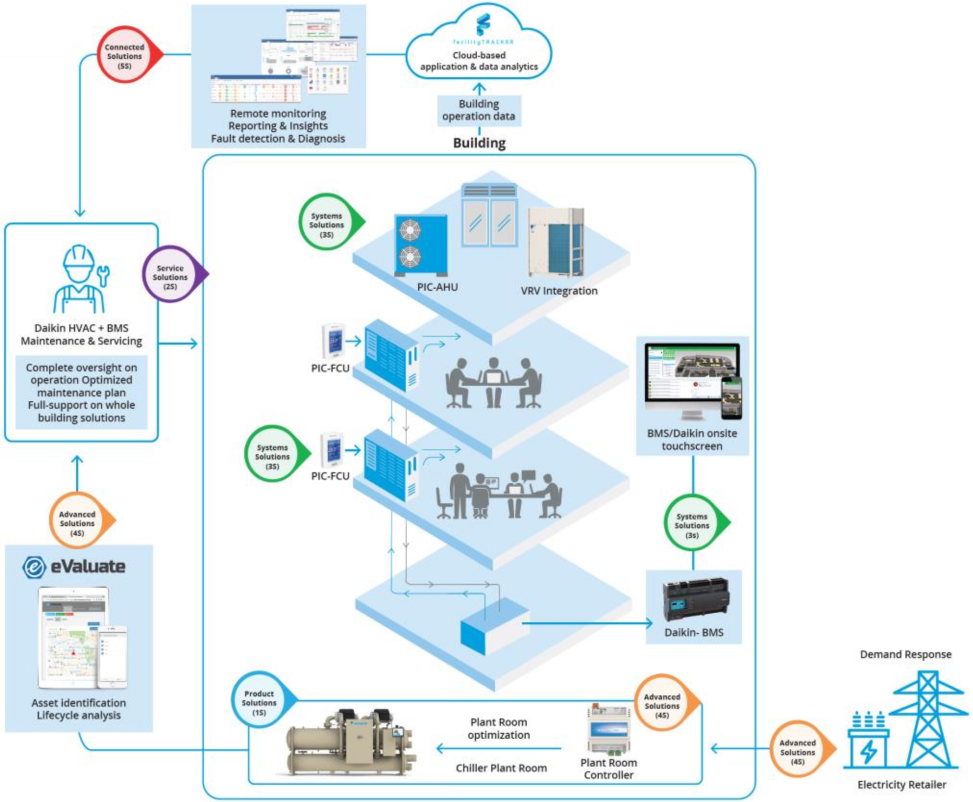
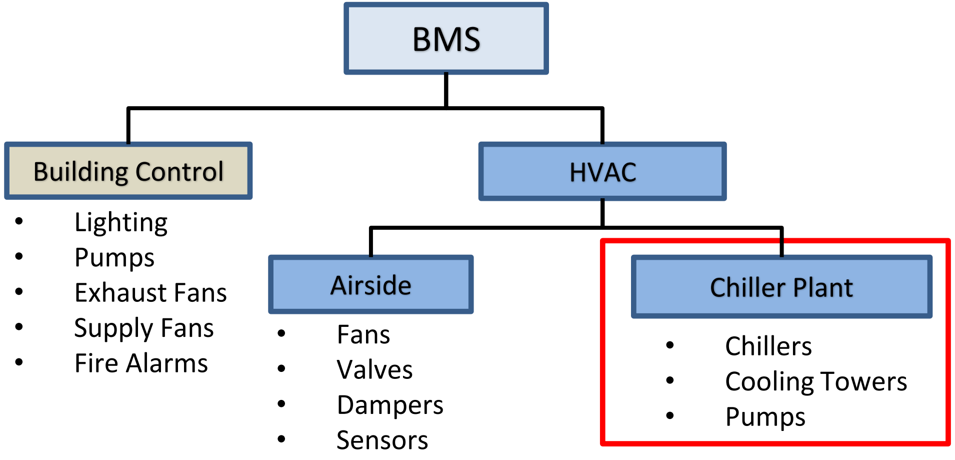
- Chiller plant is the **'heart beat'** of the overall building operation
- Optimisation and Energy Performance **starts here**
- Downstream systems can operate optimally if **consistent performance is achieved** from the chiller plant



Typical building management system design

- Standard Building Management Systems (BMS) are generic in nature and not equipment or system specific
- BMS focus on bringing in all disparate building systems together and the whole of building operation, based on predefined rules of operation
- Not usually built to compare design operational data vs actual onsite performance
- Chiller Plant is ‘just another’ system as part of the overall Building Management System



How to achieve an optimized chiller plant room?

Intelligent Plantroom Management
- Beyond Traditional BMS approach -

- Real-time analytics
- Diagnostics and M&V system
- Continually readjusting of chiller plant
- Optimal performance

PLANT MEASUREMENT AND VERIFICATION

PLANT PERFOMANCE MONITORING

PLANT DIAGNOSTICS AND REPORTING

PLANT CONTINOUS COMMISSIONING AND TUNING

PLANT CONTROL AND AUTOMATION

PLANT OPTIMISATION

Comfort:

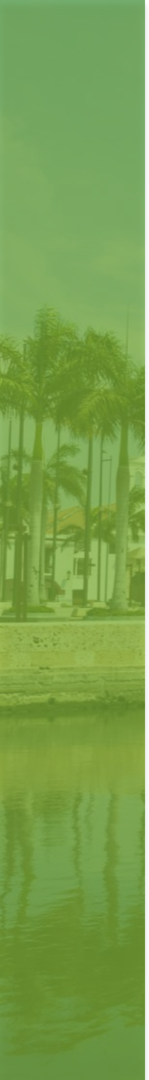
Ensures the right operating conditions

Efficiency:

Optimized efficiency based on equipment actual performances & building profile & needs

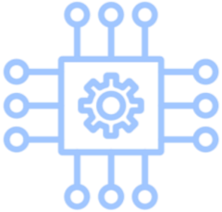
Cost:

Lowers operation & maintenance costs



Intelligent Plantroom Management
- The benefit of AI in Chiller Plants -

- Advanced mathematical optimization algorithms, primarily for 3 purposes
  - ✓ **Equip. data models:** Machine Learning to learn and minimize error to continuously calibrate the model
  - ✓ **Chiller Plant Optimization:** Finding optimal control performance (Temp. setpoints, target loads, chiller combinations…
  - ✓ **Alerts:** Predictive fault detection, based on deviations from target efficiency



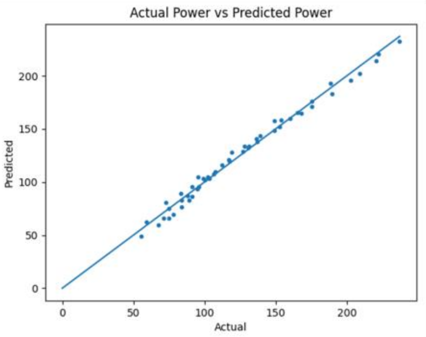
AI-Machine Learning Backed Data Models

AI-Automatically Generated Control Algorithms

Automated Alerts if Operation Deviate from Target Efficiency

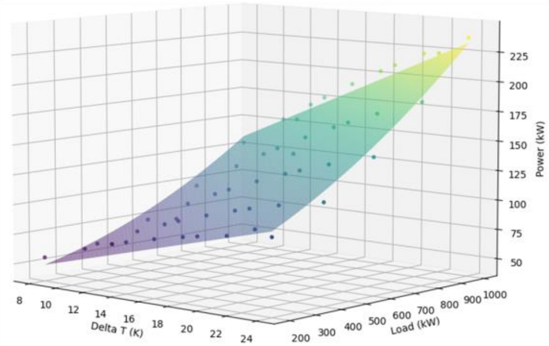
AI Machine Learning Strategies
- Equipment Data Models -

Model



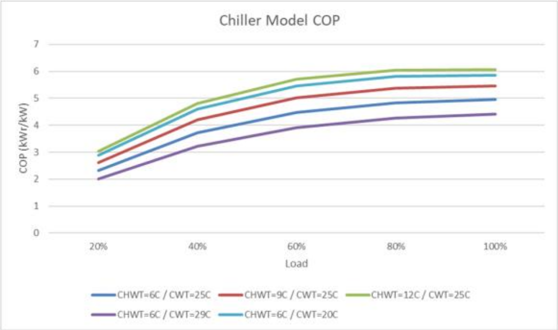
Optimization algorithm minimizes the difference between the actual power & model predicted power

Mathematical



Results in a mathematical model predicting the power as a function of cooling load, LCHWT & ECWT

Actual



The COP curves are then derived

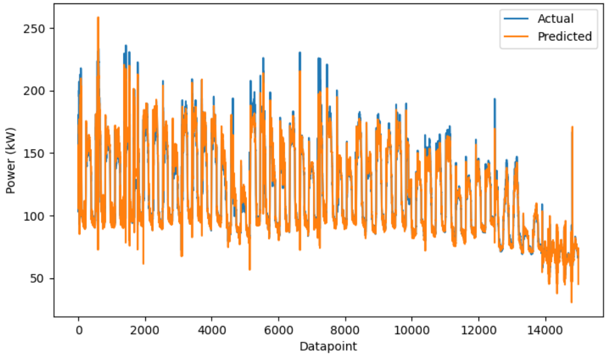
AI Machine Learning Strategies
- Equipment Data Models -

Learning chiller performance:

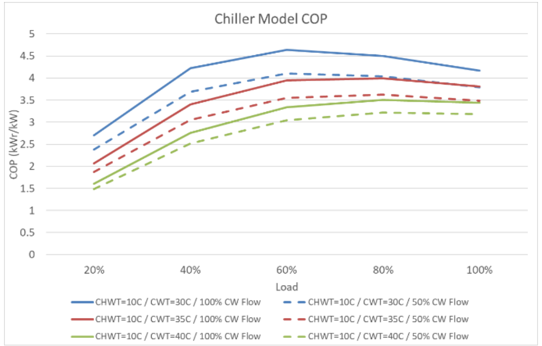
$$Power_{chiller} = P(Load, T_{ECW}, T_{LCHW}, Flow_{CW})$$

Table: Chiller learning results with site data

	Site A	Site B			Site C	
Chiller n°	2	1	2	3	1	2
MAE (kW)	4.1	2.6	2.8	3.9	11.0	10.6
MAE/Mean	4.6 %	2.4 %	2.4 %	3.4 %	6.5 %	6.4 %
R-squared	0.949	0.990	0.984	0.979	0.949	0.938



Site B, Chiller 1 predicted power compared to the actual measured power



Site B, Chiller 1 predicted COP from chiller model for a range of conditions

AI Optimization Strategies
- Mathematical optimization of plant room -

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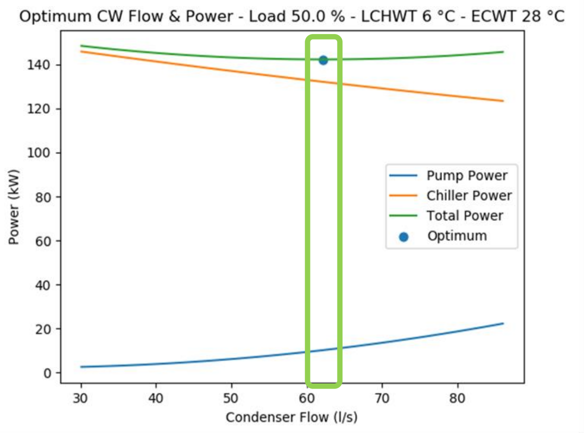
$$\underset{Load_i\,,\,Flow_{CW,i}\,T_{LCT}}{\text{Minimize}}\ Power_{plant} = \sum_{i=1}^{n} P_{chiller,i} + \sum_{j=1}^{m} P_{cw\,pump,j} + \sum_{k=1}^{p} P_{coolingtower,k}$$

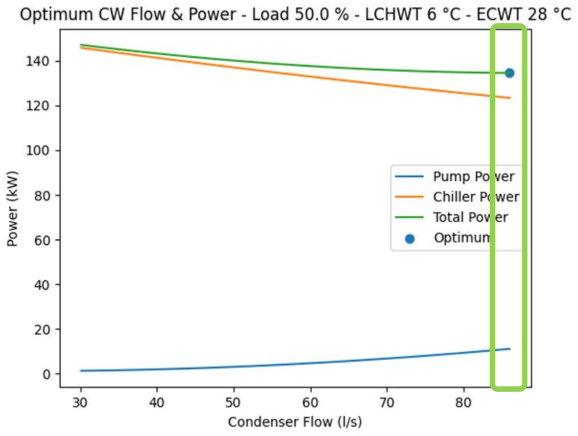
	Optimization Strategy	Achievable in PLC Control	Achievable in iPlant Manager	Estimated Savings (with iPM implementation)
(1) Optimization of plant room	**Chilled Water Leaving Temperature Setpoint Optimization**	*Yes**	**Yes**	• **1 to 1.5% savings** in kW/TR in fixed speed chillers • **2 to 3% savings** in kW/TR in VFD chillers
	Condenser Water Entering Temperature Setpoint Optimization	*Yes**	**Yes**	• **1 to 1.5% savings** in kW/TR in fixed speed chillers • **2 to 3% savings** in kW/TR in VFD chillers
	Smart Variable Flow	*Yes**	**Yes**	• **Variable Primary Flow 3.0%** • **Variable Secondary Flow 4.0%**
(2) Smart Sequencing	**Smart Sequencing**	**No**	**Yes**	• **2 to 4% typical savings** for the whole plant
	Optimized Start/Stop	*Partially**	Predictive Optimized Start/Stop and Staging Control	• **1 to 1.5% typical savings** for the whole plant

AI Optimization Strategies
- Mathematical optimization of plant room -

- Maximize energy & cost savings by determining the optimum operation to reduce the "lift", or head pressure
  - ✓ Condenser Water Entering Temperature Setpoint Optimization
  - ✓ Chilled Water Leaving Temperature Setpoint Optimization
  - ✓ Smart Flow



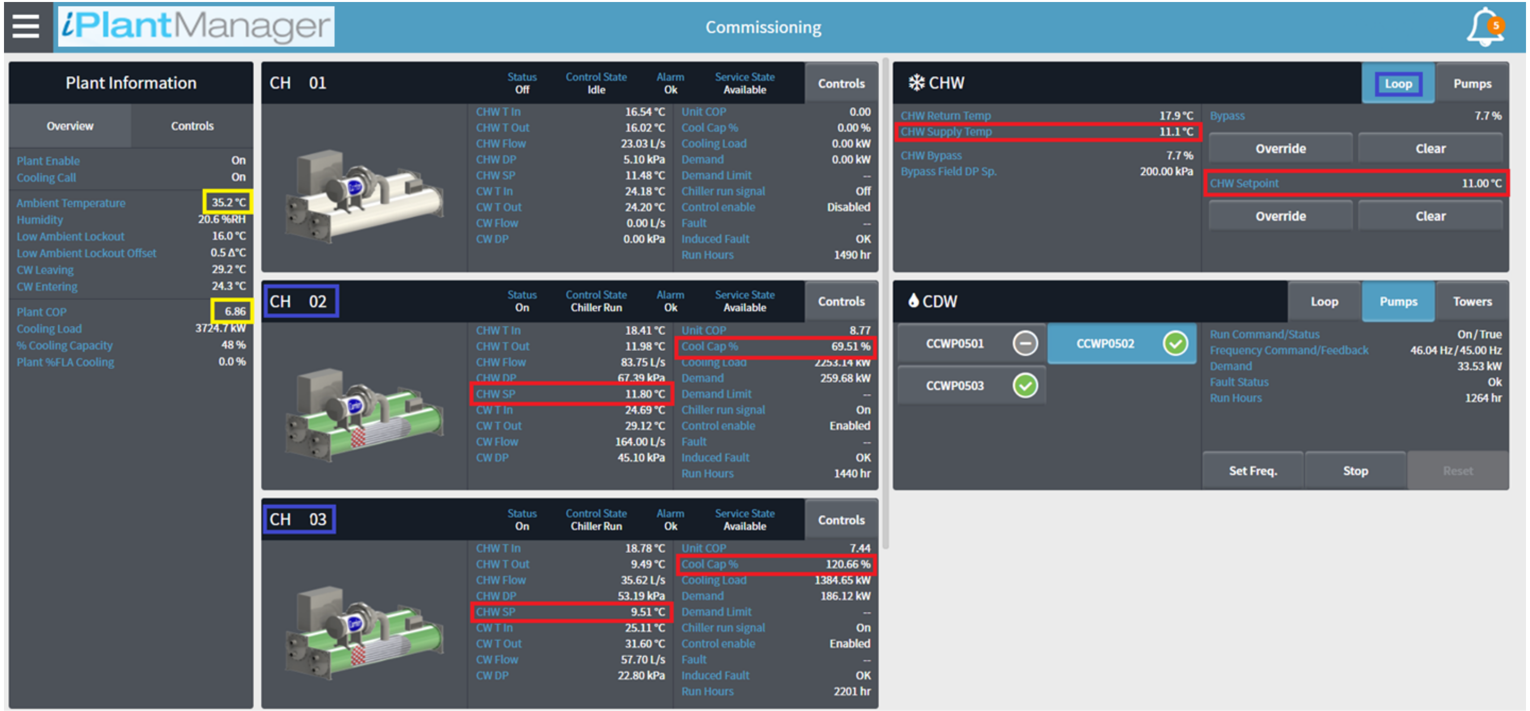
Chiller/Pump set 1: Pump rated Power 22 kW
Optimal CW Flow 60 L/s



Chiller/Pump set 2: Pump rated Power 14 kW
Optimal CW Flow 85 L/s

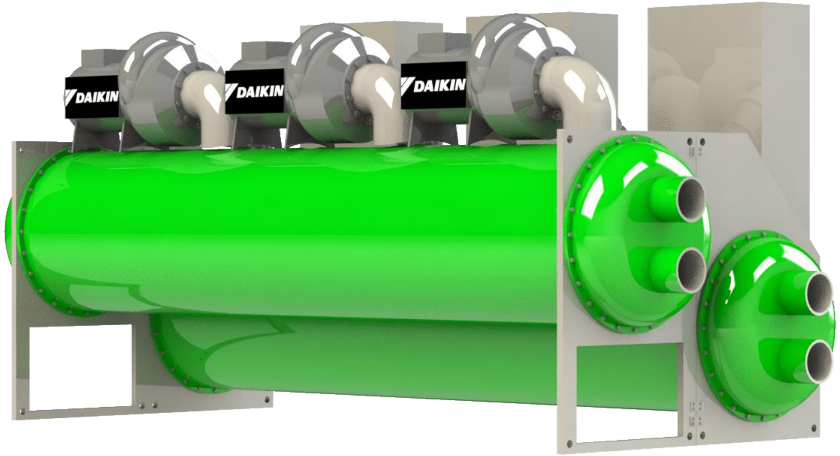
AI Optimization Strategies
- Smart Sequencing -

- Select the most efficient load point for each chiller and chiller combination based on each chiller performance curves at different CHWT and CWT



AI-based predictive models
- Fault Detection & Diagnosis -

- Autonomously defines the "Rating" in which the units are operating
  - ✓ GREEN, YELLOW and RED operating areas
  - ✓ Units are still running but underperforming with respect to design conditions



- **Diagnostics & Analytics**
  - ✓ Detects variables from the plant and provide info on the system status

		Month To Date			Year To Date		
Unit 1:Chiller1 (Water Cooled Flooded Chiller)		Current	Previous	Variation	Current	Previous	Variation
Total Cooling Produced	[kWh]	106,610	36,668	191%	106,610	72,733	47%
Total Electricity Consumed	[kWh]	21,513	7,660	181%	21,513	26,989	-20%
Total Electricity Cost	[Dollar]	4,195	1,494	181%	4,195	5,263	-20%
Average Unit Efficiency		1.6	6.5	-75%	1.6	0.0	0%
Specific Energy Cost	[c/kWh]	3.9	4.1	-3.4%	3.9	7.2	-45.6%
Diagnostics							
Chiller Short Cycling		19%					
Power Surging		18%					

Intelligent Plantroom Management
- In summary -

Measure — Verify — Diagnose — Adjust

1.Measure

Measure the key data points and calculate the efficiency of each chiller and ancillary devices.

2.Verify

Check instantaneous efficiency against the manufacturers design data and best-case efficiency modeling
.

3.Diagnose

Analyze the data and run in a diagnostics engine to determine the cause of any gaps between actual, design and best-case chiller and plant efficiency

4.Adjust

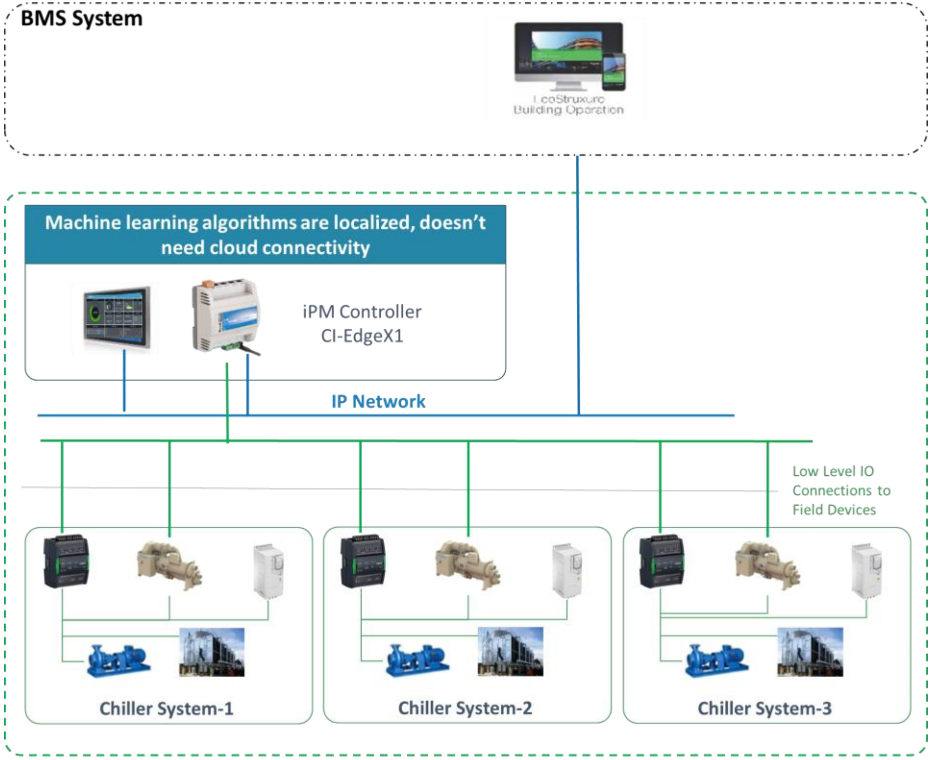
Adjust the plant through proactive automation to correct back to optimized plant efficiency.

Case Study
University, Singapore

Case Study – University, Singapore

Chiller Plant overview

- **Chiller:** 3x 250 RT
  Water cooled, Magnetic bearing chillers
- **CHWPs:** 3x 18.5 kW (40.6L/s, 30m head)
- **CDWPs:** 3x 18.5 kW (55.3L/s, 25m head)
- **Cooling towers:** 3x 11kW (55.3L/s)



Solution scope:

- **Controller:** 1 x Master iPlant Manager for controlling and optimising all plant equip.
- Connection by ModBus/BACnet to controllable equipment
- Seamless integration with SE BMS on site

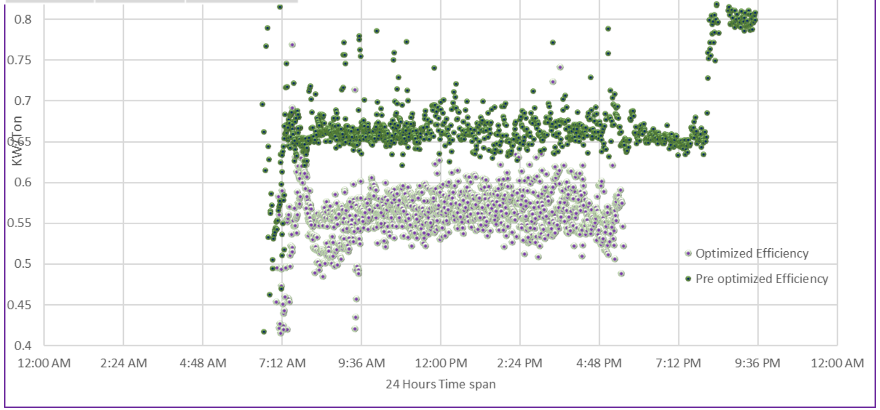
Case Study – University, Singapore

		BMS	iPM
1	Chiller operation		
	Day time operation	2 Nos. Of Chiller Based on Run time Priority	Maximum 2 Nos Based on Runtime priority
	Evening / Night operation	1 Nos.Of Chiller Based on Run time Priority	Max 2 Nos, Most Efficient chiller from prioroty chiller 1 and 2, if only one chiller to operate. Based on chiller performance analytics
2	Chilled water pump		
	Day time operation	2 Nos Of Pump	2 or 1 Nos. of Pump based on Cooling load, flow and Differential pressure requirement
	Evening / Night operation	1 Nos of Pump	2 or 1 Nos. of Pump based on Cooling load, flow and Differential pressure requirement
3	Condenser water pump		
	Day time operation	2 Nos Of Pump	3 or 2 Nos. of Pump based on condenser water system Optimization analytics
	Evening / Night operation	1 Nos of Pump	3 or 2 Nos. of Pump based on condenser water system Optimization analytics
4	Cooling tower		
	Day time operation	2 Nos Of Cooling tower	3 or 2 Nos. of Cooling tower based on heat rejection, Condenser water return temperature and cooling tower approach
	Evening / Night operation	1 Nos of cooling tower	3 or 2 Nos. of Cooling tower based on heat rejection, Condenser water return temperature and cooling tower approach

Case Study – University, Singapore

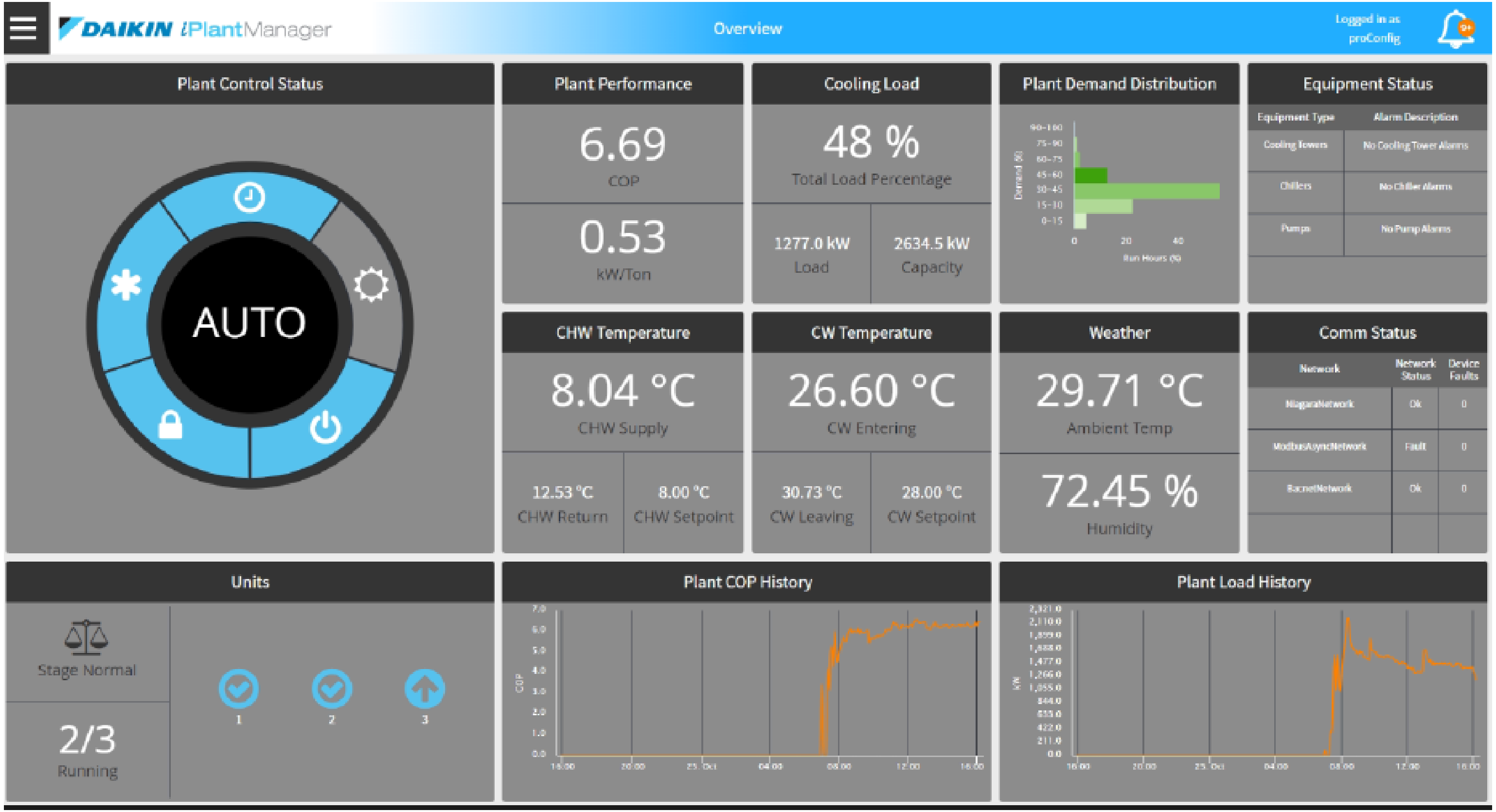
- iPM assumes full plant control and optimization of the plant
- It utilizes on-board, real-time analytics, diagnostics and M&V system to continually readjust chiller plant for optimal performance
- **Optimized performance:** 0.54 kW/RT
- 14% savings in average, with up to 22% reduction on energy consumption during normal operation (lower savings during school holiday periods)

CHILLER PLANT OVERALL EFFICIENCY		
BEFORE OPTIMISE (kW/Ton)	AFTER OPTIMISED (kW/Ton)	OPTIMISATION (%)
0.63	0.54	**14%**



ROI: 14 months

Case Study – University, Singapore



Case Study – University, Singapore

Learning chiller data models

Case Study – University, Singapore

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Condenser Water System Optimisation

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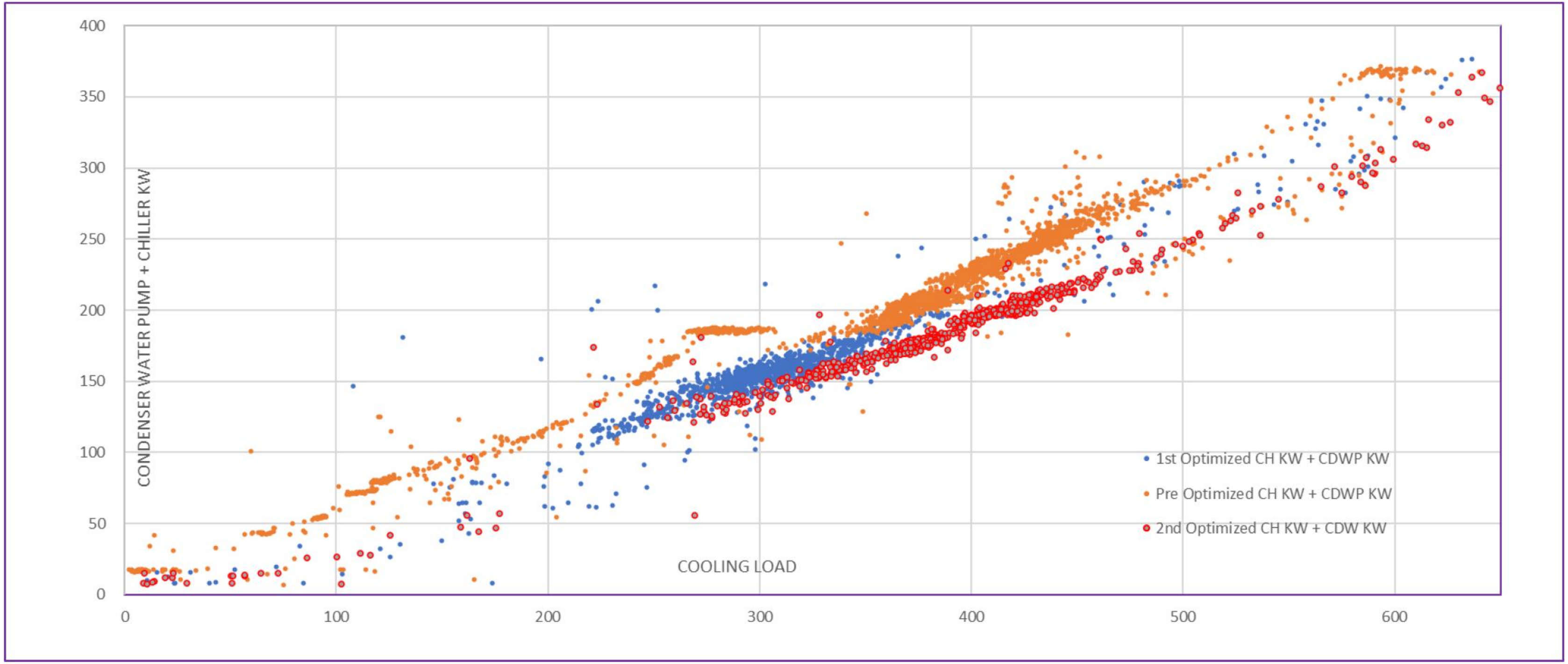
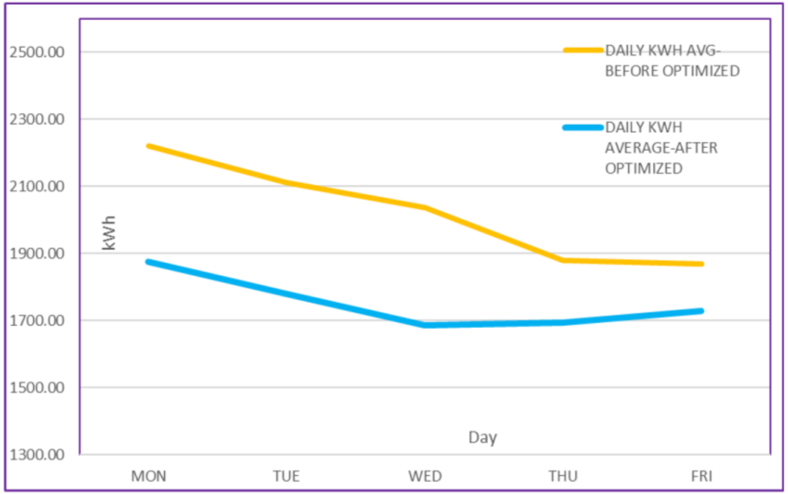
Condenser Water System Optimisation



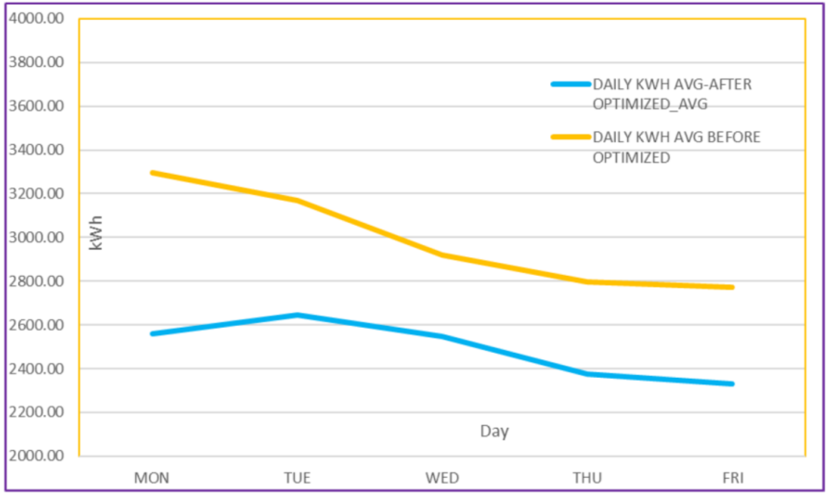
Case Study – University, Singapore

Power consumption comparison

Before and after daily average kWh consumption of Block 04 chiller plant during term holiday



Before and after daily average kWh consumption of Block 04 chiller plant during normal operation



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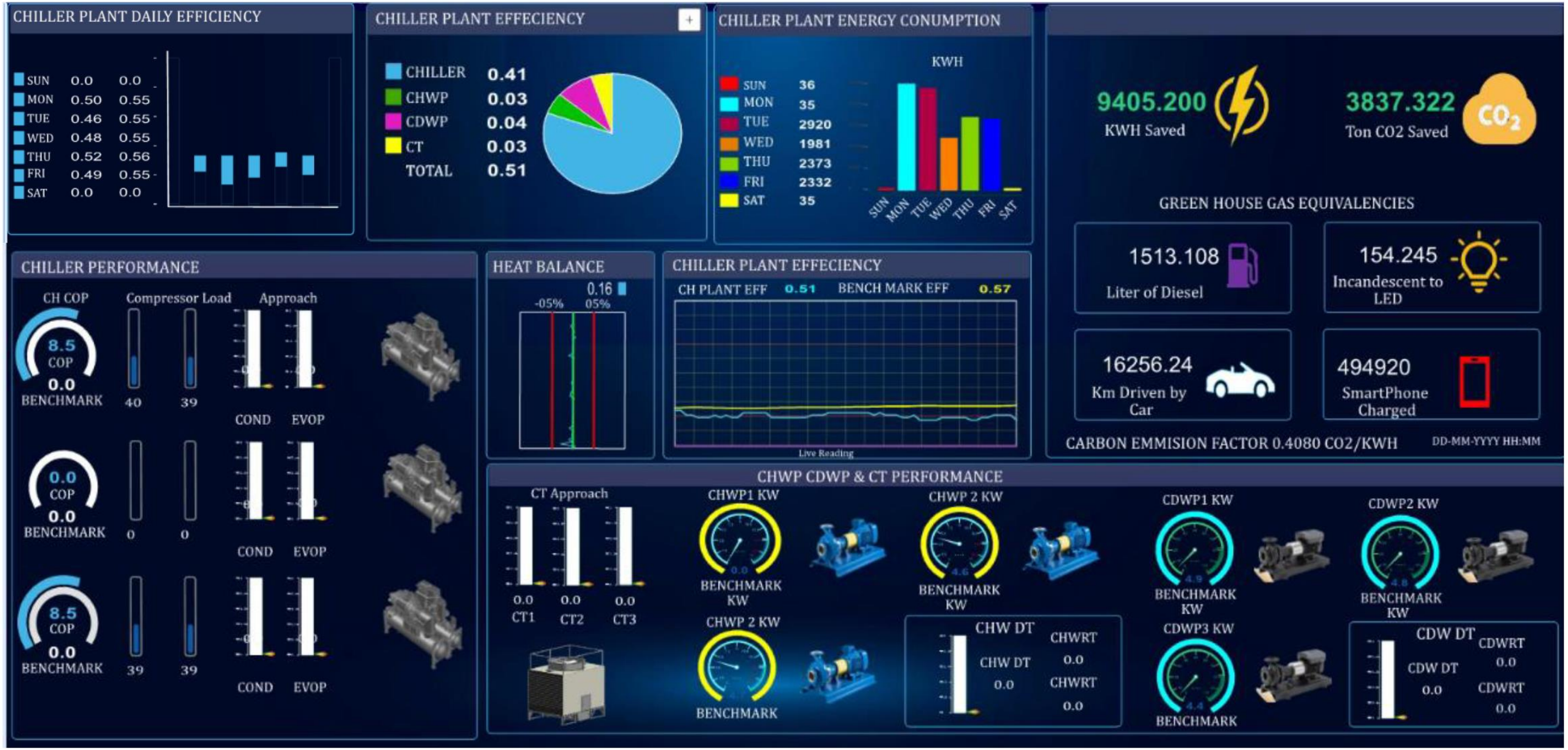

In summary

- Towards a sustainable, carbon-neutral world, efficient equipment must not be considered independently
- **Integration is key,** with simpler configuration and plug-&-play solutions
- **Data-driven operations:** Next-Gen smart energy savings sit between digital expertise and core control know-how
- **Paradigm shift:** From equipment to smart buildings to smart cities, combine technology for innovative solutions and dynamic adaptation to changing conditions

¡GRACIAS!

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