Engineering with passion
用心創造

ATAL
(Stock code : 1977)

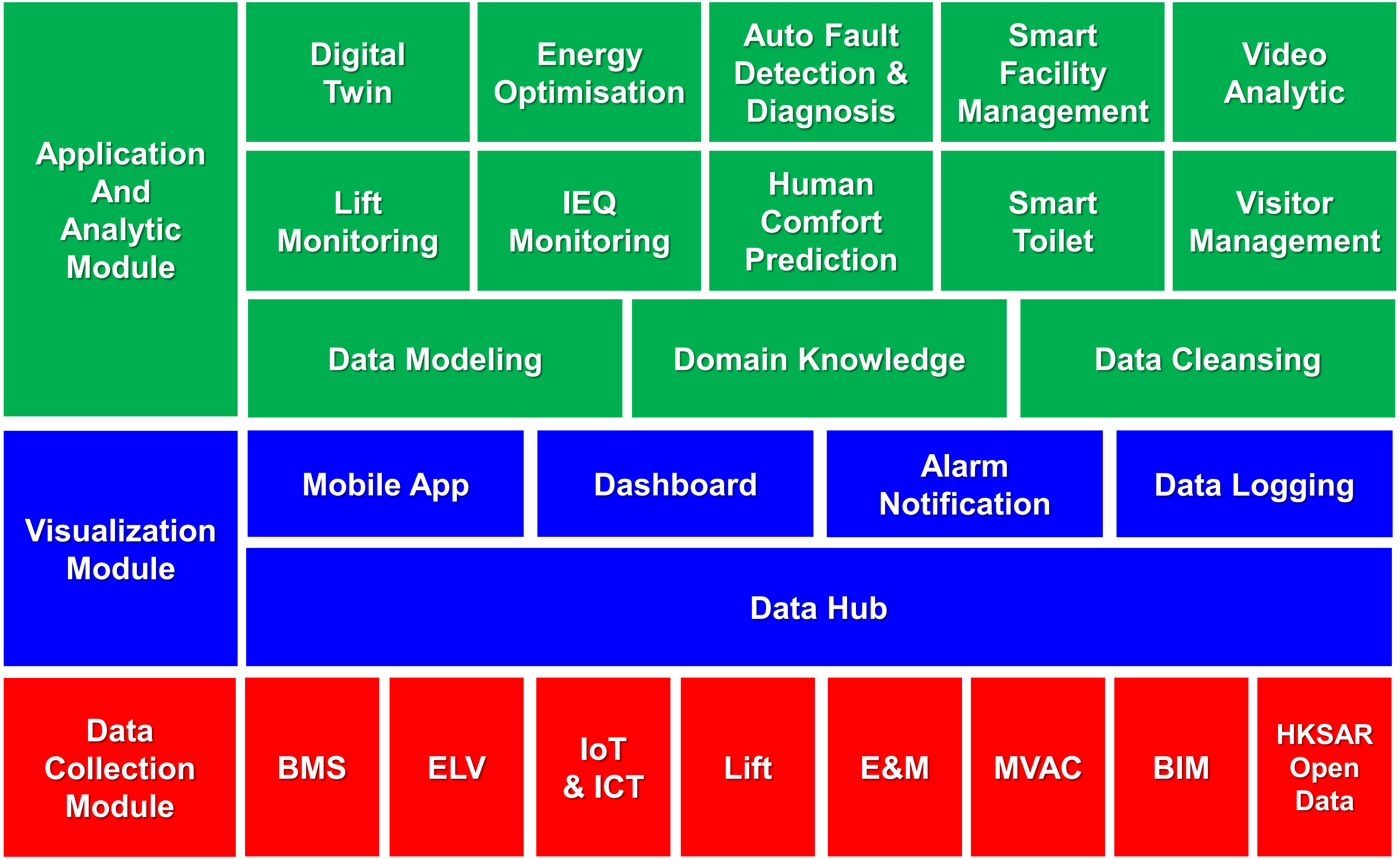
Building Green Workplace with IoT
Smart Building and Big Data Analytics

Derek So

2022 March

ATAL Smart Building Platform Architecture

ATAL



Data for Green Workplace

Indoor Environmental Quality Analytics

Air Quality
- CO_2
- CO
- PM2.5, PM10, PM1.0
- TVOC
- Formaldehydes
- NO2
- Ozone
- Ammonia

Thermal Quality
- Air temperature
- Relative Humidity

Lighting Quality
- Light/Daylight level

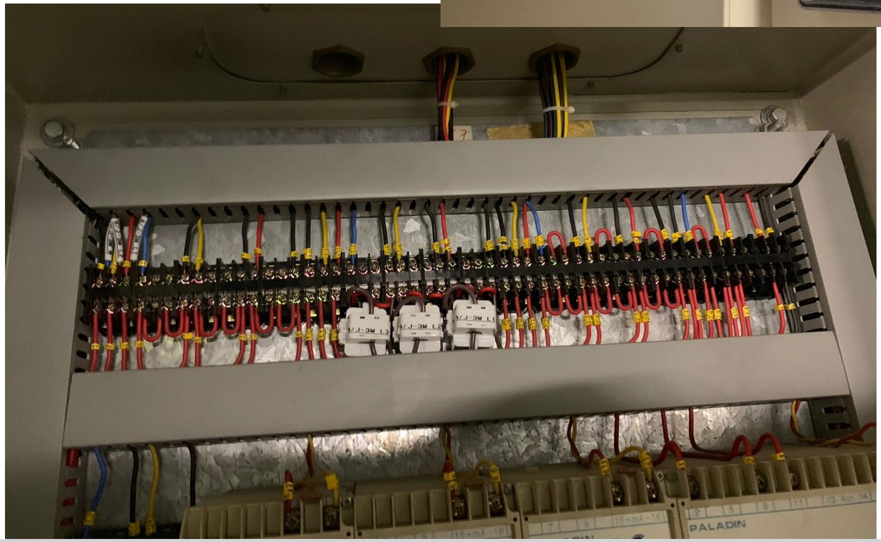
Spatial Quality
- Occupancy

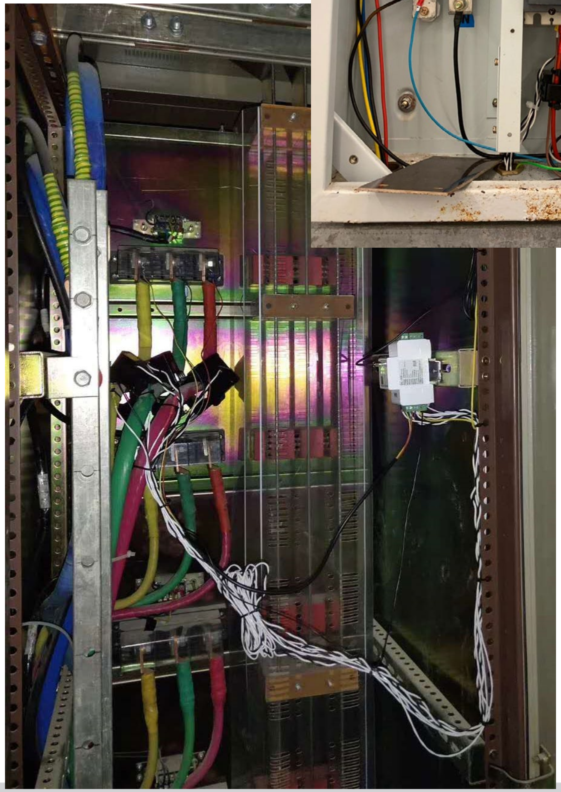
Acoustic Quality
- Background sound levels

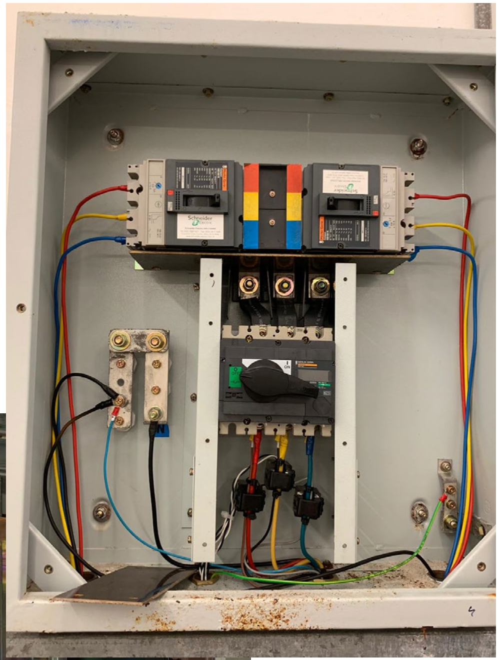
Measuring Elements:

1. Temperature (°C)
2. Relative Humidity (%)
3. CO_2 (Carbon dioxide) (ppm)
4. PM1.0 (μg/m3)
5. PM2.5 (μg/m3)
6. PM10 (μg/m3)
7. TVOC (ppb)
8. CO (Carbon monoxide) (ppm)
9. NO_2 (Nitrogen dioxide) (ppb)
10. HCHO (Formaldehyde) (ppb)
11. O_3 (Ozone) (ppb)
12. Illuminance (Lux)
13. Noise level (dBA)
14. PIR Motion Detector
15. Ammonia (ppm)

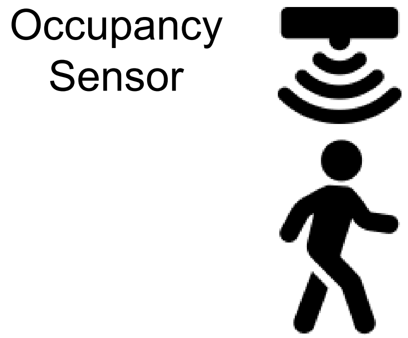
Energy Consumption Monitoring





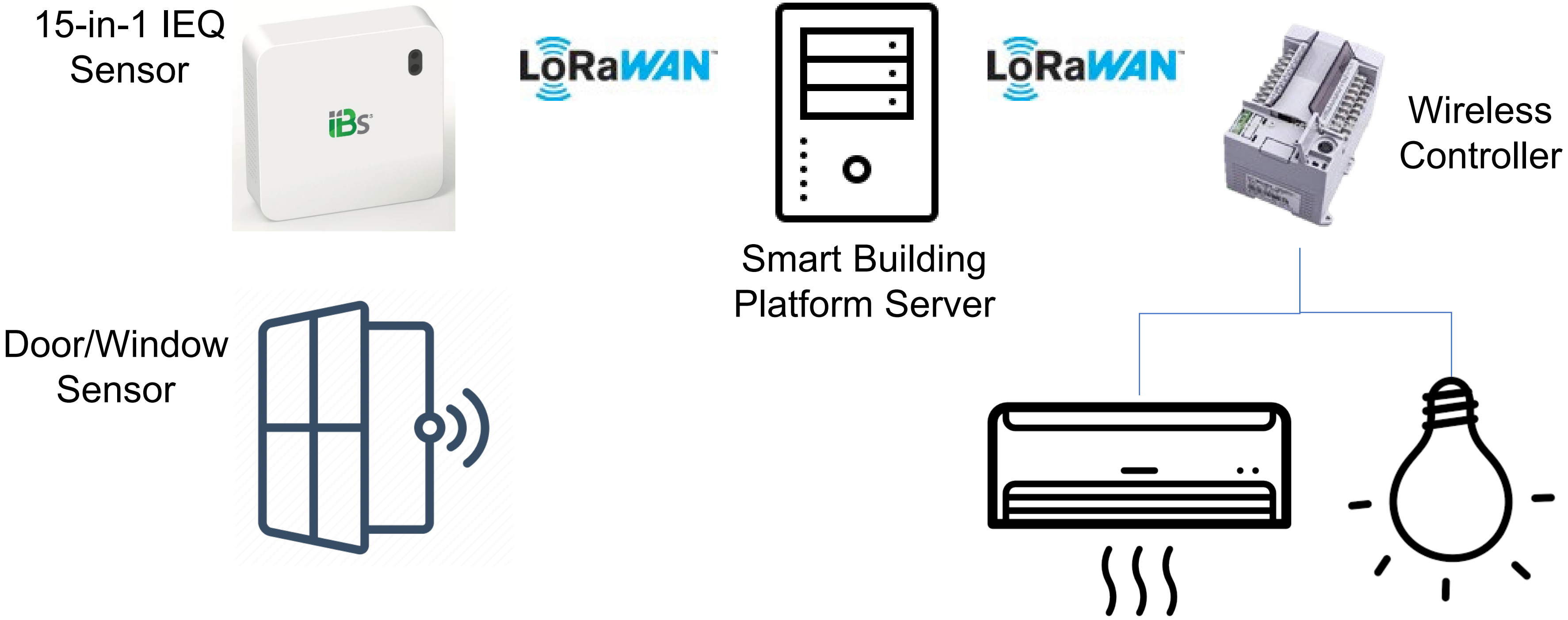


Wireless Facilities Control For Energy Saving

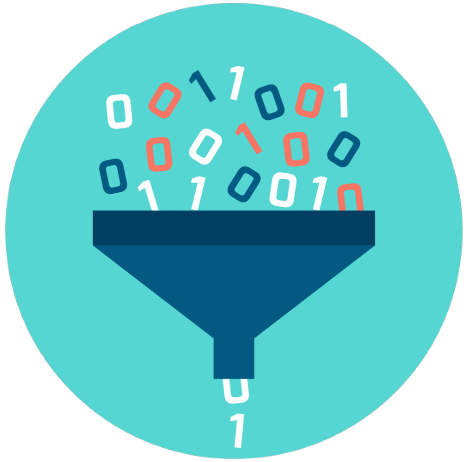


We can turn on/off the A/C, Lighting based on:

1. People presence
2. Indoor Environmental Quality
3. Window/Door Open
4. Others



Data Analytic for Green Workplace



Intelligent Energy Management

- Use minimum energy
- Automate all control processes

Fault Detection & Diagnostics

- Automatically detect and diagnose abnormal equipment
- Provide actionable insight

Data Visualization

- Interactive platform to visualize actual energy performance
- Filter all noise

From Digital Map Navigation to Energy Optimization

- Digital Map → Equipment Modelling
- Real Time Traffic → Cooling Load
- Navigation → System Control

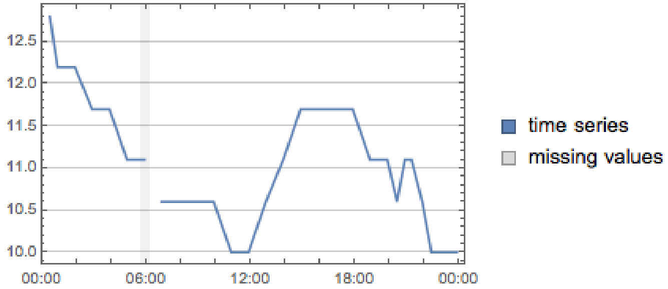
Garbage In,

Garbage Out

- Measurement Errors (e.g. Sensor Bias)

- Missing Data/Points

$$\hat{x}^i = x^i + \delta_x + V_x^i$$

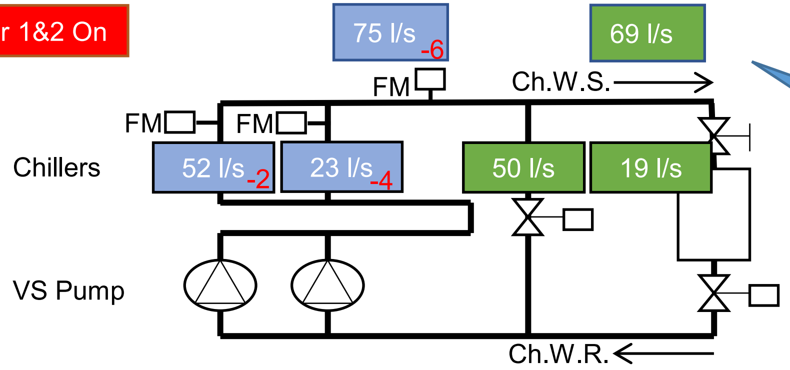


- Incorrect time index

	Ch_1_ChW_FR	Ch_1_ChWS_Temp	Ch_1_ChWR_Temp	Ch_1_Power
2017-01-06 03:00:00+08:00	0	18.1648	15.4429	0
2017-01-06 04:00:00+08:00	0	18.1648	15.3874	0
2017-01-06 05:00:00+08:00	0	18.2204	15.2762	0
2017-01-06 06:00:00+08:00	0	18.2204	15.054	0
2017-01-06 07:00:00+08:00	0.0459368	18.2759	14.943	0
2017-01-06 08:00:00+08:00	99.0872	18.2759	14.7763	0
2017-01-06 09:00:00+08:00	71.6166	18.2759	14.6652	0
2017-01-06 10:00:00+08:00	76.1184	18.2759	14.5541	0
2017-01-06 11:00:00+08:00	73.8675	18.2759	14.3319	0
2017-01-06 12:00:00+08:00	71.5247	18.2759	14.2764	0
2017-01-06 13:00:00+08:00	76.0266	8.49915	13.4986	397.6
2017-01-06 14:00:00+08:00	72.03	7.9992	13.0542	316.1
2017-01-06 15:00:00+08:00	78.2316	7.94365	13.4431	342.5
2017-01-06 16:00:00+08:00	77.9559	8.05475	13.832	363.3
2017-01-06 17:00:00+08:00	77.7722	8.4436	13.7764	392.6
2017-01-06 18:00:00+08:00	69.1819	8.05475	13.7208	359.8
2017-01-06 19:00:00+08:00	85.8112	7.8881	13.5542	345.9
2017-01-06 20:00:00+08:00	69.1819	7.94365	13.832	359.9
2017-01-06 21:00:00+08:00	71.4788	7.94365	13.832	354.8
2017-01-06 22:00:00+08:00	0.0459368	7.9992	13.5542	343.3
2017-01-06 23:00:00+08:00	0.0459368	8.05475	13.3875	339
2017-01-07 00:00:00+08:00	0	8.05475	13.8875	398.5
2017-01-07 01:00:00+08:00	0	8.16585	12.7765	314.6
2017-01-07 02:00:00+08:00	0.0459368	8.3325	12.4987	302.2
2017-01-07 03:00:00+08:00	0.0459368	11.4433	11.11	0
2017-01-07 04:00:00+08:00	0.0459368	11.5544	11.1655	0
2017-01-07 05:00:00+08:00	0	11.721	11.2766	0

Sensor FDD - Sensor Bias Evaluation (Simplified Example)

Chiller 1&2 On

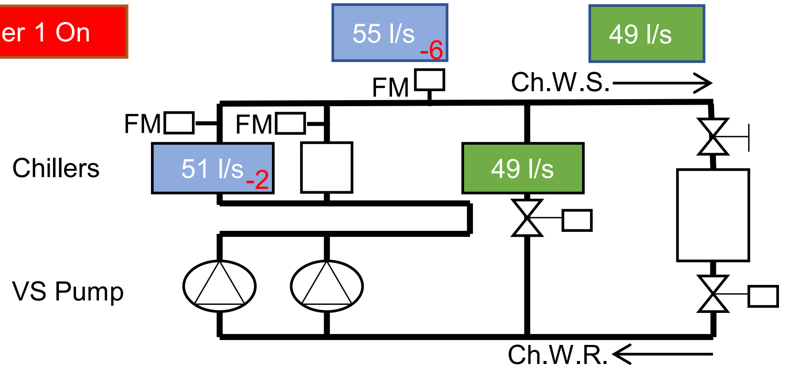


>8%
(e.g. CL: 4.18x6x4 =100kW)

$R_1 = -c_0 + c_1 On_1 + c_2 On_2$

52+23-75 = 0= $-c_0 + c_1 On_1 + c_2 On_2$ - (1)

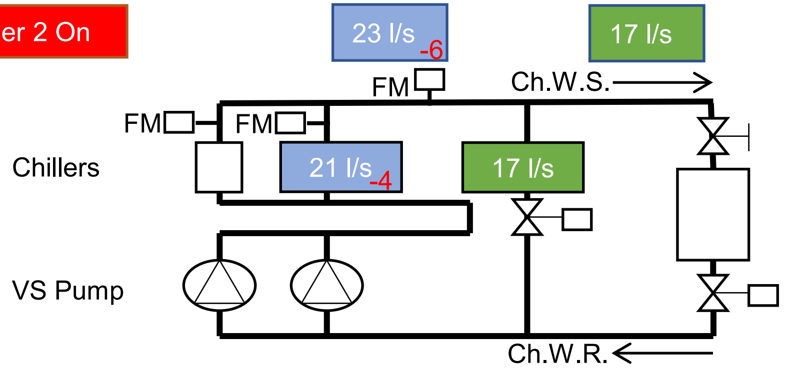
Chiller 1 On



$R_2 = -c_0 + c_1 On_1$

$51 - 55 = -4 = -c_0 + c_1 On_1$ - (2)

Chiller 2 On



Sensor Bias

Main Pipe: $c_0 = 6$

Chiller 1: $c_1 = 2$

Chiller 2: $c_2 = 4$

$R_3 = -c_0 + c_2 On_2$

$21 - 23 = -2 = -c_0 + c_2 On_2$ - (3)

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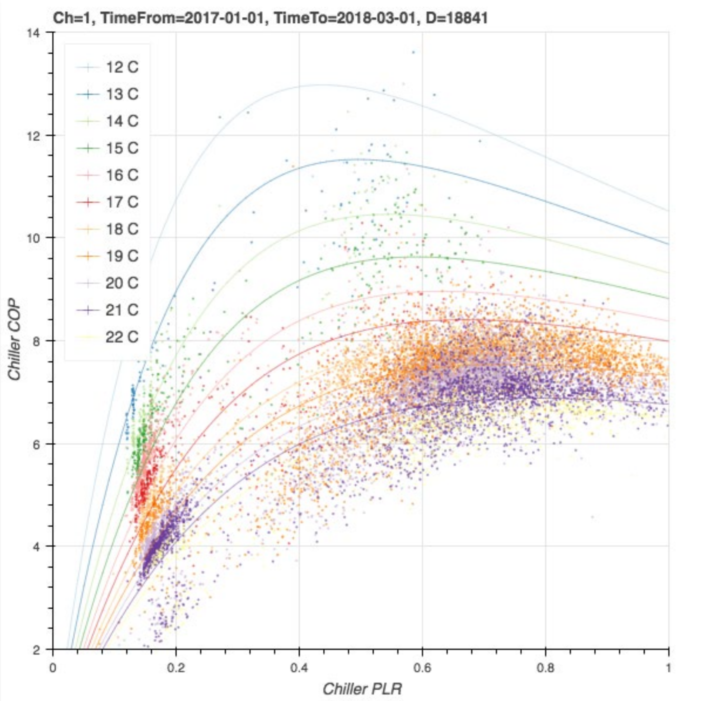
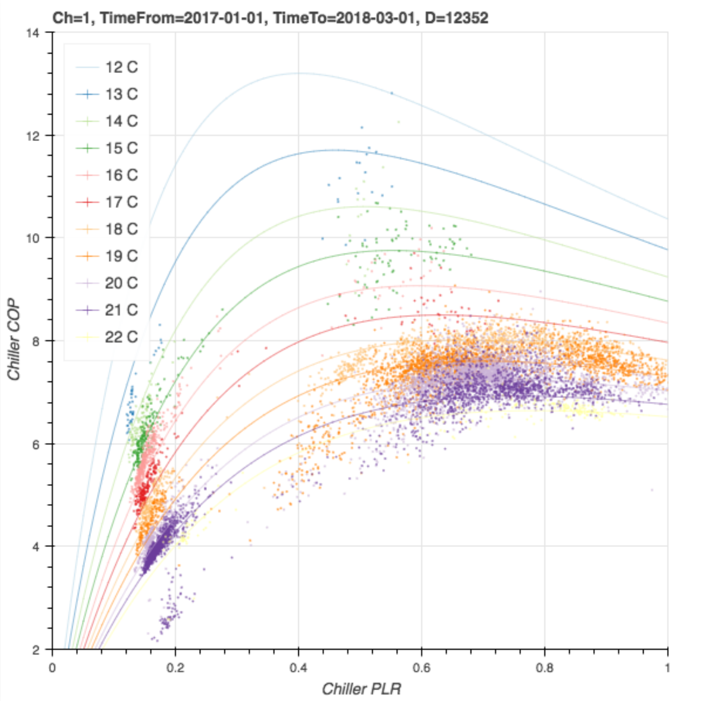
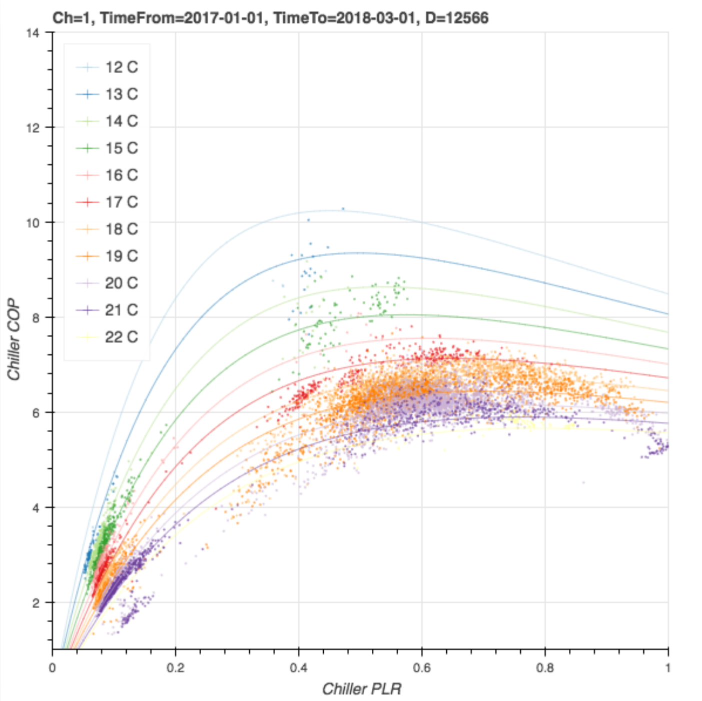
Raw data	With Data Cleansing	With Sensor Bias Correction + Data Cleansing
	Discard noisy and non-steady state data	Correct flow and temp. sensor biases

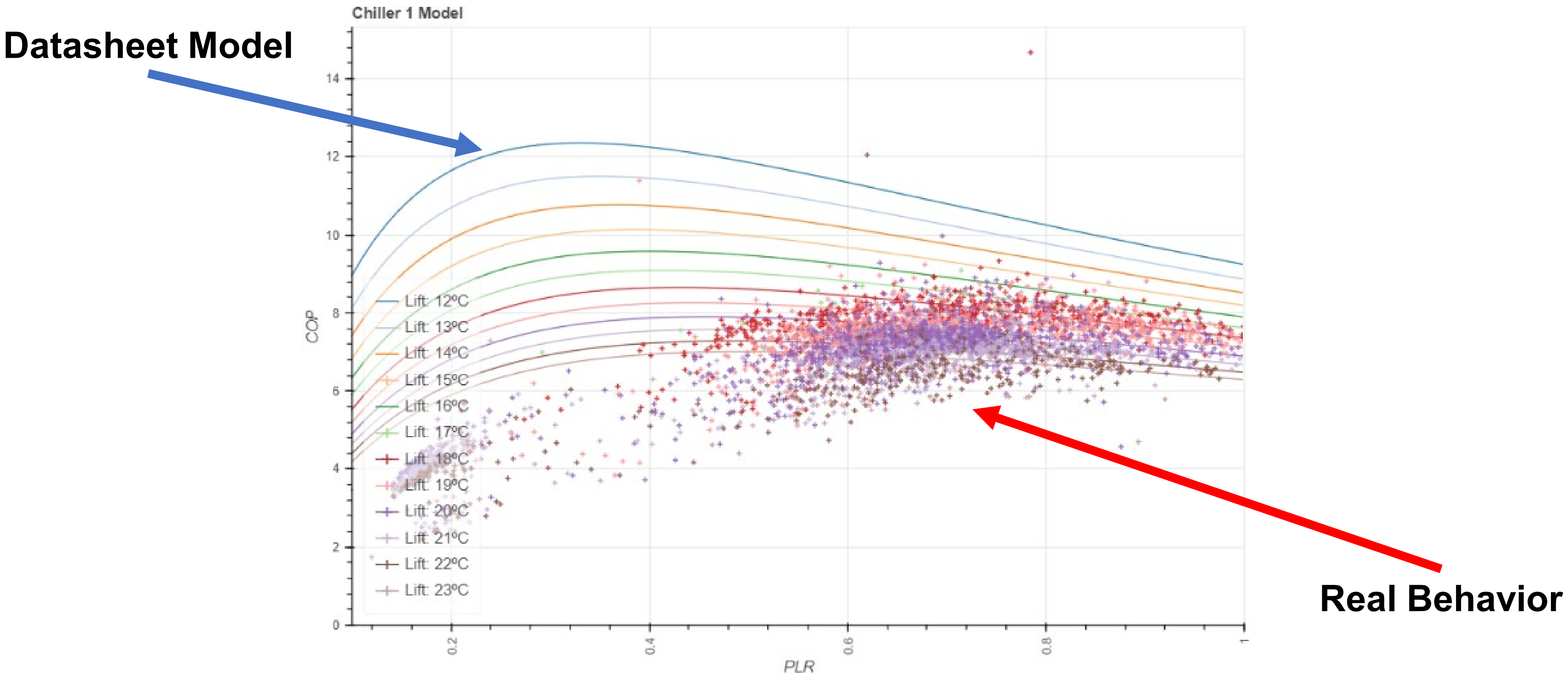




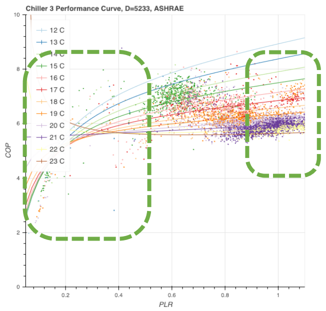
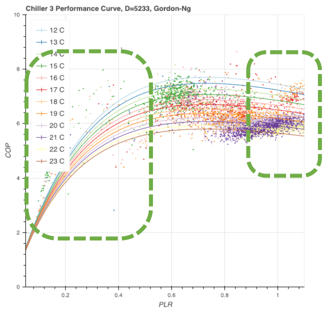
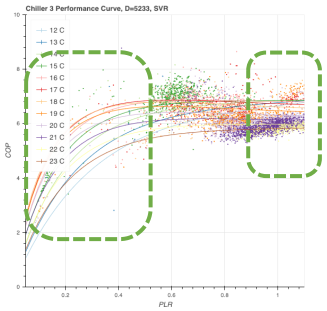
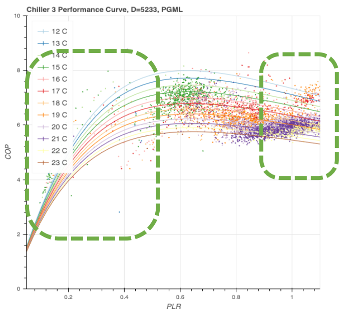


Building Equipment Model

Datasheet vs Real behavior



Modelling Techniques Comparison

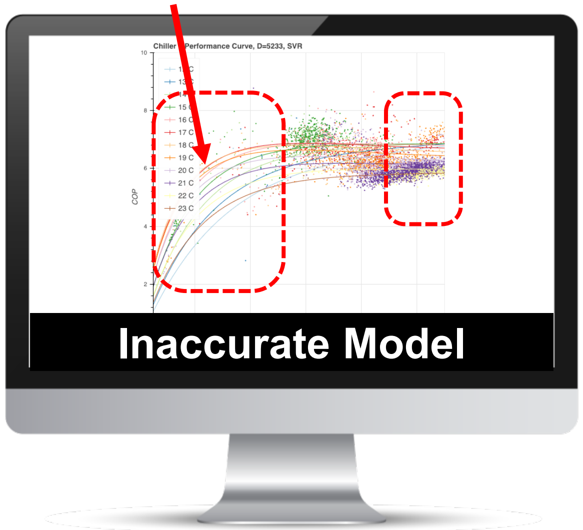
	Empirical Model	Physical Model	Machine Learning Model	Physics-Guided Machine Learning Model
Structure	$w = a_0 + a_1 PLR + a_2 PLR^2 + a_3(T_{ci} - T_{chws}) + a_4(T_{ci} - T_{chws})^2 + a_5 PLR(T_{ci} - T_{chws})$	$\Delta E = \sum Q - \sum W = 0 = Q_{ch} + Q_{ch}^{Leak} - Q_{cd} - Q_{cd}^{Leak} + W_{in} - Q_{cp}^{Leak}$ $\Delta S = \sum \frac{Q}{T} = 0 = \frac{Q_{ch} + Q_{ch}^{Leak}}{T_e} - \frac{Q_{cd} + Q_{cd}^{Leak}}{T_c} + \Delta S_{Int}$	$\arg\min_f \underbrace{Loss(\hat{Y}, Y) + \lambda R(f)}_{\text{Typical loss function}}$	$\arg\min_f \underbrace{Loss(\hat{Y}, Y) + \lambda R(f)}_{\text{Typical loss function}} + \underbrace{\lambda_{PHY} Loss.PHY(\hat{Y})}_{\text{Physical Inconsistency}}$
Features	Describe the relationship between dependent (y) and independent variable (x) without explaining the mechanism	Derived based on the physics laws *(e.g. 1st and 2nd laws of thermodynamics)*	Derived based on machine learning algorithm	Derived based on machine learning algorithm Constrained by physics principles *(e.g. COP increases with reduction in chiller lift)*
Model				
Pros	Simple	Allow confident extrapolation outside the range of available data	Flexible	Flexible and obey physics principles No assumption needed *(e.g. no energy loss)*
Cons	**No predictability outside** the range of available data	With **assumptions** (*e.g.* ***no energy loss***) *Additional work is needed for a special type of chiller (e.g.* ***absorption chillers****)*	**May violate physics principles** outside the range of available data	Require high domain knowledge
Accuracy	No predictability outside the range	High Accuracy	No predictability outside the range	**High Accuracy +**

Building Equipment Model with Missing Data

Machine Learning
- Deep learning can't be performed
- Violation of physical principles

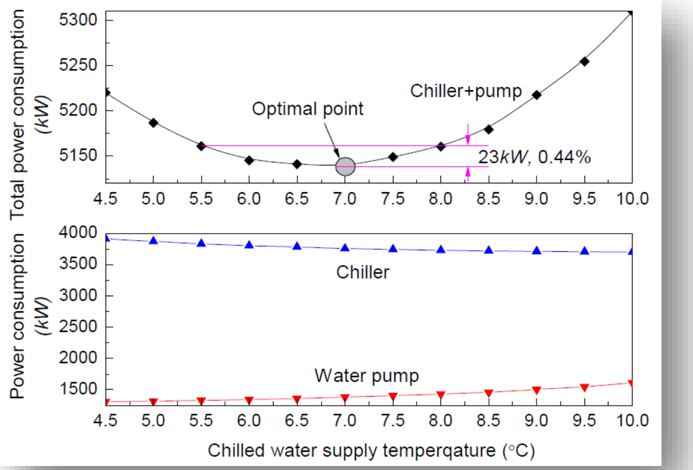
PGML
- Applying physics laws for interpretable results
- Representing actual equipment performance

Intertwined → Wrong Prediction



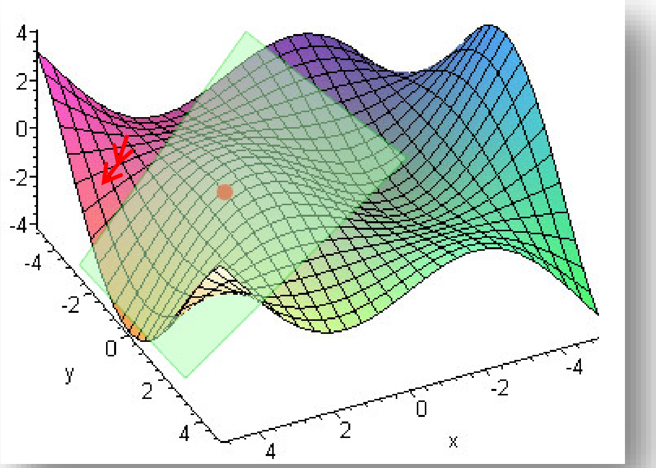
The FIRST in the World to Apply PGML in Energy Optimization And Successfully Overcomes Data-related Issues

1-D search: T_{ChWS}



2-D search: x & y

$$\Delta z = \frac{\partial f}{\partial x} \cdot \Delta x + \frac{\partial f}{\partial y} \cdot \Delta y$$



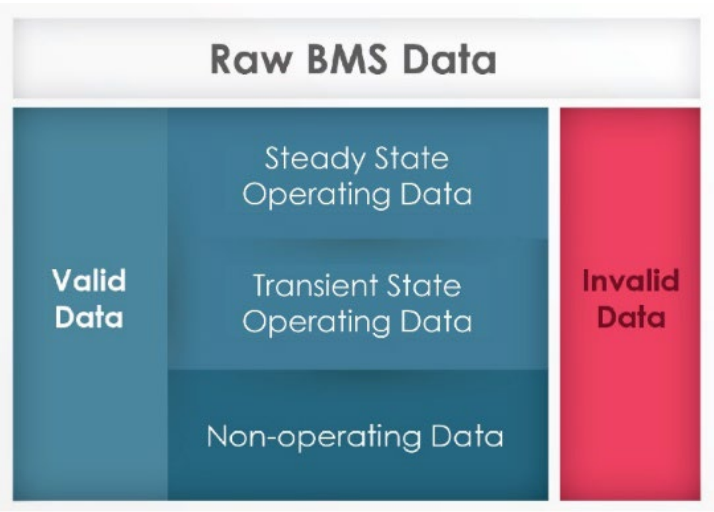
N-Dimension Optimisation Search

- Chilled water supply temperature set point
- No. of chillers to be run
- No. of chilled water pumps to be run
- Chilled water pump speed to meet chilled water flow rate demand
- Condenser water pump speed
- No. of cooling towers to be run
- Cooling tower fan speed

Real-time search for the optimal operation points

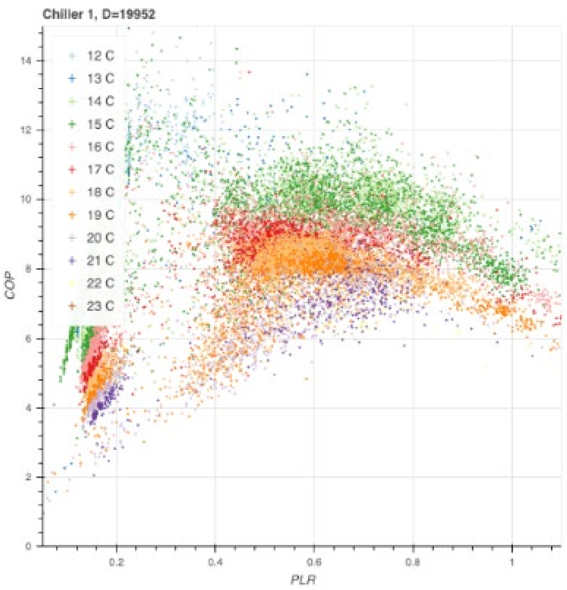
Energy Optimization by Big Data

AI-based Data Processing



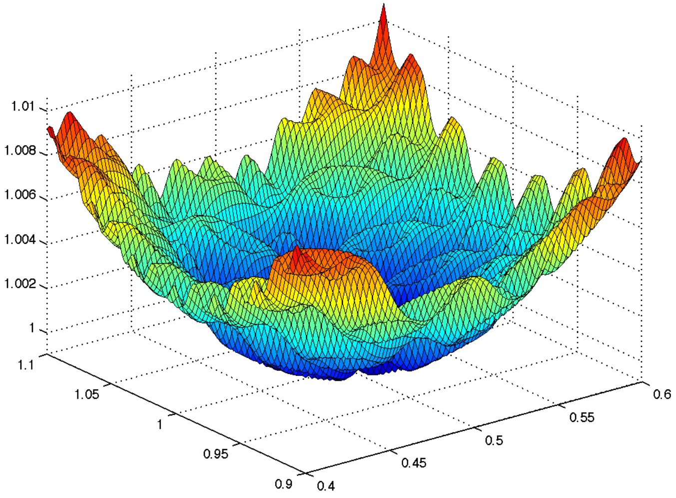
ML Application

Development of Equipment Models



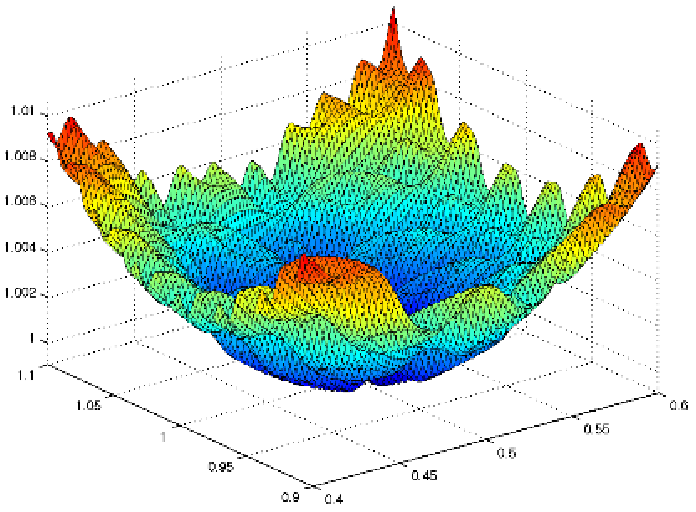
ML Application

Real-time Optimization



Energy Optimization by Big Data

- Real Data
- Dynamic
- Continuous
- Each equipment has its unique PGML model
- N-Dimension optimisation search



Recognitions

ATAL

Silver Award
銀獎
HONG KONG ICT AWARDS 2019 香港資訊及通訊科技獎

2021 ASHRAE Technology Award

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Jeff H. Littleton
Executive Vice President

jlittleton@ashrae.org

October 16, 2020

Mr. Pan Lee	Mr. Franco Mok	Mr. Dave Chan	Mr. Kenneth Lee
ATAL	ATAL	ATAL	ATAL
18/F, Paul Y. Centre	18/F, Paul Y. Centre	18/F, Paul Y. Centre	18/F, Paul Y. Centre
Kwun Tong, Hong Kong	Kwun Tong, Hong Kong	Kwun Tong, Hong Kong	Kwun Tong, Hong Kong

Subject: 2021 ASHRAE Technology Award – Honorable Mention

Dear Mr. Lee:

It gives me great pleasure to inform you that you have been selected as an Honorable Mention winner of an ASHRAE Technology Award in the Commercial Buildings – Existing Category for the 28 Hennessy Road project in Hong Kong. The ASHRAE Technology Awards program recognizes outstanding achievement in the design and operation of energy efficient buildings. The form of the award is a plaque for winning entrants and building owners.

Your project will be featured in the March 2021 issue of the *ASHRAE Journal*. Complete details regarding submission requirements for the *Journal* will be sent to you within the next month.

Please complete and return the enclosed forms regarding publicity and plaque information to honorsandawards@ashrae.org **by November 1, 2020.** Some award winners would like their employers to be advised of their selection. The enclosed Employer Notification is provided to you for delivery to your employer.

Please accept my personal congratulations.

Sincerely,

Jeff H. Littleton
Executive Vice President

Association of Energy Engineers – International Award

Association of Energy Engineers

May 3, 2021

Dr. Pan Lee
Assistant Technical Manager
ATAL Building Services Engineering Ltd
13/F, Island Place Tower No. 510
King's Road North Point, Hong Kong
Hong Kong, China

Dear Dr. Lee,

The Association of Energy Engineers is pleased to notify you that from the many nominations submitted to the AEE Awards Committee, you have been selected to receive the following International Award:

2021 ENERGY INNOVATOR OF THE YEAR

Congratulations from all of us at AEE!

AEE gives out prestigious awards each year to individuals and organizations that have achieved national and international prominence in promoting the practices and principles of energy engineering and energy management.

This award, recognizing your outstanding accomplishments in the energy industry, will be presented the evening of Wednesday, October 20, in New Orleans, LA The AEE Awards Banquet will be held at the Ernest N. Morial Convention Center where the **2021 AEE World Energy Conference & Expo** will be taking place. We hope you will be present to accept this award in person. We will contact you in the next few weeks with further details.

An official press release will be issued a week or two prior to the presentation of the awards, and your company is welcome to also issue one at that time. In the meantime, feel free to share this information informally with your colleagues, friends, and family. Articles in internal company newsletters are also acceptable at this time.

Again, we extend our warmest congratulations to you on having been chosen for this high honor.

Cordially,

Bill Kent
Executive Director

Carl Salas
Awards Chair

INTERNATIONAL AWARDS

Deadline for 2021 award nominations is Feburary 22, 2021.

REGIONAL AWARDS

Deadline for 2021 award nominations is Feburary 22, 2021.

LOCAL AWARDS

Awards at the local level may be presented by AEE Chapters. To find out if there is an awards program in your area, contact your closest AEE Chapter.

Derek So

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Website: www.atal.com

Thank You