Building Energy Quotient on Improving Facilities Performance

THE PAST, THE PRESENT, AND THE FUTURE

23 APRIL 2018

Generating Great Returns. Improving The Environment

AGENDA

ABOUT BUILDING ENERGY QUOTIENT (BEQ)

1. What is ASHRAE Building Energy Quotient
2. Benefits of BEQ
3. Different from Green Building Programs and Benchmarking Programs
4. How does the Rating Work – In Operation & As Designed

MGM MACAU – IN OPERATION

1. Baseline Establishment
2. Energy Efficiency Improvement Projects and Achievements
3. Continuous Monitoring and Improvement Building Performance –Data Driven Commissioning
4. Energy Management System and EUI
5. Energy Reporting and EUI Improvement

MGM COTAI – AS DESIGNED

1. Operation Driven Design and Peak Demand Management
2. Green Design and Efficient Equipment and System
3. Continuous Monitoring and Improvement Building Performance –Data Driven Commissioning

FUTURE OF BEQ FOR MGM

ASHRAE BEQ

Building Energy Quotient is a building energy rating/scoring program that provides information on a building's energy use

ASHRAE'S BUILDING EQ

RATE YOUR BUILDING EFFICIENCY

Establish the energy performance baseline and compare to similar buildings with same climate.

IMPROVE BUILDING ENERGY PERFORMANCE

Act on the assessment on the energy performance actionable recommendations.

Power by ASHRAE

Building EQ is powered by ASHRAE and rests on ASHRAE methodologies and standards along with the experience of qualified practitioners.
These characteristics distinguish Building EQ and assure owners that they are receiving reliable and co nsistent results and recommendations.

BENEFITS OF BEQ

Benefits

- Help building owners make informed decisions managing their building portfolios
- Identify Actionable Recommendations
- Building labeling to recognize high performance
- Ability to assess effectiveness of energy efficiency measures after implementations

HOW DOES BEQ WORK

BUIDLING EQ PERFORMANCE SCORE

The score compares the candidate's building's EUI to a baseline (median) EUI for that building type

$EUI_{Building}$/ $EUI_{Baseline}$) X100

EUIs are calculated for source energy using US national site-to-source ratio

The score ranged from zero (zero net energy) to 200 or beyond. The baseline value of 100 represents medium (similar to mid-point).

Building and Median EUIs are calculated for source energy.

Building EQ also provides The building's site energy EUI and Energy Cost Index.

Score Range	Energy Performance
≤ 0	Net zero or energy producer
1-25	75-99% energy savings over median
26-55	45-74% energy savings over median
56-85	15-44% energy savings over median
86-115	Within 15% of median energy use
116-145	16-45% more energy than median
>145	>45% more energy than median

HOW DOES BEQ WORK

IN OPERATION

- Actual metered energy consumption
- Influenced by operational and occupancy variables
- Improved by upgrading building *physical characteristics of building, system or operating procedures*
- The Indoor Environmental Quality cannot be compromised by energy savings
- Applicable for buildings after 12 months of operation
- Follow-up assessment after improvement

AS DESIGNED RATING

- Simulated standardized energy use
- Independent of operational and occupancy variables
- Base on results of standardized energy models of as-built conditions
- Improved by upgrading *physical characteristics of building, system*
- Applicable for new and existing buildings

MGM MACAU

Since first opening its doors to the public, MGM have been on the forefront of building operation optimization and constant reduction of its energy use.

THE JOURNEY STARTS IN MGM MACAU

- A Preliminary **Energy-use Analysis (PEA)** was conducted to review the utility bills, tariffs, load profiles, and peak demand of the property.
- An energy audit **(ASHRAE level 2)** was then conducted to understand our energy use and **potential energy management opportunities (EMOs)**. A baseline is then created.
- Since that, our team has implemented numerous EMOs in the following areas at MGM Macau:
  - BMS and controls
  - HVAC
  - Lighting
  - Kitchens
  - Hotel
  - Data-based commissioning

CHILLER PLANT OPTIMIZATION

- HVAC takes up almost half of MGM Macau’s energy consumption a key focus in our energy management effort.
- A plant operational assessment was conducted to optimize plant operations.
- As a result, a list of EMOs have been uncovered. This also sparked investigation that further uncovered more EMOs:

2011 ENERGY SAVING HIGHLIGHTS

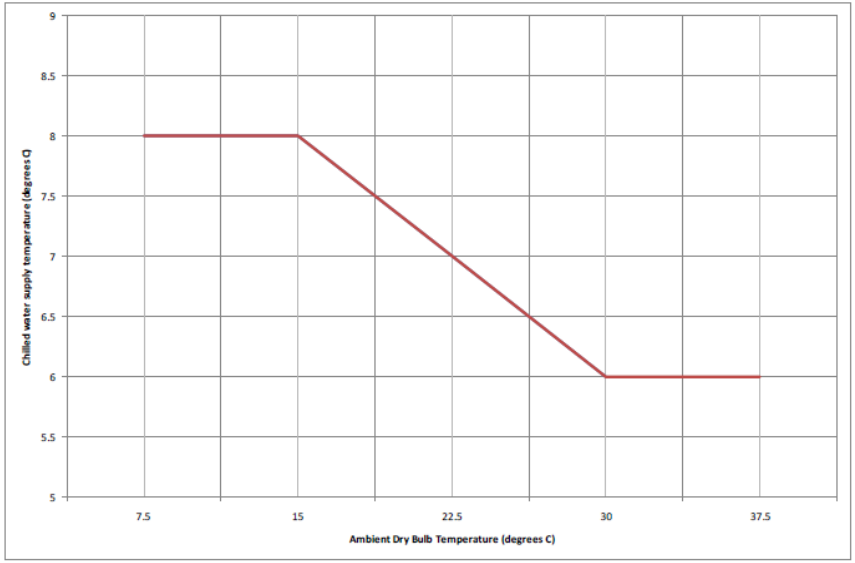
- Chiller Optimization (Staging and controls)
- Casino AHU economizer mode
- Boiler operational optimization
  - Reduced boiler bottom blow down
  - Standby boilers optimization

CHILLER OPTIMIZATION- BMS AND CONTROLS

- Goal is to ensure that we are collecting the right data and the data is correct before any EMOs is implemented.
- A BMS operational review was conducted to review BMS performance.
- As a result, the following recommissioning works are performed:
  - Sensor re-calibrations.
  - VAV system re-balancing.
  - Removal of system override.
  - Review of system “bugs”.
  - BMS access hierarchy review.
- A list of EMOs were also uncovered:
  - Adding Hotel FCU controls.
  - Re-activation of summer/winter mode.
  - Sub-metering and trending.
  - Equipment operation schedule review

CHILLER OPTIMIZATION

- Chiller Control logic and staging review
- Chilled water supply temperature reset.



2012 ENERGY SAVING HIGHLIGHTS

- LED replacement and de-lamping
- VSD installations
- PAU fan speed control optimization
- CDWP impeller trimming
- Kitchen KEAF operating scheduling

LED REPLACEMENT & DE-LAMPING

- Obvious payback and proven technology.
- Started in BOH and Casino areas, then move onto rooms.
- Started from MR16, PAR, and GU4 lights, then move onto cold cathode, spotlights with dimmers and fluorescent tubes.
- Delamping is done in BOH corridors, stair cases, and parking lots.

Figure 1: LED Halogen 35w IRC Replacement Options

Product Name	Definity MR16 W27 FL	MR16 20 ADV	ER2006	Tornado 12V AC/DC	Master LED 4W	Master LED 7W MR16 Dim	OSRAM 35W Infra Red Coated Dichroic
GLS Conversion / Hal Replacement	25W	20W	35W	35	20	35	35
Lamp Base	GU5.3	GU5.3	GU5.3		GU5.3	GU5.3	GU5.3
Power (Watt)	6	5.5	6	5.5	4	7	35
Voltage (V)	12	12	12	12V	12	12V AC/DC	12
Lamp Color (CCT)	2700	2800	2800	2800	2700	2700	2700-2900
Luminous Flux (lm)	275	190	198	215	160	310	Approx 500
Lm/W	46	35	33	39	40	45	N/A
Luminous Intensity (CBCP/cd)	550	500	-	850	700	1450	1200
Beam Angle	40	36	24, 36	24	24	15	10
Color Rendering Index (CRI)	85	80	82	80	80	80	100
Power Factor		0.95			0.53		
Diameter (mm)	50.05	50	50	50.2	50.1	50	50
Length (mm)	47.9	49	60	47	46.1	53.7	45
Weight (g)	50	55	50	-	-	45	
Lifetime (hrs)	25,000	25,000	25,000	35,000	45,000	40,000	5,000
Warranty Period	3 yrs	3 yrs	1.5 yrs	5	7	2	N/A
Cost per lamp (MOP)	208	124	123	80	102	195	32
Lifetime Comments	Have a minimum light output of 70% of the initial rated light output at the end of life (L70)	Minimum 70% Lumen Maintenance at end of life of 25,000 hours	90% of Lumens can be achieved at end of lamp life	No detailed information beyond 35,000 hours	Lifetime of 45,000 hours defined as the number of hours when 50% of a large group of identical lamps below 70% of its initial lumens.	Lifetime of 40,000 hours defined as the number of hours when 50% of a large group of identical lamps below 70% of its initial lumens.	Lifetime of 35w OSRAM IRC are approximately 5,000 hours

VARIABLE SPEED DRIVES

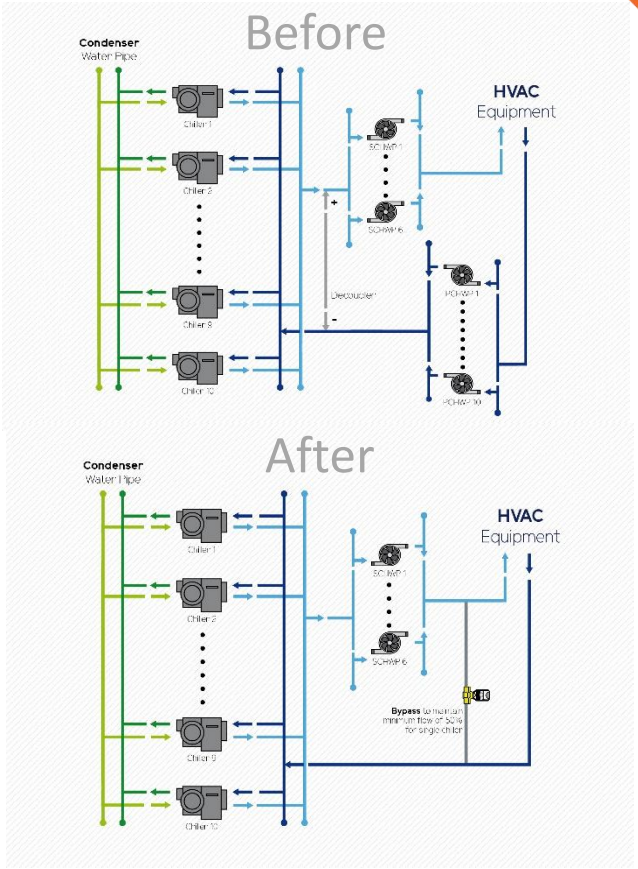
- VSD addition on all HWPs, CDWPs, CHWPs and KEAFs.
- Introduced CHWP differential pressure reset control.
- The same is done to all AHU and PAU supply and exhaust air fans

2013 ENERGY SAVING HIGHLIGHTS

- Decoupler to variable system
- Further LED replacements
- HWPs and HX control optimization
- Swimming pool setback mode

DECOUPLER TO VARIABLE SYSTEM

- Oversized secondary chilled water pumps to shoulder site chilled water pumping requirement.
- Pumping power controlled by differential pressure reset.
- Remove complete set of primary chilled water pump, reducing energy (about 1,400 MWh) and maintenance cost.



2014 ENERGY SAVING HIGHLIGHTS

- Heat pump Replacement
- Cooling tower low flow weir dams and pairing
- Hotel DC FCUs
- Further LED replacement

HEAT PUMP PROJECT

MOVTIVATION

- The Steam Boilers are hugely oversized:
  - Planned to support the full scale laundry for guest and staff initially.
  - Max. capacity 2*7,500(kg/hr where actual consumption is 1,700 kg/hr in summer and 2,500 kg/hr during spring and autumn.
  - High heat losses through chimney stack, boiler body and blow down water with hunting problem.

- LPG is a more costly energy relative to Electricity

BOILERS AND HEAT PUMPS

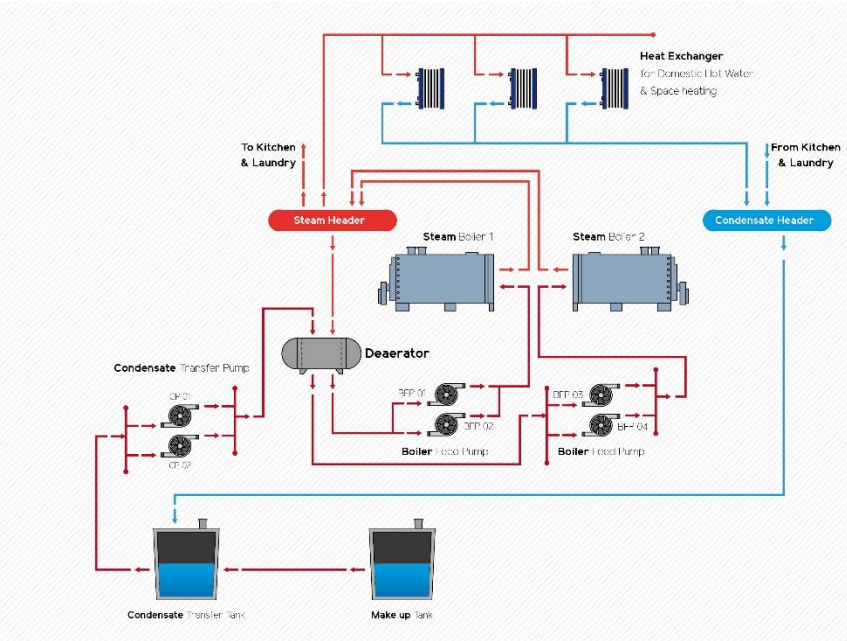
APPROACH

- Install 2 nos. of smaller steam boiler with 800 kg/hr to support.
  - ❑ Kitchen Equipment
  - ❑ Laundry
  - ❑ Swimming Pool Heating

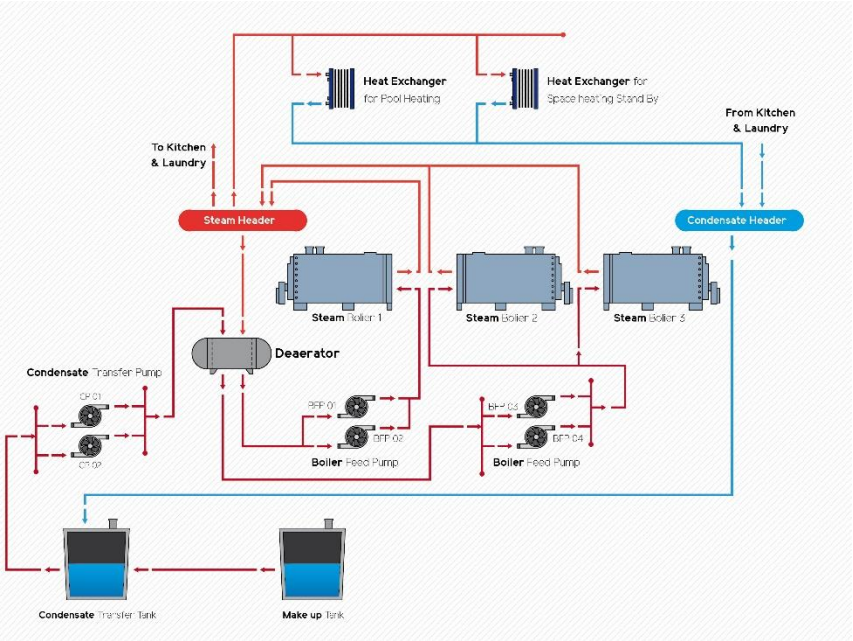
- Dismantle one old boiler and reserve one for backup.
- Install 3 nos. of 850 kW heat pump to support:
  - ❑ Domestic Hot Water for both Podium and Hotel
  - ❑ HVAC Space Heating

BOILERS AND HEAT PUMPS

BEFORE

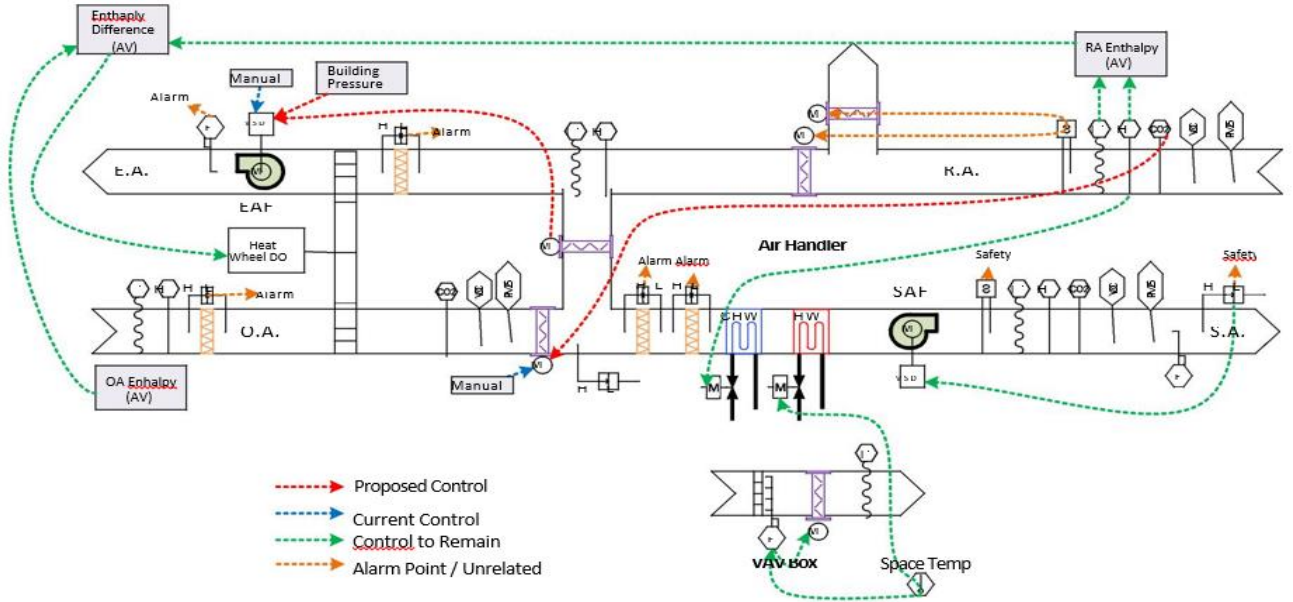


AFTER



AIRSIDE OPTIMIZATION

- Control outside air via economizer dampers based on IAQ
- Temperature Control
- Building Pressure Control



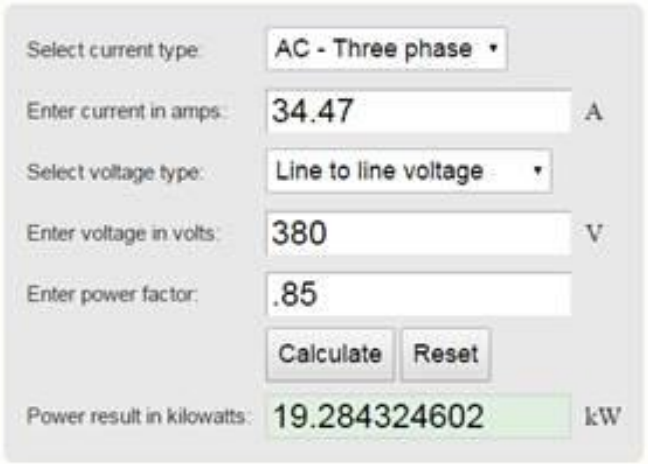
KITCHEN DCV

- Introducing VSDs to KMAFs in addition to KEAF VSDs.
- When kitchen is idle, KEAFs ramps down, resulting in less makeup air required and less cooling demand

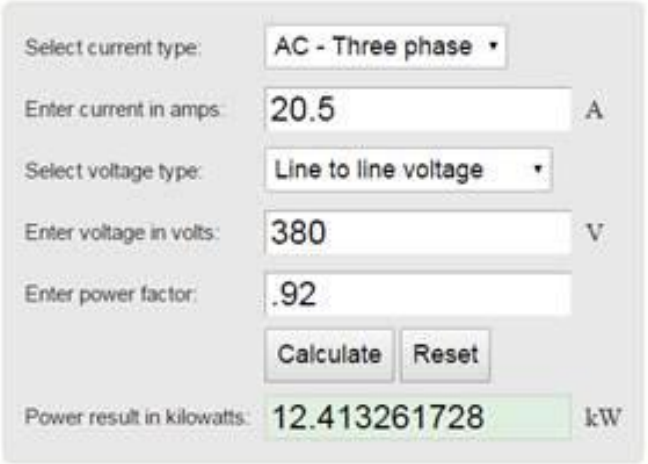
EC FAN TECHNOLOGY

- Introducing EC fans to cold rooms and airside equipment.

AC Supply Air Fans (SAFs)



EC SAF replacement



INNOVATION THROUGH TECHNOLOGY

- With numerous energy saving projects implemented through the years, most of the easy and semi-easy to implement projects have been done.

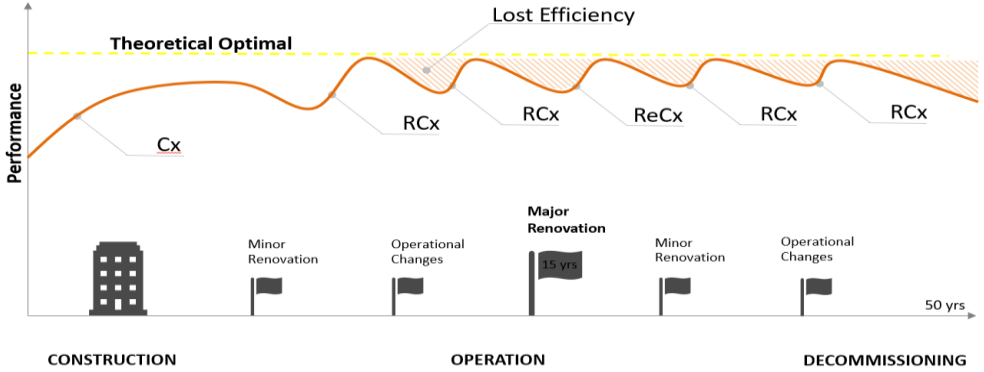
- Thus to achieve additional energy savings requires more a more innovative and intelligent solution.

- With the advancement in IoT and big data analytics, MGM introduced a data analytics platform in 2015 to further optimize its building operations.

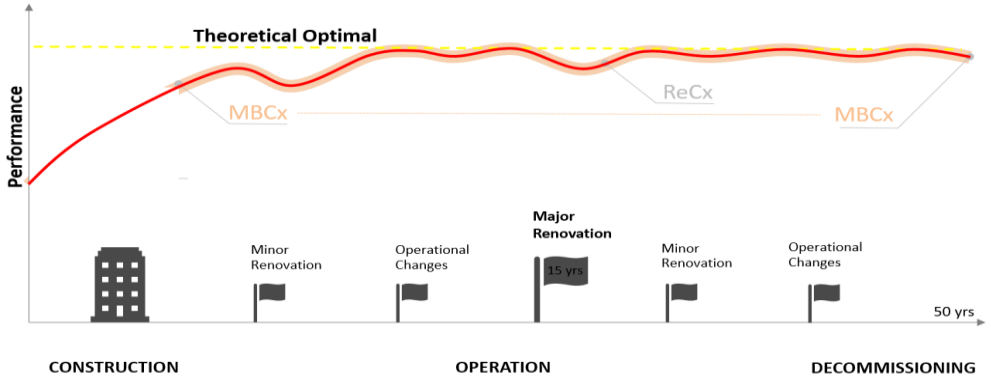
- This platform contains a set of analytical rules that constantly monitor the operations of equipment and systems → this enables FM to continuously commission its system to maintain optimal efficiency.

DATA-DRIVEN COMMISSIONING

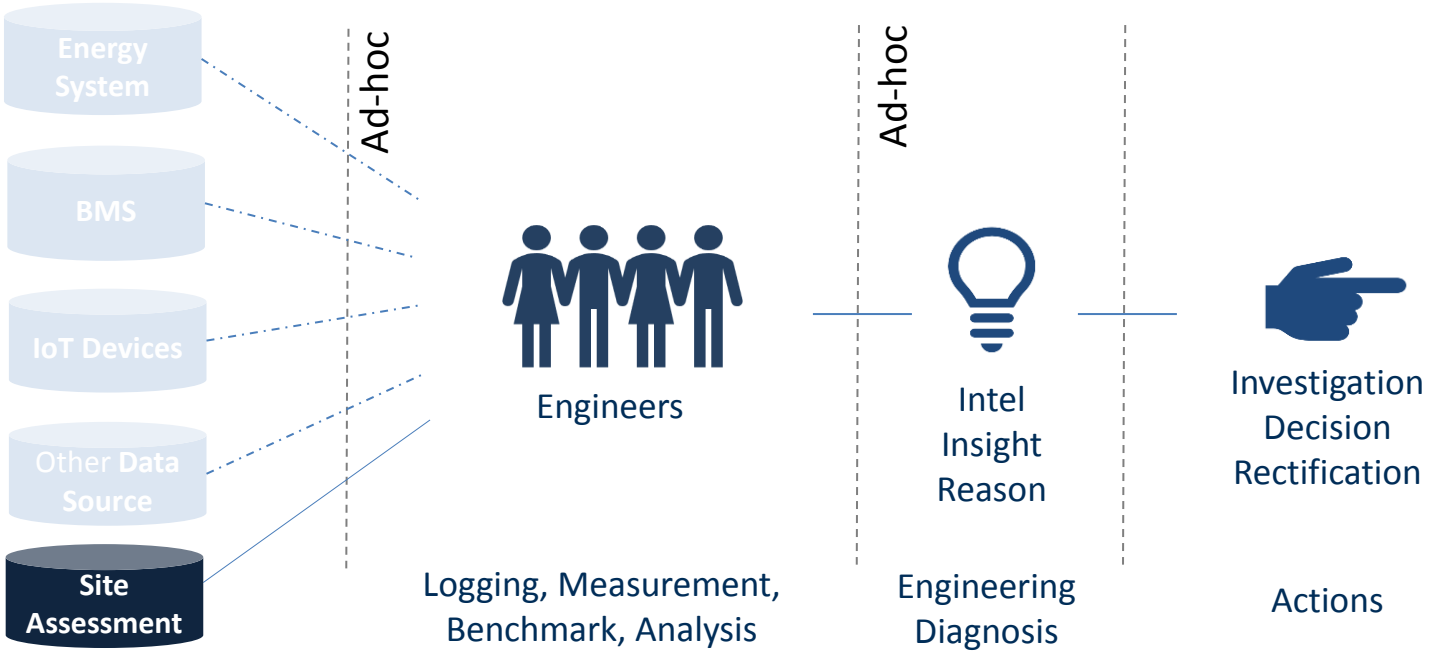
Typical - periodic Fine-tuning (often costly and labor-intensive)



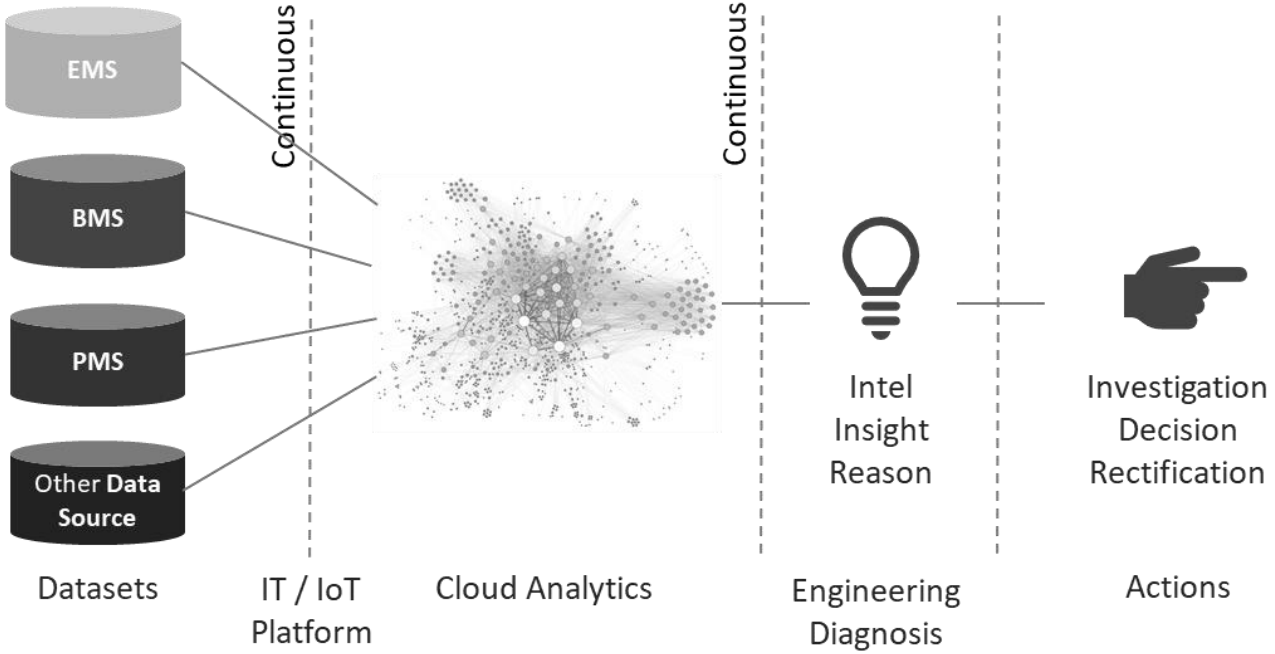
Data-Driven Continuous Commissioning (persistent & optimal performance)



TYPICAL RETRO-COMMISSIONING



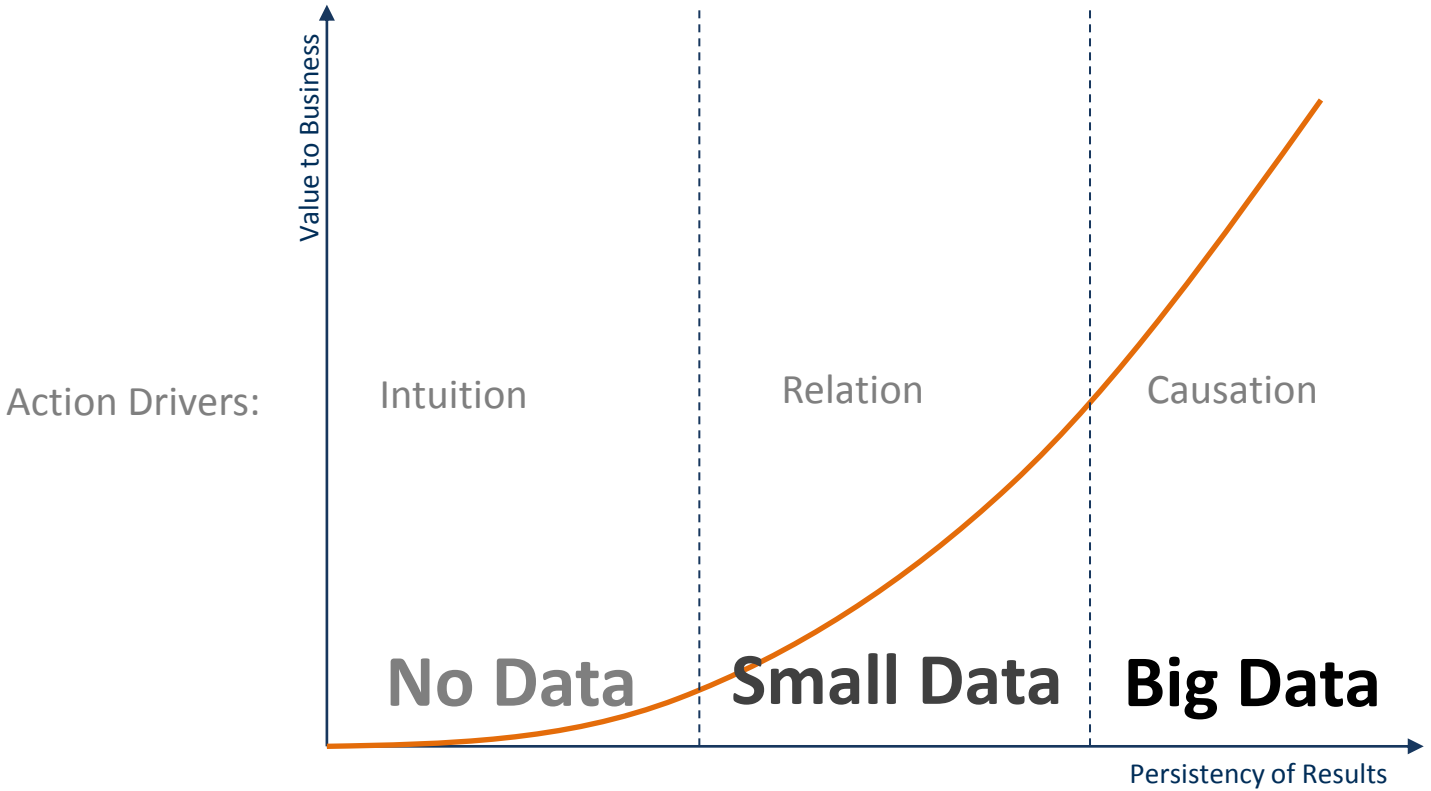
DATA-DRIVEN COMMISSIONING



DATA-DRIVEN COMMISSIONING

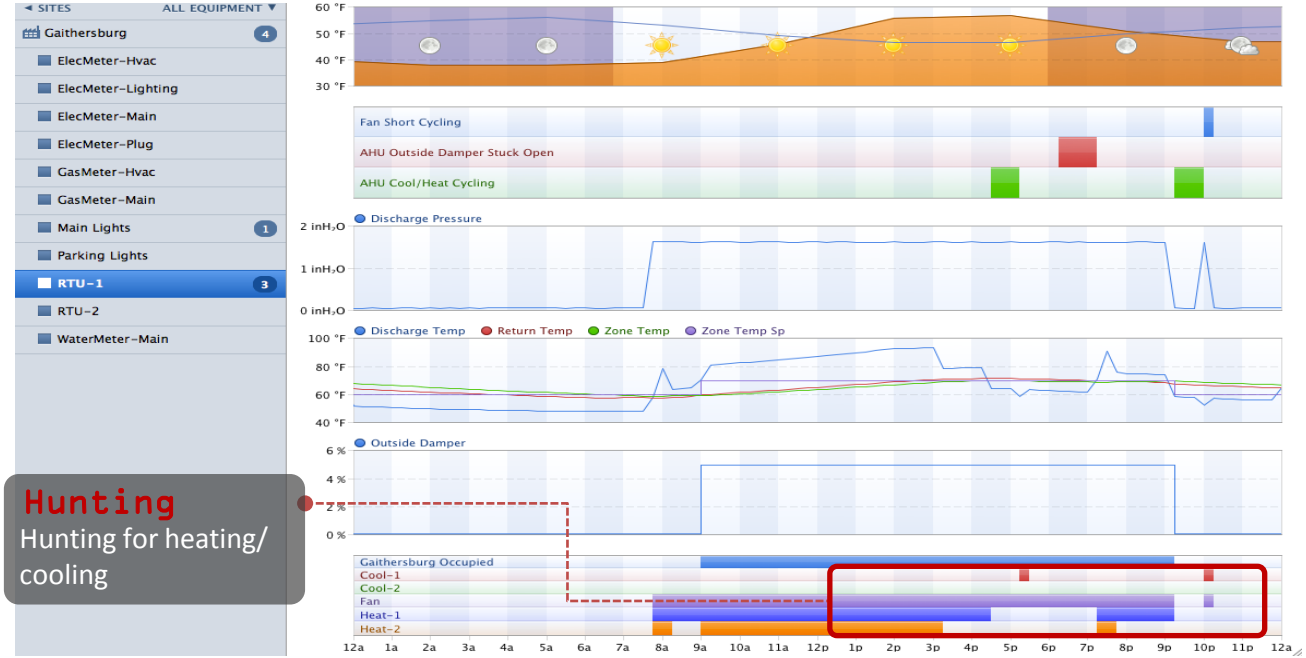
Conventional Commissioning	Monitoring-based Commissioning (MBCx)
Through data and site investigation	Through data and mass coverage
Once off project – human driven	Continuous – Computer analytics based
Thorough health check	Health/Fitness Tracker

DATA-DRIVEN COMMISSIONING



DATA-DRIVEN COMMISSIONING

CONTROL ISSUES - HUNTING

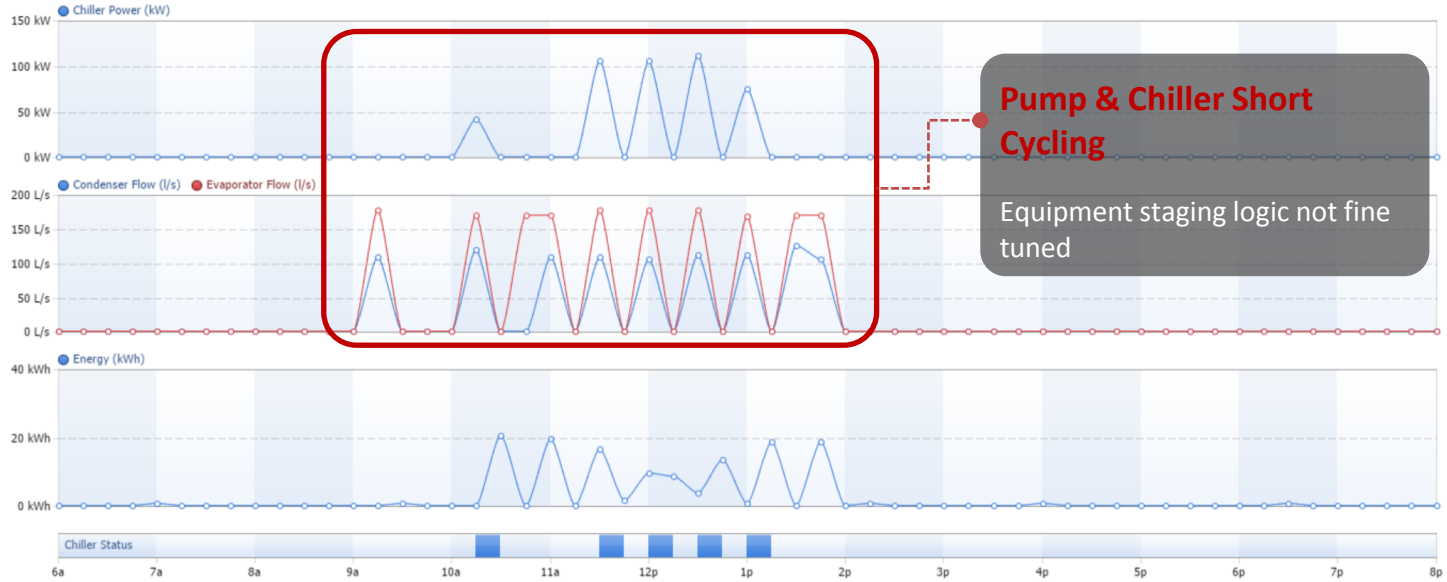


Hunting

Hunting for heating/ cooling

DATA-DRIVEN COMMISSIONING

CONTROL ISSUE - SHORT CYCLING



Pump & Chiller Short Cycling

Equipment staging logic not fine tuned

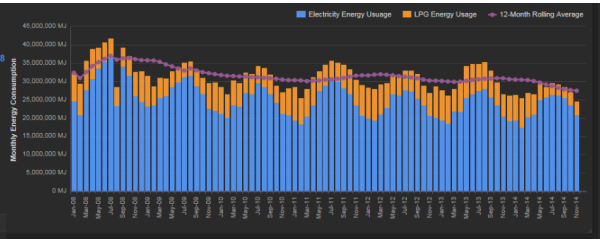
DATA-DRIVEN COMMISSIONING

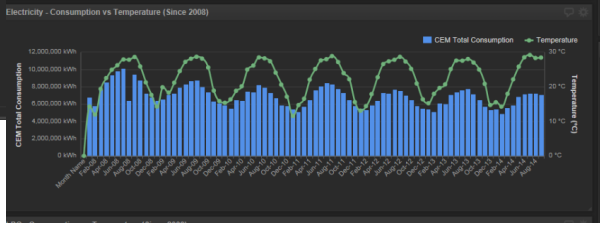
MAINTENANCE ISSUES - STUCK VALVES

ENERGY REPORTING

- To better monitor BEQ and building performance, MGM has introduced a robust real time energy tracking and reporting system.
- Reports are automatically generated regularly and sent to the related staff for review and corresponding actions.

	Last Week	This Week	% Change
Total Building Load	657,505.61	663,153.66	1%
Chiller Consumption (kWh)	90,386.75	98,736.25	8%
Average Chiller COP	7.27	6.72	-8%
Chiller + CWP + CT Consumption (kWh)	119,437.75	124,713.00	4%
Average AHRAE COP	5.51	5.32	-4%
Total Plant Consumption (kWh)	144,764.55	147,860.50	2%
Average Total Plant COP	4.54	4.48	-1%

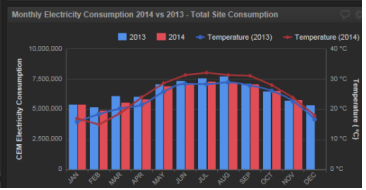




Source	Actual Consumption	% Difference	Cost	% Difference
Electricity (kWh)	5,802,000	0.42%	$7,260,515	-0.09%
LPG (kg)	81,965	-57.77%	$645,886	-53.37%
Water (m3)	60,783	10.67%	$353,010	10.70%
CEM/LPG Energy (MJ)	24,600,215	-9.62%	$7,906,401	-7.22%

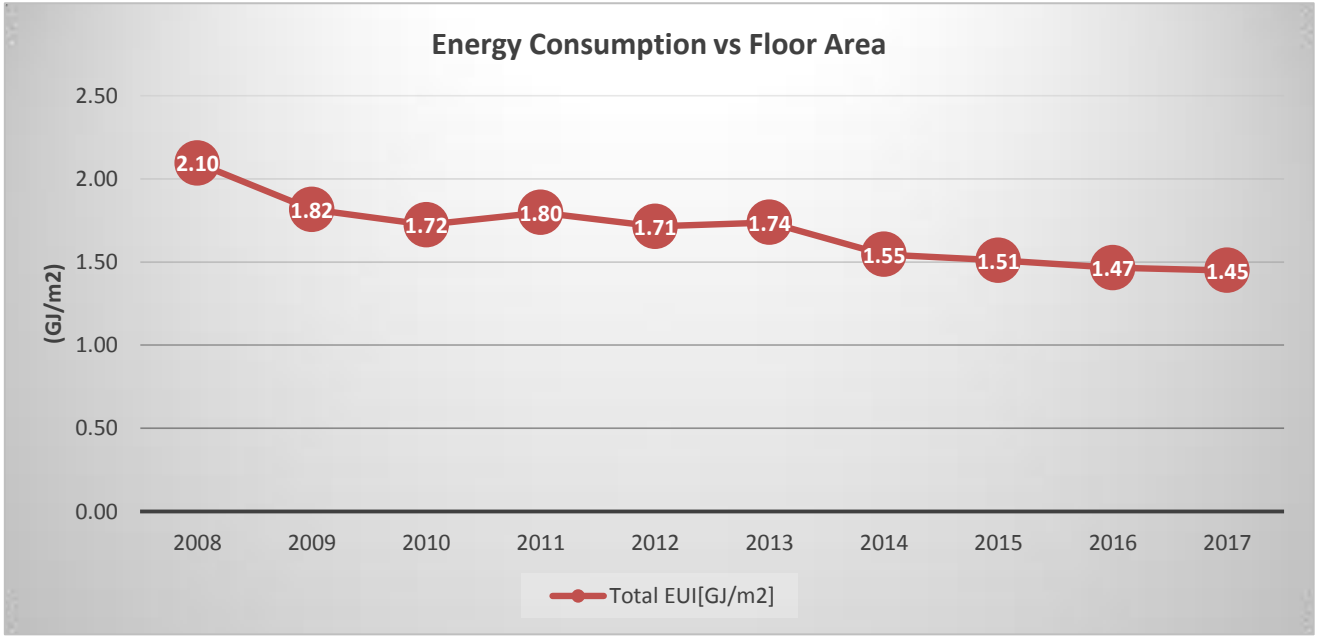
Source	Actual Consumption	% Difference	Cost	% Difference
Electricity (kWh)	75,318,280	-9.16%	$97,400,768	-2.94%
LPG (kg)	1,283,151	-43.00%	$12,966,924	-43.97%
Water (m3)	734,614	-0.42%	$4,263,080	-0.34%
CEM/LPG Energy (MJ)	329,272,556	-10.23%	$110,367,691	-8.85%

Source	Actual Consumption	% Difference	Cost	% Difference
Electricity (kWh)	69,967,800	-3.12%	$90,708,418	-2.98%
LPG (kg)	1,130,527	-45.33%	$11,449,837	-44.26%
Water (m3)	681,407	0.70%	$3,954,030	0.66%
CEM/LPG Energy (MJ)	304,672,342	-11.91%	$102,158,254	-8.66%



EMS AND IMPROVING EUI

- Through the certification of ISO50001, MGM has further established a solid framework to track its energy performance.
- As a result of years of effort, MGM Macau has seen steady decrease in its EUI.

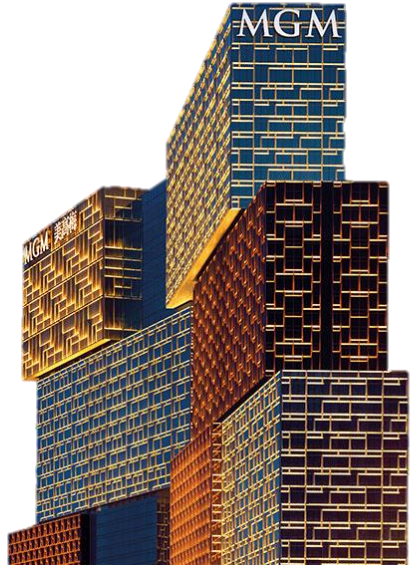


Major Green Achievements

- HK Green Building Award 2017
- ISO 50001 Energy Management System (the whole property) – 2016, 2017
- ASHRAE Technology Award for innovations in energy efficiency for Asia Pacific Region, 2015,Macao Green Hotel Award, Gold Award, 2014
- Energy-Saving Concept Award, 2014
- Excellence Award for Energy Savings, Group Hotels C Champion, 2013
- Excellence Award for Energy Savings, Group Hotels C Champion, 2012
- Macao Green Hotel Award, Bronze Award, 2012
- Energy-Saving Concept Award, 2012

MGM COTAI

MGM COTAI has incorporated many state-of-art technologies and energy efficient systems into its design. Although opened just very recently, the planning and design of MGM COTAI began in as early as 2012.



OPERATION DRIVEN DESIGN

- MGM Macau has generated a wealth of operational data and lessons learnt.
- This knowledge and experience can be used as the basis of the MGM COTAI Operation-Driven Design (ODD).
- ODD brings an operational perspective to the development process in order to:
  - Ensure the building is energy efficient, economical, and fine-tuned to operate well.
  - Inject an operational perspective and knowledge into the design process.
  - Right size equipment and minimize capital cost

OPERATION DRIVEN DESIGN

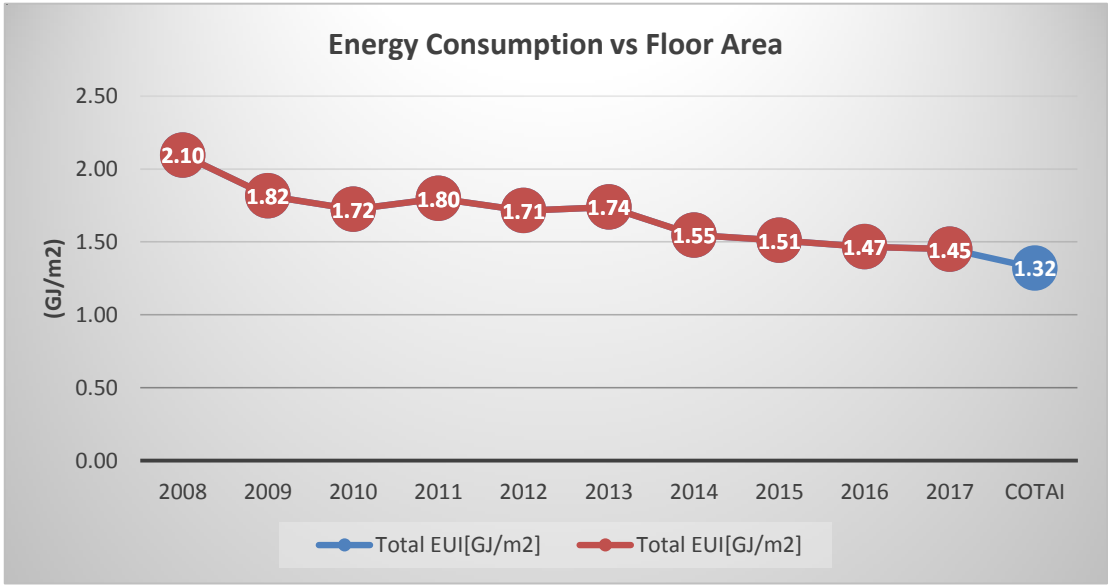
- During the design stage, an energy model was constructed based on:
  - Physical characteristics.
  - Major energy systems.
  - Operational characteristics.
  - Operational data from MGM Macau.

- There are several objectives to the energy modelling:
  - Quantify energy savings.
  - Identify strategies, technologies, practices, and areas that aid in achieving these savings.
  - Compare established model with notable standards.

Model Functional Space (EMSD Survey Reference)	Area (m^2)	EMSD² Survey Data -Actual data from existing bldgs. 2010 (MJ/m^2/annum)	MGM COTAI-Baseline Model (MJ/m^2/annum) from MGM Macau 2010 baseline	MGM COTAI-Baseline Model (MJ/m^2/annum) from MGM Macau 2014 baseline	MGM COTAI-Design Model (MJ/m^2/annum)
Hotel (B8: Hotel)	131,978	898	1,391	1,103	887
Podium (B26: Central Services for Shopping Arcade	234,455	2,302	1,848	1,466	1,343
F&B (B5: Other Eating and Drinking Place	7,417	5,729	10,807	8,570	8,261
Overall (%Reduction from Survey Data)	**373,850**	**1,874**	**1,865 (1%)**	**1,479 (21%)**	**1,319 (30%)**

OPERATION DRIVEN DESIGN

- Through ODD, MGM COTAI was able to further reduce its EUI by 9.8% as compared to MGM Macau.
- In one instance, the heat pump was resized to 7.5 MW from the originally 16 MW after reviewing the ODD model.

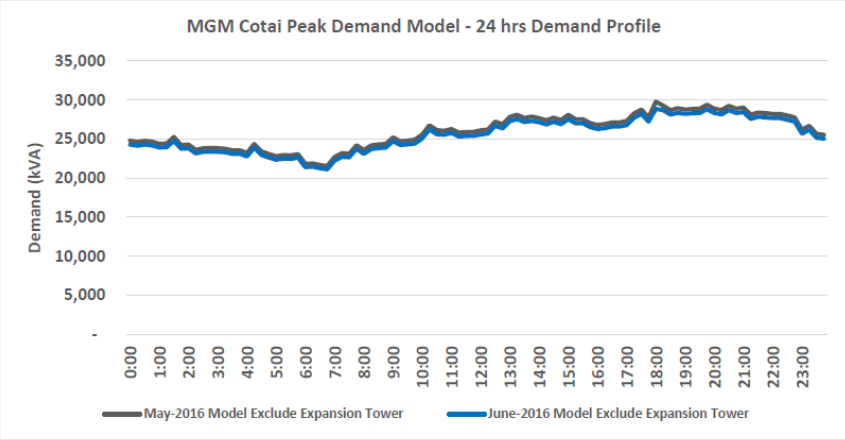


PEAK DEMAND MODELLING

- During the design of MGM COTAI, there was an electrical demand limit of 30,000 kVA imposed by CEM.

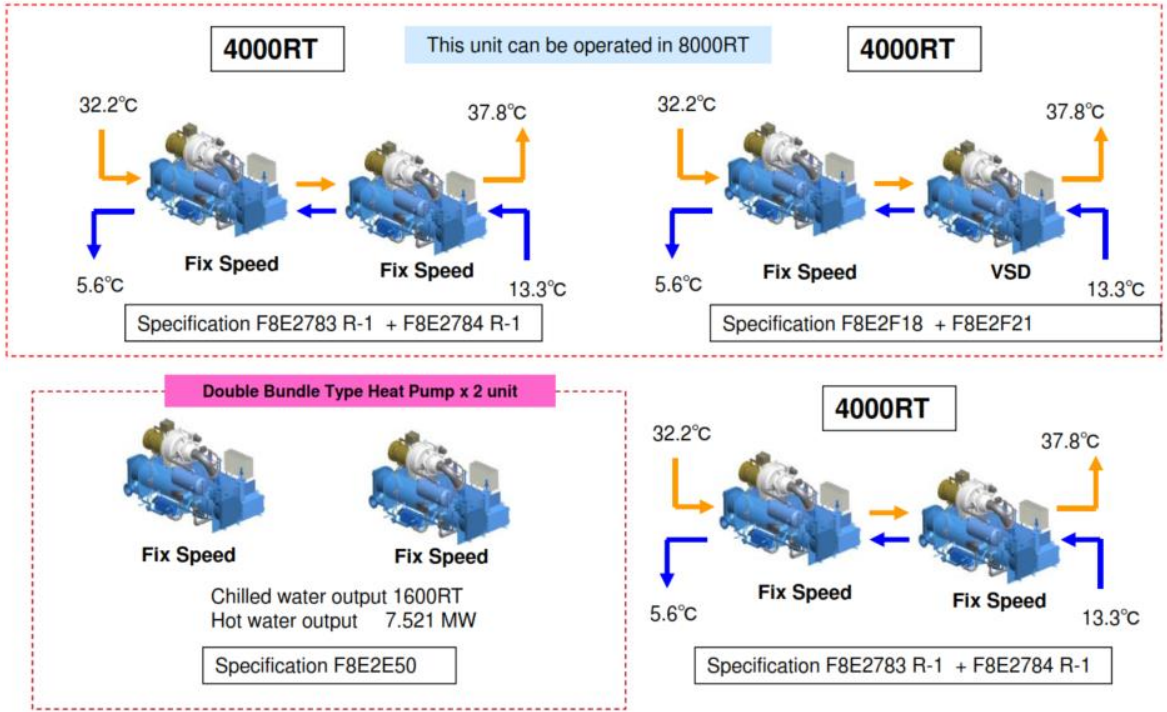
- An additional power substation would need to be built at MGM COTAI if the limit is exceeded.

- A peak demand modelling exercise is conducted and as a result, MGM COTAI is able to limit its demand to below 30,000 kVA.



SERIES COUNTER FLOW DESIGN

- MGM COTAI employs a series counterflow chiller (SCF) configuration with:
  - 6 x 2000 RT chiller, with one of them a VSD chiller.
  - The chillers are grouped in pairs, supported by a pair of heat pumps at 7.5 MW.



BENEFITS OF SCF

- A SCF arrangement yields significant energy reduction as compared to standard parallel-parallel configuration due to reduced lift:
  - Upstream chiller operates at a higher CHWST = higher refrigerant temp/pressure at evaporator.
  - Downstream chiller operates with lower CDWLT = lower refrigerant pressure.
  - Since each of the pair chillers has two refrigeration circuits, the reduced lift effect is multiplied (x4).

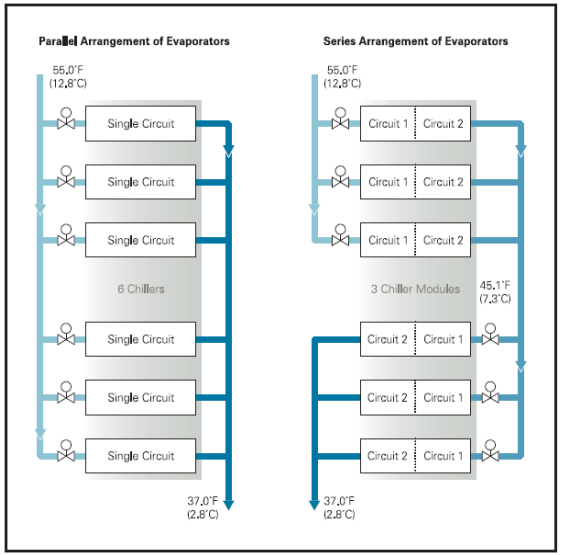


Figure 3: Comparison of evaporator layouts.

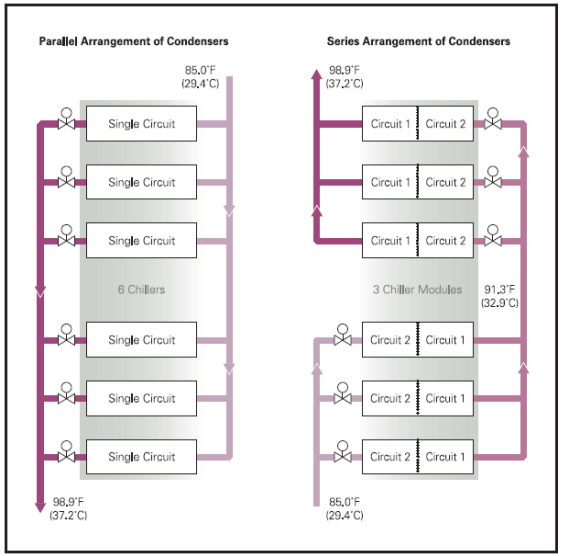
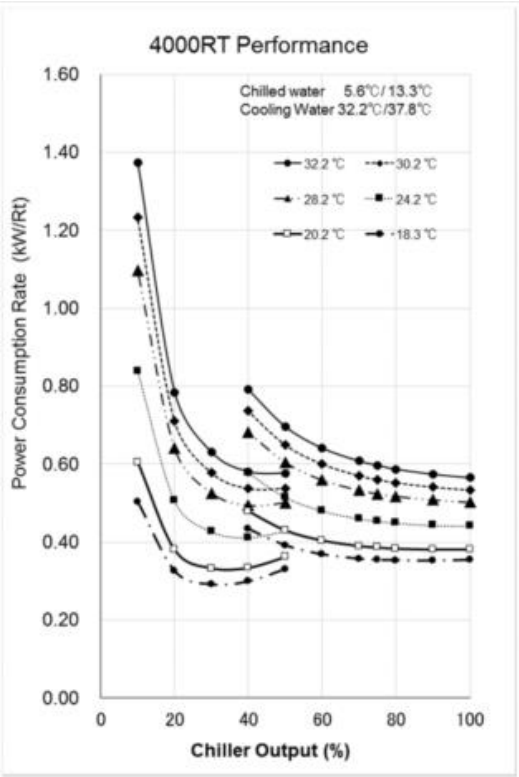


Figure 4: Comparison of counterflow condenser layouts.

SCF PERFORMANCE



CHILLER DESIGN

0-7.5MW

Lead

Fix Speed

Fix Speed

HEATING

COOLING

0-1600RT

(Driven by Heating Load)

Lead

0-4000RT

CHILLER DESIGN

0-7.5MW

Lead

HEATING

COOLING

0-1600RT

(Driven by Heating Load)

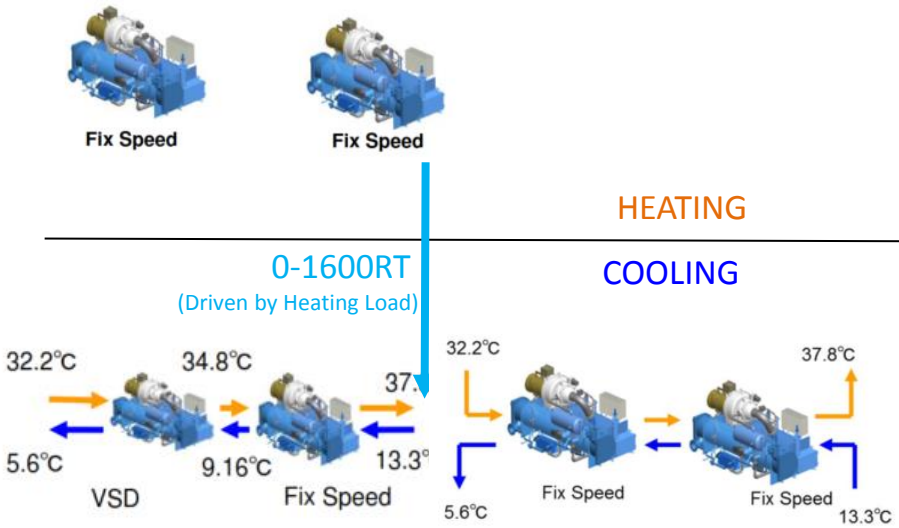
Lead

0-4000RT

CHILLER DESIGN

0-7.5MW

Lead



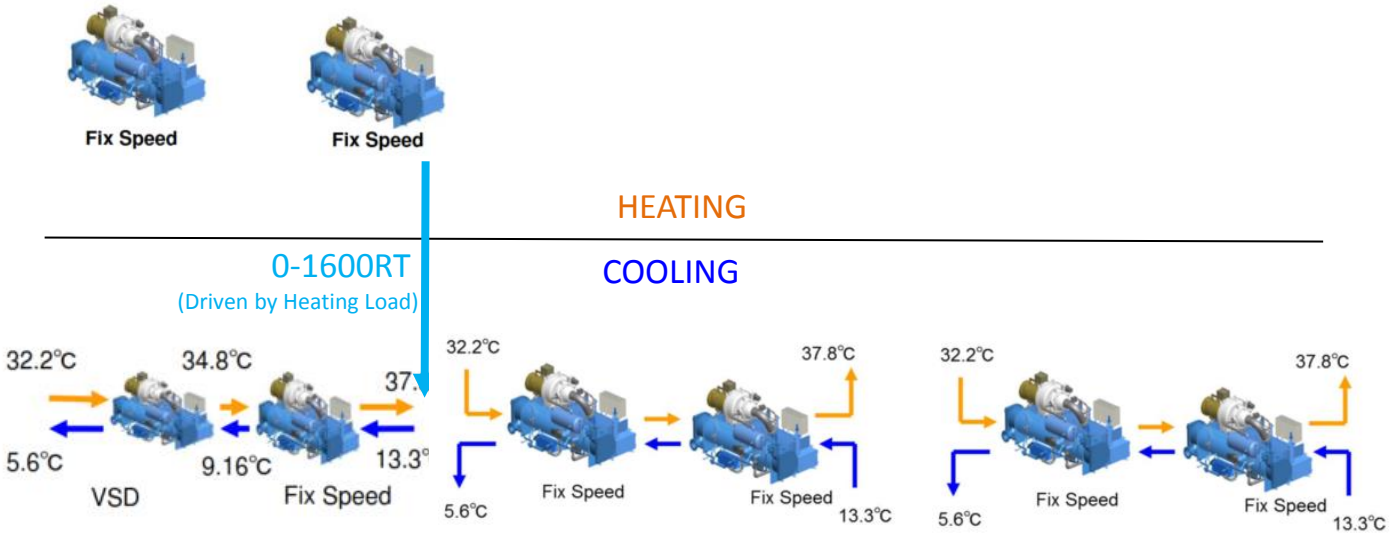
Lead + **Base**

0-4000RT + 4000RT

CHILLER DESIGN

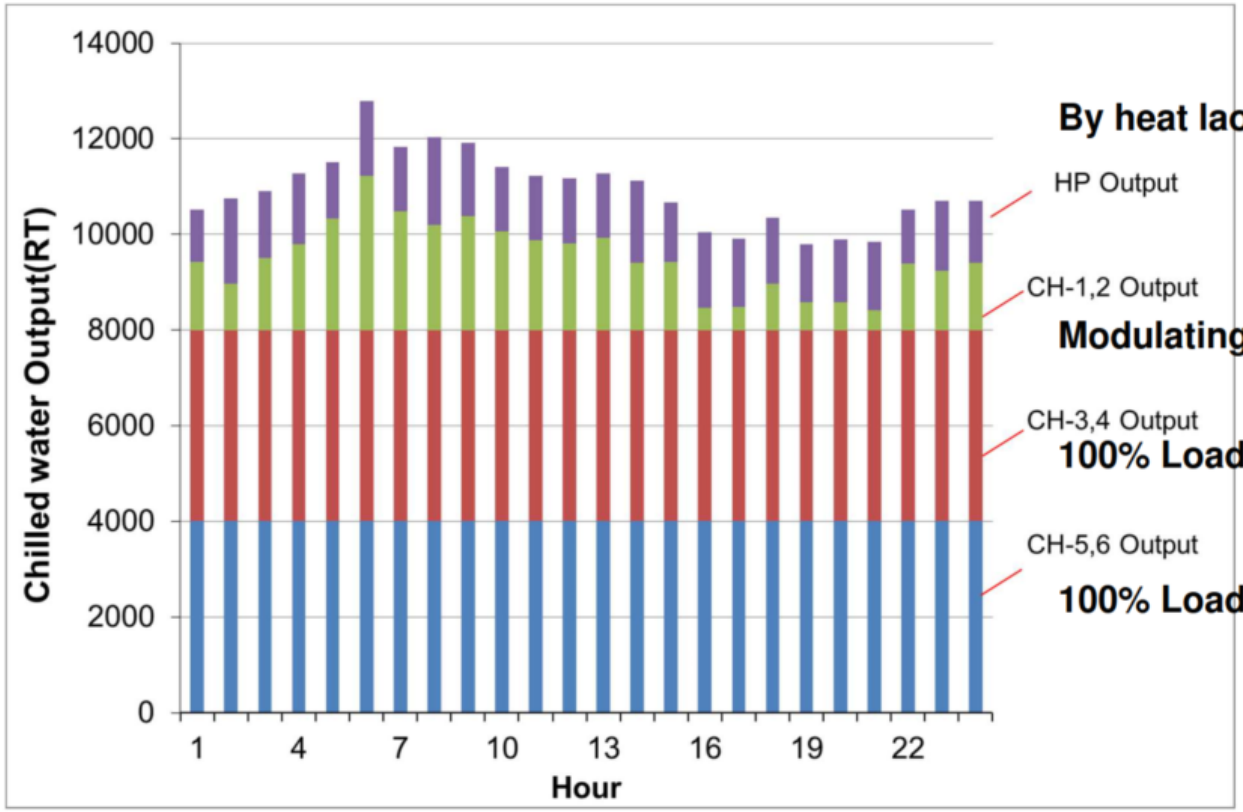
0-7.5MW

Lead



Lead 0-4000RT + **Base** 4000RT + 4000RT

CHILLER DESIGN



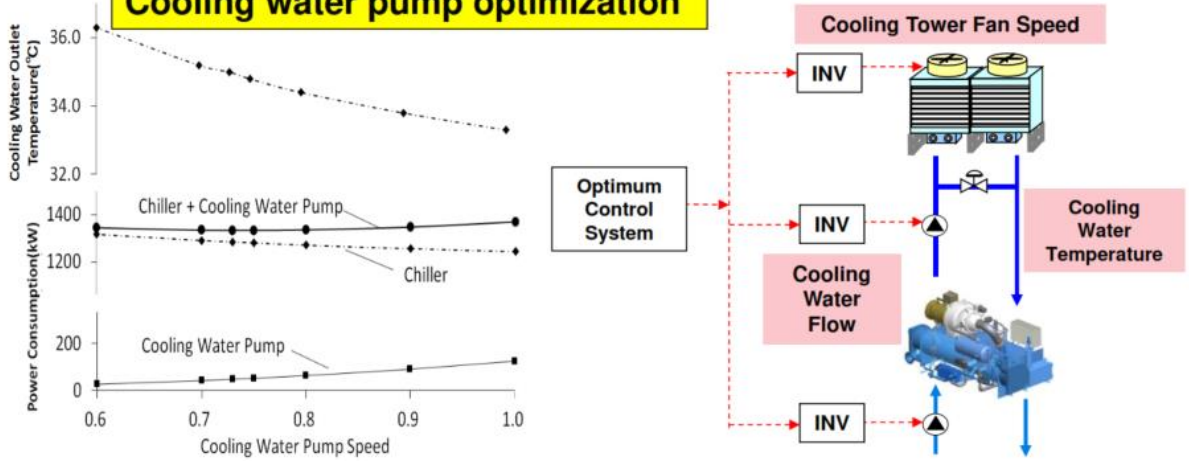
CHILLER DESIGN

Target of chiller system optimization is minimize the total power consumption P_{all}.

$$P_{all} = P_{chiller} + P_{ch\_pump} + P_{cw\_pump} + P_{CT}$$

P_{all}	Total system power consumption	(kW)
$P_{chiller}$	Chiller power consumption	(kW)
P_{ch_pump}	Chilled water pump power consumption	(kW)
P_{cw_pump}	Cooling water pump power consumption	(kW)
P_{CT}	Cooling tower fan power consumption	(kW)

Cooling water pump optimization



OTHER GREEN FEATURES

Energy
- Fresh air rate design in accordance to ASHRAE 62.1.
- Energy-efficient heat pumps that utilize waste heat for pre-heating of make up water.
- EC FCUs in all hotel guest rooms.
- 100% LED lighting.
- Property-wide VSDs.
- Kitchen DCV.
- Advanced digital metering for electricity and gas; submetering of water use and thermal energy.

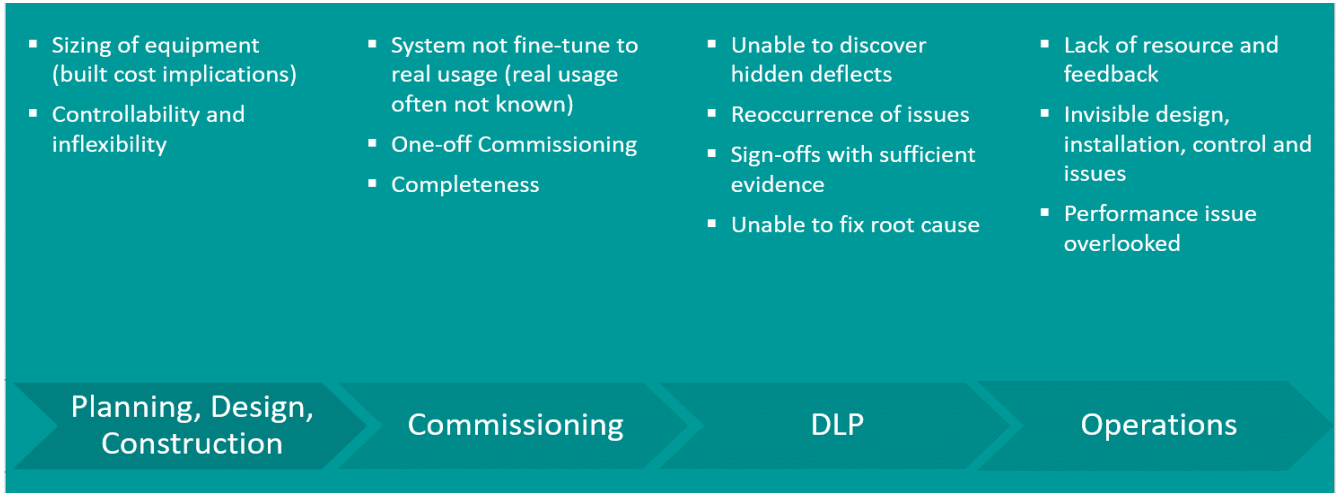
Water
- 100% adoption of low flow faucets, handheld showers, and toilets.
- 100% adoption of low flow fixtures in BOH except kitchens and janitor rooms.
- Drip irrigation for green walls.

Others
- Property-wide recycling for paper, metals, plastic, cooking oil, and e-waste.
- Food waste composting.
- Indoor garden with over 100,00 plants and 2,000 species.

DATA ANALYTICS ON DLP

- In conventional commissioning & DLP period, we often work against time to ensure completeness of commissioning.

- The diagram below shows challenges faced by building owners during the commissioning and DLP period.



DATA ANALYTICS ON DLP

- The use of data analytics can help improve the identification, tractability, and transparency of commissioning and DLP by:
  - Reduces commissioning effort.
  - Reduces time for investigation and ratification during DLP.
  - Protect MGM from contractor’s liability.
  - Evidence-based acceptance with continuous monitoring.

DATA-DRIVEN COMMISSIONING

DESIGN ISSUES - UNDERSIZING

Undersizing

Supply air temperature failed to reach setpoint – undersized equipment

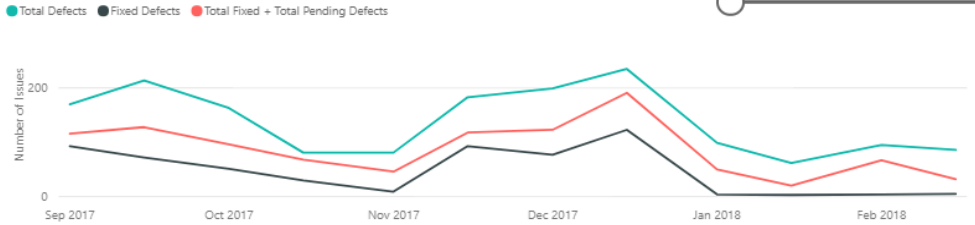
DATA-DRIVEN COMMISSIONING

MGM Cotai DLP Management Defects Summary Report

Executive Summary

Actual Defects Trending

Overall Site Defects Trending



Slicer

date

9/1/2017 2/15/2018

Performance Indicator

Bi-Weekly Defects Break Down (Major Plants)

Slicer

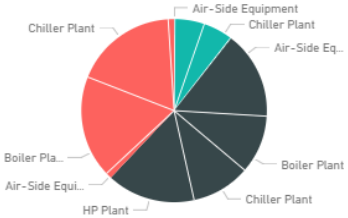
Equipment Group

Select All | Air-Side Equipment | Boiler Plant | Chiller Plant | HP Plant

Slicer

Defects Status

Select All | Fixed | No Feedback | Pending to be Fixed



Defects Break Down Summary

Major Plant	Fixed	No Feedback	Pending to be Fixed	Total
Air-Side Equipment	5	600	40	**645**
Boiler Plant	200	400	700	**1300**
Chiller Plant	200	400	700	**1300**
HP Plant	5	600	40	**645**
Total	**410**	**2000**	**1480**	**3890**

DATA-DRIVEN COMMISSIONING

Bi-Weekly Defects Break Down (Major Plants)

Slicer

Defects Status

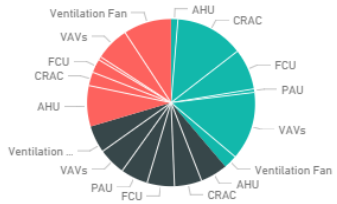
Select All	Fixed	No Feedback	Pending to be Fixed

Slicer

Equipment Category

Select All	AHU	CRAC	FCU	PAU	VAVs	Ventilation Fan

Air Side Defects Status Break Down



Defects Break Down Summary

Equipment Category	Fixed	No Feedback	Pending to be Fixed	Total
AHU	10	40	60	**110**
CRAC	100	40	20	**160**
FCU	60	40	20	**120**
PAU	5	40	5	**50**
VAVs	100	40	50	**190**
Ventilation Fan	20	40	70	**130**
Total	**295**	**240**	**225**	**760**

Bi-Weekly Defects Summary (Equipment Type)

Slicer

Equipment Category

Select All	AHU	CRAC	FCU	PAU	VAV	Ventilation Fan

Slicer

Defects Status

Select All	Fixed	No Feedback	Pending to be Fixed

Equipment Category	Equipment	Defects	Defects Status	Defects Status Feedback	Estimated Completion Date	Completed
AHU	AHU-1F-01	aahu01	Fixed	Fixed	Saturday, 5 August 2017	YES
AHU	AHU-1F-02	aahu02	Pending to be Fixed	Waiting for P.O.	Thursday, 5 October 2017	
AHU	AHU-1F-03	aahu03	No Feedback			
AHU	AHU-1F-04	aahu04	Pending to be Fixed	Waiting for P.O.	Thursday, 5 October 2017	
VAV	AHU-1F-04	avav29	Pending to be Fixed	Waiting for P.O.	Thursday, 5 October 2017	
CRAC	CRAC-1	acrac29	Pending to be Fixed	Waiting for P.O.	Thursday, 5 October 2017	
FCU	FCU-1	afcu2	Pending to be Fixed	No time	Tuesday, 5 December 2017	
PAU	PAU-1F-04	apau16	No Feedback			
PAU	PAU-1F-04	apau24	No Feedback			
Ventilation Fan	SF-1	afan2	Pending to be Fixed	Waiting for P.O.	Thursday, 5 October 2017	

ACHIEVEMENTS

- With its robust green designs, MGM COTAI is awarded the Three-Star certification under the China Green Building Design Label.
- MGM COTAI is the largest property and the first mega-size complex project in Macau to have achieved the Three-Star certification.
- The Three-Star certification is equivalent to LEED platinum.

THE FUTURE OF BEQ FOR MGM

MGM Macau

- Although numerous EMOs have been implemented through the years, enhancement in operation transparency through technology enables MGM Macau to continue to curb its energy consumption.

- Future plans include:
  - Equipment and system retro-commissioning (e.g. airside equipment, boilers etc).
  - Guest thermal comfort improvement through IoT.

MGM COTAI

- Although opened just recently, there are opportunities for further optimization during DLP.

- Future plans include:
  - Continuous effort on building optimization during DLP.
  - Collection and analysis of operational data.
  - Data analytics for continuous improvement.