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RP1026: Evaluation of Next-Generation Automated Fault Detection & Diagnostics (FDD) Tools for Commercial Building Energy Efficiency

Part I: FDD Case Studies in Australia

Australian Government

Department of Industry, Innovation and Science

Business
Cooperative Research
Centres Programme

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Acknowledgements

Disclaimer

Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 2

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Contents

LOW CARBON LIVING CRC

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 4

LOW CARBON LIVING CRC

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial
Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 5

List of Tables

LOW CARBON LIVING CRC

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 7

List of Figures

Acronyms

AFDD	Automated Fault Detection & Diagnostics
AI	Artificial Intelligence
BI	Business Intelligence
BIM	Building Information Model
BMCS	Building Management & Control System
CRCLCL	Cooperative Research Centre – Low Carbon Living
DLP	Defects Liability Period
FDD	Fault Detection & Diagnostics
FM	Facility Manager
HVAC	Heating, Ventilation & Air Conditioning
HVAC&R	HVAC & Refrigeration
IT	Information Technology
IoT	Internet of Things
M&V	Measurement & Verification
Mt CO_2-eq	Mega-tonnes CO_2 equivalent
NABERS	National Australian Built Environment Rating System
O&M	Operation & Maintenance
OT	Operational Technology

Introduction

Beyond expensive building and equipment upgrades and retrofits, re-commissioning (analogous to performing a comprehensive tune-up on your car) and automated fault detection and diagnostics (FDD) for building systems offer significant energy efficiency opportunities in commercial buildings.

With Heating, Ventilation & Air Conditioning (HVAC) systems attributed to 40-50% of commercial building energy consumption (46 Mt CO_2-eq. p.a.) in Australia (Pitt & Sherry, 2012), FDD tools and services are driving energy savings and emissions reductions, in addition to improved maintenance practices and outcomes from commercial building HVAC systems and more recently other building energy systems.

Literature on related building case studies suggest that virtually all buildings have some sort of HVAC operational problems, and the vast majority of buildings are not carefully tuned or commissioned (Claridge et al., 1994; Piette et al., 1996, Clarke et al., 2015). It is estimated that performance degradation, improperly tuned controls and malfunction of HVAC systems and equipment wastes up to 16% whole building energy (Mills, 2009). An independent evaluation of FDD and ongoing commissioning tools and techniques in the United States demonstrated average energy savings of 10%, with as much as 25% in some cases, and found the median normalised cost to deliver commissioning for existing buildings was ($3.20/m^2) with a payback time of 1.1 years (Mills & Mathew, 2009).

Project Scope

With numerous commercial offerings and delivery models for FDD solutions available in the Australian market, it is often difficult for potential customers and end users to determine which solutions offer the most value considering factors such as implementation cost, ease of use, energy savings, improved maintenance practises and outcomes, and ultimately improved comfort and productivity of the building occupants.

The scope of this project was to undertake a rigorous and systematic independent evaluation of the potential benefits of automated FDD solutions delivered as a managed service in Australia. The intent of the evaluation is to encourage greater uptake of FDD tools and services in Australia by assisting building owners, operators and HVAC&R maintenance contractors to evaluate and select their preferred FDD solution for future roll-out across their respective building or portfolio, therefore significantly increasing the energy efficiency of commercial building stock in Australia.

The main objective of this Final Report (Part I), is to highlight key benefits and outcomes made possible through the implementation and ongoing use of automated FDD solutions in Australian commercial building stock. A subsequent confidential report (Part II) will provide an objective performance evaluation of some of the leading FDD solutions in Australia.

WHAT IS FDD?

FDD is an area of investigation concerned with automating the processes of detecting faults within building systems and diagnosing their causes.

While there are several software tools and applications that have proven beneficial for building operations and energy management, one software application showing promising results and cost effectiveness is fault detection and diagnostics or FDD.

FDD are a subset of the larger category of analytic software related to buildings. Analytics are critical because buildings are becoming more complex, new systems are being introduced into buildings that bring with them vast amounts of data, and energy consumption metrics and key performance indicators are now of great interest to operators and corporate management. In general, analytic software tools and services primarily support technicians and engineers in the field who are dealing with both the everyday issues of building operations as well broader issues of complicated systems, bid data, advanced technology and higher expectations for building performance. The analytic tools and services provide insights into building systems resulting in reduced energy consumption, improved building performance and lower operation and maintenance costs (Sinopoli, 2012).

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 10

FDD is an area of investigation concerned with automating the processes of detecting faults with physical systems and diagnosing their causes.

FDD itself is frequently described as consisting of three key processes: fault detection, fault isolation, and fault identification. The first, fault detection, is the process of determining that some fault has occurred in the system. The second involves isolating the specific fault that occurred, including determining the kind of fault, the location of the fault, and the time of detection. The third process, fault identification, includes determining the size and time-variant behaviour of a fault. Together, fault isolation and fault identification are commonly termed fault diagnostics. In most cases, detection of faults is relatively easier than diagnosing the cause of the fault or evaluating the impacts arising from the fault (Katipamula & Brambley 2005).

Fault detection and diagnostics for HVAC systems are not new. For many years, FDD has been an active area of research and development in the aerospace, process controls, automotive, manufacturing, nuclear, and national defence fields and continues to be today. Over the last decade or so, efforts have been undertaken to bring automated FDD out of the research domain with limited real-world examples and laboratory trials, and into the HVAC&R industry through a range of commercially available FDD tools and services.

More recently, the technology has matured to a point where more powerful FDD solutions have been developed and refined, and are now commercially available to the HVAC&R industry. Like all new technology, FDD solutions that are implemented properly and backed by the support of building operation and maintenance (O&M) domain experts where required (either in-house or external service providers), are demonstrating enormous value in improving the operational performance of commercial buildings and high energy consuming HVAC systems.

Figure 1. shows a classification of the different types of FDD methods that underpin many if not all of the solutions available commercially. The coloured boxes highlight the most common methods we see in use today, including Rule-Based methods and Process History-Based (data driven) methods. Exact definitions of these methods can be found in the seminal article by (Katipamula & Brambley 2005).

Rule-Based methods include simple limit checks (which server as the basis for alarms), logical rules or expressions based on physical first principles of HVAC and other building energy systems, and expert systems that invoke a database or library of targeted rules and thresholds or other expert knowledge that may be better suited to a particular climate zone, building type, building system or piece of equipment.

Process History-Based (data driven) methods including Black-Box and Grey-Box methods are emerging as viable automated FDD techniques in their own right (Sands & Macelroy, 2006; Wall et al., 2011; Li & Wen, 2014; Guo et al., 2017), and have also been shown to complement Rule-Based methods, particularly for HVAC and other building energy systems where rules may be non-existent or difficult to define, or for more complex multi-variable systems where large amounts of historical data from different input sources is available.
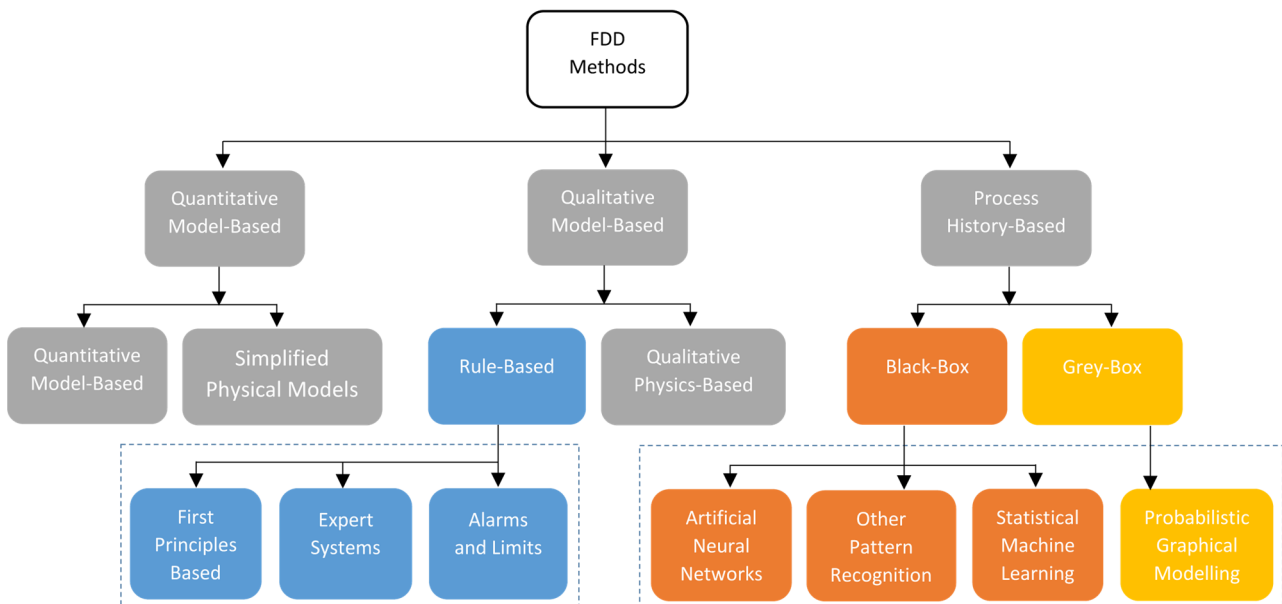
Figure 1. Types of Automated FDD Techniques (adapted from Katipamula & Brambley, 2005)

What FDD Features to look for…

With a plethora of building energy-related services and solutions now claiming to offer some form of advanced analytics or fault detection functionality, it is important to understand the key features to look out for and how to differentiate those solutions that can really add value to improving building operational performance and ultimately the triple bottom line.

A key challenge that currently exists is ensuring analytics solutions are not too sensitive so as to create an overwhelming number of results or false alarms, but sensitive enough not to miss critical issues. Another challenge is ensuring that identified faults and operational issues are prioritised and presented in a way that facilitate actual remedial actions for best practise O&M, without causing information overload.

When considering potential FDD solutions, be sure to inquire about the underlying automated techniques or algorithms employed, as opposed to straight manual investigation by engineers and domain experts (which may incur unnecessary labour costs), and how the FDD results can be shared and used to benefit all stakeholders involved towards achieving best practise in the O&M of buildings.

For rule-based methods, FDD solutions that use hierarchical rule sets with inherent knowledge of inter-system dependencies (e.g. AHUs depend on primary plant supply) can help in more accurately detecting system and equipment faults and with less false alarms. Likewise, many solutions are beginning to utilise process history-based (data driven) methods either as stand-alone techniques or to compliment more traditional rule-based methods. Be sure to inquire about the amount of historical data required to achieve meaningful results, and what other input data sources can be integrated to improve the FDD results and insights.

Collating and extending the advice by leading experts in the HVAC&R Industry (Clarke et al., 2015), some of the questions professionals should be asking themselves when investigating automated FDD solutions include:

- Does it provide a real-time multi-user interface as well as periodic reporting for delivery of actionable insights?

- Can it integrate and utilise BMCS data, energy/power sub-meter data, and other building and external systems data?

- Can it pinpoint the source of failure at the sub-system or equipment level?

- What are the upfront and ongoing costs, and are there any extra or hidden costs?

- What data and information is required to fully implement the solution and what is the setup time?

- Can it integrate with maintenance processes and work-order systems to remove manual handling and data entry to fast-track rectification works?

- Does it provide the flexibility to adopt new emerging technology such as, data-driven FDD methods, predictive maintenance and intuitive visualisation tools?

Future Trends in FDD

An emerging trend that is being driven by advances in artificial intelligent (AI) and machine learning is that of automated prognostics or data-driven predictive maintenance. Prognostics address the use of automated methods to detect and diagnose degradation of physical system performance, anticipate future failures, and project the remaining life of physical systems in acceptable operating state before faults or unacceptable degradations of performance occur. Together with automated FDD, these methods provide a cornerstone for condition-based predictive maintenance of HVAC&R and other engineered building systems.

Emerging AI and machine learning tools will enable large amounts of data from disparate data sources, such as BMCS, sub-metering, localised high resolution weather data, building occupancy, thermal comfort, building information models (BIM) and commissioning data, to be analysed in a way that provides meaningful insights into the longer term performance and degradation of HVAC systems and equipment. It can estimate remaining time to failure (or time before reaching an unacceptable level of performance), the rate of degradation, and the nature of the failure if it were to occur.

Finally, the Internet of things (IoT) and convergence of information technology (IT) and operational technology (OT) is at peak hype, and is promising to transform the facility management sector. By assembling an unprecedented amount of data from one or multiple buildings, IoT and business intelligence (BI) solutions will open up data-rich environments creating opportunities for new smart building applications and actionable insights only just starting to be realised. These include increased energy savings from more efficient devices that provide intelligence at the edge of subsystems; cloud-based processing that enables enhanced data analysis of device or system functionality; enhanced operational efficiency through two-way connectivity and greater insights from more granular operational performance data; and preventive maintenance capabilities from devices that can sense anomalies before they become costly problems (Jung & Talon, 2017).

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 12

FDD Case Studies in Australia

The following section presents a range of FDD cases studies from some of the leading service providers in Australia. There are of course many more solutions available and emerging in the Australian market. The intent of these case studies is to highlight key benefits and outcomes made possible through the implementation and ongoing use of automated FDD solutions in Australian commercial building stock.

As is presented, a range of different outcomes as a result of using automated FDD solutions is evident, including straight electricity and gas savings, life cycle cost decision support, increased NABERS star ratings, improved comfort conditions and reduced comfort complaints, and improved maintenance practises and prioritised actionable insights.

It is important to understand that automated FDD solutions have underlying software and algorithms that are either purpose built (in-house), or built and customised on top of more standard software frameworks, platforms or components that may not necessarily provide all of the required analytics out of the box. Examples (non-exhaustive) of the later include Clockworks, Kaizen, SentientSystem, SkySpark, and visualisation tools such as Tableau and Power BI. There are no clear advantages or disadvantages in either of these software architecture approaches, however if a more standard analytics framework is used, the point of difference most often comes down to the quality of the service offering (or algorithms developed by the FDD solution provider) accompanied by the software analytics framework.

Over the next few years, building analytics (of which Automated FDD technology is a foundational component) will continue to evolve, with the more broader analytics and BI market beginning a new wave of disruption that promises to uproot the status quo with building controls, operation and maintenance. As a first step, the authors encourage prospective end-users of automated FDD technology to contact the FDD solution providers listed in this report and discuss with them the features and benefits of their solution, using the previous section as a guide.

Table 1 Index of FDD Case Studies

Page	Case study Project:	Key FDD Outcomes:
17	Melbourne Museum, Melbourne VIC	Yearly savings of 20% in electricity and 28% in gas
25	Commercial Office Tower, Sydney NSW	1.5 Star to 5 Star NABERS rating in 24 months
35	Commercial Office Tower, Canberra ACT	Improved thermal comfort conditions while achieving 15% total electricity reduction and 19% total gas reduction
43	Melbourne Airport, Melbourne VIC	Reduction in the avoidable energy cost , number of comfort anomalies, and number of maintenance anomalies
53	Public Hospital, Brisbane QLD	Decisions-support to reduce the life cycle cost of operation, and aided electricity, gas and facility management contract negotiations
59	Research Laboratory Facility, Canberra ACT	20% decrease in monthly energy consumption and 744MJ/m² decrease in site energy intensity

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 13
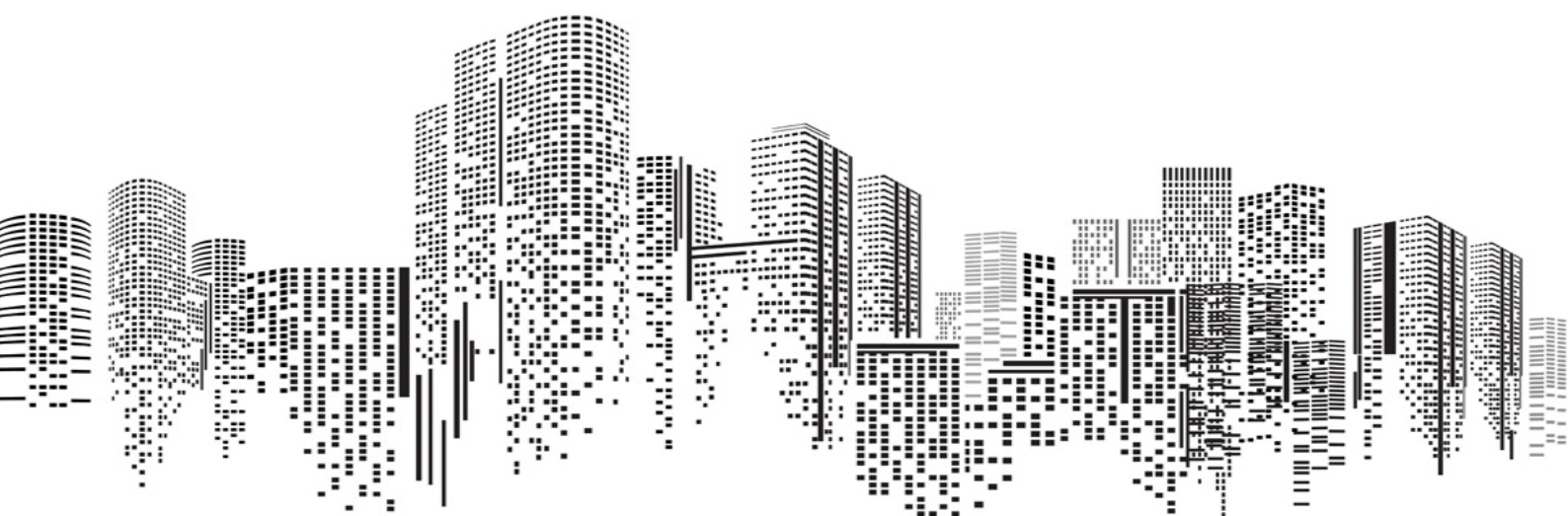
Here's what existing FDD users are saying…

"Using CIM Enviro, we have achieved a seven half-star jump for $48,000 Opex, but most impressively, for no Capex expenditure "

- Associate Director | Asset Management, NSW

"The introduction of Synengco FDD for at our hospital site will enable us to use predictive techniques to proactively manage our energy usage."

- Facilities Maintenance Manager, QLD

"Building Analytics by Schneider Electric has helped us improve our proactive maintenance program of critical assets enabling us provide a high level of service to our customers"

- Mechanical Asset Manager, VIC

"Automated FDD deployment has enabled our organisation to save a lot of energy and cost, and in becoming proactive about building management. The C&E Analytics tool has detected not only faulty equipment, which would have been picked up only later through maintenance processes, but also behaviour that would have not been known without the tool"

- Sustainability Manager, ACT

"Coppertree Analytics has been an integral part in driving our maintenance activities and lowering our energy consumption. It's implementation has helped streamline our maintenance, which means more time can be spent fixing problems instead of identifying them."

- Senior Building Manager, ACT

"CIM Enviro has allowed Museum Victoria to find faults from the BMCS system that cannot be diagnosed by normal fault finding alone."

- Project Manager, VIC

"The ACE Platform has contributed to a sharp reduction in energy usage at Melbourne Museum."

- Project Manager, VIC

"The Joule AnalytiX platform integrates with our existing BMCS and helps us get the most from our contractors."

- Operations Manager, NSW

FDD Case Studies in Australia

ACE Platform
by CIM Enviro

A Balance Sheet Optimisation Technology

CIM Enviro's technology, the ACE Platform, is a real-time Balance Sheet Optimisation portal that seeks to streamline the three biggest expense items in property management budgets:

- Energy (~28%)
- Repairs & Maintenance (~40%)
- Maintenance Contracts (~29%)

Pricing is based on delivering a target payback of 6-12months and a target cost saving of between 14% and 32%.

Figure 2. ACE Platform (Melbourne Museum) – A Typical Expense Breakdown *
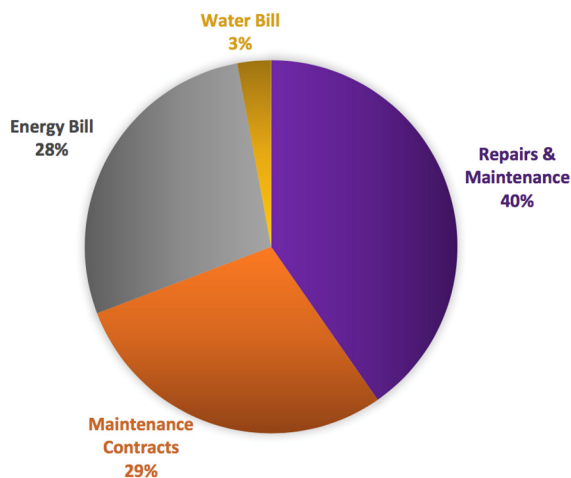
* Based on financial data sourced from Annual Financial Reports for three Australian companies, spanning 2014-2017.

Features

The ACE Platform's Application
Users of the ACE Platform typically have one driver in common, namely: getting *more* out of their existing systems and assets for *less* cost. This market-led mantra has seen the ACE Platform being used to resolve the following twelve common pain-points in property management:

1. Energy Optimisation (at pump, fan & valve level)
2. Preventative Maintenance Planning
3. Defects Liability Protection & Reporting (DLP)
4. Monthly Contractor Performance Reporting
5. NABERS Uplift & Protection
6. Hot & Cold Tenant Complaint Optimisation
7. Asset-level OPEX & CAPEX Forecasting (1-3yrs)
8. Streamlining Maintenance Contracts
9. New Asset Commissioning Validation
10. 24/7 BMS Performance Reporting
11. Asset Lifecycle & Criticality Reporting
12. Energy & Asset Sustainability Reporting

To date, the ACE Platform has been used on: commercial office-towers, universities, museums, galleries, aircraft hangars, casinos, hotels, shopping centres, state and federal government assets, printing presses, prisons, research facilities, large sports clubs, schools and large banks.

A Quick End-to-End Overview
The ACE Platform continuously sifts through massive stores of data, measuring temperatures, pressures, flows, set points, and control commands, amongst other things. The platform gathers a few thousand data points every five minutes, which is a finer level of granularity than meter-level analytics software. Once the ACE Platform registers an asset-level performance deterioration, the machine learning logic then: (1) diagnoses the precise root cause, (2) designs the required solution, and (3) quantifies the $ impact on the energy bill.

Company Ethos No. 1: Preventative, not Reactive
By streaming real-time building performance data across energy and maintenance practises, anytime an asset moves even slightly away from its optimal performance-level, the ACE Platform registers the performance deterioration.

Users of the ACE Platform are therefore empowered to drive a preventative maintenance agenda across their buildings, instead of the customary and reactive fix-on-fail programmes, which typically cost three-times more. Furthermore, tenant hot & cold complaints, *which account for approx. 60% of all complaints,* typically reduce to <5%.

Company Ethos No. 2: More for Less
For many years now, industry has been supplied with solutions offering paybacks around two-to-three-years. As technology improves, so too should payback periods.

Today, the average payback of an ACE Platform user is 5.7 months, with savings ranging from 14% (lowest) to 32% (highest). This step-change in payback and return-on-investment is enabled by removing the need to install multiple new hardware devices on-site to obtain data, e.g. sub-meters.

CIM Enviro has consolidated its data acquisition capability down into one mobile phone-sized device, which takes less than 5seconds to install, and uses a building's existing network of sensors and controllers to obtain the required data.

Contact

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E: tom.ray@cimenviro.com | **P:** +61 (0) 406 761 702

Case Study Project: Melbourne Museum

Location:	Melbourne, VIC
Asset Type:	Cultural Institution
Sector:	Public
Objectives:	• New BMS Commissioning Validation • Energy Savings
Key Outcomes:	• $203,000 reduction on energy bill • $35,000 saving from resetting demand threshold • 20% Electricity Reduction (kWh) • 13% Demand Reduction (kVA) • 28% Gas Reduction (GJ) • 117 BMS and Mechanical-Asset Faults Identified

Case Study Overview

Covering 70,000m^2, Melbourne Museum is the largest museum in the southern hemisphere. Year-on-year, the museum consistently ranks as one of the top tourist destinations in Australia, with an annual footfall of almost one million visitors. In 2016, the museum invested heavily in a new BMS to help meet the ever-evolving demands of managing a complex public asset that houses sensitive cultural installations.

All too often, the assets and systems building owners inherit are not to the standard they paid for. With this in mind, and combined with a commitment to ensuring maximum value-for-taxpayer-money, the museum employed independent technology provider CIM Enviro, to continuously monitor and validate the real-time commissioning of their new BMS. Using an independent set of real-time 'digital eyes-and-ears' throughout Defects Liability Period (DLP), the museum has been provided with real-time data-driven assurance that the asset they will inherit from their BMS contractor in a few months will be fully optimised and free of defects.

Over the last nine months, CIM Enviro's technology, the ACE Platform, has identified 117 BMS and mechanical-asset faults across the estate, which would have otherwise gone unnoticed and been loaded onto the museum, post DLP, as additional risk. Resolving these 117 issues has the museum on course to reduce their annual energy bill by $203,000 this year, *a 20% reduction on electricity and 28% on gas,* in addition to a $35,000 saving from resetting their demand threshold, *a 13% reduction.*

All this was achieved for a 4-and-a-half-month payback, which represents a 300%-to-400% step-change from many existing industry practises. In a time when asset owners and operators are required to deliver *more for less*, CIM Enviro has provided the answer, in the form of advanced machine learning and continuous data analytics to optimise total building performance.

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 17

ACE Platform (Melbourne Museum) – Top 5 Issues Identified

Summary of Top 5 Issues Identified

Table 2. ACE Platform (Melbourne Museum) - Summary of Top 5 Issues Identified

ID / Rule Name	Equipment	Rule Description	Solution	Benefit	Energy Savings (kWh)	Cost Savings ($)
AHU00013 Supply Air Temperature Poor Control-(Monitoring Chilled And Hot Water Valves)	AHU-4-10	The alarm is generated since AHU's supply air temperature is not within +/-1°C of the supply air temperature set-point when AHU is operating.	1. Check and calibrate the supply air temperature sensor. 2. Check for valves' leakages. 3. Check the CHWV and HWV control strategy. 4. Check the chilled water leaving temperature and it's set-point.	Energy & Thermal Comfort	82,579	$1,274
VAV0008-1 Low Air Flow w/Damper not open fully	VAV-622	This alarm is generated when the VAV airflow is below the desired airflow by 20l/s or more and the damper is not fully open	1. Check and calibrate air flow sensors. 2. Check the operation of the dampers. 3. Check the control strategy.	Thermal Comfort	N/A	N/A
VAV0008-2 High Air Flow w/Damper not fully shut	FAVAV-219	This alarm is generated when the VAV airflow is above the desired airflow by 20l/s or more and the damper is not fully closed	1. Check and calibrate air flow sensors. 2. Check the operation of the dampers. 3. Check the control strategy.	Energy	6,320	$1,264
AHU00011-3 Economy Cycle To Be Enabled-3	FCU-2-01	Economy Cycle should be enabled when all of the following conditions are met: 1. The supply fan is enabled and status is being received. 2. RA enthalpy - OA Enthalpy > 2 kJ/kg 3. Cooling is required and chilled water valve is open.	1. Check and calibrate the return and outside air temperature and relative humidity sensors. 2. Check the economy cycle control strategy 3. Check how the enthalpies are calculated	Energy	22,293	$4,458
AHU00016-1 Chilled Water Valve Leakage	AHU-1-03	Air handling unit supply air temperature is lower than return air temperature by more than 2°C, however all the outside air dampers and chilled water valve are closed and air handling unit supply fan is operating.	1. Check and calibrate the supply and return air temperature sensors 2. Check for chilled water valve leakage. 3. Check for outside air damper leakage.	Energy	12,752	$2,550

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 18

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Issue: AHU00013 - Supply Air Temperature Poor Control

Figure 3. ACE Platform (Melbourne Museum) – Issue ID: AHU000013

Issue: VAV0008-1 - Low Air Flow w/Damper not open fully

Figure 4. ACE Platform (Melbourne Museum) – Issue ID: VAV0008-1

FDD Rules Engine APP 2:42 PM
Alert evaluated at 2017-07-26 2:42:39 PM
VAV0008-1
This alarm is generated when the VAV airflow is below the desired airflow by 20l/s or more and the damper is not fully open

Solutions:
1. Check and calibrate the airflow sensors.
2. Check the operation of the dampers.
3. Check the control strategy.

Melbourne Museum
Missing - Evaluated Description
VAV-622-70622
   Equipment id: 165356241108, Site: Melbourne Museum
   Variable Air Volume Current Air Flow = 507.68 l/s
      fav_id: 165356243458   2017-07-26 14:30:44 (Australia/Melbourne)
   Variable Air Volume Desired Airflow = 540 l/s
      fav_id: 165356243459   2017-07-26 14:30:44 (Australia/Melbourne)
   Variable Air Volume Damper Position = 57.23 %
      fav_id: 165356243462   2017-07-26 14:30:44 (Australia/Melbourne)
Monitor Task #4027   VAV0008-1   Rules Wiki

Data Point History Graph
-24hrs/+24hrs (81kB) ▼
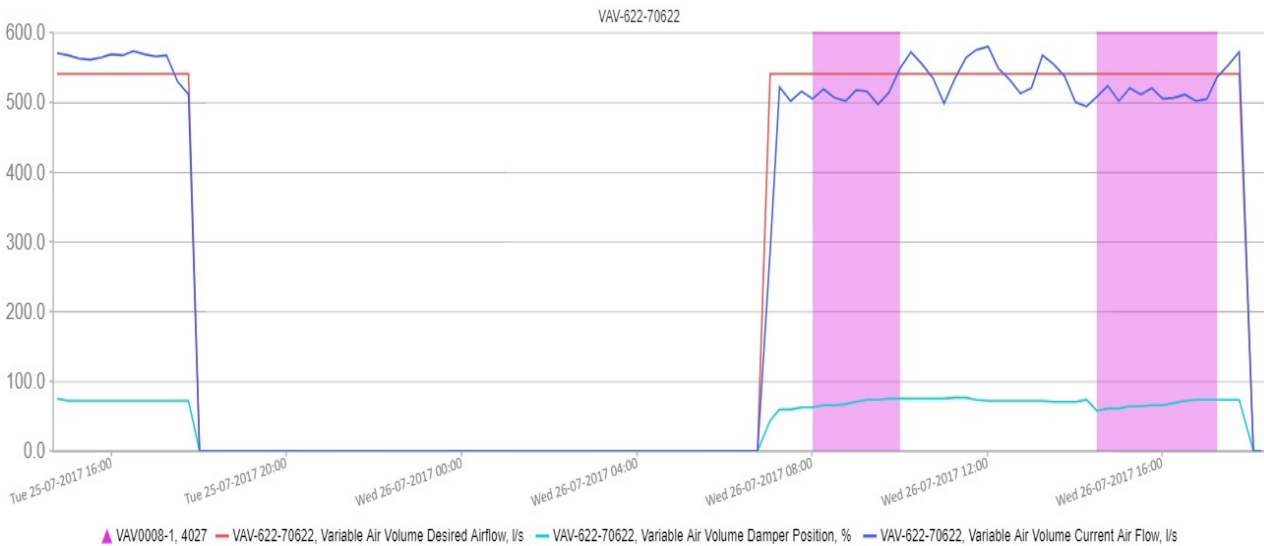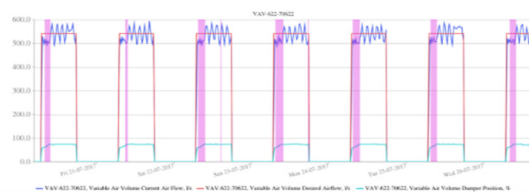
Issue: VAV0008-2 - High Air Flow w/Damper not fully shut

Figure 5. ACE Platform (Melbourne Museum) – Issue ID: VAV0008-2

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial
Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 21
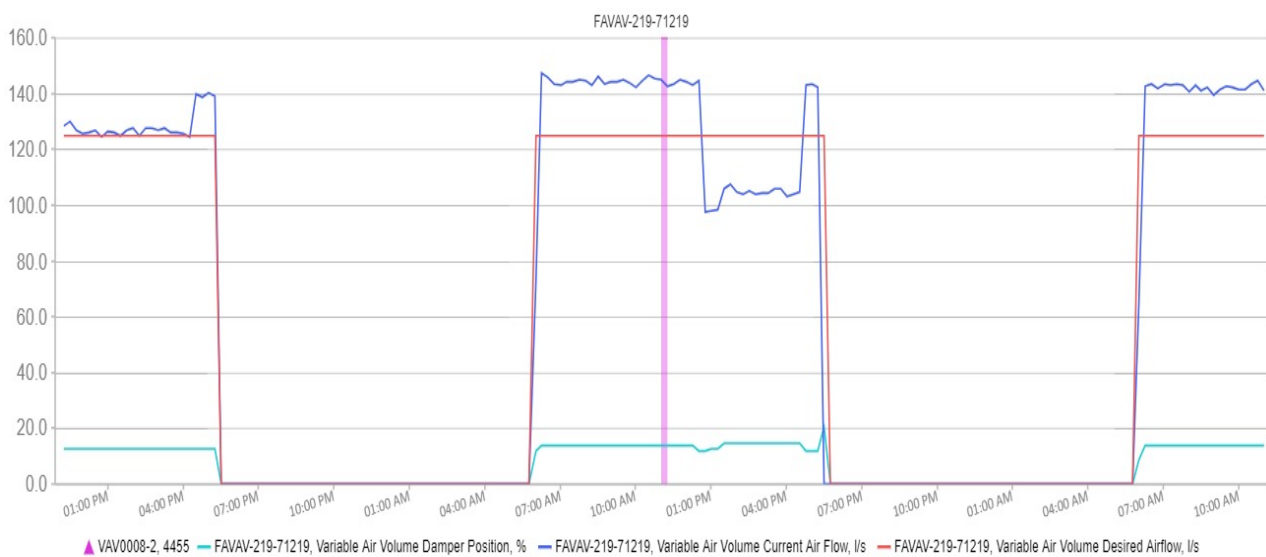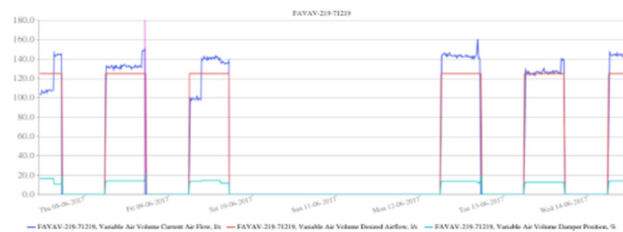
Issue: AHU00011-3 - Economy Cycle To Be Enabled-3

Figure 6. ACE Platform (Melbourne Museum) – Issue ID: AHU00011-3

Alert evaluated at 2017-07-27 1:48:41 PM
AHU00011-3
Economy Cycle should be enabled when all of the following conditions are met,

1. The supply fan is enabled and status is being received.
2. RA enthalpy - OA Enthalpy > 2 kJ/kg
3. Cooling is required and chilled water valve is open.

Solution:
1. Check and calibrate the return and outside air temperature and relative humidity sensors.
2. Check the economy cycle control strategy
3. Check how the enthalpies are calculated

Melbourne Museum
.
FCU-2-01-2098308
   Equipment id: 165356241014, Site: Melbourne Museum
  Unit Chilled Water Valve Position = 5.46 %
    fav_id: 165356242584 2017-07-27 13:46:13 (Australia/Melbourne)
  Unit Outside Air Damper Position = 1 %
    fav_id: 165356242592 2017-07-27 13:46:14 (Australia/Melbourne)
  Unit Return Air Enthalpy = 37.88 kJ/kg
    fav_id: 165356242591 2017-07-27 13:46:14 (Australia/Melbourne)
  Unit Supply Air Fan Enable = 1 On/Off
    fav_id: 165356242586 2017-07-27 13:46:13 (Australia/Melbourne)
  Unit Supply Air Fan Status = 1 On/Off
    fav_id: 165356242587 2017-07-27 13:46:13 (Australia/Melbourne)

AHU-COMMON-SIGNALS
   Equipment id: 165356240934, Site: Melbourne Museum
  Unit Outside Air Enthalpy = 28.25 kJ/kg
    fav_id: 165356241492 2017-07-27 13:46:19 (Australia/Melbourne)

Monitor Task #4351   AHU00011-3   Rules Wiki
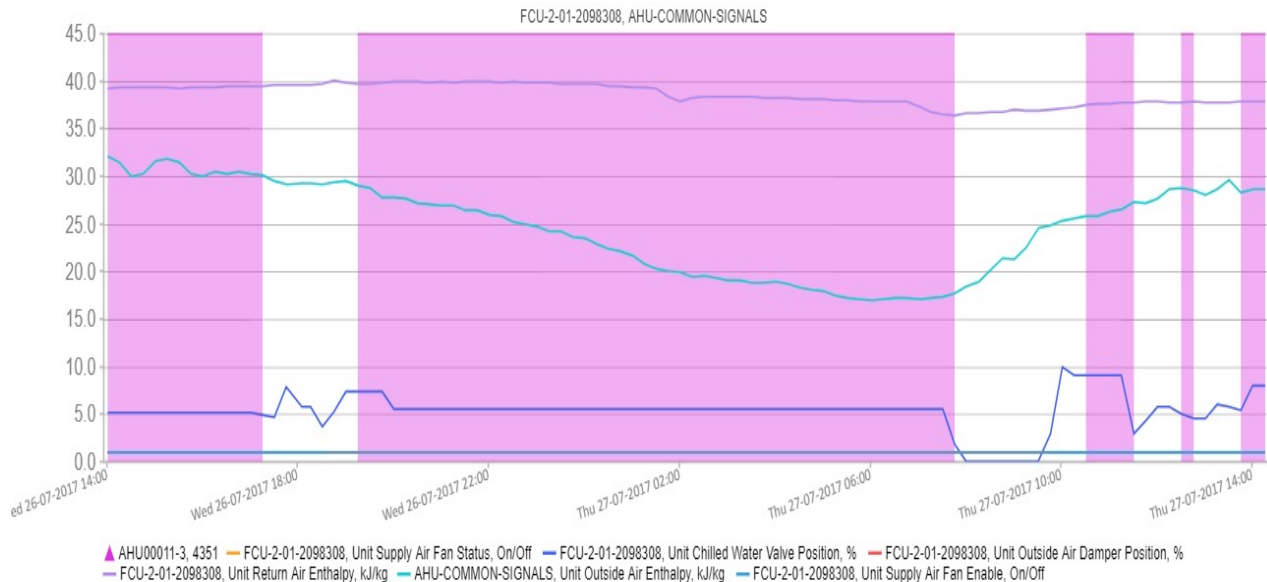
Issue: AHU00016-1 - Chilled Water Valve Leakage

Figure 7. ACE Platform (Melbourne Museum) – Issue ID: AHU00016-1

FDD Rules Engine APP 3:36 PM
Alert evaluated at 2017-07-26 3:36:49 PM
AHU00016-1

Air handling unit supply air temperature is lower than return air temperature by more than 2°C, however all the outside air dampers and chilled water valve are closed and air handling unit supply fan is operating.

Solution:

1. Check and calibrate the supply and return air temperature sensors
2. Check for chilled water valve leakage.
3. Check for outside air damper leakage.

Melbourne Museum

.

AHU-1-03-2098308

Equipment id: 165356240904, Site: Melbourne Museum

Unit Chilled Water Valve Position = 0 %
  fav_id: 165356240913   2017-07-26 15:31:15 (Australia/Melbourne)
Unit Outside Air Damper Position = 0 %
  fav_id: 165356240915   2017-07-26 15:31:15 (Australia/Melbourne)
Unit Return Air Temperature = 20.98 °C
  fav_id: 165356240909   2017-07-26 15:31:15 (Australia/Melbourne)
Unit Supply Air Fan Enable = 1 On/Off
  fav_id: 165356241024   2017-07-26 15:31:16 (Australia/Melbourne)
Unit Supply Air Fan Status = 1 On/Off
  fav_id: 165356240929   2017-07-26 15:31:15 (Australia/Melbourne)
Unit Supply Air Temperature = 17.51 °C
  fav_id: 165356240918   2017-07-26 15:31:15 (Australia/Melbourne)
Unit Minimum Outside Air Damper Position = 0 %
  fav_id: 165356240914   2017-07-26 15:31:15 (Australia/Melbourne)

Monitor Task #3116   AHU00016-1   Rules Wiki
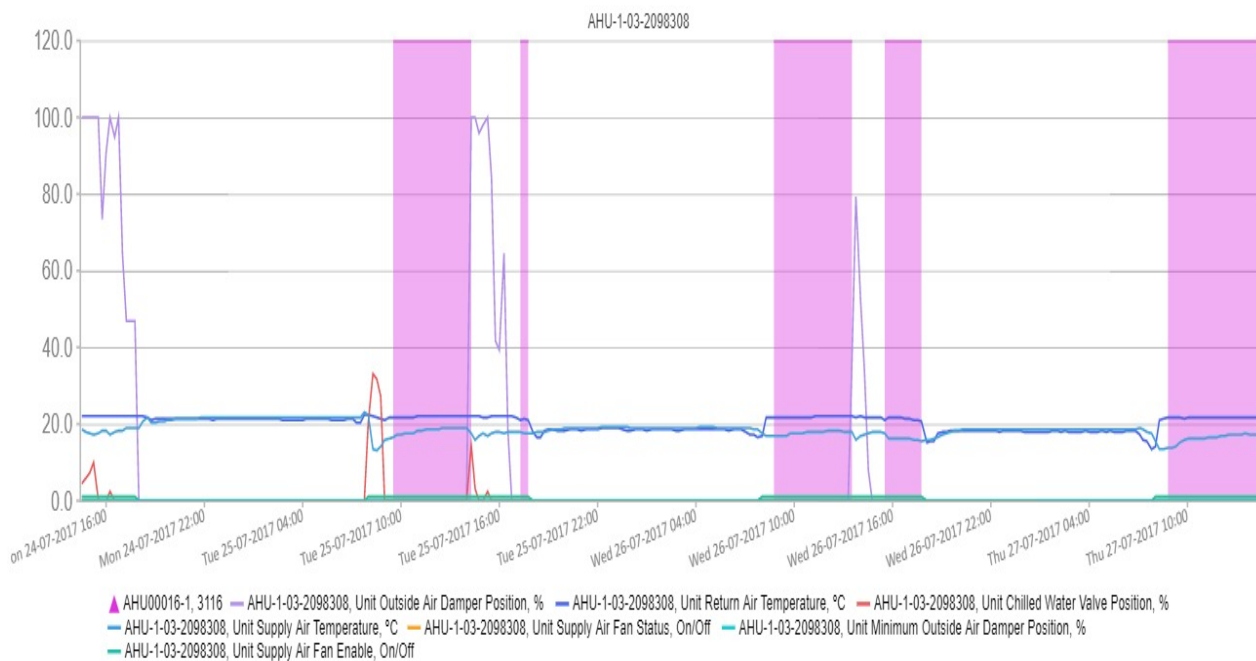
ACE Platform (Melbourne Museum) – Demonstration of Outcomes

Annual Energy Summary

Table 3. ACE Platform (Melbourne Museum) – Annual Energy Summary

Time Period	Electricity Saving (kWh)	Electricity Saving (%)	Demand Saving (kVA)	Demand Saving (%)	Gas Saving (GJ)	Gas Saving (%)	Cost Savings ($)
July 2016 to July 2017	1,190,080	19.9%	4,128	13%	19,561	27.66%	$203,471

Note: All savings numbers presented in this case study have been verified by the client (i.e. building owner and/or facility manger).

END OF CASE STUDY

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 24

Case study Project: 99 Elizabeth Street

Location:	Sydney, NSW
Asset Type:	A-Grade Commercial Office Tower
Sector:	Private
Objectives:	• NABERS Improvements • Tenant Complaint Reductions
Key Outcomes:	• 1.5stars to 5stars in 24 months for $48,000 OPEX, no CAPEX. • Reduced tenant temperature complaints to less than 5%.

Case Study Overview

Approximately 24 months ago, Kyko Group (landlord) set CBRE (operator) a target of achieving a 4.0 NABERS star rating on one of their A-grade commercial offices. Typically, a six half-star jump requires significant Capex investment. With continual and rapid step-changes in data analytics, CBRE went to market in search of a smarter way of getting 'more for less' for their client, Kyko Group.

After 24 months and, in partnership with CIM Enviro, CBRE have not only exceeded their 4.0-star target, by achieving 5.0 NABERS stars, they're actually on track to reach 5.5 stars next year. Using CIM Enviro, CBRE have achieved a seven half-star jump and a 13% gas reduction for $48,000 OPEX, but most impressively, for no CAPEX expenditure.

Furthermore, tenant comfort complaints have reduced to less than 5%, as CIM Enviro's solution (the ACE Platform) preventatively targets potential hot and cold complaints, which typically account for 60% of all tenant complaints in a commercial office. In total, 69 building performance faults were identified and resolved, 52 BMS faults and 17 relating to large equipment lifecycle issues.

Together, Kyko Group, CBRE and CIM Enviro have demonstrated the benefit of collaborating with new machine learning technology, in pursuit of getting 'more for less' for FMs and their landlords.

ACE Platform (99 Elizabeth Street) – Top 5 Issues Identified

Summary of Top 5 Issues Identified

Table 4. ACE Platform (99 Elizabeth Street) - Summary of Top 5 Issues Identified

ID / Rule Name	Equipment	Rule Description	Solution	Benefit	Energy Savings (kWh)
AHU0001 Mismatch Alarm	AHU-N-8	The alarm is generated when the status feedback does not correspond with the output command status for longer than a defined time delay period.	1. Check the status switch. 2. Check and ensure that AHU's fan is not manually overridden.	Energy	71.5
AHU0007-1 High CO_2 parts per million (ppm)- MOAD	AHU-N-3	Return CO_2 level is higher than CO_2 set-point (e.g. 800 ppm) and main outside air damper is not fully open.	1. Check and calibrate the CO_2 sensor. 2. Check the operation of the main outside air damper. 3. Check the control strategy and tune the PI loop.	Air Quality	N/A
AHU0008-1 Low Supply Air Static Pressure	AHU-N-13	Air handling unit supply air static pressure is not tracking the supply air static pressure set-point and it is continuously lower than the set-point by at least 20 Pa when the air handling supply air fan is operating.	1. Check and ensure that fan is operating at it's maximum speed and is not manually overridden. 2. Check and calibrate the static air pressure sensor. 3. Check and ensure that the fan belt is not loose or is not dislocated. 4. Check and ensure that the current static air pressure set-point matches the design or commission value obtained based on the spaces' air flow requirements. 5. Check and ensure that the fan is not undersized for the current required static air pressure set-point.	Thermal Comfort	N/A
AHU0008-2 High Supply Air Static Pressure	AHU-C-1	Air handling unit supply air static pressure is not tracking the supply air static pressure set-point and it is continuously higher than the set-point by at least 20 Pa when the air handling supply air fan is operating.	1. Check and ensure the fan is not operating at it's maximum speed and is not manually overridden. 2. Check and calibrate the static air pressure sensor. 3. Check and ensure that the current static air pressure set-point matches the design/commissioning value obtained based on the spaces' air flow requirements. 4. Check and ensure that the fan is not oversized for the current required static air pressure set-point.	Energy	77.9
AHU00013-WLT Supply Air Temperature Poor Control (with reference to CHWLT & HWLT)	AHU-N-13	The alarm is generated since AHU's supply air temperature is not within +/- 1°C of the supply air temperature set-point when AHU is operating.	1. Check and calibrate the supply air temperature sensor. 2. Check the operation of the chilled and hot water valves. 3. Check the CHWV and HWV control strategy. 4. Check the chilled water or hot water leaving temperature and their set-points.	Energy & Thermal Comfort	23,120

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 26

ACE Platform (99 Elizabeth Street) – Technical Deep-Dive into Top 5 Issues Identified

Issue: AHU0001 – Mismatch Alarm

Figure 8. ACE Platform (99 Elizabeth Street) – Issue ID: AHU0001

Alert evaluated at 2017-05-27 6:33:35 PM
AHU0001
The alarm is generated when the status feedback does not correspond with the output command status for longer than a defined time delay period.

Solution:
1. Check the status switch.
2. Check and ensure that AHU's fan is not manually overridden.

99 Elizabeth St
AHU Supply Air Fan Feedback: 1 Does Not Match AHU Supply Air Fan Command: 0
AHU-N-8
   Equipment id: 122406567960, Site: 99 Elizabeth St
   Unit Supply Air Fan Enable = 0 On/Off
    fav_id: 122406568352   2017-05-27 18:16:30 (Australia/Sydney)
   Unit Supply Air Fan Status = 1 On/Off
    fav_id: 122406568353   2017-05-27 18:16:30 (Australia/Sydney)
Monitor Task #4650   AHU0001   Rules Wiki

Legend: ▲ AHU0001, 4650 — AHU-N-8, Unit Supply Air Fan Status, On/Off — AHU-N-8, Unit Supply Air Fan Enable, On/Off

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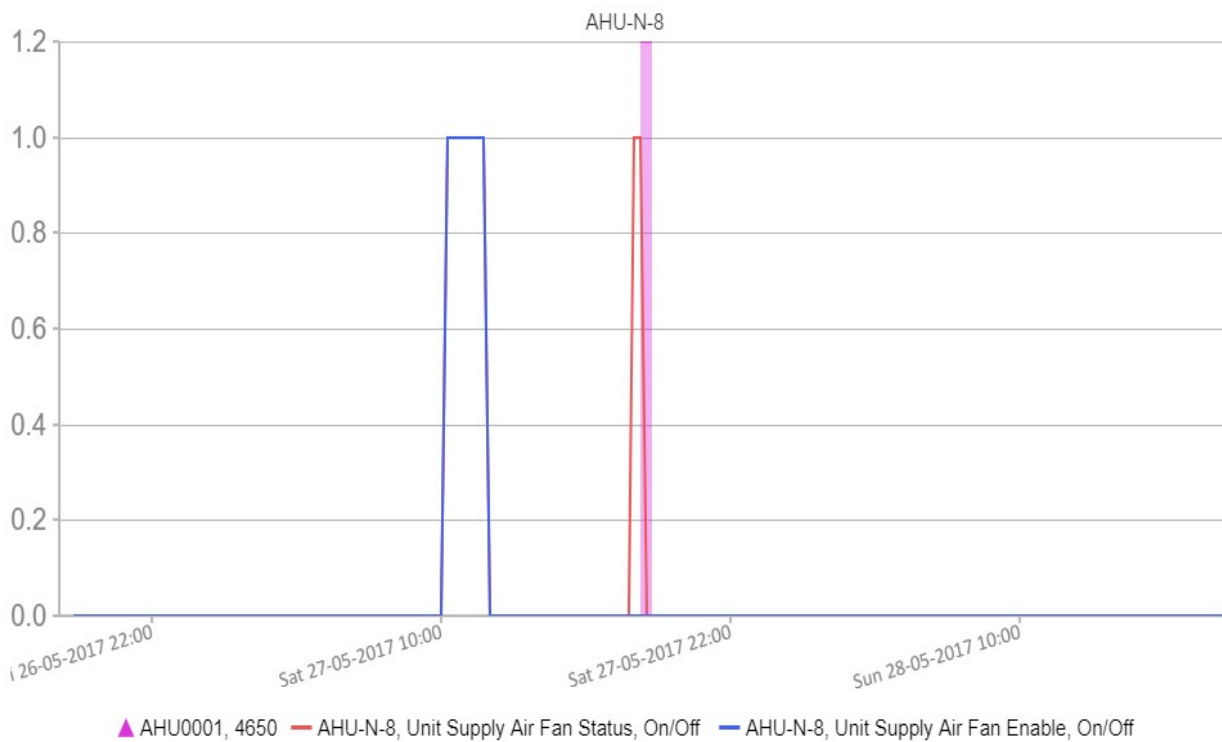
Issue: AHU0007-1 – High CO_2 parts per million (ppm)-MOAD

Figure 9. ACE Platform (99 Elizabeth Street) – Issue ID: AHU0007-1

Alert evaluated at 2017-07-03 12:13:05 PM
AHU0007-1
Return Co2 portion is higher than the setpoint and the outside air damper is not still fully open.

Solution:
1. Check and calibrate the Co2 sensor.
2. Check the operation of the outside air damper.
3. Check the control strategy.

99 Elizabeth St
Missing - Evaluated Description
AHU-N-3
   Equipment id: 122406567945, Site: 99 Elizabeth St
  Unit Outside Air Damper Position = 35.03 %
    fav_id: 122406568131   2017-07-03 12:00:34 (Australia/Sydney)
  Unit Return Air Co2 = 870.11 PPM
    fav_id: 122406568139   2017-07-03 12:00:35 (Australia/Sydney)
  Unit Return Air Co2 Setpoint = 800 PPM
    fav_id: 122406568138   2017-07-03 12:00:35 (Australia/Sydney)
  Unit Supply Air Fan Status = 1 On/Off
    fav_id: 122406568128   2017-07-03 12:00:34 (Australia/Sydney)

Monitor Task #3373   AHU0007-1   Rules Wiki

Data Point History Graph
-24hrs/+24hrs (66kB) ▼
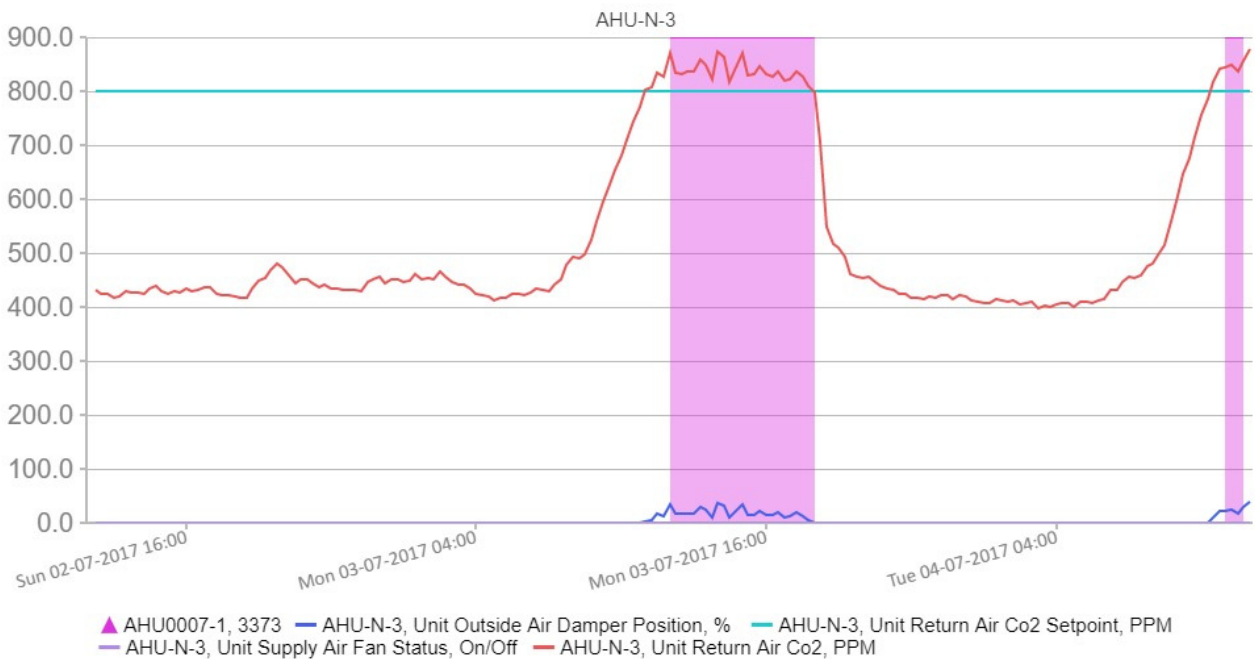
Issue: AHU0008-1 - Low Supply Air Static Pressure

Figure 10. ACE Platform (99 Elizabeth Street) – Issue ID AHU0008-1

Alert evaluated at 2017-05-16 10:10:31 AM
AHU0008-1
Air handling unit supply air static pressure is not tracking the supply air static pressure setpoint when the air handling is On.

Solutions:
1. Check and ensure that fan is operating at it's maximum speed and is not manually overridden.
2. Check and calibrate the static air pressure sensor.
3. Check and ensure that the fan belt is not loose or is not dislocated.
4. Check and ensure that the current static air pressure setpoint matches the design/commissioning value obtained based on the spaces' air flow requirements.
5. Check and ensure that the fan is not undersized for the current required static air pressure setpoint.

99 Elizabeth St
Missing - Evaluated Description
AHU-N-13
  Equipment id: 122406567975, Site: 99 Elizabeth St
  Unit Supply Air Fan Enable = 1 On/Off
    fav_id: 122406568578   2017-05-16 10:05:33 (Australia/Sydney)
  Unit Supply Air Fan Speed = 100 %
    fav_id: 122406568580   2017-05-16 10:05:33 (Australia/Sydney)
  Unit Supply Air Fan Status = 1 On/Off
    fav_id: 122406568579   2017-05-16 10:05:33 (Australia/Sydney)
  Unit Static Air Pressure = 133.44 Pa
    fav_id: 122406568587   2017-05-16 10:05:33 (Australia/Sydney)
  Unit Static Air Pressure Setpoint = 170 Pa
    fav_id: 122406570743   2017-05-16 10:05:35 (Australia/Sydney)
Monitor Task #3318   AHU0008-1   Rules Wiki
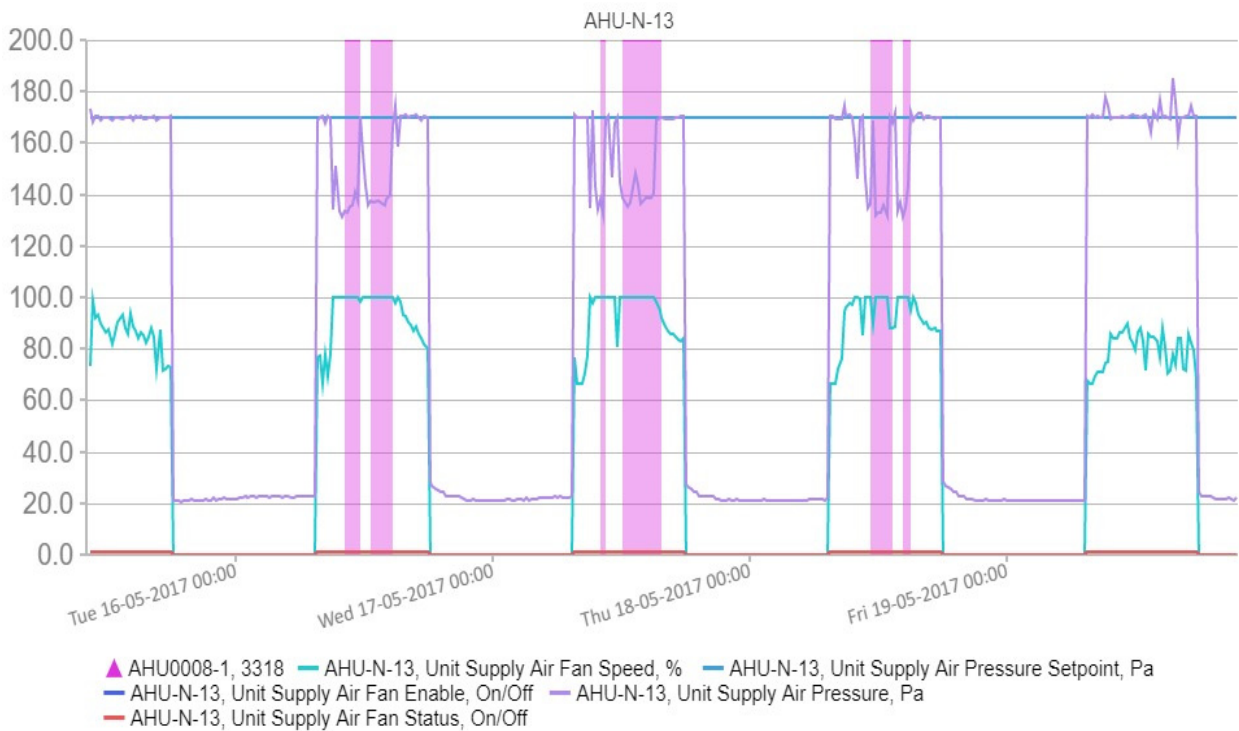
Issue: AHU0008-2 - High Supply Air Static Pressure

Figure 11. ACE Platform (99 Elizabeth Street) – Issue ID: AHU0008-2

AHU-C-1

▲ AHU0008-2, 3322 — AHU-C-1, Unit Supply Air Pressure Setpoint, Pa — AHU-C-1, Unit Supply Air Fan Enable, On/Off — AHU-C-1, Unit Supply Air Fan Status, On/Off — AHU-C-1, Unit Supply Air Pressure, Pa — AHU-C-1, Unit Supply Air Fan Speed, %

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Issue: AHU00013-WLT - Supply Air Temperature Poor Control

Figure 12. ACE Platform (99 Elizabeth Street) – Issue ID: AHU00013-WLT

FDD Rules Engine APP 5:54 PM
Alert evaluated at 2017-06-01 5:53:57 PM

AHU00013-WLT

The alarm is generated since AHU's supply air temperature is not within +/-1°C of the supply air temperature set-point when AHU is operating.

Solutions:

1. Check and calibrate the supply air temperature sensor.
2. Check the operation of the chilled and hot water valves.
3. Check the CHWV and HWV control strategy.
4. Check the chilled water or hot water leaving temperature and their set-points.

99 Elizabeth St
.

AHU-N-13
   Equipment id: 122406567975, Site: 99 Elizabeth St
   Unit Chilled Water Valve Position = 0 %
     fav_id: 122406568576 2017-06-01 17:47:39 (Australia/Sydney)
   Unit Hot Water Valve Position = 100 %
     fav_id: 122406568577 2017-06-01 17:47:39 (Australia/Sydney)
   **Unit Supply Air Fan Enable = 1 On/Off**
     fav_id: 122406568578 2017-06-01 17:47:39 (Australia/Sydney)
   Unit Supply Air Fan Status = 1 On/Off
     fav_id: 122406568579 2017-06-01 17:47:39 (Australia/Sydney)
   Unit Supply Air Temperature = 21.30 °C
     fav_id: 122406568585 2017-06-01 17:47:40 (Australia/Sydney)
   Unit Supply Air Temperature Set Point = 22.50 °C
     fav_id: 122406568586 2017-06-01 17:47:40 (Australia/Sydney)

CHILLERS_COMMON_SIGNALS
   Equipment id: 122406568110, Site: 99 Elizabeth St
   Chilled Water Common Supply Temperature = 13.10 °C
     fav_id: 122406569838 2017-06-01 17:48:34 (Australia/Sydney)

HWB-COMMON-POINTS
   Equipment id: 122406568135, Site: 99 Elizabeth St
   Hot Water Common Leaving Temperature = 59.50 °C
     fav_id: 122406568031 2017-06-01 17:48:28 (Australia/Sydney)

HWB-COMMON-POINTS, AHU-N-13, CHILLERS_COMMON_SIGNALS

▲ AHU00013-WLT, 3102 — AHU-N-13, Unit Hot Water Valve Position, %
— HWB-COMMON-POINTS, Hot Water Common Leaving Temperature, °C — AHU-N-13, Unit Supply Air Temperature Set Point, °C
— AHU-N-13, Unit Chilled Water Valve Position, % — AHU-N-13, Unit Supply Air Fan Enable, On/Off
— CHILLERS_COMMON_SIGNALS, Chilled Water Common Supply Temperature, °C — AHU-N-13, Unit Supply Air Fan Status, On/Off
— AHU-N-13, Unit Supply Air Temperature, °C

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 31

ACE Platform (99 Elizabeth Street) - Demonstration of Outcomes

Annual Energy Summary

Table 5. ACE Platform (99 Elizabeth Street) - Annual Energy Summary [*]

Time Period	Electricity Saving (%)	Gas Saving (%)
July 2016 to July 2017	8.3%	13%

[*] Note: Reported reductions were achieved on top of occupancy increasing from 50% to 100%.

NABERS Rating

- Took building from 1.5 stars (indicative) to 5 stars (official rating) in 24 months, for $48,000 in OPEX, with no CAPEX.

- Our target was 4.5 stars.

Thermal Comfort Improvements

Reduced tenant hot & cold temperature-related complains to less than 5% (verified by client).

Note: All savings numbers presented in this case study have been verified by the client (i.e. building owner and/or facility manger).

<div align="center">END OF CASE STUDY</div>

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial
Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 32

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CopperTree Analytics

Beginning with your time, your people, and your finances, CopperTree Analytics aims to help you use your resources more efficiently

CopperTree's 'Kaizen' platform extracts the data from your Building Automation System, securely streams it to our Vault cloud servers, and then analyses it to provide you with a comprehensive picture of your building's energy use and system operations.

Kaizen gives you the tools you need to make the best decisions for increasing your building's energy efficiency whilst ensuring your building is operating at peak performance. Kaizen utilises a sophisticated analytics engine that helps detect faults within your building and monitors your BMS for changes in operation.

Kaizen also utilises KPI reporting to scorecard like systems for quick and easy comparison. KPI reporting is a powerful tool when searching for problem areas within your building, it allows you to focus in on and fix issues without wasting time investigating trouble free pieces of equipment.

The advanced metering facility housed in Kaizen covers all key traditional utilities such as water, gas and electricity, plus renewables such as solar and wind energy, it enables the user to track and monitor consumption.

Features

- AFD (Automated Fault Detection) - AFD provides a simple way for you to see your buildings operation. Continuous monitoring and analysis of your building's systems is performed and insights are sent to the user. The Kaizen Insight Log tells staff where they should spend their time, which means less time diagnosing and more time fixing.

- Golden Standard – Kaizen's Golden Standard tool continuously monitors and reports on the state of every point in your BMS. When changes occur, an insight is generated and the user notified, this means commissioned values are retained and changes tracked.

- Logic Builder – Ability to create algorithms through our 'Logic Builder' using block coding. Block coding uses predefined code in 'blocks' that are dropped onto the screen and linked together, this creates a user-friendly coding platform that anyone can use.

- Community Library of Algorithms– CopperTree is big on shared knowledge, we have a community library of algorithms that have been created by users all around the world and uploaded to the cloud. The algorithms can be imported into your building and used or modified to suit your needs. There are currently over 1000 algorithms to choose from.

- Inbuilt EMS – Kaizen not only acts as an analytics platform but also an energy management platform. Kaizen energy view allows the user to setup and view consumption meters as well as having a suite of energy reports.

- Public API – Kaizens API allows easy integration to third party systems. Data from any system can be sent to Kaizen for analysis

- User friendly – Kaizen was developed in the field by people with over 30 years' experience. Our focus was to build a user-friendly platform that anyone could use without sacrificing functionality. From navigation to reporting and even algorithm creation the platform is intuitive and straight forward.

Contact

Chris Stamatis | Director

E: cps@cutree.com.au | **T**: 1300 812 048

Case study Project: Commercial Office Tower

Location:	Canberra ACT
Asset Type:	Commercial Office Tower
Sector:	Private
Objectives:	• Demonstrate the effectiveness of analytics on high performing buildings • Use analytics to drive maintenance and tuning activities
Key Outcomes:	• 15% reduction in total electricity consumption • 19% reduction in total gas consumption • Better thermal comfort conditions achieved through data driven maintenance

Case Study Overview

Our Kaizen analytics platform has been implemented at the commercial office tower pictured below since October 2015 and has formed an integral part of building tuning and maintenance. The building is a 12 story, 40,000 square meter premium grade office building located in the heart of Canberra.

When Kaizen was first installed it was tracking at a 5.7 star NABERS rating, Kaizen was installed to help drive maintenance outcomes and tuning activities. After 18 months of data driven maintenance and tuning the building is tracking at a 5.96 star NABERS rating. This correlates to an energy reduction of 15.6% or 188,000kWh and a gas saving of 19% or 850,000MJ.

Kaizen was utilised on an already high performing building to show the effects of targeted maintenance and tuning through analytics. It proves the value of analytics not only on underperforming buildings that are easy to achieve large saving, but on buildings that are of a high grade and efficiency.

LOW CARBON LIVING CRC

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 35

Coppertree Analytics (Commercial Office Tower) – Top 5 Issues Identified

Summary of Top 5 Issues Identified

Table 6. Coppertree Analytics (Commercial Office Tower) - Summary of Top 5 Issues Identified

System		Insight	Benefit	Water Savings (litres)	Energy Savings (kWh)
Main Water Meter		Out of hours water consumption has exceeded predicted target	A new strategy was put in place that saw the pumps start at different times and ramp up slowly to circulate the chemical. Based off insight frequency a potential yearly impact of 24,000 litres was avoided.	24,000	-
129 VAV Boxes		Minimum airflow setpoint incorrect causing over cooling	It was found that the zone temperature KPI index increased from 74% to 84%, that is 74% of VAV's were meeting zone temperature before the change and 84% after the change. It was also found that AHU fan energy reduced on average 40% after the change, that's a forecasted saving of 44,000kWh when compared the previous 12 months.	-	44,000
Boilers		Operating with a low temperature differential Operating for short periods while supply temperature is still high.	Tuning works took place leading into the winter period 2017 (March-April) and have helped reduce the building gas consumption by 58% on average when compared to last year.	-	-
VAVs		Low KPI Scores	In the early stages of data driven maintenance an overall VAV KPI score was used to target the worst performing VAV, this KPI combined airflow and temperature control parameters. VAV maintenance and tuning is an ongoing process and forms a part of the monthly maintenance.	-	Contributed to overall 15% reduction in total electricity consumption
AHUs		Low KPI Scores	Early on it was flagged that the AHUs weren't controlling to pressure and temperature setpoints as closely as they should. Over the last 18 months all AHU's have been tuned to better control pressure and temperature while lowering energy consumption in the process. KPI reports form an integral part of maintenance and tuning as they show clearly if tuning has negatively impacted control or where problem areas lie so maintenance can be targeted.	-	Contributed to overall 15% reduction in total electricity consumption

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 36

Coppertree Analytics (Commercial Office Tower) – Technical Deep-Dive into Top 5 Issues Identified

Issue: Main Water Meter

INSIGHT: Out of hours water consumption has exceeded predicted target

DATE: 20/11, 26/11, 27/11, 30/11, 1/12, 2/12 in 2015

Excessive out of hours water consumption was detected in late 2015, as can be seen below there is roughly 2m³ (2000 litres) of water consumed at 2am. An algorithm was created to see what equipment was operational between 2-3am on the days the fault occurred, and it found that several pumps where operational on the days that the insight occurred. After talking with the facility manager, it was found a chemical dosing control strategy had been implemented which saw all condenser water pumps start to circulate the chemical. All pumps were starting at once which was causing the cooling tower sumps to be sucked dry and topped up, when the pumps stopped the excess water would spill to the overflow line. A new strategy was put in place that saw the pumps start at different times and ramp up slowly to circulate the chemical. Based off insight frequency a potential yearly impact of 24,000 litres was avoided.

Figure 13. Coppertree Analytics (Commercial Office Tower) – Issue: Main Water Meter
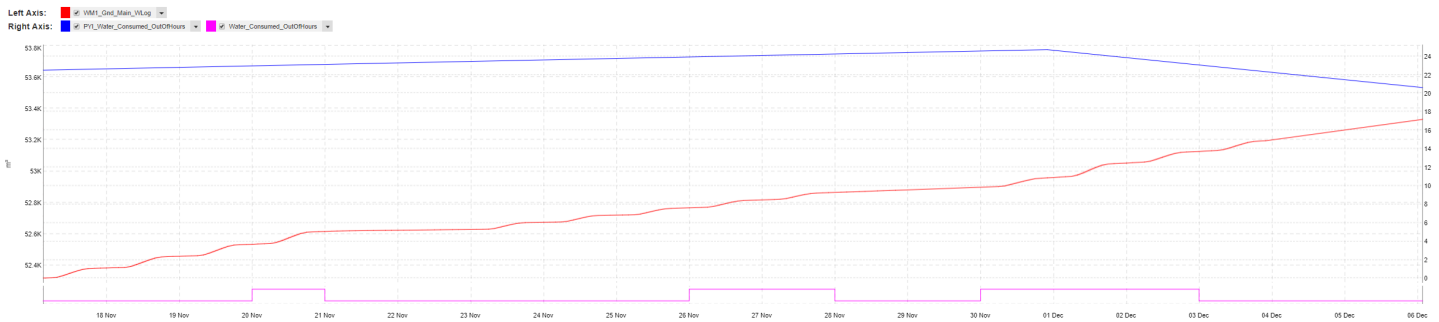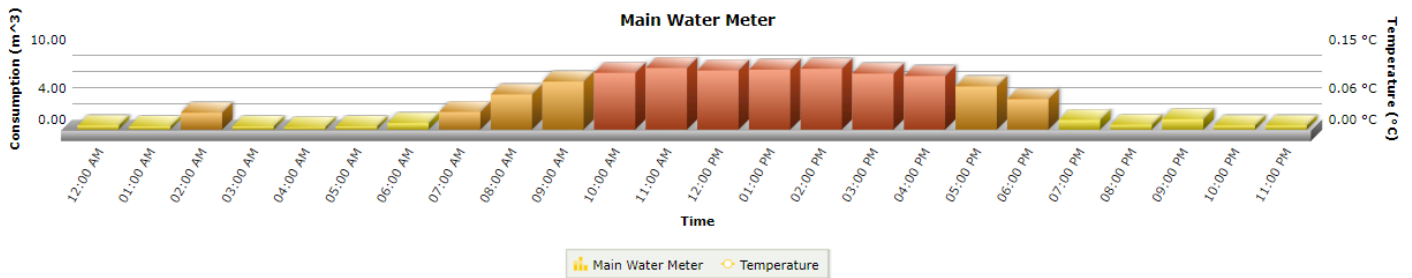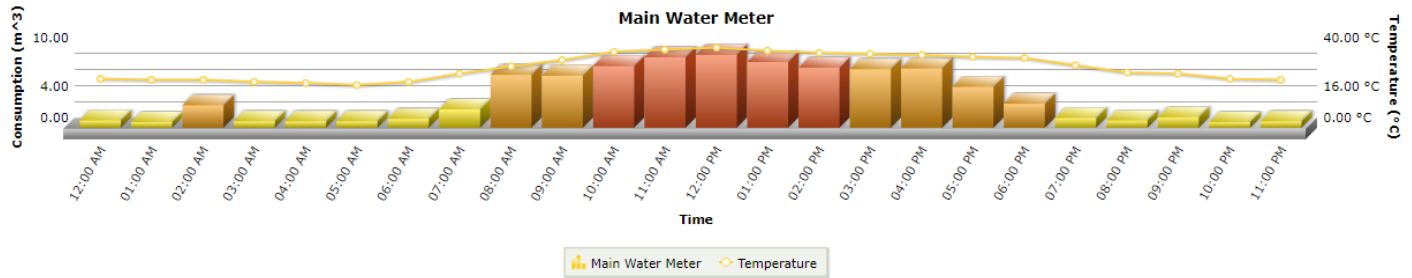
Issue: 129 VAV Boxes

INSIGHT: Minimum airflow setpoint incorrect causing over cooling

DATE: Scattered

A revised algorithm set was uploaded in September 2016 to find VAV boxes that where overcooling due to the minimum airflow setpoint being too high. It was found that 129 VAV boxes where overcooling and could have their minimum airflow setpoint dropped. The minimum airflow setpoints were adjusted to 30% of maximum (50l/s was absolute minimum) across the board to lower the effects of overcooling and lower AHU fan speeds to save energy.

Thermal comfort was important and VAV zone temperature KPI's were monitored and used very closely to determine if the changes had a negative effect. It was found that the zone temperature KPI index increased from 74% to 84%, that is 74% of VAV's were meeting zone temperature before the change and 84% after the change. It was also found that AHU fan energy reduced on average 40% after the change, that's a forecasted saving of 44,000kWh when compared the previous 12 months.

Figure 14. Coppertree Analytics (Commercial Office Tower) – Issue: 129 VAV Boxes
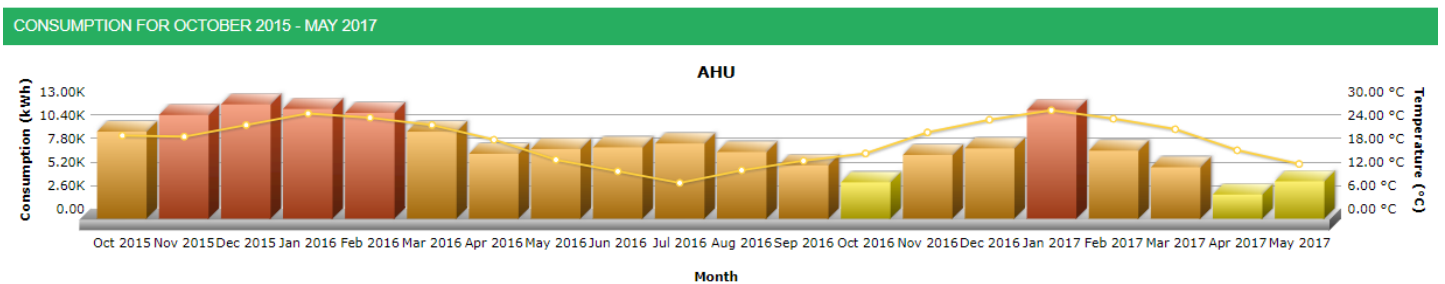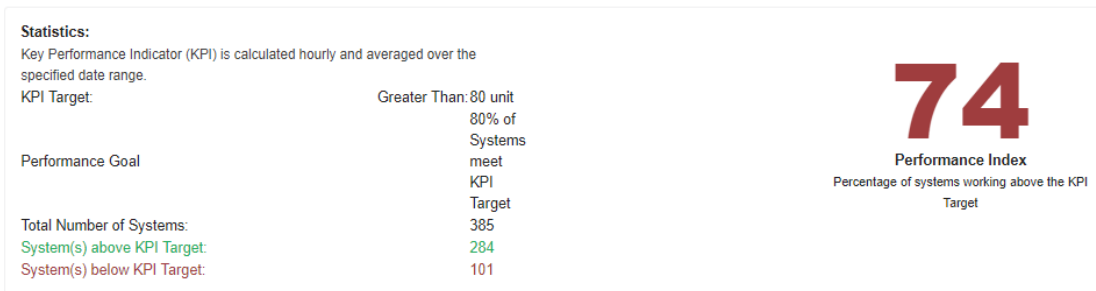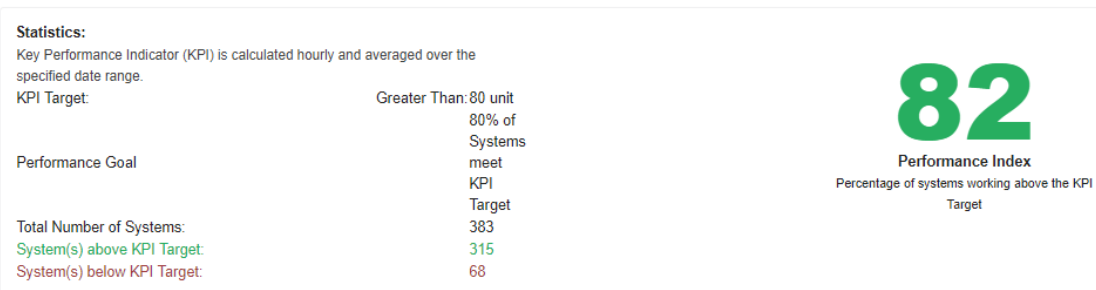
Issue: Boilers

INSIGHT:

Operating with a low temperature differential

Operating for short periods while supply temperature is still high.

DATE: Scattered through 2016 and early 2017

Boiler tuning works were commenced early 2017 due to multiple insights indicating unnecessary operation. The boilers looked to operate in times of low building load causing a very low temperature differential across the boiler (lower than 3 degrees for longer than 1 hour a day). An insight was also generated due to very short periods of operation with a high supply temperature to begin with, indicating that the boiler start delay could be extended to allow the thermal inertia in the hot water system to satisfy the low load.

These tuning works took place leading into the winter period 2017 (March-April) and have helped reduce the building gas consumption by 58% on average when compared to last year.

Figure 15. Coppertree Analytics (Commercial Office Tower) – Issue: Boilers
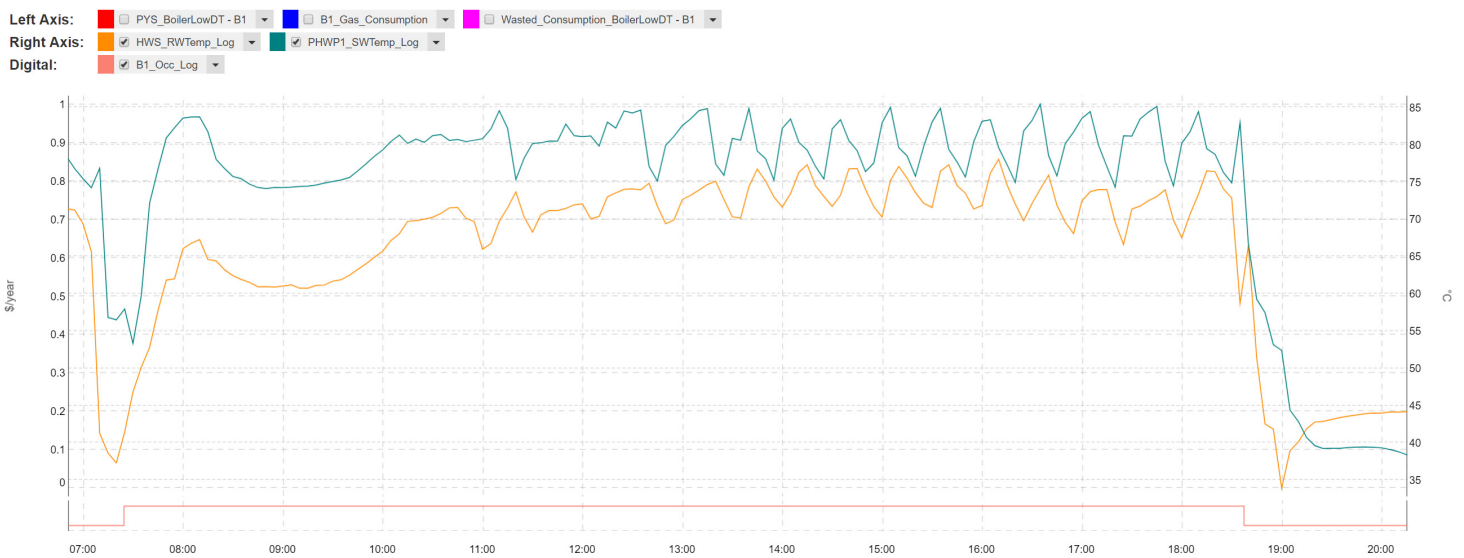
🟡 Low	B1	The boiler has been running while the HHW delta-T was low, suggesting the building did not require heating at that time.	
🟠 Medium	B2	Operational for short period of time while supply temperature is high indicating unnecessary operation	
🟡 Low	B2	The boiler has been running while the HHW delta-T was low, suggesting the building did not require heating at that time.	
🟠 Medium	B3	Operational for short period of time while supply temperature is high indicating unnecessary operation	
🟡 Low	B3	The boiler has been running while the HHW delta-T was low, suggesting the building did not require heating at that time.	

Issue: Tuning of VAVs

INSIGHT: Low KPI Scores

DATE: Initial Installation

50 Marcus Clarke has a data driven maintenance schedule in place that sees the traditional preventative maintenance plan placed aside and maintenance tasks driven from analytical insights and KPI reports. Very early on it was flagged that multiple VAV's weren't controlling to airflow and temperature setpoints as closely as they should. Over the last 18 months all VAV's have been tuned to better control airflow and temperature, greatly improving thermal comfort conditions.

KPI reports form an integral part of maintenance and tuning as they show clearly if tuning has negatively impacted control or where problem areas lie so maintenance can be targeted. In the early stages of data driven maintenance an overall VAV KPI score was used to target the worst performing VAV, this KPI combined airflow and temperature control parameters. The worst performing VAV's were then investigated and issues rectified. An example below is VAV-C2-10-L11, in Oct-2015 its KPI score was the lowest at 26%, as of last month its performing at 86%. VAV maintenance and tuning is an ongoing process and forms a part of the monthly maintenance.

Figure 16. Coppertree Analytics (Commercial Office Tower) – Issue: Tuning of VAVs
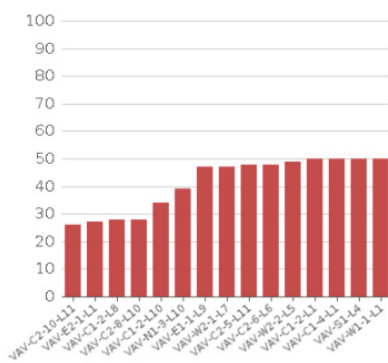
System	KPI
VAV-C2-10-L11	26
VAV-E2-1-L1	27
VAV-C1-2-L8	28
VAV-C2-8-L10	28
VAV-C1-2-L10	34
VAV-N1-3-L10	39
VAV-E1-1-L9	47
VAV-W2-1-L7	47
VAV-C2-5-L11	48
VAV-C2-6-L6	48
VAV-W2-2-L5	49
VAV-C1-2-L1	50
VAV-C1-4-L1	50
VAV-S1-L4	50
VAV-W1-1-L1	50

VAV-S2-1-L10	85
VAV-C1-10-L11	86
VAV-C1-2-L10	86
VAV-C1-3-L11	86

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Issues: AHUs

INSIGHT: Low KPI scores

DATE: Initial Installation

50 Marcus Clarke has a data driven maintenance schedule in place that sees the traditional preventative maintenance plan placed aside and maintenance tasks driven from analytical insights and KPI reports. Very early on it was flagged that the AHU's weren't controlling to pressure and temperature setpoints as closely as they should. Over the last 18 months all AHU's have been tuned to better control pressure and temperature while lowering energy consumption in the process.

KPI reports form an integral part of maintenance and tuning as they show clearly if tuning has negatively impacted control or where problem areas lie so maintenance can be targeted.

Figure 17. Coppertree Analytics (Commercial Office Tower) – Issue: Tuning of AHUs

AHU Supply Pressure KPI Report
Oct 01, 2015 to Nov 30, 2015

Statistics:
Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

KPI Target:	Greater Than: 75 unit
Performance Goal:	75% of Systems meet KPI Target
Total Number of Systems:	9
System(s) above KPI Target:	4
System(s) below KPI Target:	5

44
Performance Index
Percentage of systems working above the KPI Target

AHU Supply Pressure KPI Report
Jun 01, 2017 to Jun 30, 2017

Statistics:
Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

KPI Target:	Greater Than: 75 unit
Performance Goal:	75% of Systems meet KPI Target
Total Number of Systems:	9
System(s) above KPI Target:	8
System(s) below KPI Target:	1

89
Performance Index
Percentage of systems working above the KPI Target

AHU Supply Temperature KPI Report
Oct 01, 2015 to Nov 30, 2015

Statistics:
Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

KPI Target:	Greater Than: 75 unit
Performance Goal:	75% of Systems meet KPI Target
Total Number of Systems:	9
System(s) above KPI Target:	3
System(s) below KPI Target:	6

33
Performance Index
Percentage of systems working above the KPI Target

AHU Supply Temperature KPI Report
Jun 01, 2017 to Jun 30, 2017

Statistics:
Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

KPI Target:	Greater Than: 75 unit
Performance Goal:	75% of Systems meet KPI Target
Total Number of Systems:	9
System(s) above KPI Target:	7
System(s) below KPI Target:	2

78
Performance Index
Percentage of systems working above the KPI Target

Note: All savings numbers presented in this case study were provided by the FDD solution provider.

END OF CASE ST

LOW CARBON LIVING CRC

RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 41

Schneider Electric EcoStruxure Building Advisor
powered by Clockworks

Schneider Electric

Actionable Information to Increase Energy Savings, Improve Reliability, and Enhance Building Comfort

Every day, facility managers are challenged with operating and maintaining complex facilities and systems with limited resources, while at the same time achieving energy, sustainability, and comfort performance goals. Building Advisor helps facilities teams cut through the noise of day to day operations to identify, prioritize, and address the system issues that matter most. By combining automated analytic technology with expert services, we help you act on the issues that have the most impact to reduce costs and consumption, optimize the use of limited maintenance resources, and improve comfort and reliability.

EcoStruxure Building Advisor uses advanced, cloud-based automated fault detection and diagnostics to not only identify problem conditions, but also guide resolution through suggested proposals and actions. Along with periodic and regular reviews, this actionable information allows you to close the gap between information and fact based decision making, to better organise internal and contract resources for quicker, more efficient repairs and commissioning services.

Built on scalable enterprise software architecture, EcoStruxure Building Advisor can be used in one building or in multiple facilities across your portfolio. It is compatible with most existing building management systems and requires little to no additional hardware or software.

Features

Across a range of facility systems and types, EcoStruxure Building Advisor provides insight into facility and system performance. The software includes libraries of diagnostics that are highly configurable, and rapidly deployable, to provide quickly valuable information tailored to your facility systems. This library has been applied to facilities all over the world, across a range of complex university and industrial laboratories, healthcare institutions large and small, and commercial and corporate real estate portfolios. Our approach to analytics, which shares an analytic library globally, means that all customers benefit from a constantly advancing diagnostic library informed by customers all over the world.

The library spans a broad range of systems, including complex built-up air handlers, simple rooftop units, heating and cooling plant equipment, cogeneration facilities, zone equipment of many types, process water systems, and many other facility systems. Our service and support ensures that the information the diagnostics create is accurate and actionable, and we help to address the highest priority issues through field services.
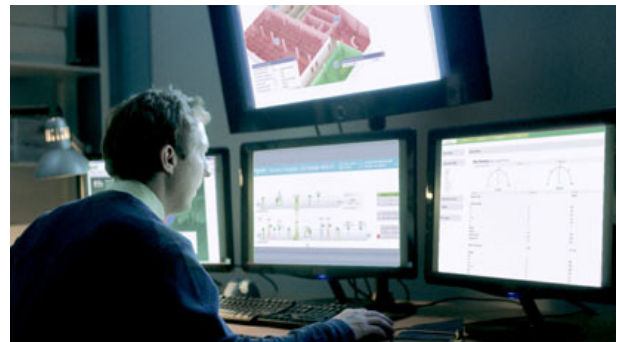
Benefits

Facilities teams experience many benefits transforming their facility operations to adopt analytic technologies and smart maintenance and services, including:

- Optimised operational performance

- Cost-effective yet comprehensive monitoring of all facility assets to find hidden issues and costs

- Increased system reliability and availability

- Reductions in major equipment energy consumption and cost

- Improvements in comfort and reductions in comfort complaints

Our objective is simple, we work with you to manage facilities smarter and better.

Contact

www.schneider-electric.com.au/en/work/support/customer-care/contact-sales.jsp

www.ecostruxurebuildingadvisor.com

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 42

Case study Project: Melbourne Airport

Location:	Tullamarine (Melbourne) VIC
Asset Type:	Airport
Sector:	Private
Objectives:	- A proactive response to occupant comfort, equipment uptime and energy efficiency - Transition from traditional, labour intensive BMS and HVAC problem finding and maintenance, to an approach utilising technology to target activity for most impact - Improved labour efficiency by reducing inspection and test tasks - Continuous improvement in occupant conditions - Availability of information for capital planning
Key Outcomes:	- Adoption of new processes to prioritize resolution of facility issues based on data-driven monitoring and measured performance - Reduction in the avoidable energy cost resulting from equipment faults - Reduction in the number of comfort anomalies caused by zone equipment issues - Reduction in the number of maintenance anomalies on major equipment

Case Study Overview

Melbourne Airport catered to over 33 million passengers and more than a third of Australia's airfreight in 2016. The site is physically vast, with strict security controls, both of which increase time to inspect and maintain equipment on site. The airport has experienced strong growth and is forecast to continue, with the airport projecting to cater for 50 million passengers by 2030. Construction, refurbishment and fitout projects are constantly underway as the airport expands to meet it's growing passenger numbers and prepare for the future.

Cost effective delivery of all services is vital to ensure the airport remains an attractive place for airlines to service, and provide a quality customer experience.

The Schneider Electric Building Advisor platform was deployed at Melbourne Airport to drive maintenance activity, with the following objectives in mind:

- A proactive response to occupant comfort, equipment uptime and energy efficiency
- Transition from traditional, labour intensive BMS and HVAC problem finding and maintenance, to an approach utilising technology to target activity for most impact
- Improved labour efficiency by reducing inspection and test tasks
- Continuous improvement in occupant conditions
- Availability of information for capital planning

Success of the maintenance methodology is primarily validated by tracking the reduction in number and severity of anomalies.

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 43
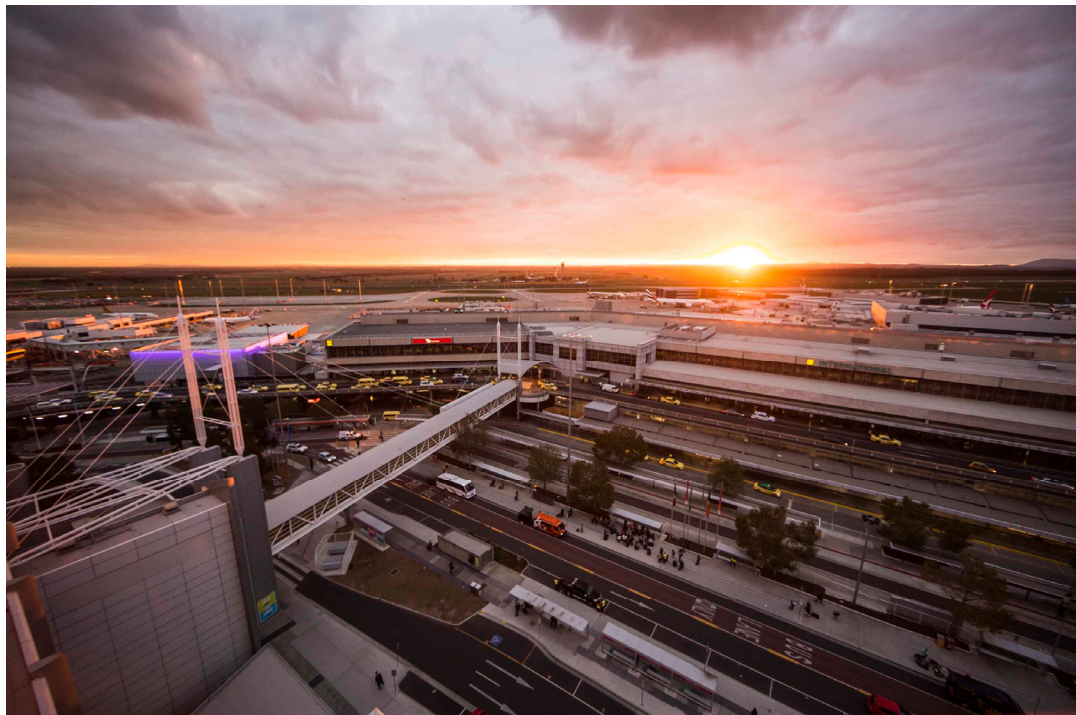
EcoStruxure Building Advisor

Building Advisor is an automated fault detection and diagnostics platform combined with building services to help customers adopt a proactive approach to building operations. The solution uses cutting-edge technology and actionable information derived from building system data to increase energy savings, improve reliability and enhance building comfort. The platform uses highly configurable libraries of analytic algorithms to process complex system data unique to each facility. These analytics find and prioritise opportunities to better maintain, repair and optimize system performance to save energy, reduce costs, improve comfort, and extend equipment life. This solution is provided to customers in eighteen countries, in buildings large and small, across multi-national portfolios to help facilities teams focus on what matters.

Schneider Electric EcoStruxure Building Advisor (Melbourne Airport) – Top 5 Issues Identified

The major plant at Melbourne Airport is well designed and maintained, and had been optimised prior to the Building Advisor deployment. The bigger challenges were to maintain the expanding site in a cost effective manner to ensure the airport continues to remain an attractive place for airlines to do business, and to prioritise activity on such a large and varied site.

Below are a sample of the typical issues identified by Building Advisor. In the past, these issues would have been identified via a customer complaint or during a scheduled maintenance inspection. They are now addressed with a more proactive approach using condition-based maintenance drive by fault detection.

Issue: Zones not meeting setpoint

Identifying, and more importantly prioritising, zones not meeting setpoint allows a proactive approach. Causes include passing or blocked valves, doors being left open or units undersized to address the area load.
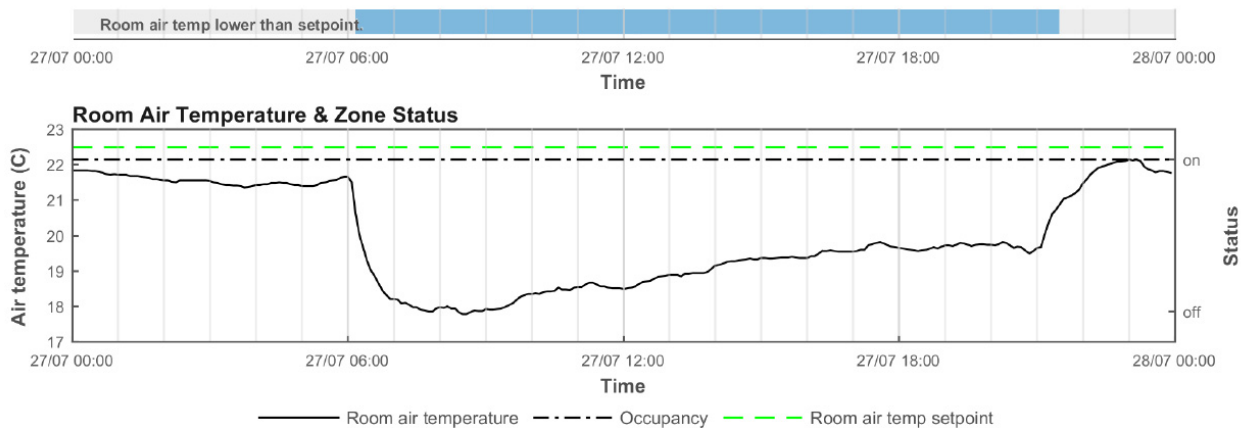
Issue: CO_2 Sensors failing

CO_2 sensors are used extensively to reduce outside air requirements and therefore save energy. Failed sensors, which read high, cause units to use increased outdoor air, thus increasing energy use.
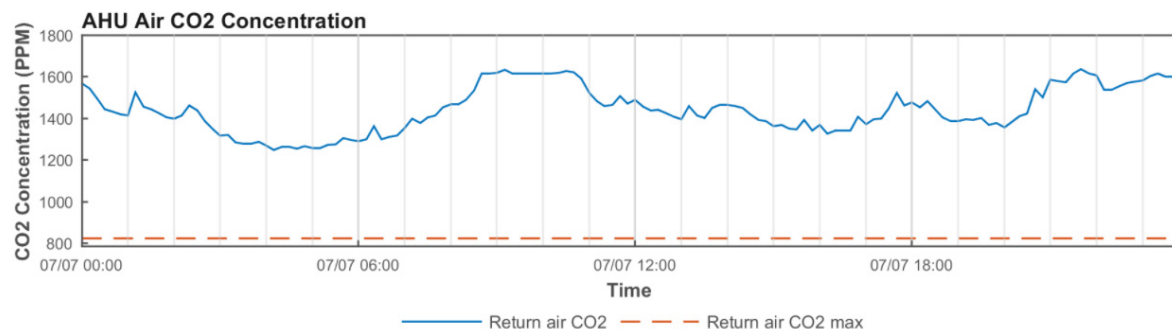
Issue: Fan on while unoccupied

Not all areas of the airport operate 24/7. On occasion tenants manually override units at the mechanical switchboard, increasing airport energy consumption unnecessarily. Building Advisor allows easy identification and rectification of these issues.
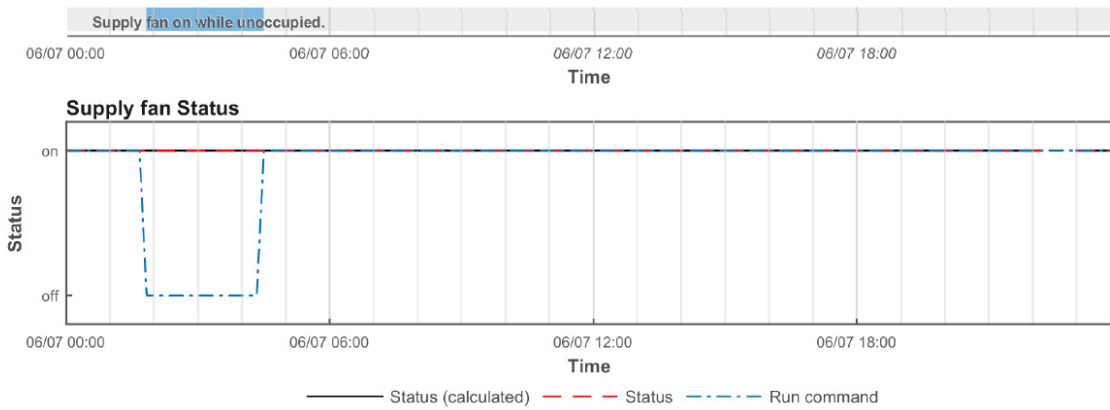
Issue: Air handling equipment not maintaining pressure

Often caused by variable speed drive faults or blocked filters, a timely response prevents occupant comfort complaints.
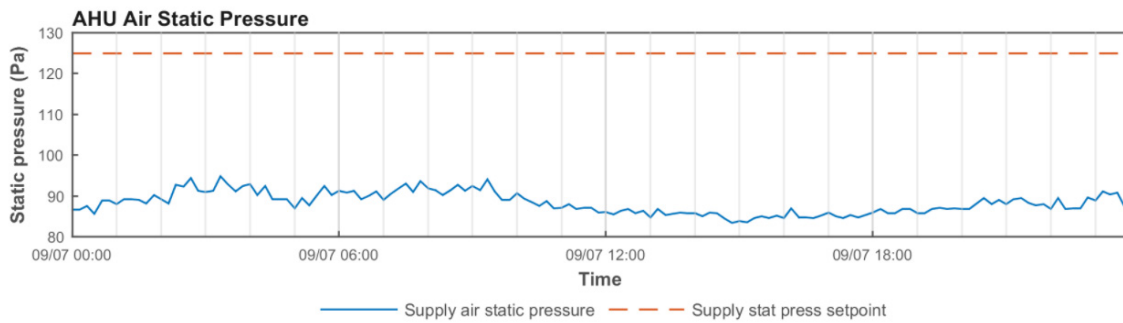
Issue: Pressure and temperature sensor failures

Given the large volume of small units and VAVs spread throughout the site, using Building Advisor to identify pressure and temperature sensor faults results in considerable time savings.

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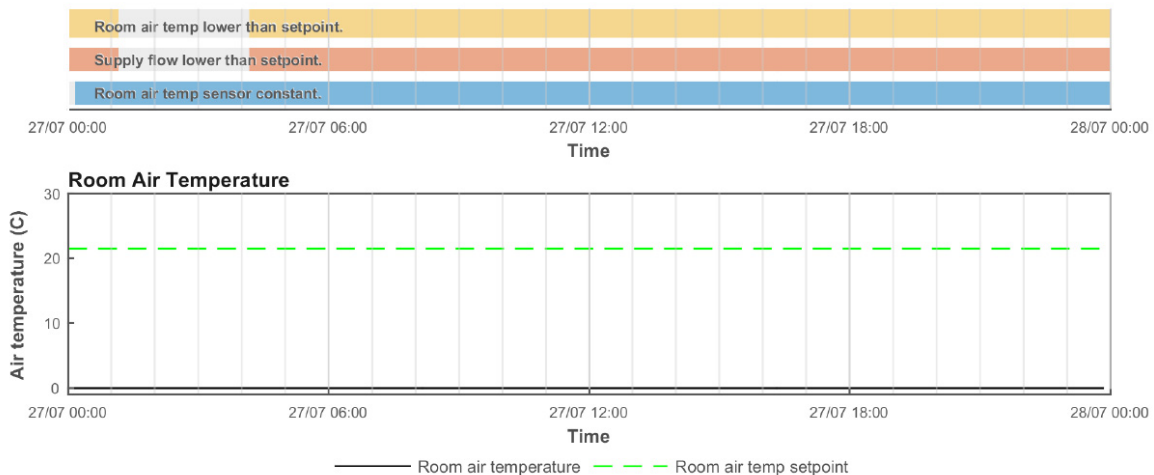
Schneider Electric EcoStruxure Building Advisor (Melbourne Airport) – Demonstration of Outcomes

Figure 18 shows the results of an analytics driven maintenance approach over a 13 month period. These results show a reduction in energy cost, number and severity of issues, even allowing for the large increase in equipment volume when equipment in Terminal 4, the new low cost carrier terminal, was added in February 2017.

Figure 18. Schneider Electric Building Advisor (Melbourne Airport) – Results of an analytics maintenance approach
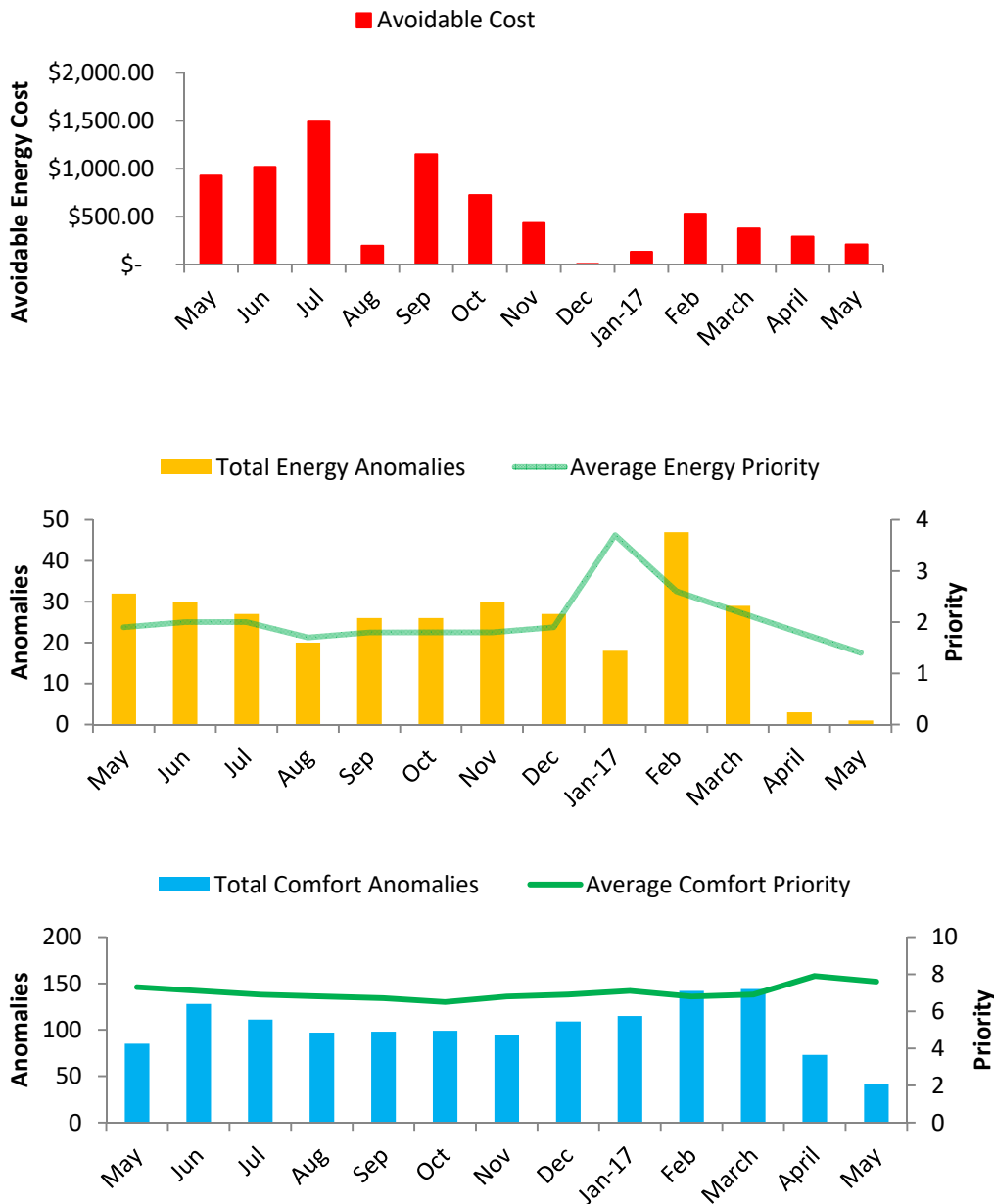
Note: All savings numbers presented in this case study were provided by the FDD solution provider.

END OF CASE STUDY

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Synengco
powered by *SentientSystem*

Helping you do more in less time using real-time analytics and decision support

Synengco's product, SentientSystem, digitally replicates asset-intensive operations to run analyses that support decision makers in their efforts to improve performance. The most successful use of SentientSystem has been in the power generation industry, which it was originally developed for. It's real-time monitoring and optimisation capabilities are used by our power generation customers to achieve significant and sustained performance improvements across their asset portfolios.

Digital replications of complex systems and the environment they operate in are configured in SentientSystem as self-learning fundamental models of the system, made up of equipment components and process connections. This is used to monitor equipment performance in real-time. As well as this, dynamic baselines, tuned from historical operation, are used to predicted equipment performance. Performance improvements are achieved by various SentientSystem modules that use the monitored and predicted equipment performance to aid short, medium and long term decisions.

SentientControl achieves real-time optimisation through learning the influence that key operator control points have on asset behaviour and automatically taking action to bias those control points to improve system efficiency.

SentientAlert detects equipment faults based on short term statistical changes in process variables compared against their predicted behaviour. This enables personnel to act quickly to mitigate the harm of failures and also helps speed up root-cause analysis when faults do occur.

SentientDeviation compares current equipment performance against a baseline, such as last overhaul or best practice. This is used to calculate the financial impact of changed equipment performance. Performance managers are able to use this to quantify benefits of maintenance, new technology or capital works on equipment.

Features

In the same way that Building Information Models (BIM) are used as digital twins of an asset's *form*, SentientSystem creates a digital twin of an asset's *behaviour*. Synengco uses this to build key data-driven decision making capabilities of our customers.

Modelling
An information model of the customer's assets and operations is built to contextualise disparate sources of knowledge and data into a common point of truth.

Monitoring
Analysis techniques that run on the information model and associated data are used to monitor and report the assets' and whole-of-system performance.

Prediction
Machine learning is used to learn the monitored behaviour of the operation so that short and long term changes can be quantified and corrective actions can be triggered.

Optimisation
Advanced control algorithms, that use the monitored performance and learned behaviour, emulate best-practice operator decisions to improve efficiency automatically.

Contact

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LOW CARBON LIVING CRC

Case study Project: Power Station Performance Monitoring and Optimisation

Location:	Kogan Creek Power Station near Chinchilla, Queensland
	Callide Power Station near Biloela, Queensland
Asset Type:	Power Station (Generator)
Sector:	Public
Objectives:	• Reduce risk of equipment failure
	• Increase system performance
Key Outcomes:	• Reduced operating costs and greenhouse gas emissions through real-time optimisation of soot blowing activity
	• Avoided loss of availability through early warning of equipment faults
	• Real-time decision support used by operators, engineering and managers for optimised asset management

Case Study Overview

SentientSystem digitally replicates asset-intensive operations to run analyses that support decision makers in their efforts to improve performance. For the past 10 years, SentientSystem has been successfully used in the power generation industry, which it was originally developed for. It's real-time monitoring and optimisation capabilities are used by our power generation customers to achieve significant and sustained performance improvements across their asset portfolios.

> Kogan Creek Power Station.

Challenge

Coal-fired power stations provide a critical service with high costs and low margins. The reliability and performance of these assets is therefore paramount to their viability as the electricity market transitions towards renewables.

The complexity of a power station system and the environment it operates in means decision making to maintain and improve reliability and performance is a difficult task. Figure 19 shows an example of the equipment pieces and processes of a power station modelled in SentientSystem.

Figure 19. Synengco (Power Station) – Process Flow Diagram of a typical power station
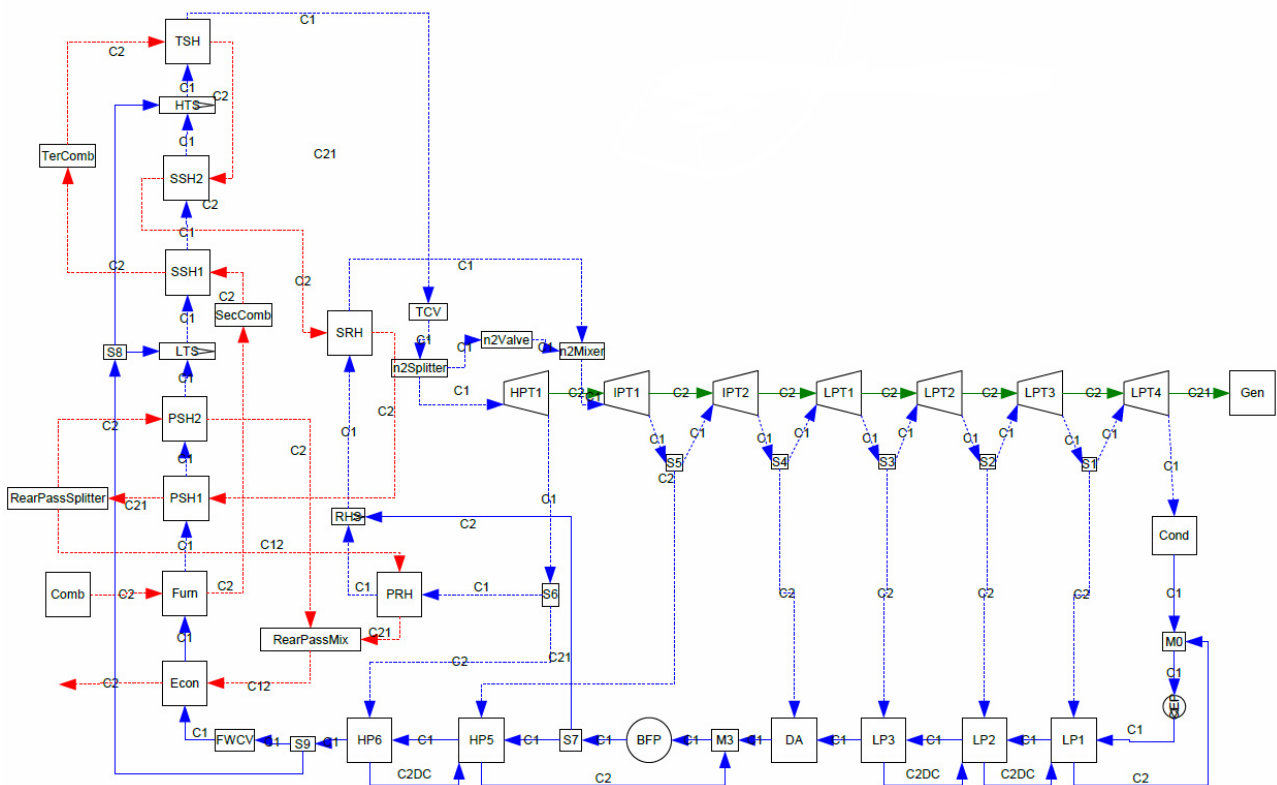
Synengco (Power Station) – Demonstration of Outcomes

The fundamental modelling capability of SentientSystem allows for soft-sensing variables that are difficult to measure with certainty, such as gas temperatures inside the boiler. By using these, SentientSystem is able to calculate the thermal efficiency of individual boiler elements and learn the effect of the soot-blowing operations that keep them clean. This learning is used to optimise the soot-blowing schedule by *BoilerClean*, a real-time optimisation algorithm that is part of the *SentientControl* module. In Figure 20, the time elapsed since last blow for each soot blower can be seen as the sawtooth trends – the higher peaks represent less frequent blowing. It shows *SentientControl* adapting the schedule when the exit gas temperature (green) decreases. Less frequent blowing is required since the boiler elements are all working effectively to take heat out of the gas. This reduction in blowing in turn reduces the waste of steam used by the soot blowing. This optimisation typically achieves a payback period of less than six months, with significant improvements to plant efficiency and reduced water usage.

Figure 20. Synengco (Power Station) – Frequency of automated soot blowing dynamically adapting to plant operating point.
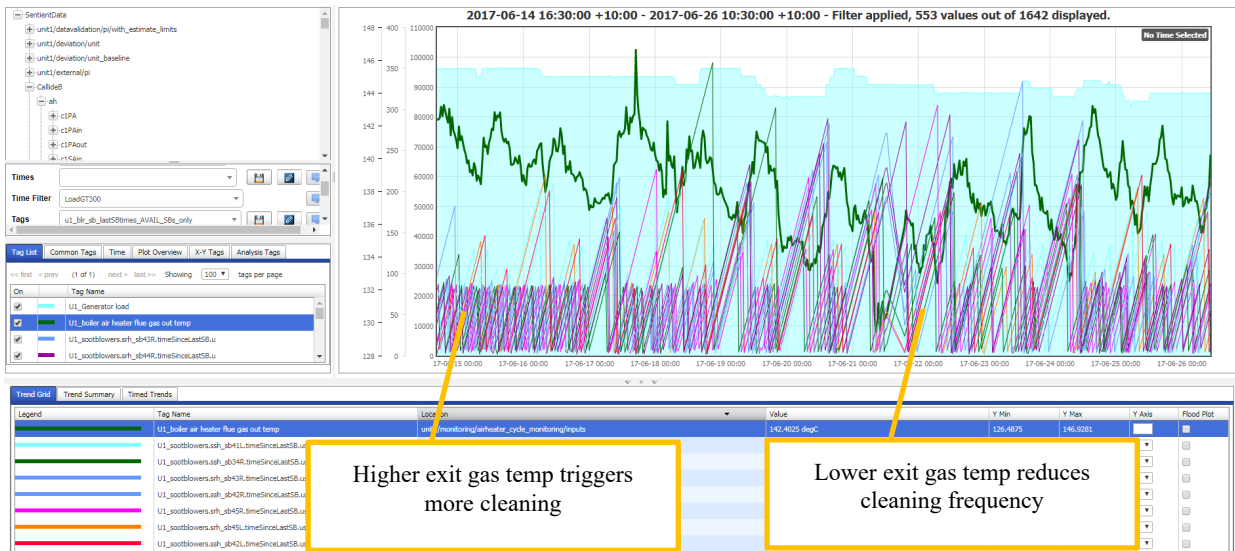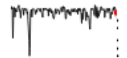
SentientAlert's early warning capability is shown in Figure 21. An alert on an air inlet fan was detected and notified after a change in behaviour. Unfortunately in this case, the lack of action led to the alerted problem causing an equipment failure a month later, resulting in significant loss of generation. When acted upon, these alerts can significantly reduce costly failures and loss of production.

Figure 21. Synengco (Power Station) – Alert of change over a month before equipment failure.
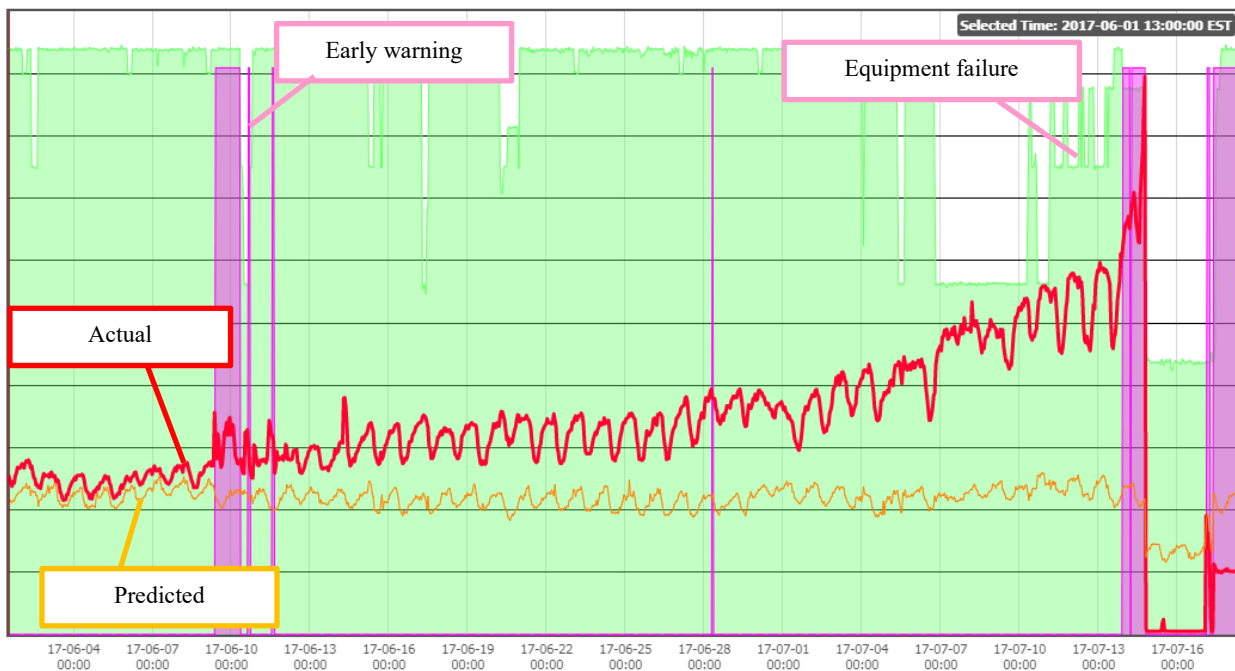
SentientDeviation links changes in equipment performance to the financial impact they represent. For example, in the screenshot in Figure 22 below, the performance change between several boiler elements since the most recent overhaul demonstrates the potential fuel savings that improving the ECON, PSH and SSH elements could make. This analysis provides quantified and prioritised decision support for managers that have to get the most out of the plant and justify costly maintenance spending, plant upgrades and/or new technologies, leading to more targeted and efficient spending of budget and a more efficient operation.

Figure 22. Synengco (Power Station) – Deviation analysis comparing financial cost of degraded boiler element performance.

Plant name	Plant units	Baseline	Actual	Fuel t	Plant Cost $	Cost $ Trend	Plant CO2 Cost $
BLR ECON TC TARGET	kW/K	-1279.9	-1224.9	139.4198	2961.2774		5998.1771
BLR PSH TC TARGET	kW/K	-576.2	-507.9	110.5000	2347.0200		4753.9700
BLR SSH TC TARGET	kW/K	-325.4	-284.0	83.4025	1771.4700		3588.1662
BLR SRH TC TARGET	kW/K	-601.3	-585.2	-16.7806	-356.4210		-721.9476

Normalised Deviation Trends vs Time
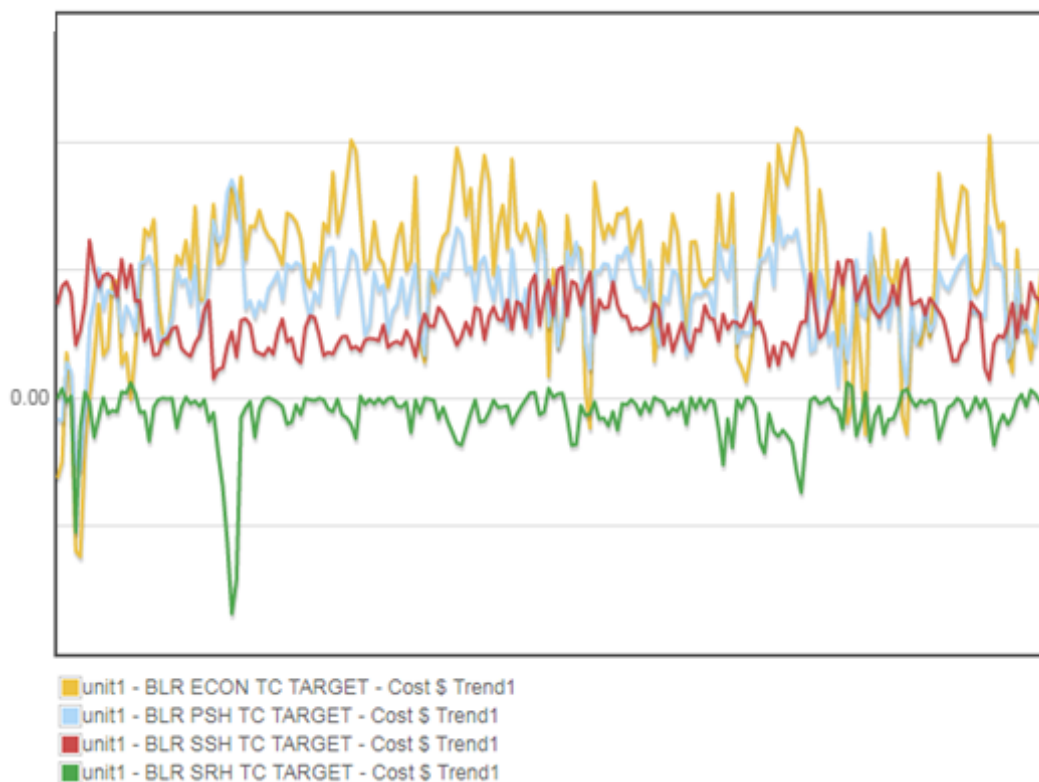
■ unit1 - BLR ECON TC TARGET - Cost $ Trend1
■ unit1 - BLR PSH TC TARGET - Cost $ Trend1
■ unit1 - BLR SSH TC TARGET - Cost $ Trend1
■ unit1 - BLR SRH TC TARGET - Cost $ Trend1

Note: All savings numbers presented in this case study were provided by the FDD solution provider.

<center>END OF CASE STUDY</center>

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 52

Case study Project: Life Cycle Optimisation of a Hospital Energy Plant

Location:	South Brisbane, Queensland
Asset Type:	Hospital
Sector:	Public
Objectives:	• Life-cycle simulation of operating and maintenance cost • Reusable model for assessing changes in service demand and energy costs
Key Outcomes:	• Supported strategic decisions to reduce the life cycle cost of operation • Aided electricity, gas and facility management contract negotiations • Model ready to be deployed in real-time for operational decision support

Case Study Overview

SentientSystem's modelling capabilities are used to build precise digital replications of asset systems and the environment they operate within. Synengco uses these to run high resolution simulations over long time periods to predict the system's life-cycle cost under various circumstances. These predictions are used to aid short, medium and long term decisions about how to operate and maintain the plant most economically. The analysis is delivered in a way that makes is easy to update and rerun as new information becomes available to ensure the best picture of the future is available to decision makers. It can also be run in real-time to monitor the actual operation so that corrective actions can be taken quickly when the plant deviates from its planned or expected behaviour.

Challenge

The building energy plant that Synengco analysed has a lot of flexibility to provide the various services that the hospital requires. However, this made it difficult for manager to know how the plant should be operated for the lowest life cycle cost. Figure 23 shows the top level model of the plant. Each equipment group contains several equipment components in the model, for example there are two reciprocating gas engines, connected in series within the 'Gas engines' block in Figure 23.

Figure 23. Synengco (Hospital) – Process Flow Diagram of Hospital Energy Plant.
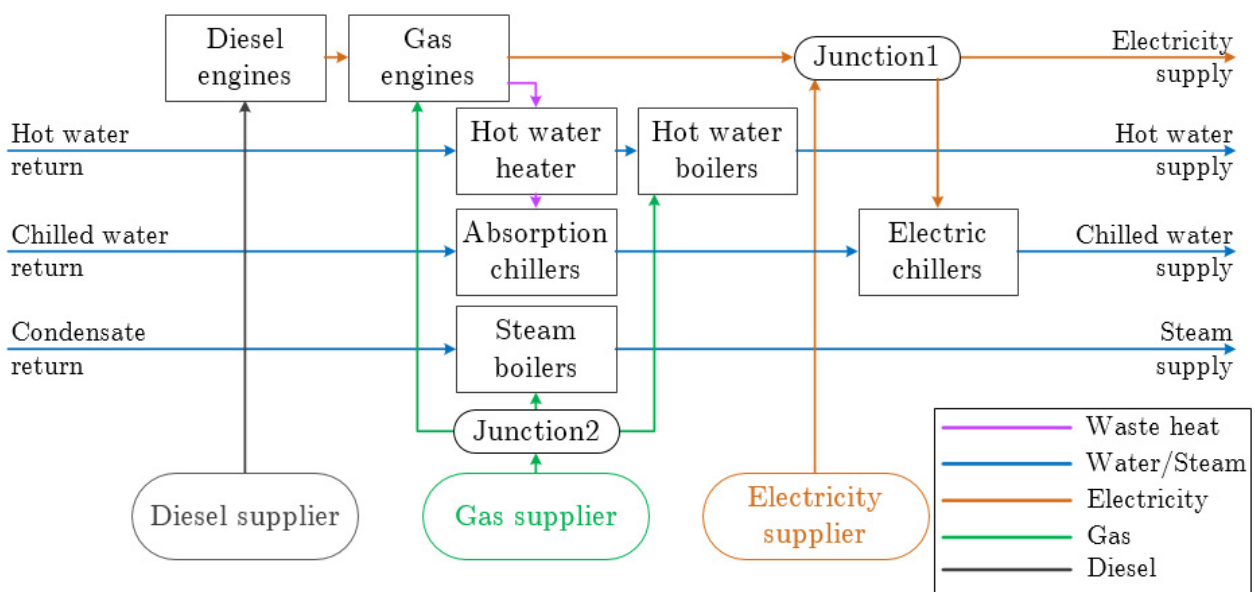
Given the price of energy supply was changing every quarter due to changes in the external environment, there was significant uncertainty as to how the energy plant should adapt to the changes. Uncertainty also existed around what opportunities that changing the plant and/or operation could bring.

Synengco (Hospital) – Demonstration of Outcomes

SentientSystem was used to build a replication of the plant and the environment it was operating within to analyse the impact that factors, such as asset control, performance degradation, maintenance, contract management and environmental/market conditions, have on operations and financials to find opportunities to improve.

Figure 24 shows the methodology used to train and run the analysis. A fundamental model of the plant was developed and tuned to represent the most recent operation. Forecasts of service demand, weather, energy cost, equipment degradation and maintenance schedule were then used to run the model over a 25 year horizon with hourly resolution to predict the total life cycle cost of the plant.

Figure 24. Synengco (Hospital) – Modelling and forecasting methodology.
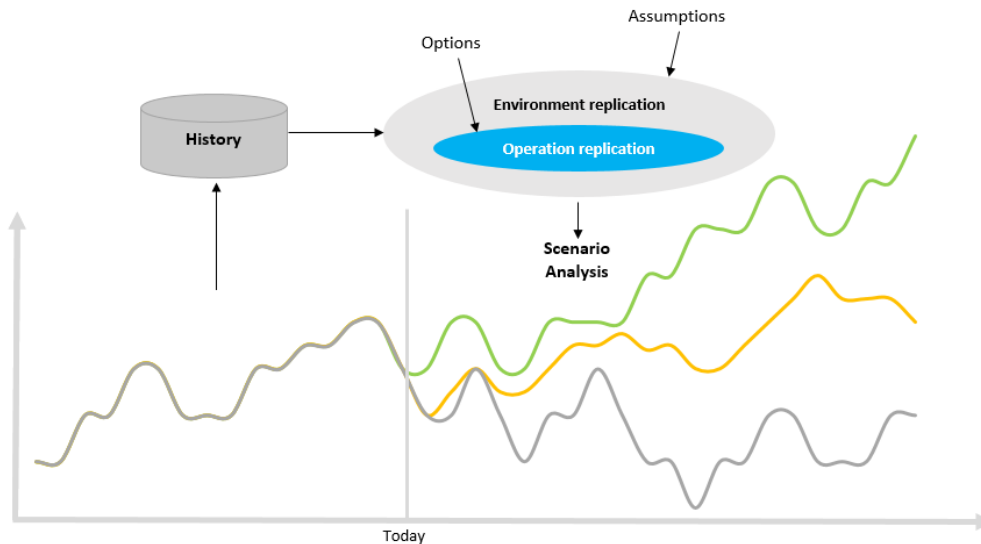
Several scenarios were devised in consultation with managers and the net present value (NPV) of each scenario was computed, as shown in Figure 25. These included on-selling services to nearby buildings, mothballing plant, seasonal operating changes and different energy contract options. The parameters of the scenarios are easily updatable as new information becomes available, ensuring the most optimal operation is achieved as the environment changes.

Key performance measures that drive operational excellence were identified and targets established to drive the lowest life cycle cost of providing the energy services. This freed up funds to be deployed on important clinical activities. Through a once off investment the improvements are returning 5 times that investment every year. Since SentientSystem is a real-time analysis engine, the models configured for this project are in a format ready for shorter term decision support, such as advanced control or fault detection.

Figure 25. Synengco (Hospital) – Scenario results.
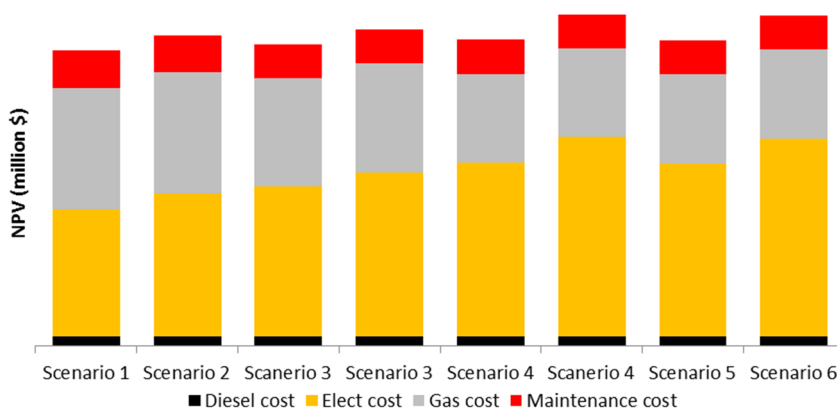
END OF CASE STUDY

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Joule AnalytiX
by UCTriX

Joule AnalytiX

Significantly reduce your building operational costs, while supporting the reduction of greenhouse gases with Joule AnalytiX on-going commissioning.

Joule AnalytiX is the evolution of DABO, an Automated Fault Detection and Diagnostic technology originally developed by Natural Resources Canada - CanmetENERGY with over 20 years of R&D invested to create technology that conserves energy in buildings. Our engineers continue to enhance the solution by developing new modules, applying big data analytics and predictive energy control management. Joule AnalytiX managed service solutions are installed in a number of facilities around the world and are providing HVAC energy optimization and Automated Commissioning for Energy without compromising occupant comfort.

Features

Information technology (data analytics) enables unprecedented efficiencies for businesses. Powerful analytics are helping organisations better manage supply chains, improve resource allocation, detect fraud and optimize many core business functions. Property is no exception. Buildings are equipped with hundreds of sensors and controls, but companies are leaving money on the table if they do not use this data more holistically to optimize their infrastructure. By applying the Joule AnalytiX solution you are able to reduce operating costs by optimizing HVAC loads, lower your utility bills, increase equipment life, improve tenant comfort, retention, and leasing rates; all while lowering carbon emissions.

Energy is a growing cost item and a mission-critical commodity for many organizations today, therefore its efficiency is a critical component of our client's sustainability strategy whilst offering favorable business benefits. Energy consumption is a significant operational expense item for most industries and buildings making up about 20% of overall operating costs. While there is a growing need for energy efficiency, most organizations:

- Will need a strategic approach to energy management
- Will need to understand their most energy consuming assets
- Will need to actively manage energy efficiently or effectively
- Will need to understand what technologies are available to drive energy efficiency

A building's performance deteriorates due to its age, usage, or functional adaptation to new uses. Traditional approaches, like Retro Commissioning (RCx) and/or energy audits, are point-in-time, stop-gap measures that are ineffective in sustaining a high level of building energy efficiency. Joule AnalytiX Managed Solutions, leverages Fault Detection and Building Performance guidelines, which enables our Automated Continuous Commissioning (ACCx), thereby helping the building to reach or exceed its original efficiency.

M&V is a module within the platform used to accurately measure the savings obtained from the software. To assess the effectiveness and determine its value, it is critical customers be able to measure savings. This requires processes and methods that are clear, transparent and robust. The M&V module gives customers a tool to accurately measure and visualize the resulting savings. M&V uses processes that are well documented and consistent with the industry-standard International Performance Measurement and Verification Protocol or IPMVP. To identify savings attributable to the application, evaluators or project stakeholders compare baseline conditions to actual conditions—the past to the present. Results are presented in real-time using online dashboards and reports.

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As at the time of writing, a concluded case study from UCTriX was unavailable for publication. Please contact UCTriX to discuss their latest FDD case studies in Australia and the Joule AnalytiX FDD solution.

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 56

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C&E Analytics
by Control & Electric

CONTROL & ELECTRIC
Building Automation | Mechanical Electrical | Switchboards | Service **PTY LTD** ACN 135 853 780

Find what matters.
Automatic analysis of energy and equipment data identifies faults and opportunities for improved performance and operational savings.

Control & Electric use Building Analytics as an essential tool to help manage the data from our BMS and metering systems and to optimise the performance and energy efficiency of our customers' buildings. We have a dedicated team of engineers focused on delivering this specialty service to our customers which goes hand-in-hand with our BMS technical capabilities.

The integrated analytics and service offering allows BMS service technicians to respond efficiently to issues identified by analytics and minimise the impact from sub-optimal equipment operation. The monitoring based commissioning provides continuous data analysis to ensure savings are maintained and any new issues can be quickly identified and corrected before they have a large impact on energy performance.

Features

- Automatically collect and analyse equipment operation and metering data

- Identify patterns, deviations, faults and opportunities for operational improvements and cost reduction

- Automatic visualisations, notifications and reporting

- Track KPIs, normalise and verify metering data

Contact

C&E Analytics
Stay tuned.

E: admin@controlandelectric.com.au | **T:** 02 6299 6233

www.controlandelectric.com.au

Case study Project: CSIRO Building 5, Black Mountain

Location:	Canberra ACT
Asset Type:	Research Laboratory Facility
Sector:	Public
Objectives:	• Utilise a Fault Detection & Diagnostic service to identify equipment inefficiencies and highlight opportunities for potential energy savings
Key Outcomes:	• 20% decrease in monthly energy consumption
	• 744MJ/m² decrease in site energy intensity
	• Real-time identification of equipment faults

Case Study Overview

The High Resolution Plant Phenomics Centre (HRPPC) Phytotron is a two storey, 3,120 m² research laboratory located at the CSIRO Black Mountain facility in Canberra, Australia. A phytotron is a building in which plants can be grown in controlled climatic conditions and combines glasshouses and controlled environment cabinets. The building was constructed in 1962 and has undergone several refurbishments since. Although the HVAC system was meeting occupant comfort and equipment environment requirements there was considered to be an opportunity for a Fault Detection and Diagnostics (FDD) tool to identify equipment inefficiencies and potential energy savings. Control & Electric implemented their FDD service from May 2016 – April 2017 as part of a 12 month FDD program. This case study provides an overview of the project and final results.

Site Information

- 24 hour research laboratory
- Annual energy consumption ≈ 2,700 MWh
- 15 greenhouses
- 100+ refrigerated cabinets
- 10 air handling units (AHUs), 2 fan coil units (FCUs)
- Wide range of seasonal temperatures in local region

Approach

A data connection was configured to the Siemens APOGEE Building Managment System (BMS) to provide near real time data which was continuously compared against a custom suite of fault detection rules developed by the Control & Electric Energy Monitoring team. These algorithms analyse the data for any patterns or outliers that would indicate faults such as simultaneous heating and cooling, excessive cycling and rapid rates of change as well as temperature and humidity instability.

Faults identified by the energy team were communicated to service personnel who can view the potential fault and then perform repairs or follow up investigations on site.

Monthly reports were delivered to the facility manager to highlight the issues identified and resolved during that period and any required actions. Each issue is summarised and assigned a severity rating, recommended actions, maintenance outcome, estimated cost with energy savings and repair progress status. The reports also showed trending energy performance compared against historical data.

Estimated energy and cost savings were assigned to each FDD rule as well as a priority level that determined the alerting threshold. The data for year on year energy comparisons and energy profiles was exported by the FDD system and compiled in Microsoft Excel. The energy savings were validated against weather conditions using a custom degree days analysis programmed into the system based on virtual software points and metering data.

Self-Reported Metrics

- <24 hours to implement FDD system
- 27 analytical rules
- High priority issues resolved within 30 days after diagnosis
- 20% average decrease in monthly electricity consumption
- 744MJ/m² decrease in site energy intensity
- 685+ tonnes reduction in CO_2 emissions (excluding gas)

Note: All savings numbers presented in this case study were provided by FDD solution provider.

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C&E Analytics (CSIRO Building 5) – Top 5 Issues Identified

The C&E Analytics FDD solution identified the following issues during the initial twelve month implementation:

- Simultaneous heating and cooling
- Valves cycling excessively
- Leaking valves
- Temperature instability
- Heating call threshold mismatch between HHW pumps and valves
- Public holidays not scheduled
- Unstable dehumidification control
- High chiller flow temps
- Boiler low supply temperatures
- Boiler short cycling
- Blocked coils

Table 7. C&E Analytics (CSIRO Building 5) – Issues identified per equipment type.

Equipment Type	Issues Raised	Issues Incorrectly Identified
AHU	27	3
FCU	3	1
Boiler	3	0
Chiller	2	0

Summary of Top 5 Issues Identified

Table 8. C&E Analytics (CSIRO Building 5) – Summary of Top 5 Issues Identified

| System	Issue
AHU 1-4 Simultaneous heating and cooling	AHU was consuming excess energy as the heating and cooling valves were in conflict and operating with an insufficient deadband.
AHU 1-4 leaking chilled water valve	A faulty actuator was flagged by FDD rules analysing the valve positions and supply air temperature.
Chiller faults	Abnormally high chiller flow temperatures were alerted before and after chiller repairs were carried out.
AHU G-2 short cycling dehumidification mode and valve instability	Valve instability present after unit entered dehumidification mode flagged by dehumidification mode short cycling and valve/temperature instability algorithms
HHW tuning – reduced demand	Tuning of non-24 hour equipment schedules, after hours heating call thresholds and resolving simultaneous heating and cooling issues significantly reduced boiler demand and pump operation.

The graphics in the subsequent section show five high importance issues that were identified by the FDD system. These faults were considered to have the highest impact on energy performance and/or maintenance savings.

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 61

C&E Analytics (CSIRO Building 5) – Technical Deep-Dive into Top 5 Issues Identified

Issue: AHU 1-4 Simultaneous heating and cooling

AHU was consuming excess energy as the heating and cooling valves were in conflict and operating with an insufficient dead-band.

Figure 26. C&E Analytics (CSIRO Building 5) – Issue: AHU 1-4 Simultaneous heating and cooling
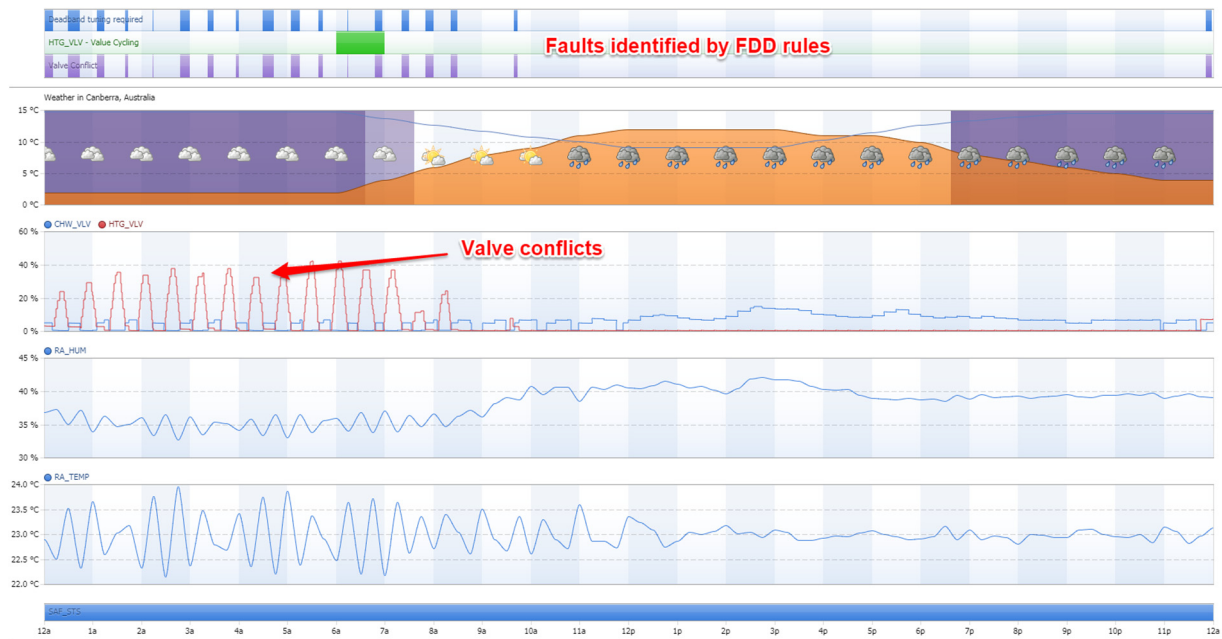
Issue: AHU 1-4 leaking chilled water valve

A faulty actuator was flagged by FDD rules analysing the valve positions and supply air temperature.

Figure 27. C&E Analytics (CSIRO Building 5) - Issue: AHU 1-4 leaking chilled water valve

Issue: Chiller faults

Abnormally high chiller flow temperatures were alerted before and after chiller repairs were carried out.

Figure 28. C&E Analytics (CSIRO Building 5) - Issue: Chiller faults

Issue: AHU G-2 short cycling dehumidification mode and valve instability

Valve instability present after unit entered dehumidification mode flagged by dehumidification mode short cycling and valve/temperature instability algorithms

Figure 29. C&E Analytics (CSIRO Building 5) - Issue: AHU G-2 short cycling dehumidification mode

Issue: HHW tuning – reduced demand

Tuning of non-24 hour equipment schedules, after hours heating call thresholds and resolving simultaneous heating and cooling issues significantly reduced boiler demand and pump operation.

Figure 30. C&E Analytics (CSIRO Building 5) - Issue: HHW tuning – reduced demand

C&E Analytics (CSIRO Building 5) – Demonstration of Outcomes

Energy Performance and Savings

Figure 31. C&E Analytics (CSIRO Building 5) – Energy profile versus time (compiled May 2017)
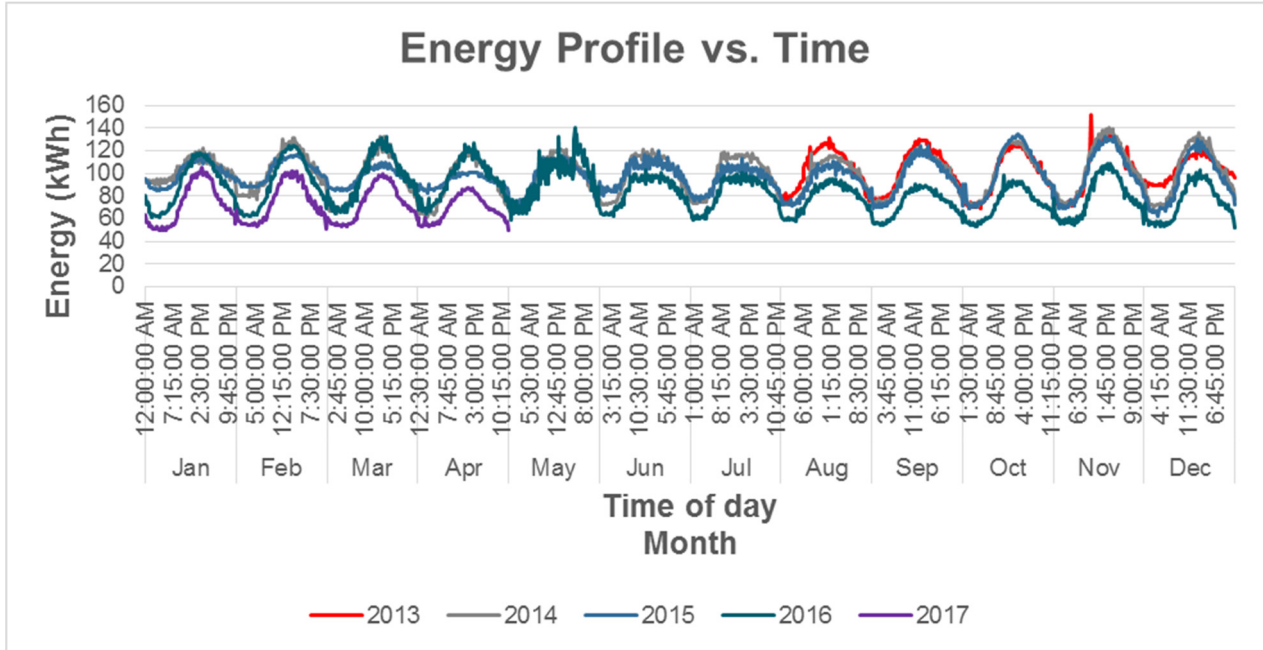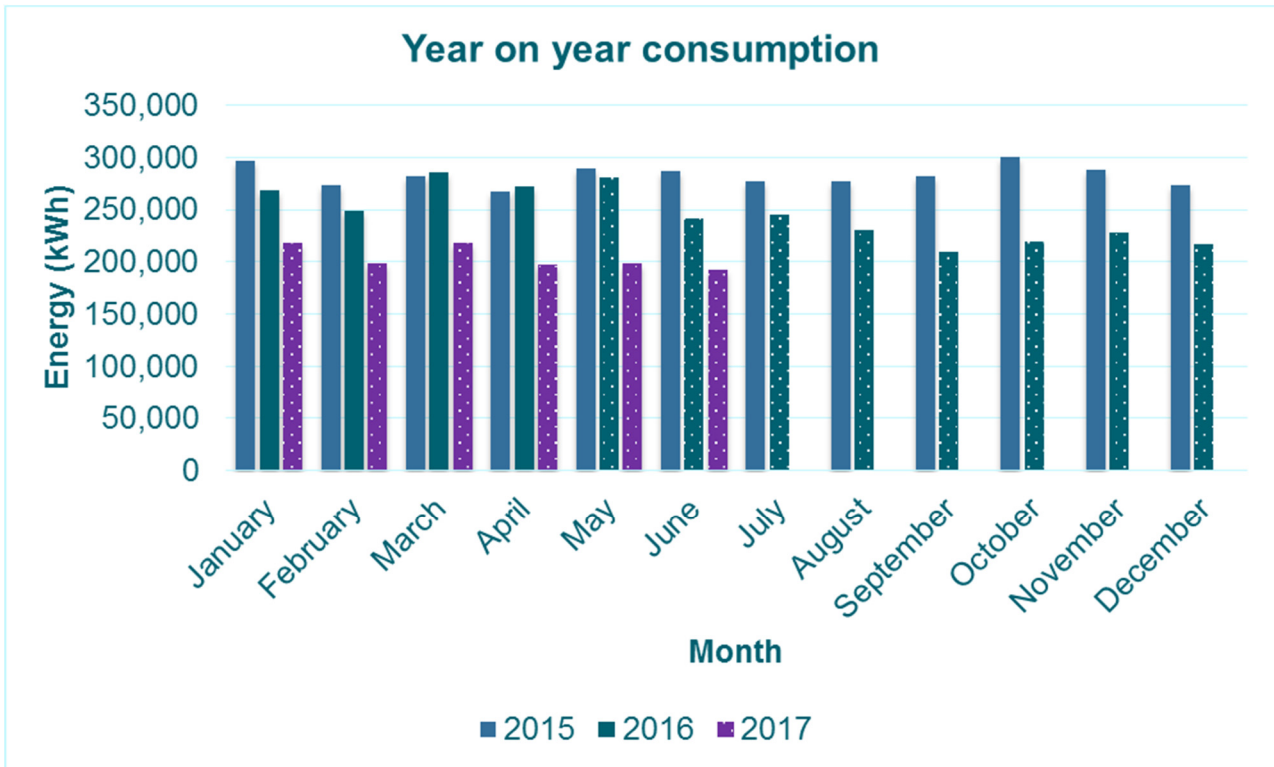

Figure 32. C&E Analytics (CSIRO Building 5) – Total energy consumption (patterned bars indicate FDD monitoring active)

Monthly Energy Performance and Savings Breakdown

Table 9. C&E Analytics (CSIRO Building 5) – Total energy consumption (shaded cells indicate SkySpark monitoring active)

Date	% Difference (2017 vs 2015)	% Difference (2016 vs 2015)	2017	2016	2015	2014	2013
January	-18.4	-10.1	216,949	265,987	296,002	211,929	
February	-22.1	-6.6	198,245	254,605	272,662	276,044	
March	-23.6	-0.9	218,486	286,050	288,771	283,157	
April	-27.2	+2.3	197,798	271,686	265,464	265,522	
May		-5.7		268,540	284,750	286,178	
June		-16.2		242,184	289,068	285,271	
July		-12.6		245,243	280,680	295,886	
August		-15.0		233,332	274,639	287,204	
September		-24.4		210,547	278,423	283,361	297,399
October		-28.0		217,304	301,734	298,881	294,165
November		-21.5		226,821	289,035	302,687	296,910
December		-21.7		220,642	281,704	300,774	300,351
Total				**2,942,941**	**3,402,932**	**3376894**	

Note: All savings numbers presented in this case study were provided by the FDD solution provider.

END OF CASE STUDY

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RP1026: Evaluation of Next-Generation Automated FDD Tools for Commercial Building Energy Efficiency - Part I: FDD Case Studies in Australia. Page 66

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