The Innovation Hub

for Affordable Heating and Cooling

DCH2 Report

Learnings from the use of FDD, Analytics and Demand Response Applications in the 3 trial buildings (hosted on the Digital Layer software platform DCH 1.2)

15 December 2020

SWITCH AUTOMATION PTY LTD

About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

i-Hub Switch Data Clearing House

The Open Data Clearing House project is to develop and deliver a proof of concept that demonstrates how technology infrastructure can underpin an open data clearing house for all Australian buildings. The solution will be tested on three CSIRO campuses by integrating their building data, and showcasing how that data can be collected in a consistent format, normalized, then used to benchmark buildings and ultimately hasten the transition to more renewable power sources and a net zero future.

Lead organisation

Switch Automation Pty Ltd

Project commencement date

1st February, 2020

Completion date

31st October, 2020

Date published

15th December, 2020

Contact name

Deborah Noller

Email

dnoller@switchautomation.com

Project website

CONTENTS

List of Figures

1. SUMMARY

1.1 EXECUTIVE SUMMARY

The CSIRO Smart Buildings Data Clearing House Platform (DCH2) is a visionary initiative which fits perfectly with the Switch view of the future of smart and connected buildings. By exposing building data to service providers, entrepreneurs, software developers, research scientists, students, and organisations owning and operating buildings, we open the door to a never-before-seen ecosystem rooted in connectivity.

The DCH2 team believe it could be an initiative that creates and supports an entire eco-system of world-class Australian-born smart building technologies, creating thousands of new jobs and upskilling of the existing workforce such as trades involved in building services and maintenance. This industry growth can grow skills and revenue for Australia and, at the same time, transition our buildings to be the most advanced smart, sustainable buildings, reducing our carbon footprint and leaving a measurable, positive impact on the planet.

The purpose of this document is to expand on the technical details of the project, enabling stakeholders to gain a more detailed understanding of the project architecture and the various technologies that contribute. The Data Clearing House is built using IP from the Switch market-tested Digital Layer. We also introduce the concept of the Marketplace which enables the vision to expand this project to an entire ecosystem of application providers and we describe how the Switch Gateway is a technical enabler to get real-time IoT data, telemetry and control capability.

2. TECHNICAL REPORT

2.0 Objectives of the DCH Project

The project is divided into three distinct phases two of which are covered by current funding and one is future state.

The first phase is to build a dedicated instance of the Switch Platform for the DCH and to license that into a CSIRO instance of Microsoft Azure cloud within one of the Australian Data Centres.

The second phase is to prove the functionality across a sample of CSIRO buildings and the third phase is future state, expanding the DCH for a Marketplace.

2.1 Phase 1: Build a Data Clearing House

- Build an **open infrastructure (DCH)** that can host building data for an ecosystem of stakeholders including building owners and operators, application providers, service companies and researchers

2.2 Phase 2: Proof of Concept Project Across 3 CSIRO Campus

- Demonstrate value of **DCH** on three CSIRO campus by collecting data and applying fault detection and diagnostics (FDD) to identify energy and other opportunities
- Objective is to demonstrate **Fault Detection and Diagnostics (FDD), visualization, work orders and analytics** to provide value from building data to stakeholders

2.3 Phase 3: Deliver a Marketplace and Create an Ecosystem

- **Provide a marketplace** where an industry can thrive
- Positively **impact energy use** of buildings
- Demonstrate that **visibility to building data** can improve the way buildings are managed

3.0 Phase 1: Build a Data Clearing House

3.1 Establish the DCH Data Centre

Set up and maintain a dedicated version of the Switch Platform within its own instance of MS Azure. The schematic below outlines the architecture and technical stack for the Data Clearing House.

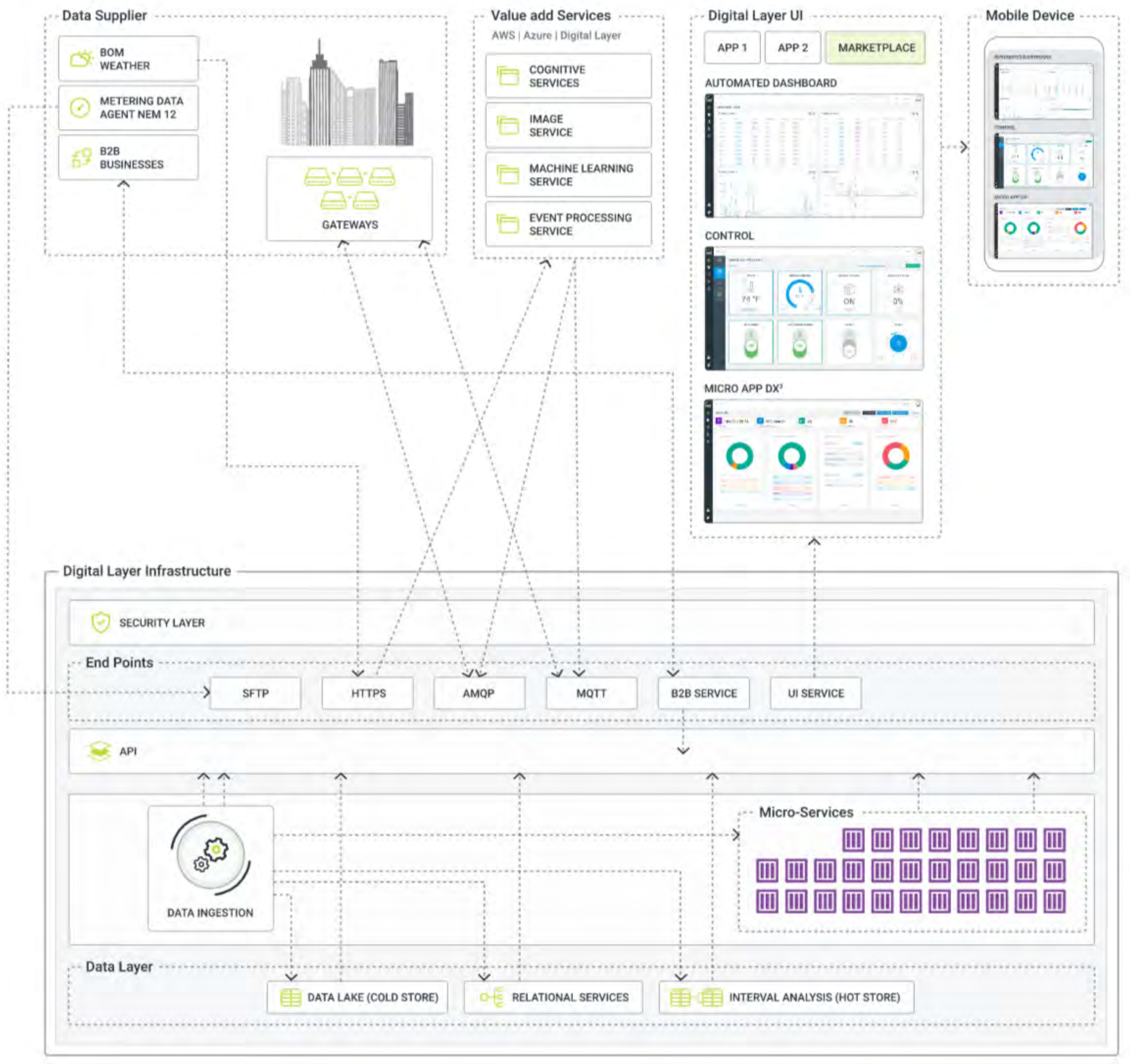

Figure 1: Digital Layer Platform

The schematic above, outlines how the various suppliers of data such as building gateways and smart IoT edge devices will interact with the DCH. These systems and devices feed data at various time-stamp intervals to the DCH via a range of methods including SFTP, MQTT and AMQP (for gateways) and email.

The DCH contains 3 primary data stores which have the following roles:

- Data Lake (Cold Store): is for batch or offline operations and stores data in its original state. For example, data supplied in a csv will be stored here is that form and can be used for downstream processing at a later time. The Data Lake will also contain the results of downstream processing like rollup summaries and advanced analytics results.
- Relational Store: is for storage and mapping of Assets, Sensors, Events and Tags. It is a fast retrieval engine and also performs the role of mapping all relationships between data entities
- Interval Analysis builds on an Azure technology called ADX and offers real-time analysis of very large volumes of data. This is a premium service and is useful for machine learning services that might be added by the DCH team or third parties. It includes sophisticated dashboarding or data presentation scenarios.

The schematic also describes the User Interface (top right) and how services and apps purchased or acquired from the marketplace will fit within the Data Clearing House ecosystem. This UI layer is hosted on the DCH and the core application is the Marketplace where users and companies will be able to purchase and/or opt into various services and apps which have been published to the DCH marketplace.

3.2 Provision all Platform Services

At the core of the DCH are various services that perform data management.

3.2.1 Data Ingestion

The DCH will support several data capture methods so a variety of data can be collected and made available to the stakeholders who own, operate and service buildings.

DCH will support any of the following methods:

- Flat file uploads
- Via API
- B2B integration with third party systems

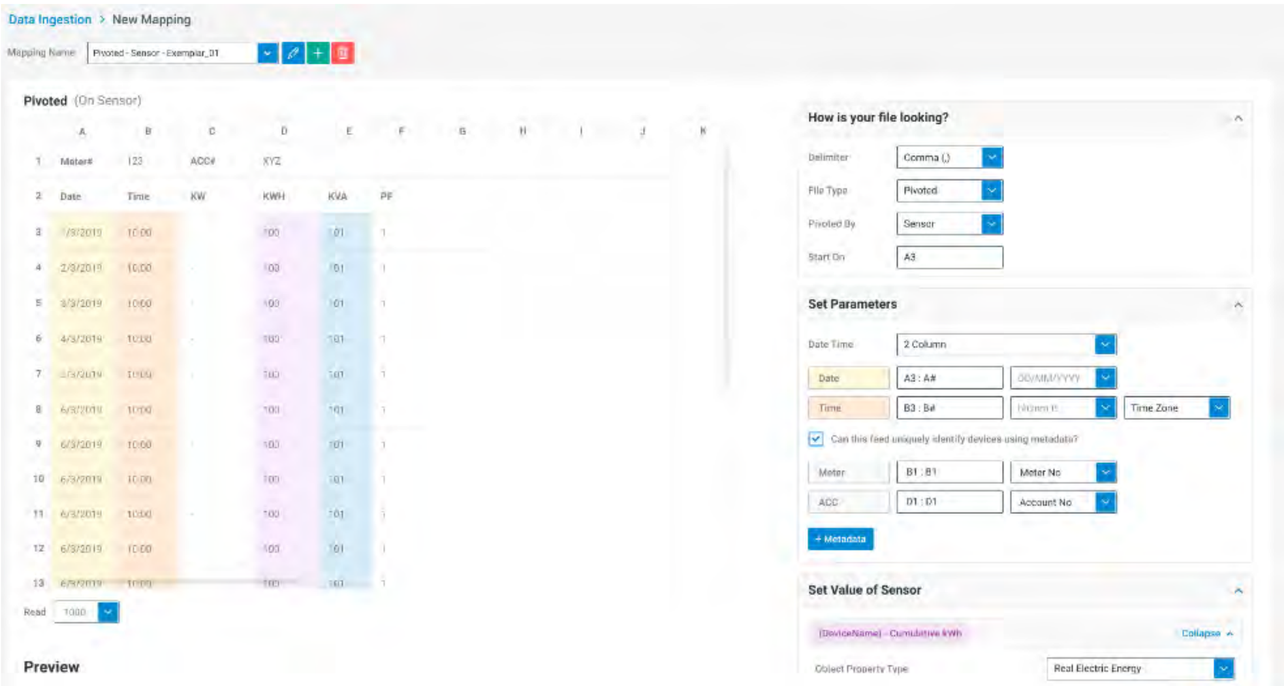

Figure 2: Digital Ingestion UI - Complex Mapping Feature

The DCH will support several data ingestion methods so that data can be integrated from almost any source, combining real-time building system data with overnight electricity-use interval data from utilities, and any other time-stamped data set such as Bureau of Meteorology data.

DCH will support:

1. Flat files (csv or similar) of any repeatable format can be mapped for automatic import, see Figure 1 above, and this importation process can be controlled and carried out by an end-user. An email and FTP server also help automate file transfers and uploads. This method is very useful for repeatable spreadsheets such as NEM12 utility or waste data.
2. An open and published API ensures that more sophisticated users such as service providers or other data platforms can automate the data collection into the DCH. Several manufacturers such as eGauge can use the API to push data directly from their meters to the DCH. This method allows for collection of real-time data without the need for a gateway. The API can directly integrate with local and or remote data sources like weather and utility based data.
3. On request the DCH can be expanded for B2B integrations to collect data from financial systems or third-party databases such as work order systems.

These various methods support the inclusion of data from external data suppliers such as weather services and metering data agents. The DCH will also support third party IoT equipment suppliers for devices such as gateways and other edge devices like sensors, meters or smart thermostats. The DCH can also accept complex forms of data including json, xml and csv in its many shapes and sizes using Switch's sophisticated data mapping tool (Figure 1, above)

The data ingestion service also performs various data management tasks such as normalization, telemetry management, and data transformation for the various data stores. There are a number of DCH data services including a rules engine, monitoring, aggregations, and normalisation.

The DCH delivers an infrastructure that can meet most standard industry technologies, patterns and practices listed below with links for further reading if interested:

- MQTT
- AMQP
- Data Lake
- Interval Analysis (ADX)
- Relational Store (SQL Server)
- Microservices Architecture
- SFTP
- https
- B2B
- Cognitive Services
- Machine Learning
- Artificial Intelligence

3.2.2 IoT Gateway Connectivity

To enable building connectivity, a Linux-based, standards-compliant, secure gateway can provide real-time integration. The Gateway enables a flexible architecture where service providers can take advantage of a comprehensive library of hardware integration drivers. The Gateway will be part of the DCH ecosystem for live connectivity of data ingestion.

Figure 3: IoT Gateway

3.2.3 Data Integrity tools

The DCH has a series of tools for ensuring integrity of data. Some of these tools are exposed in the user interface and also engineered into the DCH as platform services:

- **Missing data reports** for alerting partners and users when data has stopped posting or data that has not been delivered
- Tools that enable like-for-like comparisons, such as similar day comparisons, time-period comparisons, rolling, day, month, year comparisons.
- **Normalization** for converting disparate data into identical resolution allowing various summaries and normalizations by unit of measure or by floor area, virtual meter calculations, heat maps, interval aggregation, etc.
- **Tagging**: Any metering or control point, device or site has properties that are stored in the database. Any of these properties can be created as a tag, which means that users can group any of the properties together and apply a label. tagging is user-definable and user-managed, and those tags can then be used for reporting, analytics, automation or producing dashboards. There is no limit to the number of tags that can be applied to a given site, device or data point. As an example, the tag 'Building Era' or 'Building Type' could be applied. The user could then search for all buildings built in the 1940's that are used for sporting facilities and analyse the performance of those buildings across all the

various regional campuses. Tagging will support Project Haystack and Brick along with other future tagging models.

3.2.4 Alerts Analysis

Smart Alerts (trade name for fault detection & diagnostics (“FDD”)) is included as a service in the DCH and can be configured based on severity level to escalate the messaging. Smart Alerts are triggered by a variety of factors like severity of conditions or time, depending on the available data and nature of the logic rules. All Smart Alerts notifications can be configured with specific messaging, including suggestions on corrective actions or next steps.

The application is based on a complex event processing architecture. At its core, the application runs queries on groups of equipment sensors by correlating groups of equipment sensors over sliding windows of time. Alerts are generated using an escalating urgency pattern whereby the longer a query meets the criteria, then the higher the level of urgency, thus the more urgent the alert becomes. Alternatively, the query can escalate based on changes to offsets. The Alerts Analysis micro-application will ship with several hundred rules in our Global Alerts Library which will be automatically applied to buildings based on Project Haystack on of the standards for data tagging.

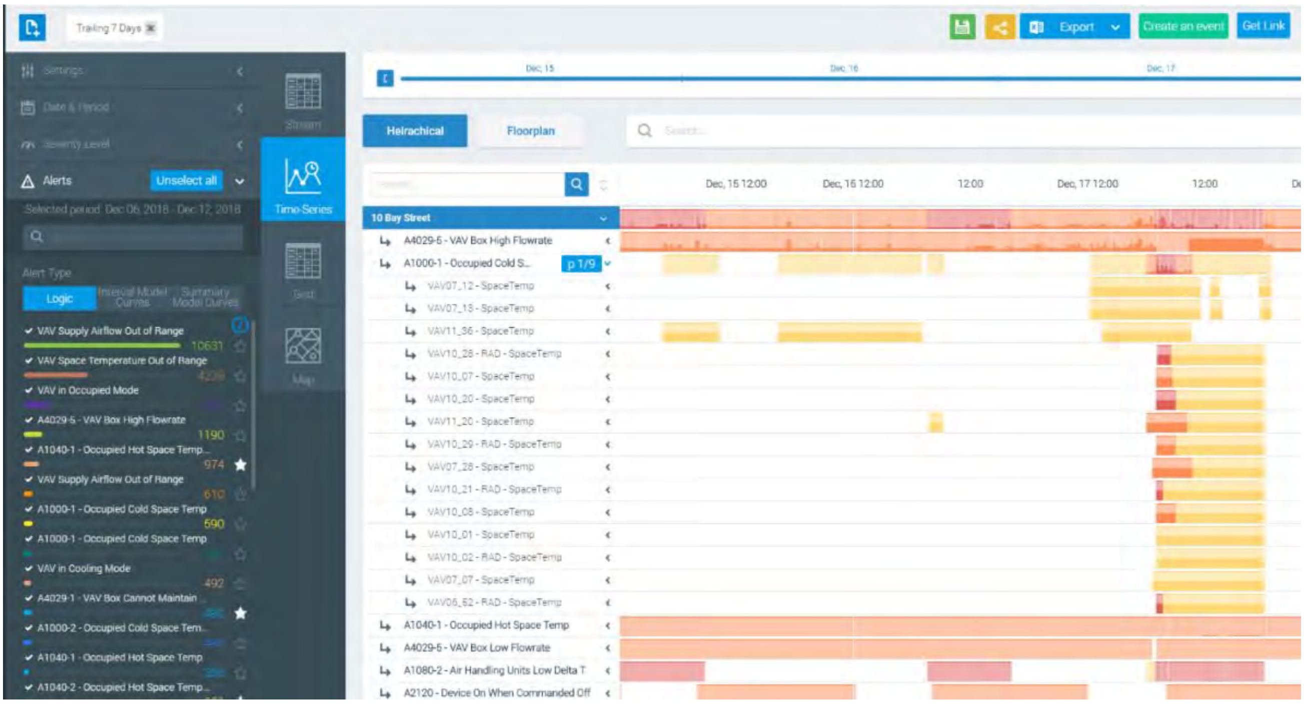

Figure 4: Alerts Analysis Micro-Application

The alert email notification might then be configured to contain a message, such as "Check RTU-1's compressor, refrigerant levels and outside air damper because it is not sufficiently cooling the air to meet supply temp setpoint." Logic modules for analytics (i.e. "Smart Alerts") or control actions can be flexibly configured for any desired applications utilizing any available data points. Logic can also be shared to similar pieces of equipment via tagging the sharing user interface page in the configuration tools.

3.2.4 Out of the Box Dashboards

The DCH can host and display interactive reports/dashboards as interactive workspaces sharable with users or user groups or be viewed by a public link. This process is seamless to all users. For example, some of our customers leverage this feature for custom visitor engagement displays in a building lobby.

Workspaces are easily configured or customized by the end user or a service provider and reporting can be automated from these workspaces or scheduled for delivery via email.

3.2,5 Accessing DCH Data

A critical element of the DCH is open, free and unencumbered access to data. The DCH opens data to allow users to directly connect to, analyse and report on their building data stored on the Microsoft Azure cloud. DCH users can utilize the APIs to connect Microsoft tools like Excel or PowerBI or to create and customize their own analyses and reports that automatically refresh from the building data.

Users should be able to build and share any reports directly and with other stakeholders or scheduled as email reports. DCH users can directly connect via the APIs to access or export data via a specified file format.

DCH provides for access via:

- Standard and Real Time Querying where external applications or approved researchers, data scientists and organisations can, depending on the pricing model, request standard data sets or use the premium interval analysis querying engine to pivot, aggregate and perform complex data science analytics over their data.
- Interval Analysis. The Interval Analysis service is incredibly fast and powerful and will provide an opportunity for Service provides to monetise this feature for premium customers.

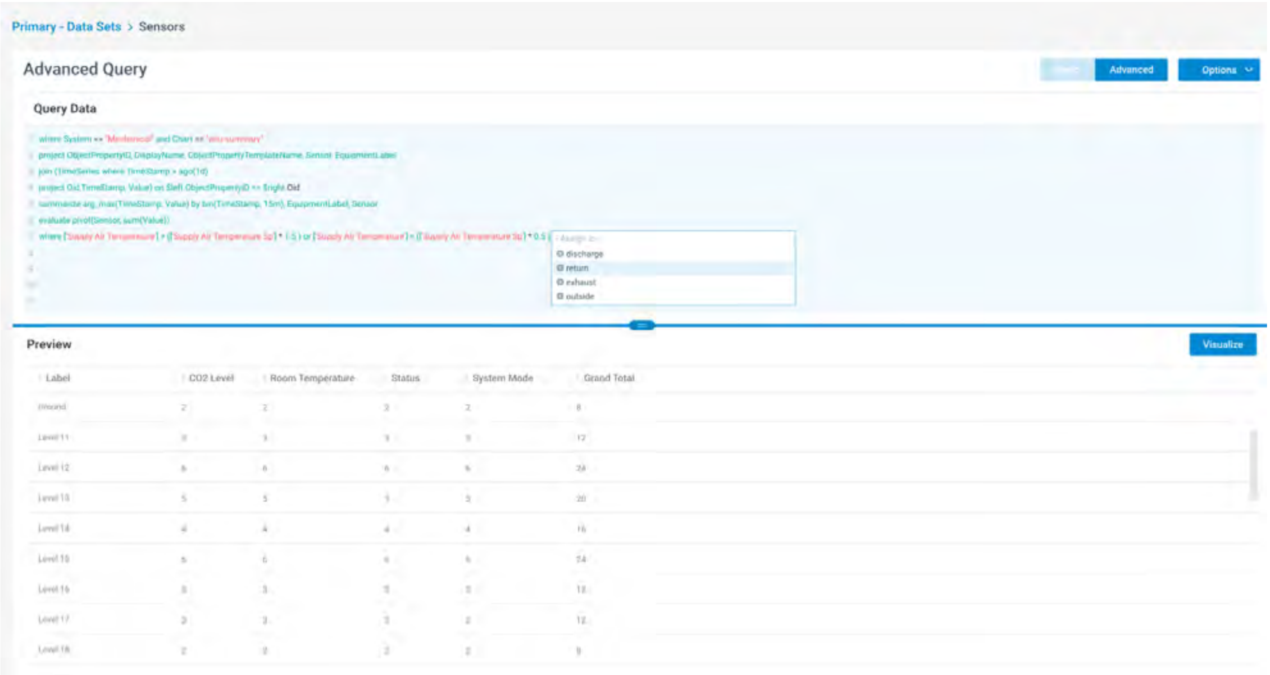

Figure 5: Premium Querying Capability

3.3 Phase 2: Proof of Concept Project Across 3 CSIRO Campus

The DCH project required a real-world demonstration of how it might be implemented and the potential benefits that the DCH could bring to both clients who own and operate buildings but also to the various participants in the industry.

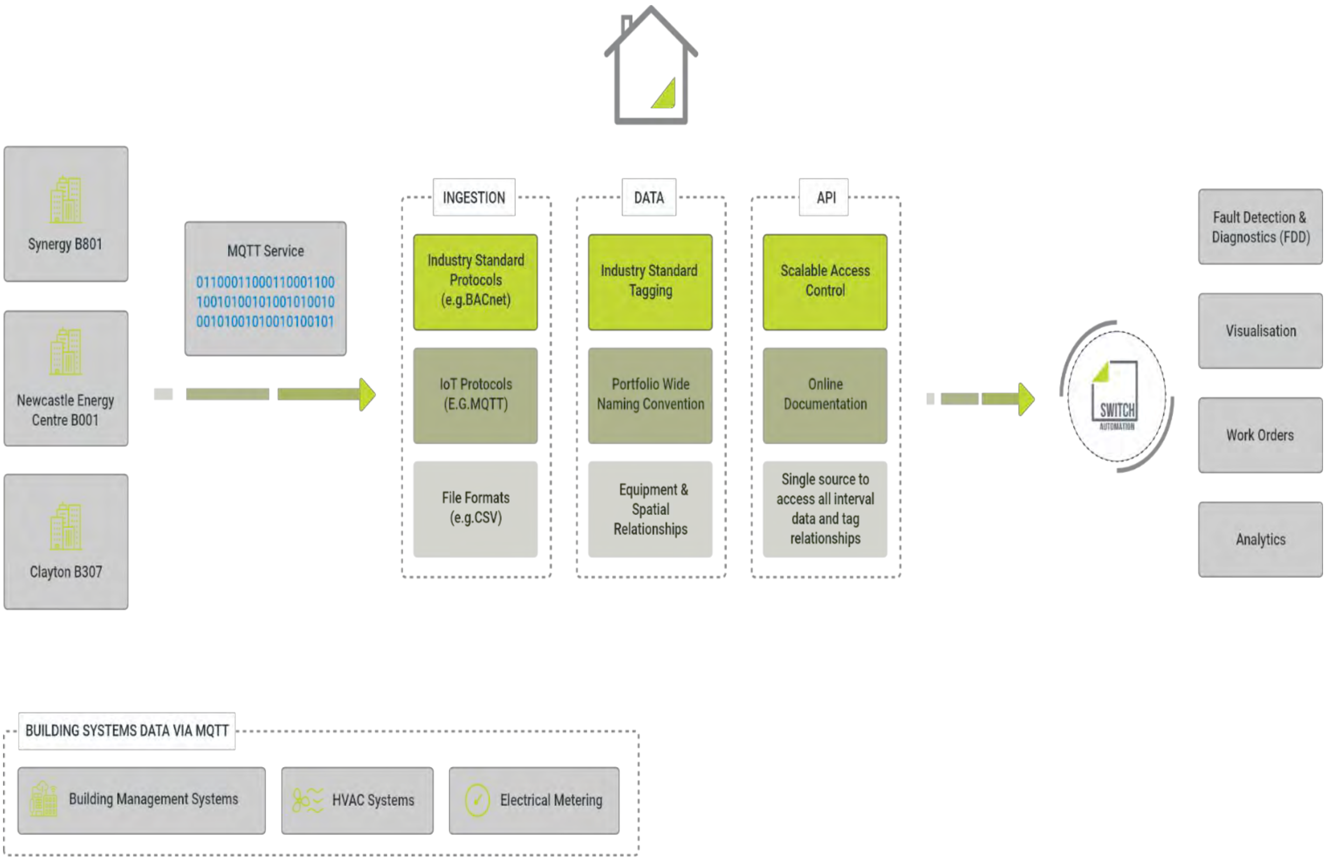

Figure 6: DCH2 proof of concept

4.0 MQTT integration and data analytics

4.1 Status of MQTT integration

Three sites were provided with MQTT capability and that data feed was provided to Switch.

Tasks completed:

1. Switch developed and tested the MQTT driver and can confirm that three sites were successfully integrated with more than 14 thousand data points detected and ingested.

2. The sites are :

    a. B001 Newcastle Energy Centre
    b. B801 Black Mountain
    c. B307 Clayton

3. Data Mapping: each of the points being streamed in real-time from each of the CSIRO buildings needs to be identified, set up in Switch data structures and named. Data points can come from any number of different data sources including equipment or edge devices. A piece of equipment or edge device might have hundreds of data points. Each data point is a time-stamped data series and provides a useful reference for the performance of the building. The usefulness of the analytics is dependent on the accuracy of data point mapping. Depending on the information that streams with the points such as naming convention applied by the technician who commissioned the equipment, this part of the process can be extremely fast or slow.

    Over 14,000 data points were mapped and data flowing to Switch data management layer had analytics applied via more than 40 fault rules.

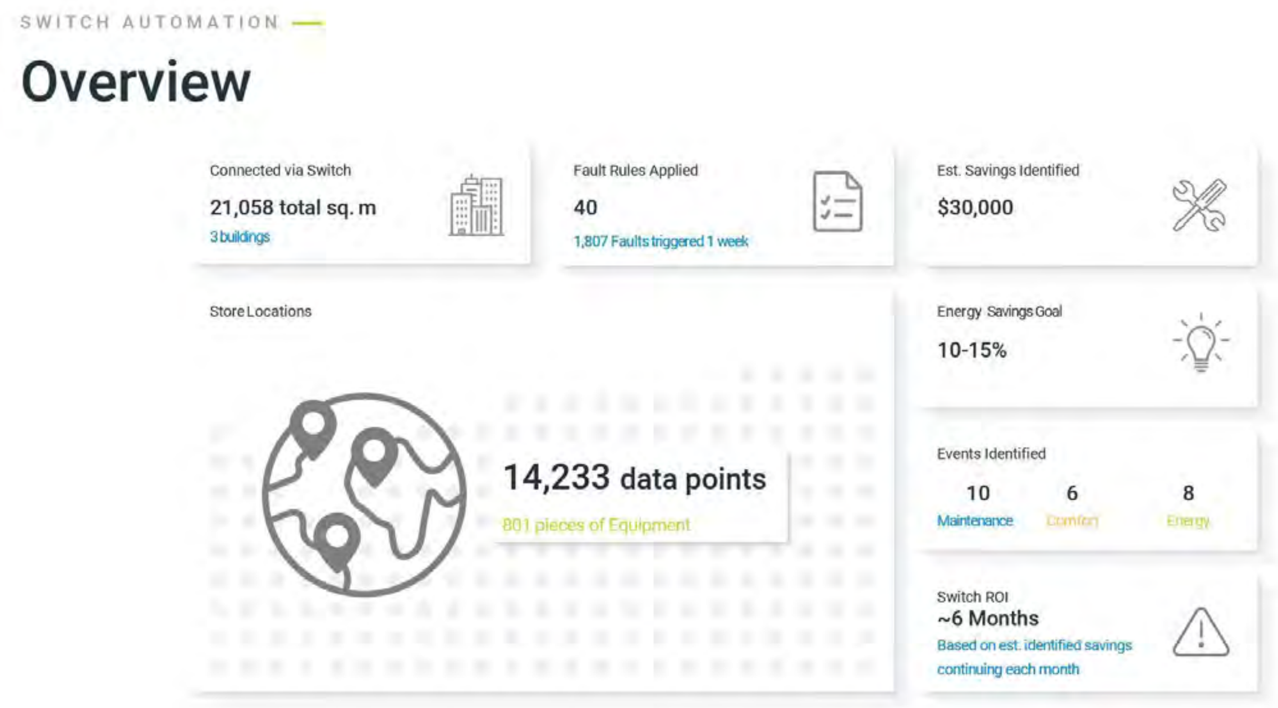

Figure 7: DCH2 Fault Detection and Diagnosis Overview

4.2 Application of FDD analytics

Following successful integration and flow of data, the DCH required some configuration to apply analytics.

1. **Data Tagging**. The data mapping was completed, and the data tagging applied. The Data Tagging is the process of grouping data points into groups to enable the application of analytics and to ensure that end-users can perform querying and reporting across the data.

2. **FDD**. The application of analytics and development of workspaces is the step after data tagging. The data mapping applies a standard naming standard to each of the data points. The data tagging takes each of those groups and assigns them into groups of similar data points. This is called tagging. There are a number of industry standards such as Project Haystack and Brick that the DCH can support. When completed, the building engineers, were able to apply analytics for alerts, reports and dashboards.

4.3 Analysis by Engineers

Engineering services is when engineers study the analytics to determine issues with building equipment or the way it has been commissioned. Essentially, they are using analytics to identify opportunities for improving building performance or energy/cost savings. The Switch engineers spent two months studying the outcome of the CSIRO analytics to determine if there were opportunities for improving building performance at one of the three campus or could make recommendations to the way buildings were commissioned to increase equipment performance.

Some examples of findings are as follows:

1. **Data commissioning issues:**
   Problem: CO_2 Sensors indicate poor calibration or faulty sensors
   Identified by: Many of the sensors are reporting below 400ppm which is not possible. Outside air is more than 400ppm. The Switch Platform applies similar FDD analytics across all sensor types, as well, in order to assess if values are reading within expected operating ranges.

   Opportunity:
   - Automated & centralised digital audit of sensors to improve accuracy and integrity of data
   - Energy savings through accurate equipment control
   - Improvement of occupant comfort (and productivity) by accurately measuring Indoor Air Quality and addressing ventilation issues

FCU.031 - 2J11 - RA_CO2	FCU	168	Synergy B801
FCU.203 - 4F06 - RM_CO2	FCU	215	Synergy B801
FCU.313 - 5F04 - RM_CO2	FCU	262	Synergy B801
FCU.310 - 5F28 - RM_CO2	FCU	283	Synergy B801
FCU.005 - 2F07 - RM_CO2	FCU	283	Synergy B801
FCU.214 - 4F34 - RM_CO2	FCU	288	Synergy B801
FCU.111 - 3F28 - RM_CO2	FCU	292	Synergy B801
FCU.212 - 4F30 - RM_CO2	FCU	294	Synergy B801
FCU.304 - 5F11 - RM_CO2	FCU	295	Synergy B801
FCU.904 - 1A03 - RM_CO2	FCU	296	Synergy B801
FCU.902 - 1F01 - RM_CO2	FCU	297	Synergy B801
FCU.115 - 3F39 - RM_CO2	FCU	304	Synergy B801
FCU.207 - 4F16 - RM_CO2	FCU	307	Synergy B801
FCU.214 - 4F35 - RM_CO2	FCU	309	Synergy B801
FCU.305 - 5F15 - RM_CO2	FCU	309	Synergy B801
FCU.004 - 2F07 - RM_CO2	FCU	310	Synergy B801
FCU.307 - 5F16 - RM_CO2	FCU	311	Synergy B801
FCU.901 - 1F02 - RM_CO2	FCU	314	Synergy B801
FCU.215 - 4F39 - RM_CO2	FCU	316	Synergy B801
FCU.303 - 5F06 - RM_CO2	FCU	316	Synergy B801
FCU.007 - 2F10 - RM_CO2	FCU	318	Synergy B801
FCU.103 - 3F06 - RM_CO2	FCU	325	Synergy B801
FCU.211 - 4F28 - RM_CO2	FCU	326	Synergy B801
FCU.204 - 4F11 - RM_CO2	FCU	330	Synergy B801

Figure 8: Indicating poor calibration or faulty CO2 Sensors

2. **Low Power Factor:**
Problem: Power factor for M42 DB-1 meter is reading 0.5

Identified by: Multiple meters identified with a power factor of less than 0.6. Low power factor will generally use more power through higher current draw. This can significantly reduce the lifespan of the equipment. A low power factor can damage voltage sensitive equipment too. If the Synergy building is on kVA rates from the utility, you could be paying up to double the utility rate. These meters particularly:
   - DBB.2
   - GOODSLIFT
   - LIFTI
   - MCC.04.03.E

Opportunity:
- Energy savings by reducing line losses
- Improved equipment service life (reduce overheating, overloading)
- Reduced utility bill (and penalties) through reduction of reactive power

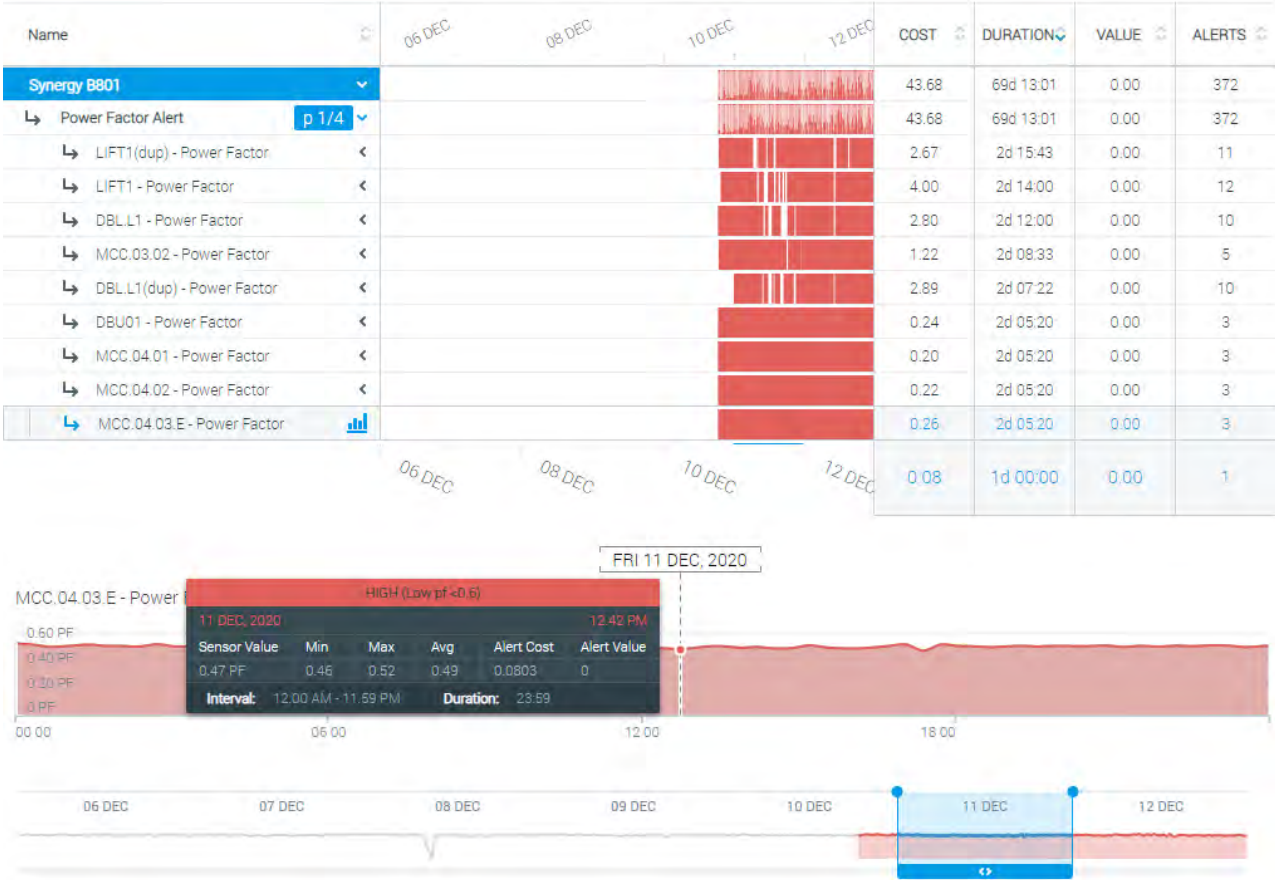

Figure 9: Indicating poor power factor

3. **Chiller – excessive cycling and cycling out of hours**
:
Problem: Chiller 1 has excessive cycling which reduces the overall COP of the plant during operation, and as a result will yield increased energy consumption. The chiller is also cycling out of hours when it should probably not be on at all.
Identified by: real time alerting on chiller reading via BMS
Opportunity:
- Reduced energy costs through:
  - Fewer chiller hours
  - Temperature stabilisation
- Improved equipment service life (reduce cycling, lubrication issues)

Energy savings of roughly $5k per year

Figure 10: Indicating excessive and incorrect chiller cycling

4. Chilled Water Plant Differential Pressure Reset Strategy

Problem: The differential pressure reset setpoint for the chilled water system is currently set to a single value while the plant is operating, independent of downstream valve control. Through analytics, it was discovered that the pressure setpoint is too high for average operation and valves are quite throttled back, resulting in higher pressure and pump power in the system.
Identified by: real time alerting on chilled water plant operating parameters reading via BMS
Opportunity:

- A chilled water reset could be implemented, and lower average chilled water pump power could be realized, if rogue zones are accounted for.
- Energy savings of over $13K per year

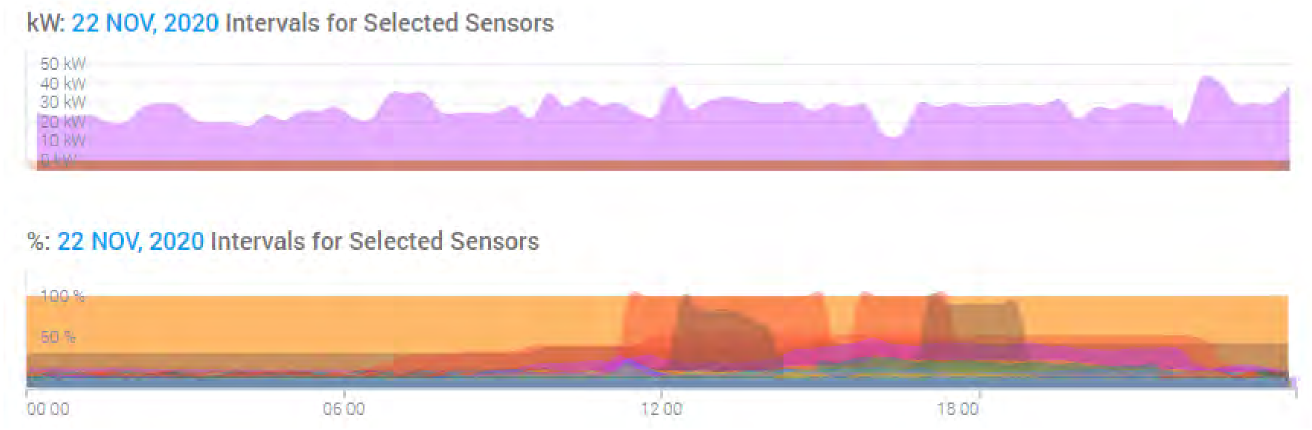

Figure 11: Indicating differential pressure reset setpoint error

4. **AHU Outdoor Air Dampers Open Above Minimum While Heating:**
Problem: A fault detection Alert detected that outdoor air dampers were open above minimum set point during heating, which unnecessarily increases heating load and increases energy consumption of the facility.
Identified by: fault detection Alert running on AHU control
Opportunity:
    - Change control such that outdoor air damper remains at minimum position while the AHU is in heating mode.
    - Energy savings of roughly $7k per year

Figure 12: Indicating excessive outdoor air

5. AHU Damper Control May Limit Economizer Capability

Problem: The return air dampers on AHUs remain open while units are in economizer mode. This dilutes the thermally advantageous outdoor air stream with warmer return air and thus increases overall cooling load
Identified by: energy analytics of AHU control data in the platform
Opportunity:

- Improve economizer performance of AHUs by controlling return air dampers closed during full economizer mode.
- Energy savings of roughly $10k per year.

Figure 13: Indicating economy cycle error

4.4 Summary of results

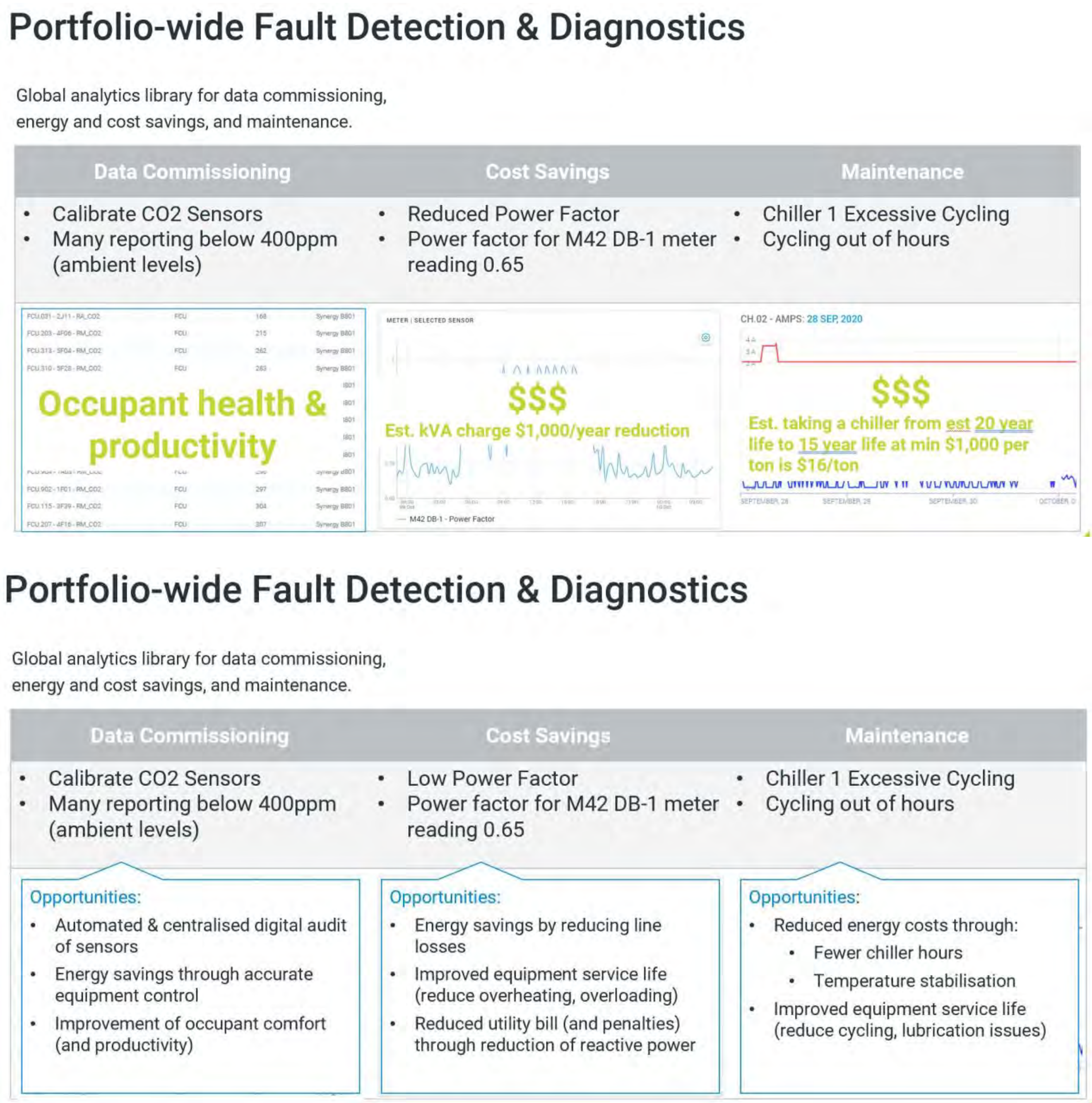

Figure 14: Overview of FDD results

5.0 DCH Marketplace – future state

5.1 The Marketplace

The Marketplace will be public facing and hosted as a main menu option inside the DCH User Interface (UI). It will enable approved users to add and remove available applications and services to their portfolio. There will be a wide range of applications ranging in complexity from simple retrieving of datasets through to full stack micro-applications.

We anticipate that the Marketplace will service several major categories of interest. For user personas such as research scientists and students it will offer raw or anonymised data sets and queries which will be able to be used for various forms of analysis including machine learning scenarios and predictive models. As mentioned previously, there will be three service tiers available, the first being a standard offering for access to large sets of data via the DCH querying tool. The UI will offer a straightforward but powerful experience to users. The second tier is a premium service that offers access to very large data sets with very fast retrieval. This service tier also offers an expert mode, which includes a power language for users to pivot, aggregate, and perform scientific functions as well as run custom R scripts across the data sets. The third tier is the Application Programming Interface (API) that can access the functionality of the other two service tiers, in addition to allowing service providers to build custom applications, dashboards, and new services.

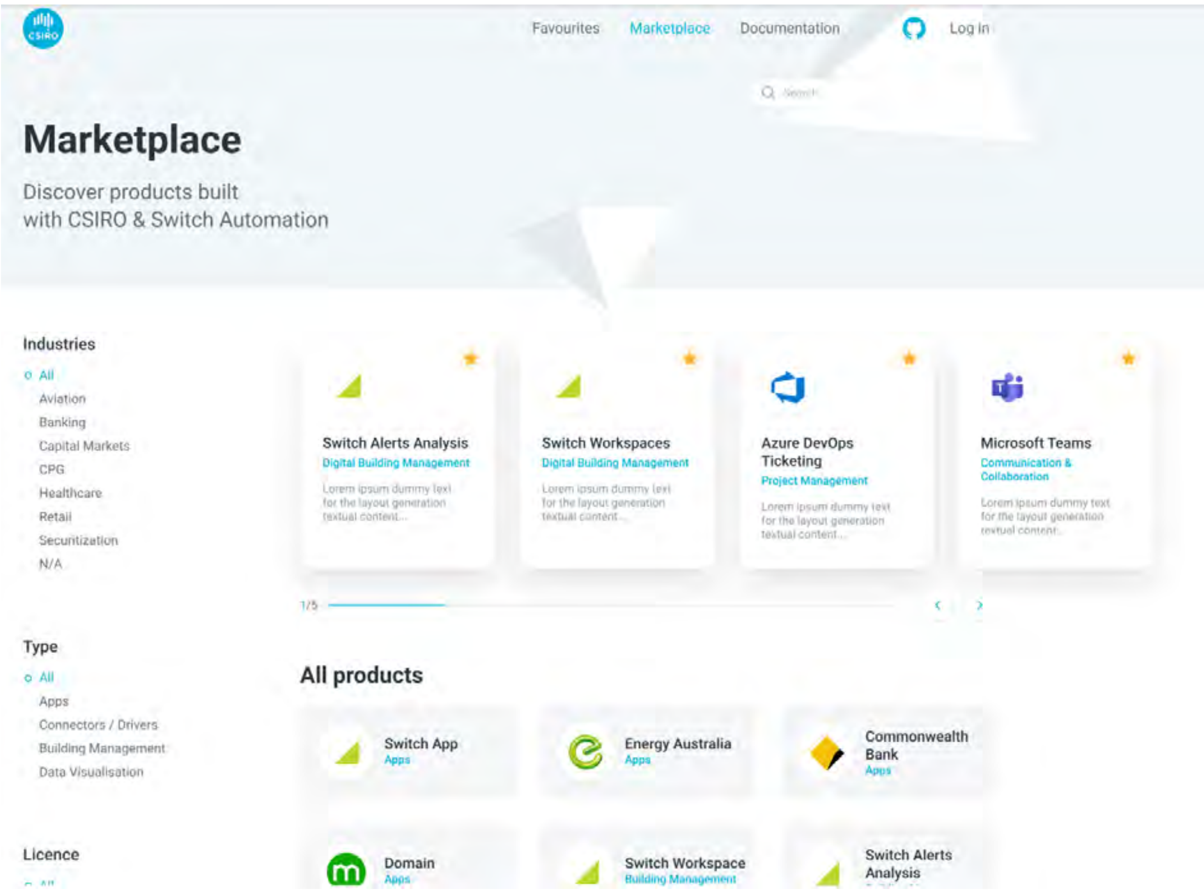

Figure 15: Marketplace UI

5.2 Visualisation software development

The other major interest we anticipate are service providers leveraging the Marketplace to build and re-sell applications including dashboards and presentation layers. The DCH will provide expert users with a visualisation software development kit (SDK) which will enable the production of fast, dynamic, and beautiful visualisations that are data-bound to similar styles of IoT devices and sensors. These visualisations will be packaged to DCH Workspaces then listed within the Marketplace. See the example below of a Workspace produced using industry standard Haystack tags and the Visualisation SDK. Switch will seed many sample solutions for this category, but we envisage this gaining a life of its own.

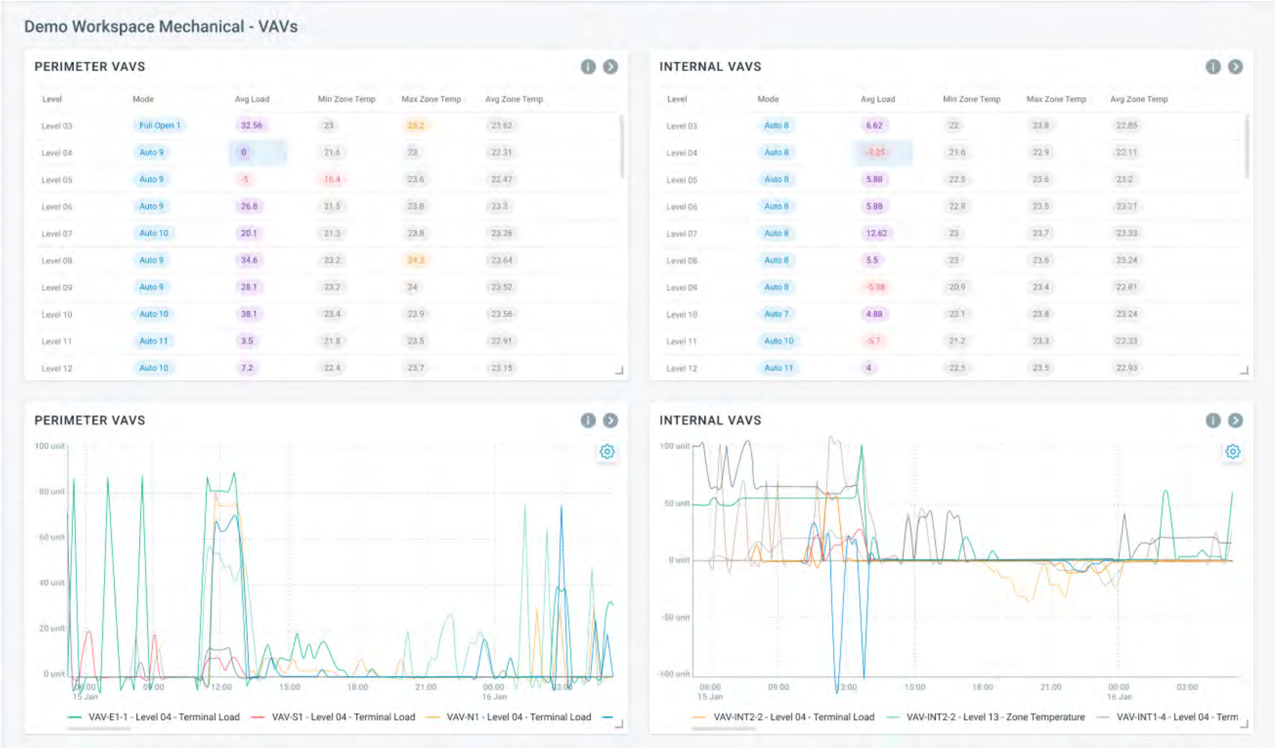

Figure 16: Dashboard build using the Visualisation SDK

More complex full-stack Marketplace items such as micro-applications can be hosted as standardised docker microservices, along with the resulting User Interface (UI). Examples of these will include many of the existing Switch services like Switch Dx3, Site Analysis, Alerts Analysis, Events, and Document Library, but in time, we anticipate other vendors providing competitive solutions to these styles of micro-applications. Below is an example of a Micro-Application called Switch Dx3 which provides a digital audit for buildings.

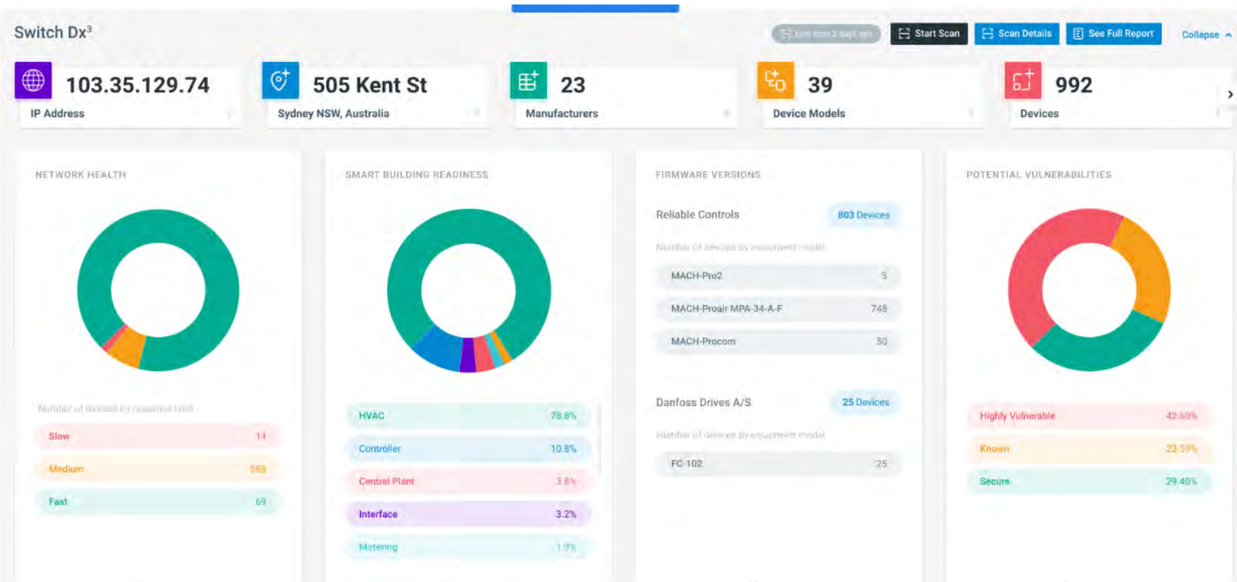

Figure 17: Switch DX³ – a digital device discovery service

5.3 Other services

Other categories of services we foresee are value-add services provided by external providers. These third-party suppliers will likely use the API to access data from the platform, then add value to it in some way. This value could take many forms including:

- Weather normalised benchmarking using regression algorithms to correlate utility consumption and weather data historically to enable the prediction of expected future consumption. Switch will seed the marketplace with examples of this type of service.
- Use of Artificial Intelligence (AI) technologies to optimise building equipment. Switch is already engaged with a third party to exercise this model where the company is pulling data from the Switch API to generate a learned set over time. Once complete, the model will monitor a live stream of data and produce optimisation control commands. These control commands will be fed back into the Control API to be actioned against the real equipment.
- Ability for Building Owners to leverage an Event Processing Engine to produce fault rules which can be used as a mechanism of tuning a building. Switch will also seed the Market with this offering

The Marketplace is an enabler of engagement and growth for the industry. Hopefully by seeding the Marketplace with example services and applications, and by publishing the required SDKs and documentation we can encourage other service providers to follow.