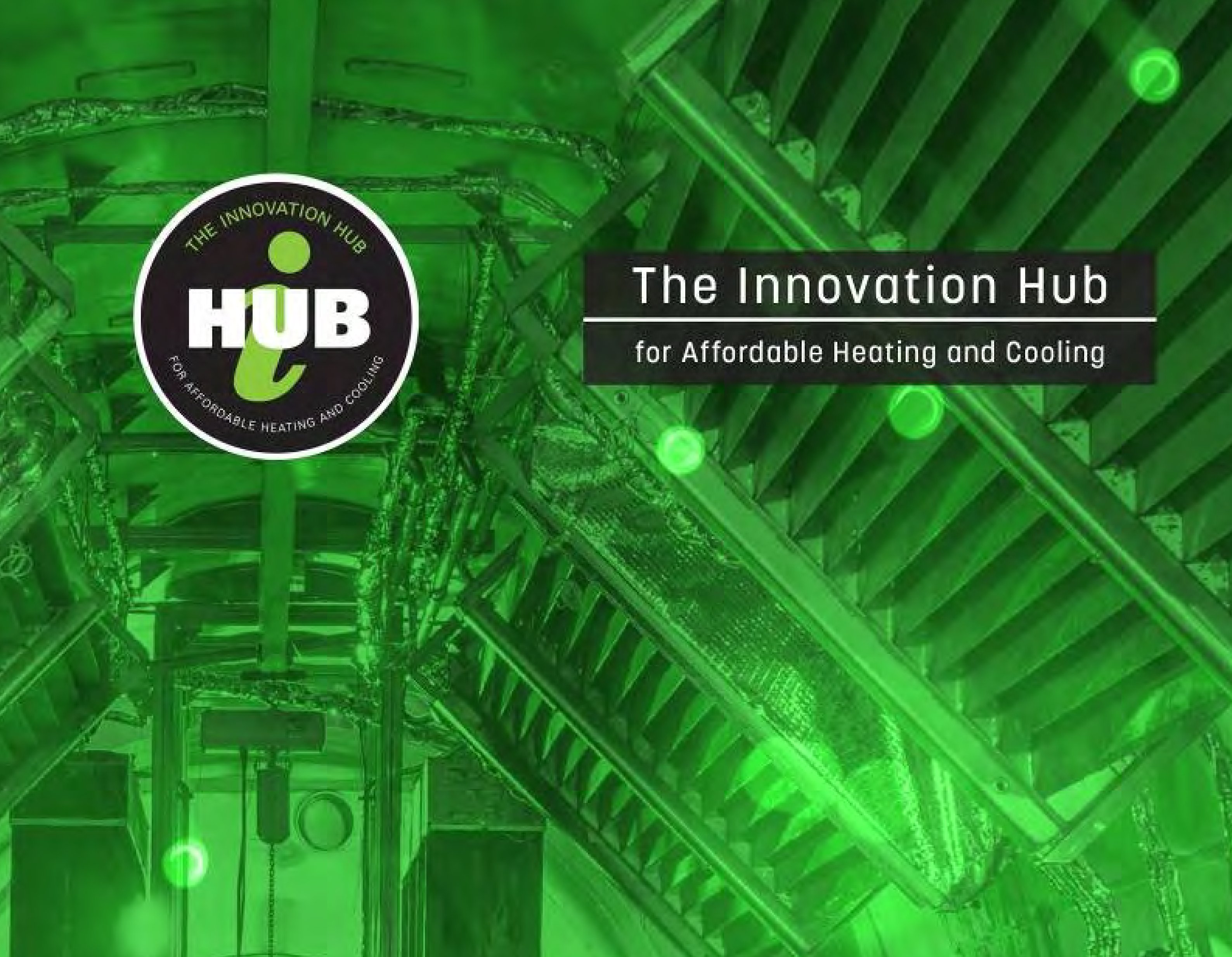

Knowledge Sharing Report

DCH at Scale: On-boarding Proof-of-Concept at a Queensland Hospital Site

27th May, 2022

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.

Primary Project Partner

Australian Government
Australian Renewable Energy Agency

DCH at Scale: On-boarding Proof-of-Concept at a Queensland Hospital Site

Metro North Hospital (MNH) has a diverse set of buildings with large variability in age and systems contained within. Like many hospital buildings, they are in constant state of flux, and receive continual and ongoing upgrades. While telemetry and sensors have the ability to generate large datasets, most of them are inaccessible due to on-premise data silos coupled with inconsistent naming conventions, while electricity and gas invoices arrive as PDF or paper documents.

Modelling data becomes a per-building activity, making scalable application development an impossibility. Without a standard metadata schema, application development cannot happen across the entire sector. This project will allow MNH to trial the CSIRO cloud based platform the Data Clearing House (DCH).

Lead organisation

Metro North Health, Queensland Government

Project commencement date

March, 2022

Completion date

27 May, 2022

Date published

27 May, 2022

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https://www.ihub.org.au/dhc9-dch-at-scale-on-boarding-proof-of-concept-at-a-qld-hospital-site/

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1 SUB-PROJECT OVERVIEW, OBJECTIVES, AND IMPORTANCE TO INDUSTRY

1.1 Overview

To on-board HVAC systems at a large complex of buildings at a QLD hospital site (circa 100,000 m2) into the iHub DCH1. This will allow scalability testing of the DCH and improve the development of the Brick building data model (schema and ontology) to support a wider range of use cases. The rich data set collated will allow development of advanced applications and services. Metro North Health (MNH) is one of 16 Hospital and Health services in Queensland and serves an estimated population of 1 million people, 23 per cent of Queensland's population. By 2031, this is expected to grow to 1,372,461 residents. MNH employs over 16,800 staff and has an annual operating budget of $3.1 billion.

MNH has five hospitals (Caboolture, Royal Brisbane & Women's Hospital, The Prince Charles Hospital, Redcliffe Hospital, Kikcoy Hospital & other small sites). It also comprises a number of residential care facilities, community health centres, mental health and oral health services, as well as outreach and home visiting services.

Bar-tech Automation are the current controls integrator at four MNH sites and have developed rich data sets for analysis and integration, meaning that we can side step procurement inertia. Established in 1993, Brisbane based Bar-tech Automation have been setting the bar high for over 25 years in the BMS and Integration sector. Bar-Tech has achieved many benchmarks, for example, controlling the largest tri-generation plant in the southern hemisphere, providing and maintaining large scale BMS solutions to major public hospitals in South East Queensland and delivering integration and monitoring outcomes to Airports and T3+ Data Centres.

The project posits that automation of on-boarding existing BMCS is achievable at scale by developing automated commissioning tools and moving towards a real-time messaging bus for building plant & equipment. The project will use an measurement and verification (M&V) application hosted in the DCH to begin to develop a baseline, and reports will be developed in a BI tool against the REETSEF KPIs for Metro North Health.

Buildings Evolved (BE) is a Digital Engineering strategy firm specialising in building-to-grid applications through successful integration of a wide range of large-scale building projects. BE have worked in the property sector for many years helping big names such as Vicinity Centres, Lend Lease, Mirvac as well as work for government departments such as the NSW Department of Education achieve data integration and energy technology goals. BE is the architect of the solution and will be a key contributor to the design, implementation, and documentation of the proof-of-concept.

Hospitals have extensive flexible demand resources and an interest in reducing their carbon footprint under mandates from State Governments. MNH is actively pursuing portfolio-wide, or Enterprise BMS for enterprise level integration of assets and energy optimisation to assist in this task, and have an interest in developing their requirements further, informed from the outcomes of this project.

1.2 Objectives

The objectives of the project were to:

1. Develop automation tools for Tridium/Niagra/ and other Building Management Systems (BMS or BMCS) to integrate with the i-Hub Data Clearing House (DCH) via the DCH Application programmable Interface (API).
2. Connect MNH buildings that have existing digital capability provided by Bar-tech Automation to DCH.
3. Test and validate data models for a complex clinical site.
4. BE to collaborate with MNH team to develop an onboarding specification.
5. Develop business Intelligence (BI) REETSEF reports (and others to show the capability as required).
6. Document lessons learned, updated approach for onboarding buildings at scale, manuals, and create reference design as required for knowledge sharing.
7. Collation of R&D reports & evaluation.
8. Presentation of the project to key forums post May 2022.

1.3 Importance to market/industry

Integration of building data from HVAC, PLC and SCADA to the iHub DCH has a precedent from the DCH1 and DCH6 projects – with technology stacks defined and under test through these research efforts. MNH will iterate and test a new array of building assets for integration into the DCH, with the element of "new" being the large-scale BMS integration and the different types of data points and their constraints unique to a hospital.

Around the world, various research institutes have piloted, tested and researched building control systems to, and hypothesised about, flexible load management to the electricity grid. BE has worked with, implemented and designed several systems from the private sector and academia in Australia and the UK and has been speaking around the world with thought leaders through Mission Innovation and the International Energy Agency (IEA). To date, most projects and systems focus on technology, financial, economic and social concerns in isolation. In this project, BE seeks to bridge these four elements to maximise the value proposition for all stakeholders.

> *"When it comes to energy, few types of facilities use more of it than hospitals and healthcare agencies. It is estimated that the average 200,000-square-foot, 50-bed hospital spends more than $680,000 USD on energy every year. Combined, healthcare facilities across the country spend roughly $6.5 billion USD on energy each year, and that number is constantly rising to meet the evolving needs of their patients. Hospitals can improve their bottom line by better managing their energy consumption. Every $1 a non-profit healthcare organisation saves on energy is equivalent to generating $20 in new revenues for hospitals or $10 for medical offices. For-profit hospitals, medical offices, and nursing homes can raise their earnings per share a penny by reducing energy costs just 5 percent." - US Energy Star.*

In Australia, the Metro North Health, are looking to embark on large scale capital program to reduce their energy consumption and to improve the delivery of health outcomes for patients over 7 - 10 years. This R&D proposal seeks to evidence the commercial readiness of the CSIRO DCH platform for projects of this nature, by engaging with a medium sized mechanical contractor (Bar-tech) and smart building Digital Engineers (Buildings Evolved) and an large scale clinical site, run by Metro North Health.

The tools needed to onboard a portfolio of complex clinical sites, at scale and pace, along with the business processes needed and critical thinking to deliver integration at this scale (75,000 to 100,000 data points) are not yet available to the wider HVAC community, unless one engages with vertically integrated multi-national organisations. Hospitals and health systems with sophisticated building automation systems in place can achieve energy-efficiency gains considerably faster. Unlocking the capability of the DCH, and the processes and tools needed to the HVAC community will bridge the gap for mechanical contractors and consultants to consult with the clinical environments across Australia driving the adoption of renewable energy technologies, guide the realisation of future zero energy buildings, and deliver flexible load to the electricity grid.

2 CHALLENGES FACED AND OVERCOME

Development of new software tools that bridge the physical infrastructure world and the software / cloud based world requires integration and connecting of hardware to digital systems. Even with a team of seasoned technologists, and project managers and engineers there will always be challenges faced. This project was no exception. Despite this everyone rose above these issues as a collaborative team and pushed on, working overtime to finish the project.

The following is a list of issues and how the team over came them:

Issue 1: The Brick metadata schema as employed by the i-Hub DCH did not handle all of the use cases the complex hospital building model needed so that all of the building locations, floors rooms etc. could be described in their entirety.

The project team led by Buildings Evolved engaged with the principal developers of the DCH to create Brick metadata models that were compatible with the implementation used by the DCH. The “dialect” of Brick used by DCH is now understood, and limitations of the implementation have been explored. These differences have occurred due to a lack of functionality and extensions being added, such as DCH energy metering Brick model. The other reason is that DCH effectively has a fork of Brick, and Brick has moved in certain directions, sometimes in a tangential manner.

Issue 2: The project started with a compressed time schedule due to multiple issues, the biggest after COVID being that the Hospital faced a 1 in 70 year historical flooding over large parts of lower QLD. This delayed the start of the project as the MNH team members were engaged with the operational requirements of the hospital and dealing with disasters.

Once the team moved to project kick off, the governance team quickly decided to meet each week in an agile fashion rather than once every two weeks, so that we could address issues quickly and reallocate work to team members, week to week. This change proved to be an effective project management step.

Issue 3: The project bumped into the DCH upgrade schedule affecting roles and permissions whilst this project was getting into its stride from a development perspective. This caused a small delay in being able to work with the Data61 (CSIRO software development) team in the compressed time lines this project was already juggling. The CSIRO Data61 team eventually freed up their technical team to assist both BE and Bar-techs developers to start working on the integration of hospital to DCH.

Issue 4: The team roster as originally forecast included a senior and junior business analyst to work 1 to 2 days a week on this project form Metro North Health’s (MNH) internal teams. After attempting to free these key people up from other work at MNH, David Walker, the Director of Sustainability asked if BE could take this work on instead which BE did. After extensive searching for hiring of a second developer or even subcontracting the work out, BE had to cut their losses and work overtime. BE faced an unprecedented labour shortage market because of the pressure COVID has put on the labour market in Australia.

Issue 5: Finalising the REESTEF reports using real MNH data was not possible until the final stretch of the project (a week after 27th of May 2022), as BE received the final data tranches from MNH’s suppliers and Bar-tech on the 26th of May which has made it challenging to process quickly and update all of the reports. In addition, the data provided was of poor quality, the NEM12 format was in a single concatenated file with multiple meters, containing data duplication. Rectifying this issue further delayed works.

3 LESSONS LEARNT

As this project was a condensed, fast paced integration project, the lessons learnt reflect the nature of this environment as the impact of these issues and delays. However this does not reflect poorly on any one partner or technology provided for the technology stack used as the project team operated in an agile way to over come the issues encountered with time they had.

3.1 DCH Commercial Service Levels Agreements not clear for technical support – Buildings Evolved

At project commencement, Buildings Evolved requested the creation of data access accounts for use in this project, tested and handed over by the CSIRO DCH technical teams. This technical request went through a series of tests, discussions, emails, meetings and out of band communication by all partners which resulted in delays of development work and compressed the project time left considerably.

Future digital integration project managers should ask of any enterprise software partner at contract negotiation phase of a project, to outline what they deem is a reasonable turn around time for technical support issues. In the software world this is called Mean time to resolution (MTR), and usually has specific commercial T&Cs which outline the support offered under the heading of 'Service Level Agreement'. Understand what the escalation procedures and lines of communication should be if a technical issue needs to be escalated is key to effective project management.

Looking ahead to a world where the DCH successfully moves to commercial readiness; a solid SLA would need to be defined going forward so that future clients can operate and plan accordingly.

3.2 DCH Large Organisational Inertia – MNH

The journey to project acceptance by MNH was one of many paths. Commercial acceptance for an initial project size that is classified as small required the review of up to 12 people, including all the way up the CEO. There is a (valid) argument that committing taxpayer funds must be done in a defensible and value-supporting manner – the existing framework provides those checks to ensure value is achieved and spending is defensible, but there may be opportunities to streamline this process at MNH by rationalising thresholds for higher delegates to be required to act as gate-keepers.

To adopt an innovative business model in any organisation, the inertia when presented with change is a substantial barrier. Having a dedicated team who has carriage of the organisation's involvement in industry-collaborative projects such as this one, rather than that carriage being placed on existing teams, may streamline acceptance of future projects and increase compliance with reporting requirements. The large organisational ideas to take away from this lesson are:

- There is a need to share widely the successes of projects like this, to demonstrate value.
- Noting that some value is lost due to bureaucratic inefficiency associated with teams having to split their time between usual duties and duties related to such projects.
- Acknowledging both of the above points, there are opportunities to increase the value-add of these industry-collaborative projects even further by ensuring the processes the organisation is required to follow are either streamlined as best they can be within legislative requirements, or is managed by a team dedicated to ensuring the successful outcome of these projects.

3.3 Building Management Systems hardware capability assessments for data management at scale – Bar-tech

With every Building Management System (BMS) comes bespoke configurations of systems as they age. Many BMS connected to buildings will be not by default set up for the intense data mining which is required when retrieving massive amounts of historical data for smart buildings and or digital readiness projects. Most will be built only for the requirements of the time. This is very evident with buildings that have 'Niagara' installations which use a Java Virtual Machines (JVM) to run their software. These JVM's from what we have experienced in this prototype project have poor memory management issues, in particular garbage management. These memory management issues, in the JVM as a software execution environment, can cause instability when collating and gathering data from buildings at scale.

As part of any future program using existing BMS infrastructure, we would suggest assuming a limited capability and scope otherwise without upgrades there will be limited data gathering at scale. As part of this project, we took the approach to assume always there is an extreme limit and simply query for small bits of data and allow the system to slowly gather the data over a longer period. Normally months or years of data can be consumed with this method every day, so it doesn't create any critical issue if the project has the time to wait to collate the data. Normally within a few days years of data can be consumed. Thus the entire database can be up to date within a few days allowing for very small updates that can be scheduled to lower the load on a system.

3.4 Dealing with Energy data suppliers is time consuming – Buildings Evolved

The data procurement phase of the project began two-weeks into the project commencement which resulted in BE receiving the data needed in the last week of the project. This was due to poor data request processes in place at each of MNH's energy suppliers. Collating MNH's asset related metadata and an authority to act authorisation letter proved quite challenging for the MNHs team having to traverse multiple different internal departments. The energy data was also of poor quality, a single concatenated file with data duplication and inconsistencies. In future projects we would suggest that project managers:

- Ensure asset meta data and supplier information is correct with the client/beneficiary before requesting information from suppliers.
- Plan for receiving data in a timely fashion by:
  - Getting contact details for a representative at the organisation who are able to help;
  - Agreeing on a time for delivering data and following up when data is not provided;
- Once data is received, spot check the data or use a data verification tool to confirm quality, check for things like:
  - consistent number of readings,
  - completeness, and
  - duplication.

This will enable better management of the data gathering process and enable project team members to flag issues in a timely manner. Ultimately this will improve project planning and delivery. Lastly, when dealing with digitally formatted energy data:

1. Do not assume asset metadata and supplier information is correct.
2. Dealing with data suppliers is time consumption so plan for this.
3. Do not assume data completeness and accuracy from data suppliers.

4 EVALUATION OF PROJECT IMPACT AND TECHNOLOGY

The tools needed to onboard a portfolio of complex clinical sites, at scale and pace, along with the business processes needed and critical thinking to deliver integration at this scale (75,000 to 100,000 data points) are not yet available to the wider HVAC community, unless one engages with vertically integrated multi-national organisations. Hospitals and health systems with sophisticated building automation systems in place can achieve energy-efficiency gains considerably faster. Unlocking the capability of the DCH, and the processes and tools needed for the HVAC community will bridge the gap for mechanical contractors and consultants to consult with the clinical environments across Australia driving the adoption of renewable energy technologies, guide the realisation of future zero energy buildings, and deliver flexible load to the electricity grid.

5 OUTCOMES & KPIs ACHIEVED

The project outcomes and KPIs of each for this project were as follows:

1. Bar-tech to evaluate the efficacy of the DCH and any further DCH development that would be required to satisfy the needs of MNH.
2. MNH would be able to track their energy performance against REESEF KPIs, provide data to third parties using role-based permissions, inform the requirements for an enterprise BMS and evaluate the overall value and security of the DCH.
3. BE to develop commercialisation documentation to support future channel partners such as Bar-tech in onboarding complex buildings to the DCH, and test deployment of existing applications and services. The quality of the documentation produced will be assessed by CSIRO to meet their expected standard.
4. The building automation onboarding software tool developed by Bar-tech will be assessed by CSIRO and BE, and deemed a success if it meets industry standard best practise software design, covering security, usability, performance and effectiveness (I.e. can it be used at pace for a complex site ?).

6 OUTCOMES

6.1 Summary of results

The following is a summary of project outputs, documentation on reference design for onboarding buildings to the DCH, software built on the reference designs, and the structured data from modelling REETSEF KPIs using the chosen BI tool; Microsoft Power BI. More and detailed information can be found in the iHub DCH9 long report1.

Documentation: *reference design for DCH on-boarding, training and manuals completed (Buildings Evolved)*

On-boarding a building from a building metadata viewpoint is challenging due to a lack of standardisation between buildings. The project investigated several methods for on-boarding slow-changing asset data at the hospital site using the Brick metadata schema to expedite the process of integrating a building ontology to the DCH and its objective functions. The following options were evaluated:

1. Using python, to generate models programmatically allows transformation of existing datasets into a Brick model.
2. Using a UI driven tool (Protege/WebProtege) we found it did not have great utility in generating a brick model due to over 180 lines of code in a simple 1 zone local demonstrator test site; this would mean 180 or more interactions with the webpage to generate a single model.
3. Using the DCH web-based Brick generation wizard, The DCH has a unique web-based wizard specifically targeted toward generation of a Brick model. While Protege/WebProtege were found to be difficult to use, this could be attributed to the general nature of the tool for RDF, rather than an RDF based tool designed specifically for generating Brick/building models. Consequently, the wizard performs well compared to the general RDF tools, but would still likely be difficult to use if on-boarding a large or complex building.

Software: *Build an integration tool set for fast on-boarding to the DCH (Bar-tech)*

1. The current implementation of DCH was found to be complex requiring bespoke knowledge for integration. Upgrades are required to enable development houses a reasonable time to interface with a database system, as a user permissions issues consumed more time than anticipated from the project budget.
2. In addition to the complexity of getting data to DCH was the complexity of getting it out of the existing system, the main requirement of this project. There were two main issues with this. The first is some complex naming conventions used across the hospital building portfolio to create "meta information." These were overcome but required several testing iterations to generate custom code to handle 'the edge cases' for generating the brick model to ingest into the DCH.
3. The second was Niagara and JAVA's lack of good memory management. This resulted in multiple stoppages and manipulation of data queries to slowly get the required data instead of getting large chunks as would be the standard approach. Time for integration of other sites would be greatly improved from the knowledge gained from this project.
4. The successful integration of these hospital buildings into the DCH will enable MNH to achieve strategic goals optimising energy performance against REETSEF KPIs. It will also inform requirements for future enterprise BMS implementations, and enable greater collaboration with research and industry partners. In addition to achieving these strategic goals, MNH would be better able to achieve operational goals related to energy performance optimisations, including balancing energy usage against achieving indoor air quality (IEQ) targets, maximising asset effective-life spans through targeted upgrades of infrastructure that are no longer performing efficiently, and determining improved HVAC load requirements for new projects.
5. For the wider iHub project, the onboarding and integration methodology, lessons learnt and documentation functions to support future channel partners such as Bar-tech in on-boarding buildings to DCH, and deployment of applications and services.

Software: *Build a dashboard application for monitoring and reporting on REETSEF performance indicators by (Buildings Evolved)*

1. 10 KPIs outlined in the REETSEF report were developed covering energy intensity, electrical demand, load-shifting, air pollution, emissions and reporting, self consumption of renewables, cost and billing.
2. The range of KPIs are clear indicators that help owners and operators of renewable and related energy technologies understand and plan to manage building assets in a changing and challenging operational environment.
3. The KPIs have been demonstrated on the hospital site using a limited data set. Greater data availability and validation of assets and their operation would have improved the results. In future, more buildings and accurate data will demonstrate the effectiveness and maturity of KPIs for validation, feedback and improvements. What has been delivered is proof that digital integration can be achieved by bringing the buildings in this project to a digital readiness state.
4. To improve upon energy efficiency or intensity analysis, additional contextual information is needed to improve the quality and effectiveness of the KPI indicators. For example, m2 is not sufficient to raise awareness of poor performance at a site compared to an energy benchmark without considering factors such as climate, building and/or equipment age, building orientation, degree of medical specialisation etc. It is only when these factors are taken into consideration that a benchmark is effective. Once poor performing sites are identified a deeper dive into operational technology, data from HVAC systems and/or the BMCS should be sought to determine causation.
5. Key takeaways from the KPIs at the hospital site are:
    a) KPI-1; m2 energy intensity was less than the benchmark, 177 kWh/m2 (although metered area was not confirmed) compared to 393 kWh/m2 benchmark average of Australian hospital sites.
    b) KPI-4; Peak demand has been declining over the past few years resulting in reduced charges and demand on the network.
    c) KPI-5; there is low co-incidence between peak electricity consumption and peak wholesale price data indicating that the site may benefit from a variable pricing contract with exposure to the wholesale price.
    d) KPI-8; maximum electricity demand occurs in the summer and autumn months and maximum demand events show the site would benefit from a peak-lopping strategy with the potential to reduce demand charges by 30-40%.
    e) Once owners and operators are aware of performance issues they can develop new business cases to assess energy data by gathering information from BMCS and telemetry data and begin to realise targeted efficiencies and benefits from operational and renewable energy technologies.e financial modelling tool has been built, adjusting assumptions or adding scenarios can be done with relative ease.

6.2 Rapid assessment of REETSEF KPIs

Breadth: The REETSEF reports are a valuable method of assessing the renewable energy integration capability of hospitals. The relative ease of acquiring utility data allows a rapid assessment of building/campus performance, allowing generation league tables of good and poorly performing buildings, thereby allowing resources to be focused on the worst performing buildings. This is where the REETSEF report provides a huge amount of value.

By itself, or in isolation, the REETSEF report does not add a large amount of value. Normalised figures such as energy intensity per bed are meaningless without context from similar building topologies. The definition of ‘good’ is statistically defined by being above the mean.

Depth: The high-level REETSEF reports completed, and the poorly performing buildings/sites identified, the next steps are to delve into machine data for each building, derived from the Building Management (& Control) System (BMCS). Traditionally, this has been enormously complicated due to differing BMCS, different naming conventions, data formats, resolutions. Everything becomes bespoke per site, making this analysis impossible for all but the service agent of the HVAC systems themselves.

The Data Clearing House (DCH), coupled with a metadata schema such as Brick, will allow consistent models to be queried for the underlying datasteam name. The DCH 9 project shows that data from a BMCS can be rapidly onboarded to the DCH allowing analysis at depth to be undertaken, and faults and issues identified at a granular level.

6.3 Engineering details

Onboarding a building: From a building metadata viewpoint is challenging due to a lack of standardisation between buildings. The project investigated several methods for on-boarding slow-changing asset data at the hospital site using the Brick metadata schema to

Building a metadata schema: A unified and standardised metadata schema would enable buildings to onboarded with relative ease, this would result in reduced costs for organisations wishing to integrate software solutions with operational technology for efficiency, management and control.

Brick is an entity-relationship or class diagram of a building, and is utilised by the DCH and other applications to build a graph database that provides foreign keys for the unique datastream name within the DCH or other time series databases[1]. This allows querying of the graph database using SPARQL to find a datastream name, or multiple datastream names. With the datastream names as a variable, a further query of the time-series database yields data from the required datastreams. A metadata schema allows a standard set of classes and naming convention to reference arbitrary names sourced from a BMS or other form of operational technology. In this way, a metadata schema simply acts as middle-ware – allowing standard database queries to reference any known arbitrary datastream name. It is envisaged that the mechanical and electrical trades will provide the relationship between the standard Brick metadata schema and the unique names that reside on their client systems.

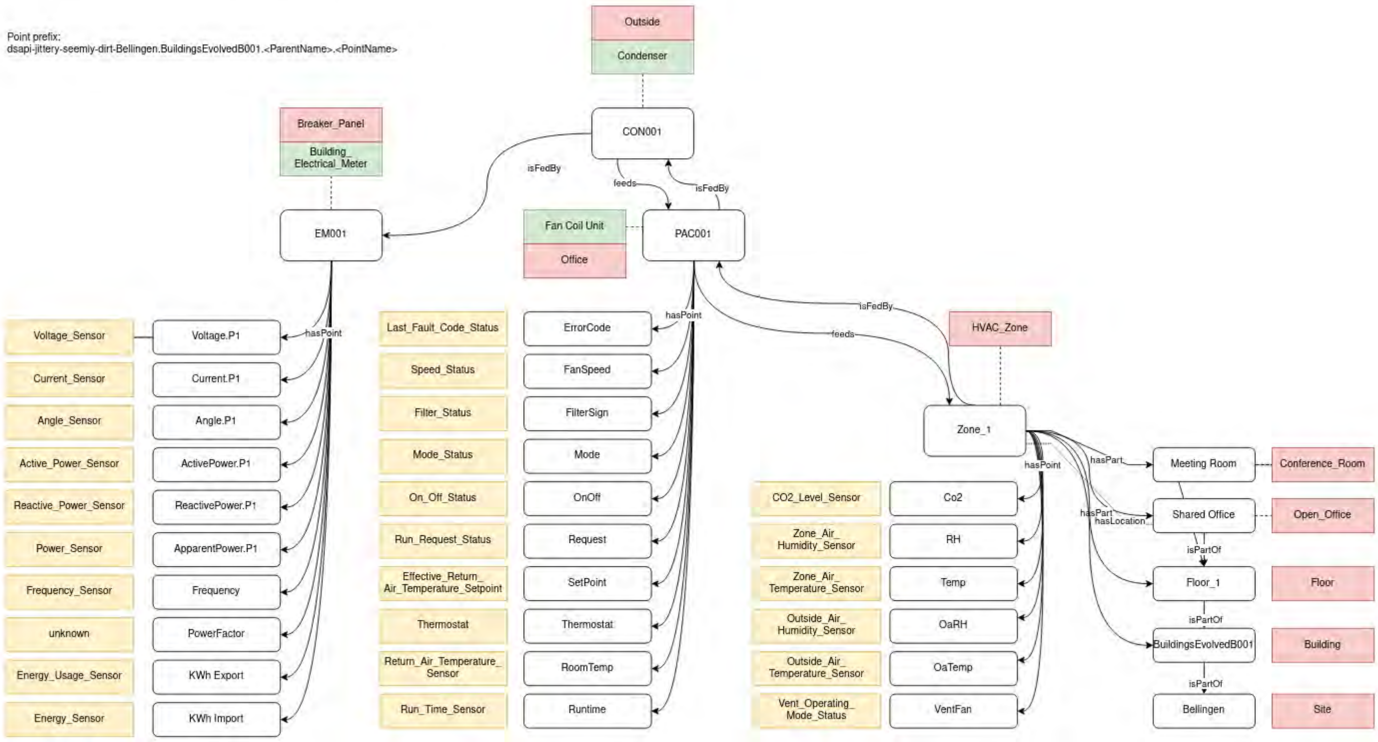

Figure 1: a diagram representing the metadata schema for the BE living lab

Brick uses the W3C standard "Resource Description Framework" (RDF) that describes the relationships between objects in the form subject, predicate and object. For example, a way to represent the idea that "zone 1 has point CO2 level sensor" would be expressed in RDF as "zone 1" (subject), "has point" (predicate), CO2 level sensor (object). Other examples from Figure are "Fan coil 1 is fed by Condenser 1" or "Meeting room is part of Floor 1". Therefore,

[1] Fierro, Prakash, Mosiman et al (2020). Shepherding Metadata Through the Building Lifecycle.

queries can rapidly generate a graph of the relationship between these objects so that an application developer using the metadata schema can easily find a list of what points zone 1 has, using the above example.

An excellent overview video is available which features the academics behind Brick Schema: Gabe Fierro and Jason Koh[2].

A reference schema is available at ref-schema.brickschema.org[3].

Building a Brick schema: There are a few methods available to generate Brick models to programmatically onboard building ontologies to software platforms such as the DCH. As discussed earlier, the following methods were investigated during the research phase of the project:

1. Using python, to generate models programmatically allows transformation of existing datasets into a Brick model.
2. Using a UI driven tool (Protege/WebProtege) we found it did not have great utility in generating a brick model due to over 180 lines of code in a simple 1 zone local demonstrator test site; this would mean 180 or more interactions with the webpage to generate a single model.
3. Using the DCH web-based Brick generation wizard, The DCH has a unique web-based wizard specifically targeted toward generation of a Brick model. While Protege/WebProtege were found to be difficult to use, this could be attributed to the general nature of the tool for RDF, rather than an RDF based tool designed specifically for generating Brick/building models. Consequently, the wizard performs well compared to the general RDF tools, but would still likely be difficult to use if on-boarding a large or complex building.

More information on building a Brick metadata schema programmatically is available in the DCH9 long report.

Energy modelling technology: Buildings Evolved have developed a sophisticated modelling tool that provides users with an interface or web-form enabling them to upload, transform and write data from the following sources to a database:

- electricity meter data agent (NEM12);
- electricity retailer invoices (ERM & Origin);
- Bureau of Meteorology (BoM);
- Australian Energy Market Operator (AEMO);
- solar irradiance data (Solcast);
- GHG gas emissions factors;
- battery management system; and
- solar PV inverters.

The technical overview of the data architecture from ingestion via the web-form, to processing and transformation, to producing KPIs and reports for analysis is shown below:

[2] https://www.youtube.com/watch?v=5w3uu_vevCA

[3] https://ref-schema.brickschema.org/#hasTimeseriesReference

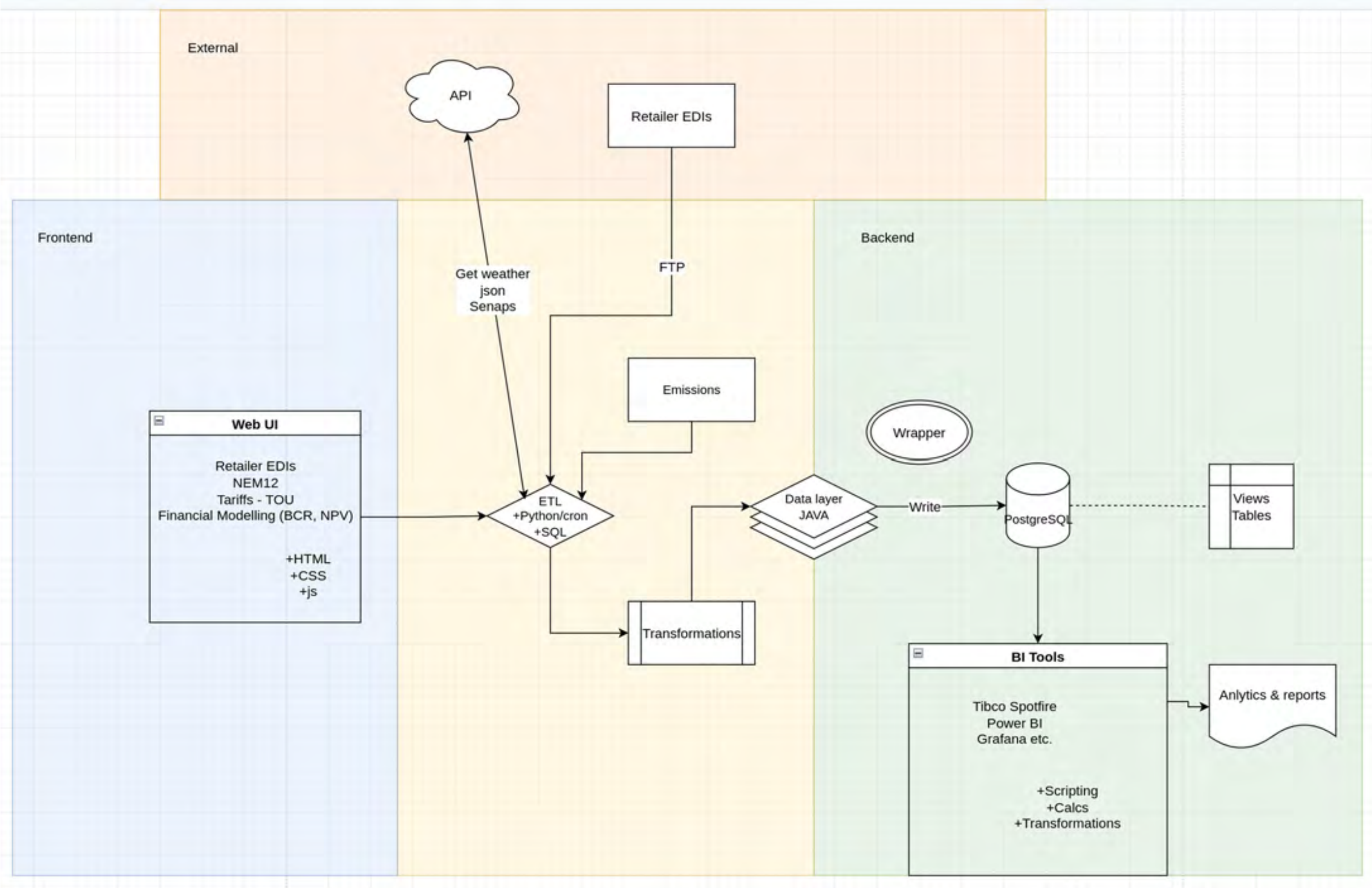

Figure 2: modelling tool process architecture

The basic architecture involves the following processes:

1. ingest data via ETL;
2. lay down data into a database;
3. allow scripts to run across datasets to calculate required outputs;
4. allow an array of scenarios and assumptions to represent different what-if scenarios for modelling;
5. automatically calculate costs on an interval-by-interval basis;
6. produce report outputs; and
7. easily allow database querying to be performed by any standardised BI reporting tools, such as Tibco Spotfire, Tableau, Power BI, Grafana or similar.

Various open-source coding languages and software frameworks were used to develop the solution including:

- Python,
- JavaScript,
- PostgreSQL, and
- React.JS, amongst others.

This architecture has user access control, logs and validation processes to ensure data completeness and accuracy. The dashboards presented below, designed from KPIs in the REETSEF report[4] used data generated from the modelling tool.

More information on the energy modelling tool by Buildings Evolved is available in the DCH9 long report.

[4] iHub, Healthcare Sector: Renewable Energy and Enabling Technology and Services Framework (REETSEF), 2020, p12.

7 CONTRIBUTION TO I-HUB OUTCOMES

7.1 i-Hub outcomes

1. Improve the control of HVAC&R compared to business as usual by demonstrating the capability within a selection of building types to reduce onsite energy use by at least 25%.

The energy management and sustainability journey Metro North Health (MNH) is on is only at the beginning stages, not withstanding the COVID pressures placed on it over the last two years. This project will allow MNH to shape new business cases to make inroads in achieving these targets over the coming years. As arguably Australia's largest hospital group this prototype should pave the way for other hospitals around the country to follow on their digital readiness journey, as MNH can provide organisational assurance that despite their day to day operations being highly complex, a large organisation can still make meaningful energy savings by working with smart building technologist collaboratively.

2. Reduce peak demand and demand charges as well as increase the hosting capacity of solar through load control combined with onsite renewable energy.

As aforementioned, with the high-level REETSEF reports completed, and the poorly performing buildings/sites identified, the next steps are to delve into machine data for each building, derived from the Building Management (& Control) System (BMCS). Traditionally, this has been enormously complicated due to differing BMCS, different naming conventions, data formats, resolutions. Everything becomes bespoke per site, making this analysis impossible for all but the service agent of the HVAC systems themselves.

The Data Clearing House (DCH), coupled with a metadata schema such as Brick, will allow consistent models to be queried for the underlying datastream name. The DCH 9 project shows that data from a BMCS can be rapidly onboarded to the DCH allowing analysis at depth to be undertaken, and faults and issues identified at a granular level.

3. Increase the value of open data platforms and deliver innovation in the built environment to deliver energy savings.

The reference architecture that has been developed on integrating the hospital sites into the DCH functions as a practical application of on-boarding buildings programmatically, reducing entry barriers and costs to integrating buildings with data platforms. In other words making data platforms more open.

The REETSEF KPIs interpreted by a business analyst using BE's data modelling tool is a demonstration of data access and analysis that is possible by integrating buildings with data platforms.

The knowledge sharing from this project functions as a blueprint to the wider HVAC community to replicate this work for new projects.

4. Improve developer and building owner decision making capabilities by demonstrating the value of non-monetary benefits of energy productivity measures.

REETSEF reports include a range of non-monetary benefits that have been identified in the long report of this sub-project.

5. Identify new technologies that can contribute to the decarbonisation of commercial buildings over the next decade.

Due the participation in this R&D piece Bar-tech have identified new ides for the development of software control algorithms that could be used to provide:

- Automatic loop tuning;
- Energy validation of A/C Equipment, and
- Optimum Scheduling of load shifting and many more.

All these algorithms are not standard practice in BMCS but are invaluable for energy efficiency in this new data enabled environment.

6. Increase available demand response by identifying 100 MW of potential within the broader i-Hub portfolio.

DCH 9 has not had sufficient time to determine the DR capability of hospitals, but will seek to pursue these answers post-project with MNH and other health districts across the nation. We plan to assist Dr Wendy Millar (QUT), as author of the REETSEF report guidelines, on providing input to answering this question in future work.

7. Change the industry paradigm to make co-design a mainstream approach to deliver lower cost and higher performance buildings.

MNH ‘s Director of Sustainability David Walker at the onset of this project outlined his long term strategy to use this work which would directly support and demonstrate this outcome for the planned capital works of $300mil over the next 7 to 10 years for the hospital portfolio. Using a data driven approach to baseline the building portfolio using the REETSEF capability developed in this project, should assist him and his teams to him succeed in this journey over the coming years.

7.2 I-Hub KPIs

1. The capability to reduce onsite energy use by at least 25% (compared to BAU), by improving the control of HVAC&R and renewable energy, is demonstrated within a selection of three building types.

Whilst not achieving any two way control to manage or make demand reductions within this prototype project, this project positions MNH so support this objective and being a distinctly different building type on boarded to the the DCH.

2. The capability of integrating HVAC load control with onsite renewable energy to significantly reduce peak demand (and demand charges) as well as increasing the hosting capacity of solar PV within the building or precinct is demonstrated within a selection of three building types.

This project did not have scope or capital to look at Solar PV at the hospital site. The existing Solar at he Hospital was immaterial in the context of the volume of energy consumed by the hospital.

3. Four Living Labs are created and operational.

The sub-project was not intended to address this KPI.

4. i-Hub living labs contribute to the performance validation of 8 new technologies that can contribute to the decarbonisation of buildings over the next decade.

The sub-project was not intended to address this KPI.

5. One B2G DCH is created and operational (DCH 2.0).

This project is directly supporting this KPI as it has developed new software tools to facilitate digital integration and on boarding of buildings at scale to the Data Clearing House which are being shared with the wider HVAC community.

6. The value of the DCH 2.0 open data platform to deliver increased innovation in the built environment and deliver further energy savings and other benefits to building owners and users is demonstrated using 6 B2G DCH Applications.

The sub-project was not intended to address this KPI.

7. A pathway to 100MW of available demand response potential (proven and demonstrated through iHub sub-projects) is identified within the broader iHub portfolio (including the broader portfolio of partners).

The sub-project was not intended to address this KPI.

8. X number of industry professionals, Y number of building owners and Z number of university students have been encouraged and provided the tools to make integrated co-design a mainstream approach to deliver lower cost and higher performance buildings.

The sub-project was not intended to address this KPI.

9. The benefits of early stage integrated design have been communicated to industry across 14 building projects.

The sub-project was not intended to address this KPI.

10. The Integrated design process is developed, documented, tested, released, and refined for different building topologies.

The sub-project was not intended to address this KPI.

8 LIST OF PROJECT REPORTS

1. Reference design
   - ➲ Found in section 3.2 DCH9 Long report as Figure 19 : Modelling tool process architecture
2. Data Governance/Cybersecurity Statements
   - ➲ The data security of the DCH has yet to be checked over by MNH's IT security team due to prior commitments and work backlogs. BE will engage with them post project completion to finalise this and engage CSIRO with feedback about the prototype DCH implementation that was provided for this project.
3. Risk management plan
   - ➲ Already submitted to the iHub. as 'i-Hub Sub-project Risk Management Plan QLD Hospitals V0.3.docx'
4. Minimum viable data product (MVDP)
   - ➲ Found in section 2.3 Brick: Building model metadata schema in the DCH9 Long report
5. List of points filtered via MVDP
   - ➲ Found in 'Figure 41 : list of data points in the DCH' in the DCH9 Long report
6. Building Data Model report
   - ➲ Found in 'Section 2.3 Brick: Building model metadata schema' in the DCH9 Long report
7. Connect hospital buildings
   - ➲ Found in 'Figure 42
8. DCH on-boarding workflow automation report
   - ➲ Found in 'Section 8 DCH on Boarding workflow automation assessment' in the DCH9 Long report
9. MNH REETSEF reporting requirements and other user stories Found in:
   - ➲ 'Section 4 Energy use intensity & Productivity KPIs'
   - ➲ 'Section 5 Environmental And Societal KPIs'
   - ➲ 'Section 6 Energy Network KPIs' of the DCH 9 long report.
10. REETSEF visualisations/analysis/reports Found in:
    - ➲ 'Section 4 Energy use intensity & Productivity KPIs'
    - ➲ 'Section 5 Environmental And Societal KPIs'
    - ➲ 'Section 6 Energy Network KPIs' of the DCH 9 long report.
11. iHub Milestone Report
    - ➲ Submitted to the iHub as: 'i-Hub Sub-Project Lessons Learnt DCH9.pdf'
12. Lessons learnt report
    - ➲ Submitted to the iHub as: 'i-Hub Sub-Project Lessons Learnt DCH9.pdf'
13. Knowledge sharing report
    - ➲ Submitted to the iHub as: 'i-Hub Sub-Project Knowledge sharing Report DCH9.pdf'
14. iHub milestone end of project report
    - ➲ Submitted to the iHub as: 'i-Hub Sub-Project Lessons Learnt DCH9.pdf'

9 NEXT STEPS

The next projects for Metro North Health should focus on being outcomes-based. These projects should focus on what the DCH can deliver from the data collated from the BMS's and what additional equipment should be monitored to get more informed results from the DCH and external operators.

For example, having energy monitoring for all the hospital buildings would allow the DCH and BE's Business Intelligence dashboard to widen the scope of and depth of reporting the current energy profile for the MNH building estate in its entirety. This will require a small investment in the meters for each building as Bar-Tech have controllers that can monitor these meters close by. The limited kWr is not accurate enough to fully validate the iHub report or give actionable data to MNH but will give them insights. Bar-Tech would assume there will be a lot more information that will be available given the separation of the buildings with their energy data. This would also be critical going forward into an environment focused on greenhouse gas reductions.

Other algorithms that could be used now are Automatic Loop tuning and energy validation of A/C Equipment, Optimum Scheduling, load shifting and many more. All these algorithms are not standard practice in BMCS but are invaluable for energy efficiency in this new data enabled environment.

This work should assist MNH 's planned capital works of $300mil over the next 7 to 10 years for the hospital portfolio. Using a data driven approach to baseline the building portfolio using the REETSEF capability developed in this project, should assist MNH to succeed on this journey over the coming years.