The Innovation Hub

for Affordable Heating and Cooling

Data Clearing House (DCH) : Public Dissemination Report

May, 2022

CSIRO

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 **Primary Project Partner**

Project title: CSIRO Senaps data platform demonstration and development of the Data Clearing House

This project will oversee development of the Data Clearing House (DCH), a cloud-based building data management and application enablement platform. The DCH connects Internet of Things (IoT) systems from buildings and supports complex data analytics. The DCH will underpin the development of applications that improve renewable energy integration in buildings and unlock new opportunities for delivering Buildings to Grid (B2G) services.

This project will investigate features of the CSIRO Senaps data platform and their suitability for the DCH. It will combine these findings with results from the DCH2 Switch data platform subproject to develop the Data Clearing House.

Lead organisation

CSIRO

Project commencement date

July, 2019

Completion date

June 2022

Date published

27 May 2022

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Project website

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1 Scope of this document

The primary objective of this project is to develop a building data management platform that overcomes the main barriers for adoption of data driven solutions for reducing building energy use, improving renewable energy integration in buildings, and unlocking opportunities for delivering buildings-to-grid services. This report summarises the technical development, user engagement and market development activities related to development of this platform. Project impact pathways have been identified and their status detailed in this report. A summary of key challenges and lessons learnt is also provided.

2 Project Details

2.0 Platform background and objectives

Digitalisation can deliver many benefits to the built environment such as productivity improvement, energy savings, carbon reduction, and energy market participation opportunities. However, the built environment sector is lagging other markets in deriving value through digital transformation. This is primarily due to lack of an ecosystem for collecting, managing and sharing of data in a secure and equitable way, limiting new innovations in this space. The built environment sector is slowly embracing digitalisation. Proliferation of low cost IoT sensors and improvements in Information and Communication Technologies (ICT) infrastructure mean that the buildings industry is now at a stage where it can reap the benefits of digitalisation. However, studies and user interviews by CSIRO have shown that only 10% of the Australia building stock (premium) are using digital technologies. The predominant share of existing buildings have neither the infrastructure to access and manage data, nor the capability to benefit from data driven innovative solutions.

There are two main barriers to data driven innovation in the buildings domain:

i) heterogeneous sources of data, from building management systems and sensors with limited standardisation. Many building owners also suffer from vendor lock in, or are unable to access their own data from proprietary systems, and

ii) buildings typically have thousands of data measurement points. To maximise the benefits that come from using this data, information about the data points, the building and the equipment (i.e. meta-data) needs to be linked to provide the context for innovators to implement new solutions. Currently building metadata is difficult to infer, and deriving context from the metadata is a manual, resource intensive and error prone exercise.

This project tackles these two challenges, specifically breaking down the above barriers to facilitate access to data *in context*, thus enabling innovation. The main objective of this project is to develop a building data management platform that overcomes the main barriers for adoption of data driven solutions for reducing building energy use, improving renewable energy integration in buildings, and unlocking opportunities for delivering buildings-to-grid services. In addition to the technical activities associated with the development of the platform, this project also aims to demonstrate the value of the platform via delivery of buildings services to 50 buildings.

Project activities have been guided by a steering committee that consists of representatives from industry as well as international experts. The project activities progressed on three fronts simultaneously: i) activities related to platform development, ii) activities related to market development and user engagement, iii) activities related to Demand Response (DR) potential estimation. A summary of these activities is provided below.

2.1 Platform development activities summary

This project has resulted in development of a cloud-based building data management and application enablement platform known as the Data Clearing House (DCH). DCH development has been backed by continuous interaction and engagement with various user groups. The project team interacted with over 50 entities belonging to three primary user groups of the platform: i) building owners/user groups, ii) application developers, and iii) system integrators. User interviews have resulted in identification and clarification of the strategic need for such a platform, the key functional features, and the potential operational models. In response to user inputs, the project team have focussed on developing the following technical features of the platform:

i) simplifying onboarding, data collection and data sharing without vendor lock-in;
ii) facilitating easy access to data and data driven application based third party services; and
iii) providing a secure platform that empowers data sovereignty.

DCH facilitates easy onboarding of buildings to the platform at scale. This has been achieved through development of tools for collection and storage of heterogeneous sources of data from Building Management Systems (BMS), IoT (Internet of Things) sensors and third-party providers. This minimises duplication of work for each building/data source. DCH's APIs (Application Programming Interface) facilitate easy data exchange between different platforms/providers.

The key technology that underpins the scalability and interoperability features of DCH are the semantic building models. Semantic models provide a ground truth for a building's components, make building data easily discoverable and interpretable, and can be modified to reflect real-world changes. These models conform to the Brick Schema, a standardised representation of building elements and their relationships. The DCH middleware, known as the Building Service Layer (BSL), is implemented as a RESTful API, backed by a graph database that stores building models as graphs. Importantly the BSL provides a query interface to these models. To allow non-programmers to benefit from the power of semantic RDF (Resource Description Framework) querying, the DCH team have built a domain-based query interface (BRIQL = Brick + SPARQL) that will be more intuitive and familiar to domain experts. The use of semantic models enables analytics to be deployed in a building agnostic way, similar to an "app store" in the smart phone context. That is, one application can be developed and deployed across multiple buildings and the same model can be re-used by many applications via the DCH application management framework.

DCH is built on CSIRO's award winning Senaps sensor data analytics platform and hence retains the core strengths of the platform such as handling of time series data in a multi tenancy framework backed by role-based permissions management.

In addition to the Application Programming Interfaces (APIs) for data source management, semantic model management and data exchange, DCH provides a web user interface (web UI) that enables authorised users to interact with the platform. The DCH web UI allows users to onboard new building data and supports construction and exploring of semantic models of buildings and building systems. Time series data visualisation and new applications hosting are also enabled through the web UI.

2.2 User engagement and market development activities summary

DCH has been used to ingest data from pilot buildings from March 2020 onwards. Currently 50 buildings have been onboarded to DCH with a further 10 buildings in the pipeline for onboarding. This includes DCH sub project partners and other industry partners who have shown interest to use DCH as a platform for their operations. The DCH User Interface (UI) and API have been made available to the project partners from Oct 2021 onwards.

Although DCH is still an early-stage platform, several benefits are already evident. DCH currently facilitates operation of 6 data driven applications. Specific examples of benefits from the platform are:

i) a look ahead (model predictive) control based battery management algorithm operating using DCH data has resulted in 6% annual energy cost savings for the building owners,
ii) a data driven chiller optimisation algorithm developer (a start-up company) has utilised DCH to deliver chiller scheduling recommendations to a building owner that has resulted in 4.3% summer energy savings, and
iii) a Net Zero Energy (NZE) feasibility assessment tool has been developed using DCH data to automate the process of studying NZE pathways for a portfolio of buildings with various Distributed Energy Resources (DER).

The Data Clearing House aspires to radically grow the number of digitally enabled buildings across Australia by reducing the cost and duplication of digital infrastructure across the various building services. A market study carried out by the project team together with consultants has identified several compelling market opportunities. Some examples are: i) although mid-tier buildings represent nearly 80% of Australian office buildings, fewer than 1% of these buildings are digitally ready. Further, this sector has significant opportunity for energy efficiency improvements due to use of outdated technologies; and ii) DCH can be used as the infrastructure to deliver government programs such as Green Lease schedules and operate as an independent Measurement and Verification (M&V) platform for verifying energy savings and flexible demand controls dispatch verification.

The stakeholder engagement activities have clearly shown that interoperability, vendor lock in, and data ownership are the key challenges facing the industry. To address these challenges an open data platform, and specifically one backed by independent governance, has been identified as a desirable solution and operational model. Over the course of the project, it has become apparent that there are many pathways for delivering value through the platform. These range from private players using specific instances of the platform for delivery of their services, to building owners using DCH as a secondary data management ecosystem.

To demonstrate the value of DCH at scale, the project team intends to add more buildings and applications to DCH in the near future. Having sufficient partners makes the platform more self-sustainable, creates awareness across the industry, and accelerates faster adoption of data and interoperability standards. To enable onboarding of more buildings, a DCH system integrator panel is being set up. This panel will have system integrators who are qualified to deliver DCH onboarding services. Panel members will have access to tools to support easy onboarding of buildings and creation of building models. It is envisaged that the panel members will help create an ecosystem enabling DCH to become a self-sustainable entity in the market.

2.3 Demand Response potential estimation activities summary

Air-conditioning is a low cost, readily available opportunity for delivering Demand Response (DR) services for electricity networks, particularly those with high penetration of renewables. Demand response takes advantage of a building's inherent thermal storage to reduce electricity demand at peak times with no discernible impact on the indoor operating environment. As part of the project, the existing potential of commercial and residential air conditioning systems to provide demand response across Australia has been estimated using a top-down approach based on disaggregation of electricity substation half-hourly data. Results indicate that peak (i.e., 99.5th percentile) demand on the National Electricity Market (NEM) could be reduced by up to 5.8% or 1.2 GW, with the time of day at which the peak occurs delayed by approximately 2 hours. Based on the timing of the available capacity, both residential and commercial buildings are suited to providing air-conditioning demand response.

An online Tableau visualisation of DR potential across Australia (see Figure 1) has been developed along with a simple financial layer based on the Regional Reference Price of electricity. This visualisation can be used to understand the timing and spatial variation of the potentially available air-conditioning demand response across different parts of the network.

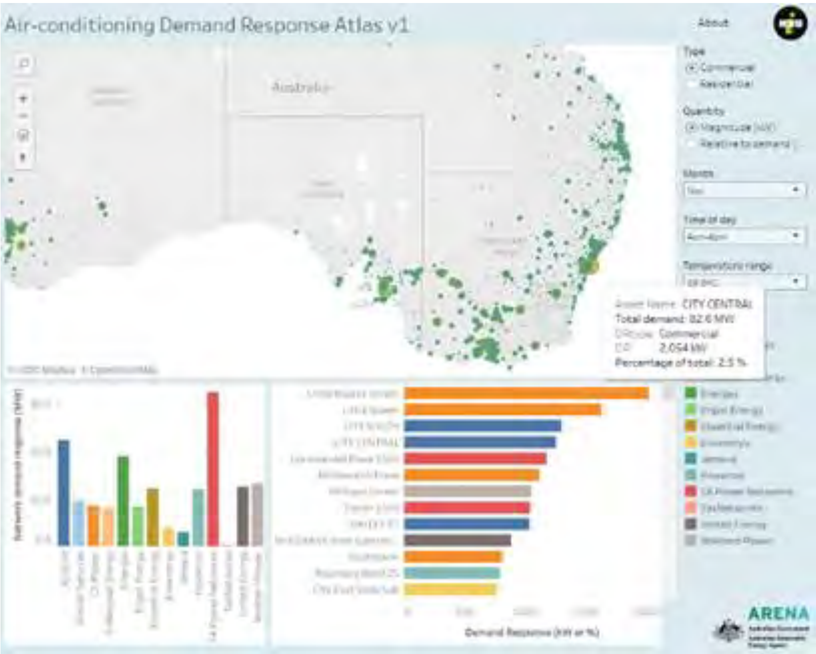

Figure 1 Screenshot of the Air-conditioning Demand Response Atlas visualisation tool.

A high-fidelity bottom-up estimation of the DR potential of two commercial building typologies (schools and office buildings) has also been carried out. Detailed representative building energy and HVAC (Heating Ventilation and Air-Conditioning) system simulation models have been constructed. These models were combined with weather data for representative NSW climate zones and used to estimate the cooling system energy reduction resulting from short-duration 2°C increases to the air-conditioning set-point temperature across varying weather conditions and at different times of the day. In addition, parametric analysis was conducted to better understand the influence of different parameters related to the building fabric (for example, insulation levels, window area and orientation) and the air-conditioning system on the available demand response.

Results indicate that in NSW the DR potential between 3 pm and 5 pm in office buildings is approximately 126 MW and in school buildings is 90 MW when the outdoor temperature is in the range of 31-35°C. This is equivalent to approximately 26% and 55% reductions in air-conditioning power for office and school buildings, respectively.

2.4 Project challenges & lessons learnt

The Data Clearing House is a disruptive technology that aims to change the way the property industry (Proptech) operates. It aims to introduce new processes while simplifying and eliminating some of the industry practices that have been used by stakeholders over a period of time. In this journey, there were various technical and non-technical project challenges experienced by the team. A summary of these challenges and learnings actions to address these challenges is provided below.

2.4.1 TECHNICAL CHALLENGES AND OPPORTUNITIES

1. **Model creation and model management**:
   DCH is one of the pioneering platforms that uses semantic models for management of building data and for deployment of data driven applications (algorithms). As a result, the project needed to address the lifecycle challenges of semantic models.
   a. **Details in the semantic models:** While it is good to have a semantic model that captures all the building entities and their relationships, the effort invested in developing a semantic model will not be obvious unless queries related to the modelled points or applications that use the model are deployed. Hence the project team faced the dilemma of choosing between developing a complete model of the building versus a model that is at least adequate for a particular application. This also raises questions about model completeness: unless the objectives/usage of the model are clearly defined, completeness is difficult to assess. Often, the project team had to incorporate updates to the model based on application specific needs.
   b. **Semantic model accuracy:** Semantic models need to accurately represent the building assets and their relationships. Access to 'ground truth' information is required for creation of semantic models. This was often not easy to find; a domain expert with prior knowledge of the building or access to the building was typically required.
   c. **Validation of model completeness and correctness**: It is a challenging task to verify that the building model entities and relationships are correctly represented. The concept of a complete model (for any future purpose or app) is a falsehood. The completeness and correctness questions become relevant only for the identified use cases (apps), though it remains difficult to validate those questions until the model is utilised. Random checks and visual inspection of the models by domain experts were some of the approaches used by the project team to verify accuracy. Improvements in model visualisation and adherence to modelling conventions helped to identify issues.
   d. **Metadata schema upgrades:** After careful evaluation, the project team selected the Brick schema as the metadata schema for semantic model development. However, all building domain ontologies, including the Brick schema, are under continuous development and undergoing upgrades. For example, during the initial stages of the project, the team used Brick 1.0.3, while later models were built using Brick 1.2. This was required to incorporate new terminologies available in the latest version of Brick.
   e. **Expressiveness of Brick ontology:** As indicated above, the Brick ontology is in active development. In DCH we found instances where required classes, relationships or properties were not included in the latest release. Whilst Brick is easy to extend this comes at the cost of non-standardisation making sharing of DCH models with other partners more complex. For example, to support site energy use-based M&V application deployment, the DCH team have introduced a set of extensions that are not currently available in the current version of the Brick schema (1.2). Constant work with the community

to consolidate and merge the leading edges of Brick development and usage is required.

f. **Domain expertise/site knowledge requirement for constructing relevant queries:** Data driven application opportunities are plenty. Ensuring the model captures all relevant points as new applications come online remains challenging. Often minor updates to the model are required. This was faced by the team while implementing site level M&V. Buildings use various types of energy meters (e.g. consumption only, net metering, generation meters), that have various types of points (single phase, three phase, real, reactive), which in turn can have different properties such as units, or methods of aggregation (instantaneous, cumulative). In addition, meters are physically connected in various hierarchical configurations. These complexities of how real-world data exists in DCH makes constructing the correct query (in this case to identify /access site level consumption data) challenging. It requires domain expertise, an understanding of the modelling conventions, and an understanding of query language/operations.

2. **Onboarding**:
   a. **Approval process for connecting buildings to DCH:** Multiple stakeholders can make the site level approval process complicated. For example, typically a system integrator will require approval and assistance from facilities management to obtain access to BMS/EMS devices, and also from the site level IT team to allow a gateway device to be deployed and configured on the site network. For some sites the BMS contractor could become an additional stakeholder and so their approval would be required. This is further compounded by site IT teams upgrading/changing network security settings without informing the site facilities team. As a result, communication to external servers (e.g. DCH) could be blocked without any notice resulting in data drop off issues.

   b. **Inadequate documentation and limited information on the site:** These issues result in additional time and effort by the onboarding team. Some examples are : locating the subnet access for communicating with the site level BMS and physical location of the port to be used for connecting gateways. Connecting Modbus devices without point level details (register numbers, units of measure) also results in additional onboarding effort.

   c. **Maintaining Data Connectivity:** There is an ongoing need to monitor that data feeds remain active. There are many reasons why data connectivity can be interrupted. Monitoring and reacting to data dropouts requires systems and resources. E.g. hardware failures, or site IT teams upgrading/changing network security settings without informing the site facilities team (which can result in communication to external servers (e.g. DCH) being blocked without any notice), both of which can result in data drop off issues.

3. **Application development and deployment**:
   a. **Query interface for application developers:** The query interface is the most critical API feature to enable application developer success. The project team recognised early on that general-purpose semantic query languages (such as SPARQL) are a friction point for developers who want to discover data streams relevant to their algorithms. The BRIQL language aims to concisely express domain-oriented queries, automatically translated to efficient SPARQL without requiring developers to understand subtle performance trade-offs. BRIQL evolved as new use-cases were discovered, reaching a stable state that can fulfill most needs.
   b. **Semantic query composition and validation:** Application developers require reference models suitable for prototyping and need to interact with modellers to determine whether query results are

both valid and complete. While graphical tools to compose queries seem intuitively desirable and might fulfill trivial cases, they are confounded by needing to account for many scenarios such as negation, filtering, and term ordering.

2.4.2 COMMERCIAL/LOGISTICAL/SOCIAL CHALLENGES AND OPPORTUNITIES

1. **Promoting DCH as a building services platform:** Surveys have clearly shown that while building energy reduction is one of the priority areas for building owners, they also expect a platform such as DCH to solve other operational issues via data. Availability of building data in a central location is a powerful resource that can be harnessed to create new value streams. This became evident when some of the pilot site owners showed keen interest to link data health alert system outputs to their facility management system tool Coriggo. As a result, availability of DCH 'connectors' for existing building asset management and facility management tools such as Coriggo, Archibus will be an attractive value proposition for DCH users.

2. **Influential role played by consultants and system integrators:** As explained in the introduction section, many buildings are not digital ready. Lack of motivation and a clear business case for upgrading a building have been cited as reasons for lack of investment from building owners. Two stakeholder groups, consultants and system integrators, can play an influential role convincing building owners to progress smart building upgrades. Consultants often develop specifications for upgrades before building owners go to market. It is important for consultants to be up to date about various digital solutions available in the market and the way to leverage them for maximising value to themselves and their clients.

   Similarly, system integrators (or their contractors) are primarily the installers of smart building hardware. They often have a say in determination of the overall solution for a building. Moreover, non-optimal installation of smart building hardware could result in diminished future benefits from the digital solutions. The project team having realised these needs and are setting up a DCH 'system integrator' panel. This panel will enable availability of technically qualified resources for onboarding of buildings to DCH and promote the benefits of DCH to partners. The panel of system integrators will receive training to manage onboarding of buildings to DCH.

3. **Model development and management role in the ecosystem:** Development of building models requires tools to be available (both on platform and off platform) to support their creation. As an evolving area, there is ambiguity around the ownership of model creation activities. Tagging of building data is currently handled by system integrators/contractors when setting up the BMS system or analytics. It is envisaged that system integrators would handle building model creation and management activities in larger buildings, whilst in small/medium sized buildings, model upgrades could be handled by facility managers. Depending upon the availability of a (platform specific) model creation toolkit, a platform may be more appealing to system integrators than others. The best approach to facilitate and up-skill a cohort of model constructors needs careful consideration.

4. **Application developer expectations:** Expectations of application providers vary. In the case of application developers who have not already entered the smart building market, on platform application (DCH) application hosting lowers the barrier to market entry by simplifying infrastructure and data access costs and providing a path to access multiple users. Interactions with established smart building application developers indicate this subset of application developers prefer off-platform hosted applications. This is primarily due to

the existing infrastructure they have already setup for hosting applications. In addition to the access to a wider market, they see value in DCH providing them access to third party data. They have also expressed desire to have standard contractual templates that enables them to protect their IP before hosting it via DCH.

5. **Changing application developers' modus operandi :** For application developers to fully utilise DCH to it's full potential, they need to make a shift to the write once(semantic) / deploy many philosophy of application development that includes utilising the querying capability of DCH. DCH needs to ensure it provides supporting material/manuals for application developers to embrace this approach.

2.5 Project impact and path forward

This project has achieved its stated objectives and is delivering the following outcomes:

- A multi tenancy data platform for securely managing building operational data has been established. This platform incorporates tools for overcoming the onboarding barriers of connecting buildings and access to data for delivering data driven innovations. This platform is available for users (building owners and application developers).
- Operational features of the platform have been demonstrated through close collaboration and interaction with sub project partners. More than 50 buildings belonging to different building typologies and with differing building hardware currently exchange data with DCH. This includes 9 sub project partners and other industry partners. Data governance and ownership of the platform was demonstrated to users and most building owners have expressed willingness to continue providing data access even after the formal completion of the project.
- Although in the early stages of utilisation, DCH is delivering value to partners via applications that utilise DCH data. DCH is also used by some of the partners as a secondary platform for easy access to data and facilitating access to service providers. A government building property portfolio uses DCH's data health/quality reporting tools for addressing energy submetering data quality issues. A project partner is utilising data from DCH to identify Net Zero Emission (NZE) pathway for their sites considering onsite DER.
- International Performance Measurement and Verification Protocol (IPMVP) option C (whole of site energy use) is available as a reference application in DCH and has been used for weather normalised energy use comparison between two periods and for quantifying the benefits of energy efficiency upgrades.
- Detailed studies carried out as part of this project have identified residential and non-residential buildings can deliver over 1 GW of flexible demand. Bottom-up modelling carried out for NSW schools and offices have identified over 200 MW DR that can be achieved through short term set point changes in HVAC systems.
- The project team have demonstrated the ability to dispatch cloud-based control signals to building systems for real-time hardware control. This is an essential component that enables network aggregators to utilise buildings as flexible resources during DR events.

Next steps:

This project has resulted in development of a digital infrastructure that can deliver impact for various stakeholders. Some of the potential opportunities pursued by the project team are listed below:

- Increase Industry adoption: DCH has achieved initial success with engaging nearly 20 industry stakeholders who use the platform now. DCH aims to help small and medium sized technology developers/industry partners and commercial building owners to benefit from the power of digital technologies without significant investment in in-house infrastructure. This will be achieved through a viable operational model with access to relevant data driven digital services that will attract more partners and service providers.

- DCH is well positioned to support large scale government initiatives such as carbon reduction and green building schemes. For example, DCH can act as a low cost, easy to deploy, independent M&V platform to verify control solutions and energy savings for flexible demand and other equipment efficiency upgrades.
- As digital infrastructure DCH can support research and new technology evaluation activities. The platform could provide researchers with access to reference datasets, evaluating buildings to grid flexibility service delivery models as well as providing data to support national and international engagement activities.

To sustain momentum and achieve commercial viability, more buildings and application providers will be added to the platform in the near term. To deliver services at scale, a platform operator will be engaged to manage the operations of the platform. This platform operator could be a not-for-profit entity that overcomes reservations of the industry players around data access and vendor lock in. Onboarding services will be managed by a panel of DCH accredited system integrators.

2.6 Project Outputs (links to other reports, materials)

This project has resulted in various knowledge sharing outputs as listed below.

What	Intended audience	Details
Journal publications	Researchers, academic community, students, government	Air conditioning demand response resource assessment for Australia, https://www.tandfonline.com/doi/full/10.1080/23744731.2020.1785813 Science and Technology for the Built Environment journal, July, 2020 Cloud-based model-predictive-control of a battery storage system at a commercial site, Applied Energy. Under review.
Conference /workshop talks	Industry stakeholders, partners,	AIRAH Big data and analytics forum 2020, " I-hub Smart Buildings Data Clearing House" webinar talk. ARBS 2022 (planned) " I-hub smart building Data Clearing House" Various I-hub webinar and summit presentations
Online tools	Industry stakeholders, partners, general public	Tableau DR visualisation tool: https://public.tableau.com/app/profile/mark.goldsworthy/viz/shared/TSBGYFHM9 DCH website (registration required to access) https://dataclearinghouse.org/ DCH introductory video: https://youtu.be/Nt1S1aJ9CPM

What	Intended audience	Details
Manuals/ reports	Government, researchers, industry stakeholders	DCH integration options: available via I-hub website DCH API manual: available via I-hub website Tridium JACE Configuration Manual 2021-2022 (available on request) DCH user manuals (initial version) – Gitbook – to be made available via I-hub website (offline documents available on request) DCH cyber security report, 2021(available on request) DCH data governance report , 2021 (available on request) DCH stakeholder engagement report 2020-21 (available on request) DCH product features report, 2022 (available on request)
Other avenues	International audience, government stakeholders	Active participation in International Energy Agency (IEA) Energy in Buildings and Communities (EBC) annex 81 " Data driven smart buildings" . Benchmarking, promoting DCH via sub task A2 " open data platforms"

3 Acknowledgements

The project leader acknowledges the support from the project team members who have contributed to the report: Zakia Afroz, Will Borghei, Mark Goldsworthy, Akram Hameed, Dan Hugo, John McCulloch, Mark Peristy .