Smart operational technologies programming for whole-building decarbonisation

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Abstract

Have you ever finished designing a new building and wondered what technologies are specified for the building? When using delegated design for building technologies, is the scope clearly defined or is it left to the vendor to decide? If you do not know the answers to these questions — or worse, you say to yourself, 'my vendor has that' — this paper is for you. Regardless of project delivery, if building owners want to democratise their building data, take advantage of digital twin technologies and advanced data layer capabilities and operate their buildings at the highest possible levels of performance, they must take control of their building's operational technologies (OTs). Delegated design of OTs is typically the root cause of building owners not controlling or owning their building performance data. This paper is intended to provide building owners with the basic framework for OT programming, which is the only way to ensure ownership and control over building performance data. Our previous Corporate Real Estate Journal paper from Vol. 12, No. 3, Spring 2023 titled 'Integration of building science and data science to de-risk an affordable strategy for building decarbonisation' provides a higher-level view of the benefits from the integration of OTs. The convergence of global challenges requires building owners *to address building performance as performance is now expected by owners, investors, occupants and governments. Merging building science and data science is the most cost-effective way to deliver expected building performance over the life of a building. Smart building infrastructure technology democratises building data and is the key to cost-effectively controlling building performance. Data is the new gold and smart operational technology programming is the new shovel.*

Keywords: building science, data science, sustainability, building decarbonisation, zero carbon, smart building infrastructure, operational technology, independent data layer

BACKGROUND

The tools and technology exist today to enable building owners to achieve very low-energy consumption and healthy building performance without spending a premium in construction costs for smart building infrastructure. Fuel poverty, inequitable indoor air quality, pandemics and poor outdoor air quality demand that we change the way we look at buildings. Irrespective of motivation, high-performance buildings are rapidly becoming table stakes in the discussion of sustainability or sustainable development. An example of this is that we know we can quantify projected energy savings (design), actual waste diversion (construction), report indoor air quality and water quality monitoring (operation) and must provide actual energy cost savings, emissions reductions, based on utility bill analysis (operating). The combination of data sets and sources required to create and democratise this data is discussed below.

Experienced building owners know that aligning the financial, social and environmental goals of sustainable buildings is best achieved by integrating building science and data science.[1] In this paper, we outline the key components of the data infrastructure that are necessary to reach democratised building data. These strategies are most applicable to non-single family residential buildings, meaning that the best building typologies include commercial, industrial, infrastructure buildings.

Building owners today are following the macro trends of standardising 'open integration' networks and controls in lieu of proprietary systems. This one move creates a single platform for all the operational technologies (OTs) across the building(s), enabling easier and more affordable access to hourly building performance data. For the purposes of this discussion, OTs can generally be defined as systems that are focused on operating or sensing physical aspects of the built environment and include: building management system (BMS) (controls), indoor air quality (IAQ) and outdoor air quality (OAQ) monitors, weather station, utility energy and water metering, security systems (access control, intrusion detection, video management systems), density analytics/occupancy and vacancy controls, lighting control, fire alarm, elevator, generator, photovoltaic (PV) array, network communications (telephone, data, Wi-Fi), etc. (see Figure 1).

Common Operational Technologies (OTs)

Building Management System (Controls), RESET Air IAQ/OAQ, Weather Station, Utility Energy and Water Metering, Security/Access Control/CCTV, Density Analytics/Occupancy & Vacancy Controls, Lighting Control, Fire Alarm, Elevator, Generator, PV Array, Enterprise Networks (Telephone, Data, Wi-Fi), etc.

Figure 1 Common OTs

Each of these OTs plays a role in liberating building data. These systems can no longer exist in isolated silos if building owners want to operate their buildings at the highest possible levels of performance. The decarbonisation of buildings will be more difficult if the OTs lack integration capabilities. Building owners are demanding more from their buildings. To understand the importance of the roles that building science and data science play in building performance and decarbonisation, a summary of both is necessary.

BUILDING SCIENCE AND DATA SCIENCE OVERVIEW

Building science, for the purposes of this analysis, refers to the passive house envelope-first methodology to building heating and cooling load reduction, which represents the highest-performing buildings based on building science before introducing renewables. The natural order of sustainability[2] is an envelope-first energy and indoor air quality methodology for new and existing buildings: passive first — active second — renewables last. The natural order of sustainability is an organic pathway to reach zero energy consumption and the healthiest of indoor environmental conditions. Building science is demonstrated using dynamic simulations from physics-based, whole-building sustainability modelling.

Data science enables smart buildings that use technology to assess and improve the performance of buildings. Data from OTs provides building owners with greater control and a deeper understanding of space utilisation, energy consumption, security, environmental and maintenance needs. OTs are a category of computing and communication systems to manage, monitor and control building operations with a focus on the physical devices and processes they use.

Building science, in isolation, delivers high-performance buildings only at one point in time. Data science, in isolation, tracks and optimises building performance over time. The merging of building science and data science (see Figure 2) achieves and maintains high-performance buildings over their life. To merge building science and data science, we must standardise the real-time, time-series, independent data layer (IDL) and extract data from operational technologies in the most cost-effective, scalable and reliable manner possible. The physics-based sustainability model uses the time-series data from OTs for calibration. Once the model is operationalised, the IDL manages the dynamic time-series data from the model to inform decarbonisation master planning, monitoring-based commissioning, interrogation-based commissioning and testing of advanced data analytics prior to deployment.

METRIC-BASED GOALS

Utilising metric-based goals or outcome-based criteria in lieu of building code-based goals and/or sustainability certification programmes is the digital thread to connect building science to data science.

Achieving the goal of cost-effective, high-performance buildings relies on the use of physics-based, whole-building sustainability modelling from pre-design through post-occupancy. A holistic approach to energy conservation measures is essential, as existing buildings will require customised whole-building solutions to reach the optimum level of decarbonisation potential.

To provide proper guidance to physics-based, whole-building sustainability modelling, building owners must set metrics-based goals for all parameters of building performance early in conceptual planning for both new and existing buildings (see Figure 3).

In fact, creating use cases to establish meters and sensors is the first step to answer the question for building owners: 'Did I get what I paid for?'

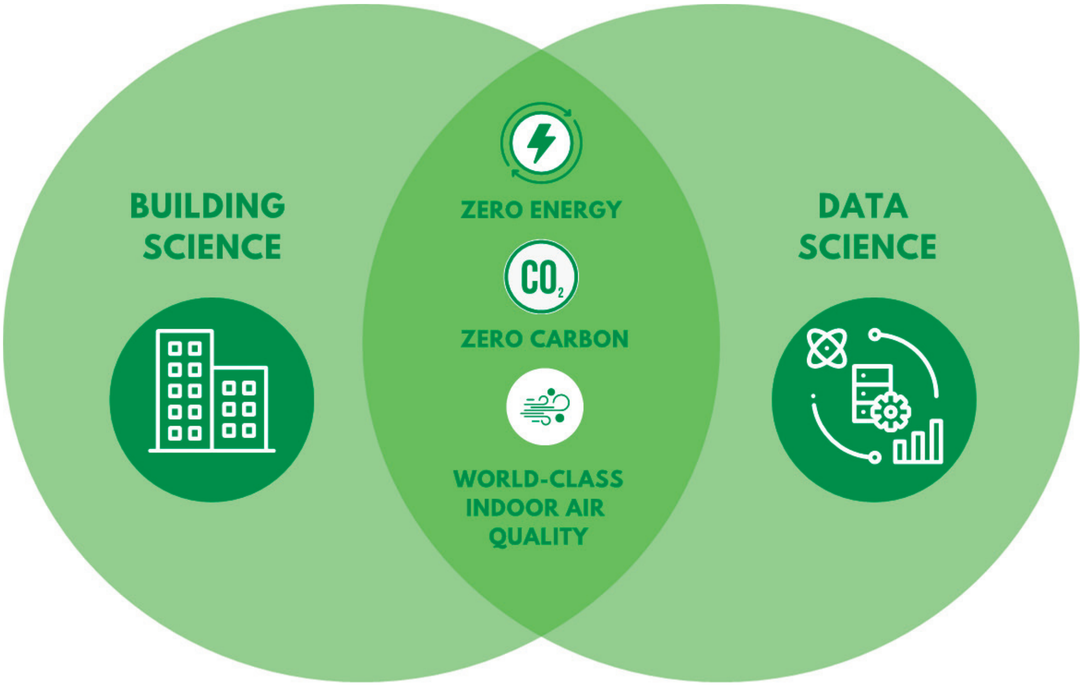

Figure 2 The merging of building science and data science

Figure 3 Building performance planning best practice

Use cases tied to the metric-based goals are considered best practices to prevent classic overdeployment of building technologies. New buildings may be easier than existing buildings to address because smart building infrastructure can be standardised without the constraints of legacy systems. Whether it is a new or existing building, thoughtful standardisation of smart building infrastructure should address technology 'openness', access to user interfaces, access to data and cyber security.

SMART BUILDING INFRASTRUCTURE

For building owners and developers to choose to invest in building technologies, they must believe that they will get an appropriate return on investment or greater value in the capabilities from OTs. In that regard, we find it helpful to break down smart building infrastructure into five critical components: OT, converged Internet of Things (IoT)/OT/IT networks, data aggregation, independent data layer and building intelligence layers (see Figure 4).

Early innovators in each of these areas were pioneers in their fields. In many cases, bringing a component solution to the market required a multifaceted, platform-based solution. To reach true open integration today, however, every component must be 'open' and enable the best providers to compete and integrate. Let us briefly examine each component of smart building infrastructure.

OT

The number of IoT meter and sensor devices grew 18 per cent in 2022 to 14.4bn globally, and it is estimated that there will be 27bn IoT devices by 2025. IoT meters and sensors are cost-effective tools to track building performance. The risk to building owners is that without careful planning and thoughtful consideration of network architecture, the addition of IoT devices may quickly become confusing, disconnected, expensive and inefficient. This is the crux of the current paper.

Converge and secure IoT/OT/IT networks

To deploy the IoT devices and integrated OT systems to gain access to the data from all the building technology systems, a converged OT network is beneficial. What was accomplished in the past with separate physical vertical networks per OT can now be accomplished with network virtualisation and software-defined networking. Each system can meet its own unique communications

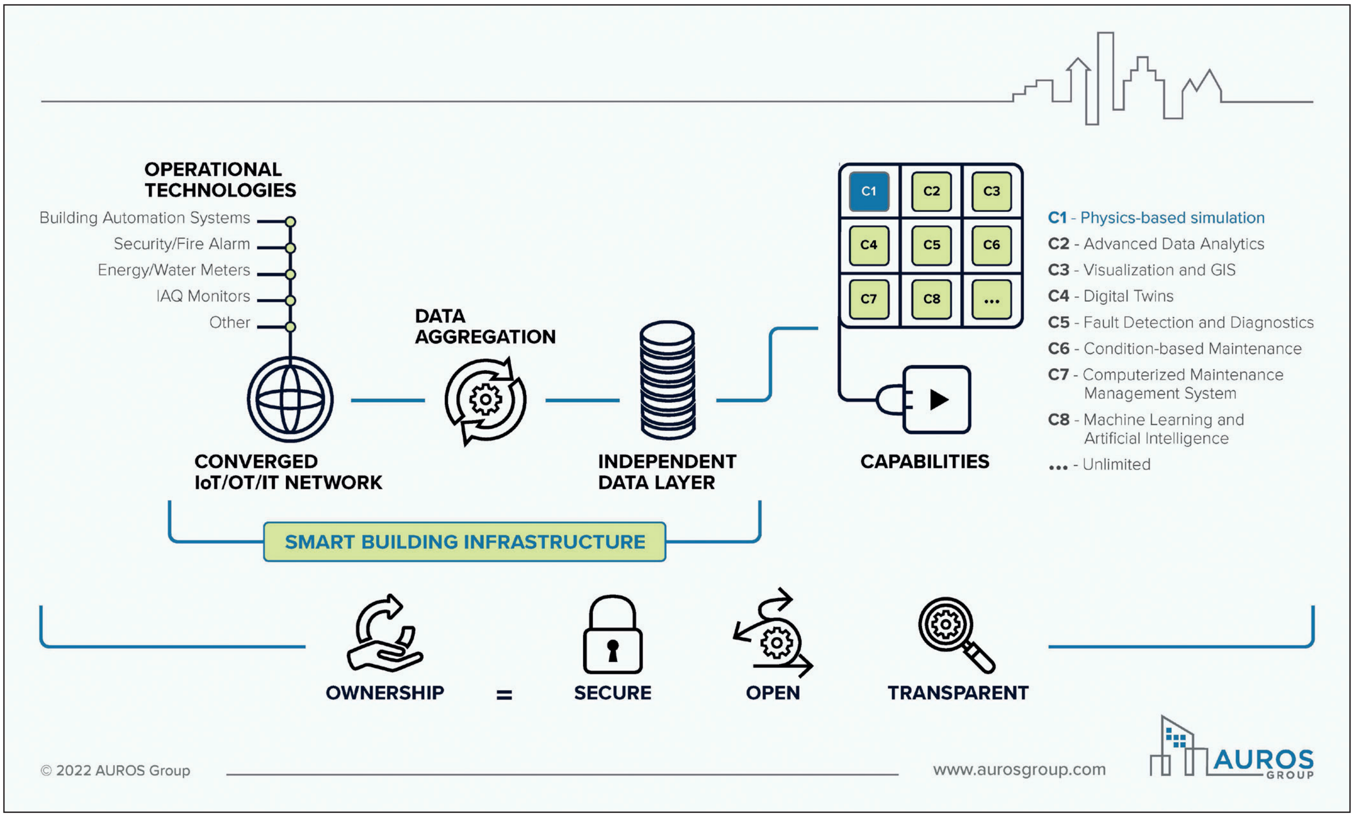

Figure 4 Democratising building data

and security requirements and sub-systems are able to communicate with predetermined logical access routes, bringing security to the edge. This topology can extend to the remote network security layer, allowing remote access to each individual system without exposing the remaining systems. This creates a layered security approach that also provides visibility to all systems and components for network management. This level of convergence, however, now makes the OT network a critical component of the building infrastructure, mandating a high degree of network security. Proper design, installation and ongoing operational management of this network has become the most critical requirement for OT teams.

Data aggregation

The data from IoT meters and sensors needs to be collected and processed and owners today expect to democratise their building data. The Niagara framework and Distech ECLYPSE Building Intelligence are among the established tools that practitioners deploy to aggregate data in buildings with multiple integrated systems and IoT devices in the built environment. Its open application programming interfaces (APIs), open-distribution business model and open-protocol support provides the freedom to scale up and down with meters and sensors, as desired, in a building. The aggregation platform connects and controls devices while normalising, visualising and analysing data from nearly any building system or subsystem and can connect to other data sources via APIs, Internet protocol (IP)-based protocols, or newer-to-market message queuing telemetry transport (MQTT) devices. The aggregation platform should be flexible and scalable to a single building or many buildings. Ultimately any aggregation framework or tool will connect to a wide variety of systems, translate protocols into a common language and be interoperable with systems upstream and downstream.

Independent data layer

Data is the key to controlling building operations. Real-time, time-series data in the built environment is usually managed by an integrated interface, commonly known as an IDL. It is important to note that the technology exists today, as described below, but you must know how to specify the technology, define interoperability and implement to achieve the expected outcomes.

Unfortunately, real-time, time-series data management systems are the most frequently overlooked part of smart building infrastructure. Most proprietary building automation systems (BAS)-BMS: 1) store their data in 'on-premises' computers with no backup; 2) have limited security and access; and 3) overwrite historical data. Building owners incorrectly assume that one of the system OT vendors has control of their building data.

With all OT data converged and normalised at the platform level, data is easily digestible and contextualised in the independent data layer. New visualisation tools, sourced from the independent data layer, can be deployed to meet different stakeholders' demands. For instance, the development of an IoT-based integrated sustainability dashboard requires a platform for interconnected devices.

Advanced data analytic layer capabilities

Data, to be usable, needs to be understood by everyone at first glance. Finding better context for data and displaying it for easy comprehension is our greatest challenge. We expect an effective dashboard to quickly demonstrate a building's performance, ideally, with the context to show if it is performing as it was invested in to perform. With the right context, visualisation becomes the cornerstone of measuring and verifying the performance of new or existing buildings.

For example, monitoring-based commissioning services import, manage and interrogate real building performance data against the whole-building energy model dynamic simulation data. Actual consumption data is compared to the simulation model to enhance building performance. Simulation profiles can be used to improve operational models or help close the performance gap by bringing design models closer to reality. Integrating building performance metrics with simulation metrics has additional benefits, as follows:

(1) Investigate the impact of retrofit options using real building data.
(2) Undertake post occupancy evaluations.
(3) Improve operational models for performance contracting.
(4) Aid in delivering a seamless handoff from construction into building operation.
(5) Help close the performance gap by simulating designs closer to reality.
(6) Testing data analytics, such as fault detection and diagnostics (FDD), prior to deployment.

The visualisation interface is technically the easiest of all the elements to solve and has the most options, so owners and project teams are lured into making visualisation decisions first. Many building owners assume incorrectly, however, that when they choose their visualisation, they are also getting a time-series database management system. The visualisation should be chosen to ensure the visualisation delivers the necessary functionality to the appropriate building stakeholders.

The smart building data infrastructure solution we describe is not expensive. In fact, when comparing the best-in-class components to proprietary solutions, the best-in-class components are typically less expensive and provide far greater value.

OT PROGRAMMING

As previously stated, OT programming is the crux of this paper. OT programming is not dissimilar to architectural programming, which is a practice of the alignment of goals and objectives and has been used for decades during the building design and planning phase of new and existing construction. Essentially, OT programming is a process that aligns the project team on the approach to building technologies. After utilising OT programming for the last few years, we wanted to discuss the lessons learned and best practices honed from experience.

The first objective of efficient OT programming is to design with the end in mind. This means that it is normally best to start the OT programming with a discussion on the IDL and advanced data analytic layer capabilities. If the building does not have an existing IDL or capability layer, then a comprehensive discovery charrette may be necessary to select the right place for the building data to reside. If the building owner has an existing IDL, then a deeper level of integration planning will be required to ensure full systems compatibility. The building owner may also consider combining the IDL and advanced data analytic layer capabilities or keeping them separate. The final decision relative to the IDL and capability layer will most likely come down to cost and criticality of the data.

A discovery process focused on the building owner's intended use of building data will help to clarify the building stakeholders, personas and workflows. This level of IDL and advanced data analytic layer capabilities programming is the subject of a subsequent paper.

Smart building infrastructure, including a properly designed OT network, permits the easy deployment of new IoT and the quick retirement of obsolete IoT. Remaining platform and network-neutral gives building owners control, transparency and ongoing access to all data to ensure they are never beholden to proprietary IoT solutions.

The first step in OT programming, after understanding the needs of the data, is to analyse the building technologies. To do this, we utilise a master OT programming spreadsheet.[3] The document is intended to identify all the commonly used building technologies or IoT/OT/IT systems. The list will have to be supplemented with the building specific technologies missing from the list. We find it best for the building owner and engineer of record to simultaneously review the list and identify the following classification for each OT, as 'must have', 'like to have', 'optional', 'not necessary' or 'future'. This begins the alignment of building technologies, as the first question is always: 'Do we want it?' To assist in this process, we recommend using the owner's project requirements (OPR) documents.[4]

If the OPR uses metrics-based goals as detailed above, then creating use cases connecting the OPR to building technologies will be critical to prevent classic overdeployment of building technologies. It should make sense, if we have an established goal as identified in the OPR, that we should then give strong consideration to any technology that can answer the question: 'Did I get what I paid for?' Obviously, this question better applies to the building science variable, but you can now see how building science and data science both have integral roles in high-performance buildings and building decarbonisation goals.

For buildings seeking decarbonisation goals, the minimum required deployment of IoT/OT/IT includes a whole-building operational model, primary source digital utility meters, indoor air quality monitors and BAS-BMS integration. With this data integrated and overlaid for real-time comparisons, we can begin to key-in on operational inefficiencies and better understand assumptions that are used in future physics-based, whole-building sustainability modelling.

The second step in OT programming answers the question: 'How much of the OT do we want?' This phase of programming requires a deeper understanding of each OT and how it helps the building owner achieve the goals and targets established in previous steps. This often-overlooked phase of programming is essential to control costs, while delivering smart building infrastructure that is capable of future expansion and contraction without sacrificing access to building data and functionality.

Once the OT is identified, it is time to establish the standardisation for each OT. OTs are either proprietary aka closed systems or open-integrated, with a variability between both. Proprietary aka closed systems typically have a negative connotation, which is why the vendors of proprietary or closed systems will classify their technologies as 'open' despite a lack of openness.

Further, experienced building owners are now developing formal standards within their organisations to define openness. This standard is normally established at the organisational level or master planning level. The standard secures a seamless connection to each of the five critical components of smart building infrastructure; OTs, converged IoT/OT/IT networks, data aggregation, independent data layer and building intelligence layers. For new buildings, this is relatively straightforward and manageable. For existing buildings, this is more complicated. Legacy systems must be carefully planned with natural triggers of life cycle, deferred maintenance and planned renovations. No rational person would argue to remove and replace a legacy system that has remaining service life, but the need for operational data cannot be ignored, which means that retrofit or modifications of the legacy systems must be considered.

OT open integration standardisation is best organised in the following categories: access to licence, data transfer, user interface access and building data ontology.

Access to the licence

Open integration means that anyone with the right training, capabilities and credentials can access the system to make updates and modifications. As an example, the following paragraph confirms if the system in question is open-integrated:

> 'The OT shall consist of the provision of all labour, materials, tools, equipment, software, software licences, software configurations and database entries, interfaces, wiring, tubing, installation, labelling, engineering, calibration, documentation, samples, submittals, testing, commissioning, training services, permits and licences, transportation, shipping, handling, administration, supervision, management, insurance, temporary protection, cleaning, cutting and patching, warranties, services and items, even though these may not be specifically mentioned in these division documents which are required for the complete, fully functional and commissioned OT.'

Open integration means that the building owner does not have to ask for permission to access the OT technology.

Another benefit of open integration is the ability to compete annual technology service agreements with various service providers without removing hardware or modifying the OT technology.

Data transfer

Data transfer can best be classified as open protocol or open integration. Open protocol-based systems support vendor agnostic protocols such as BACnet, OBiX, OPC, ModBus, SQL, JSON, CSV, XML or RESTful API. Most vendors that support proprietary aka closed systems using open protocols still tightly limit sales and deployment options. By contrast, open integration-based systems are both open protocol and can be deployed by multiple master systems integrators without the permission or support from the manufacturers. Figure 5 illustrates a data flow image that best summarises open protocol versus open-integrated data transfer.

Alternatively, the only way to extract data from proprietary or closed systems is to commission the programming of expensive and custom APIs. Not only are APIs expensive and time-consuming to create, but they are also similarly expensive to maintain as they require updates and patches to keep pace with the progress of software updates.

User interface access

With the advent of OTs and building technologies, many building owners are finding it difficult to manage access to their systems. They humorously refer to this as 'dying by credential death' or 'dying by URL death'. Planned properly, OTs can be integrated with systems such as Active Directory or other similar directory services, if the OTs are configured properly.

Single sign-on (SSO) user is an identification method that enables users to log in to multiple applications and websites with one set of credentials. SSO streamlines the authentication process for users. Some of the key benefits of SSO authentication for IT administrators and other IT team members include user adherence to password

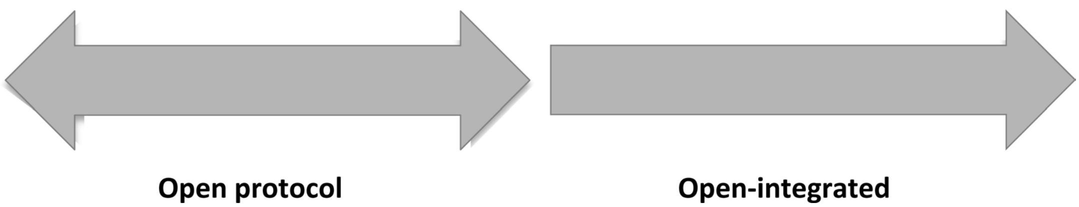

Figure 5 Open protocol versus open-integrated data transfer

rules, user password reset call reduction and administrative ability to track and control application access.

Building data ontology

Ontology is a set of concepts and categories in a subject area or domain that shows their properties and their relations between them. Data ontology is a way of linking data in formats based on concepts in a formal, organised manner. Historically, OTs share the following attributes for data: point name, point value and time stamp. Unfortunately, this is not helpful when connecting data to IDLs and advanced data analytic layer capabilities. With data ontology, building owners can quickly scale the deployment of IDLs and capabilities layers across the building stock. Operations and maintenance are further simplified with the use of ontology.

The most common types of open-source building-related data ontologies regarding OTs are Haystack and Brick. Project Haystack is an open-source suite of technologies for modelling IoT data. Brick is an open-source effort to standardise semantic descriptions of the physical, logical and virtual assets in buildings and the relationships between them. Haystack uses a tagging system with no rules for how tags can be used, resulting in subjectively applied, highly customised inconsistent modelling practices. Brick Schema includes a tagging system similar to Haystack, but more formal semantic rules promote consistency and interpretability.

ASHRAE Standard 223P: 'Designation and Classification of Semantic Tags for Building Data'[5] provides a dictionary of semantic tags for descriptive tagging of building data including building automation and control data along with associated systems.

When we attend industry conferences and vendor symposiums, there is always an overriding outstanding question: 'When will OTs align on and deliver a consensus-based standardisation for ontology?' Until the OT vendors deliver on this industry requirement, we must plan accordingly. Building owners cannot simply expect to 'plug in' their buildings to IDLs and capabilities layers. Similarly, they cannot expect the associated costs are the same irrespective of the technologies that exist in their buildings. It is far more affordable, and the ease of integration is far easier, when ontology is considered during OT programming.

Paradoxically, consider how OTs are commonly deployed for buildings. Are the engineers of record making these decisions independently from the project team? Is the OT vendor brought into the project with delegated design responsibilities to design and deploy the OT? Is the OT treated like furniture, fixtures and equipment (FF&E) and deployed post-construction without regard to the five critical components of smart building infrastructure?

Lastly, we need to consider the role sustainability plays in the selection of OTs and digital systems. Technology-based systems have a significant and negative impact on our environmental goals if not planned properly. Best practices require that we consider a holistic look at material circularity with quantitative data, encompassing metrics for source-of-life (SOL) and end-of-life (EOL). There are two programmes in the built environment, the RESET® Embodied Circularity Standard[6] and WiredScore certification,[7] that thought leaders are using to manage these challenges.

The RESET® Embodied Circularity Standard provides users with a powerful methodology for assessing, scoring and benchmarking circularity from products through to projects. RESET® Embodied Circularity is a standard and certification programme that provides quantified and third-party verified environmental data for projects and products, translating complex health and sustainability data into measurable key performance indicators. The results help users tangibly improve, benchmark and communicate progress.

WiredScore certification focuses on digital connectivity, physical elements of the building and the building infrastructure. It enables building owners and managers to understand, benchmark, improve and promote their building's digital infrastructure. The key benefit is the ability to use the certification criteria as a standard to inform the design of digital communications that will enable your OT programme.

SUMMARY

If you want to capitalise on the smart building infrastructure technologies available to building owners and achieve your building performance goals, a paradigm shift is required. High-performance buildings require an integration of building science and data science. The role of OTs in high-performance buildings is a critical component; however, we cannot deploy 'out of the box' solutions and expect integration to magically happen. We must demand more from OTs, which includes access to licences, access to data transfers, user interfaces access and ontology standards as described in this paper. The OT programming framework defined above integrates building science and data science in a holistic and cost-effective approach to ensure evidence-based performance and building decarbonisation. It delivers transparent and secure access to data that supports and defends a lifetime of investment decisions for your building.

References

(1) For more information on building science and data science, see AUROS Group, available at http://www.aurosgroup.com (accessed 30th November, 2023).

(2) AUROS Group, 'Natural Order of Sustainability', available at https://www.aurosgroup.com/post/natural-order-of-sustainability (accessed 30th November, 2023).

(3) Newcomb & Boyd, 'Master spreadsheet', available at https://www.newcomb-boyd.com/wp-content/uploads/2024/01/MASTER_OT-Programming-Spreadsheet.pdf (accessed 30th November, 2023).

(4) Newcomb & Boyd, 'Owners Project Requirements (Master)', available at https://www.newcomb-boyd.com/wp-content/uploads/2024/01/MASTER_OPR-Report.pdf (accessed 30th November, 2023).

(5) Haynes, A. (February 2018), 'ASHRAE's BACnet Committee, Project Haystack and Brick Schema Collaborating to Provide Unified Data Semantic Modeling Solution', ASHRE, available at https://www.ashrae.org/about/news/2018/ashrae-s-bacnet-committee-project-haystack-and-brick-schema-collaborating-to-provide-unified-data-semantic-modeling-solution#:~:text=ASHRAE%20Standard%20223P%3A%20%22Designation%20and,data%20along%20with%20associated%20systems. (accessed 30th November, 2023).

(6) RESET, 'RESET® Embodied Circularity', available at https://reset.build/standard/embodied/circularity (accessed 30th November, 2023).

(7) WiredScore, 'WiredScore certification', available at https://wiredscore.com/certify-a-building/wiredscore/ (accessed 30th November, 2023).