Energy Smart Buildings Readiness Guide

How to Make a Building Energy Ready

November 2018
An ICONICS Whitepaper
www.iconics.com

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Contents

1. Document History

Version	Issued By	Issue Date	Comments
1.0	Gary Kohrt	10/30/2017	
2.0	Gary Kohrt	11/9/2018	

2. Understanding of Energy Smart Building Readiness

Energy Smart Building Readiness means achieving a state by which building operational data (temperatures, pressures, power usage, equipment status, damper positions, etc.) is available to users and applications that can use such data to optimize the operation of the building and maintenance of the equipment within it. Such data is typically needed in real time or at a very high resolution (e.g., every 15 minutes or faster.)

There is a wide degree of variance in the level of instrumentation installed in buildings and thus the detail of data available. Simply put, the more data available, the more operational insight can be derived and thus improvements gained. However, typically some improvements can be obtained even with minimal instrumentation.

Once instrumented or sensed, data must be communicated to the applications and users. This requires networking, from the sensor, typically through controllers, through networks, and using open protocols that applications can understand. Available technologies are discussed further in the following sections.

Once data is made available, numerous applications can provide value from the data. Such applications include Fault Detection and Diagnostics (FDD), Energy Analysis, Business Intelligence through Dynamic Dashboards, and Machine Learning.

3. Networking

The actual data produced by a sensor (temperature) or actuator (position) must find its way to the applications described above. Those applications execute on servers running on a customer’s premise, in their data centers, or on a public computing cloud. Those servers need to receive the data via a company intranet or the internet. This ultimately means packaging data via an internet/intranet transport protocol, which we will refer to simply as an IP protocol.

Some sensors and actuators have direct IP protocols where the required higher speed communications hardware is built directly into the sensor, but this is very costly and rare. Typically, sensors are connected via a much lower-cost, two-wire, multi-drop communications wire or wirelessly via a data integration device or concentrator. That integration device or controller, with greater computing power, then delivers that data through an IP protocol and over the internet or intranet. See the following diagram.

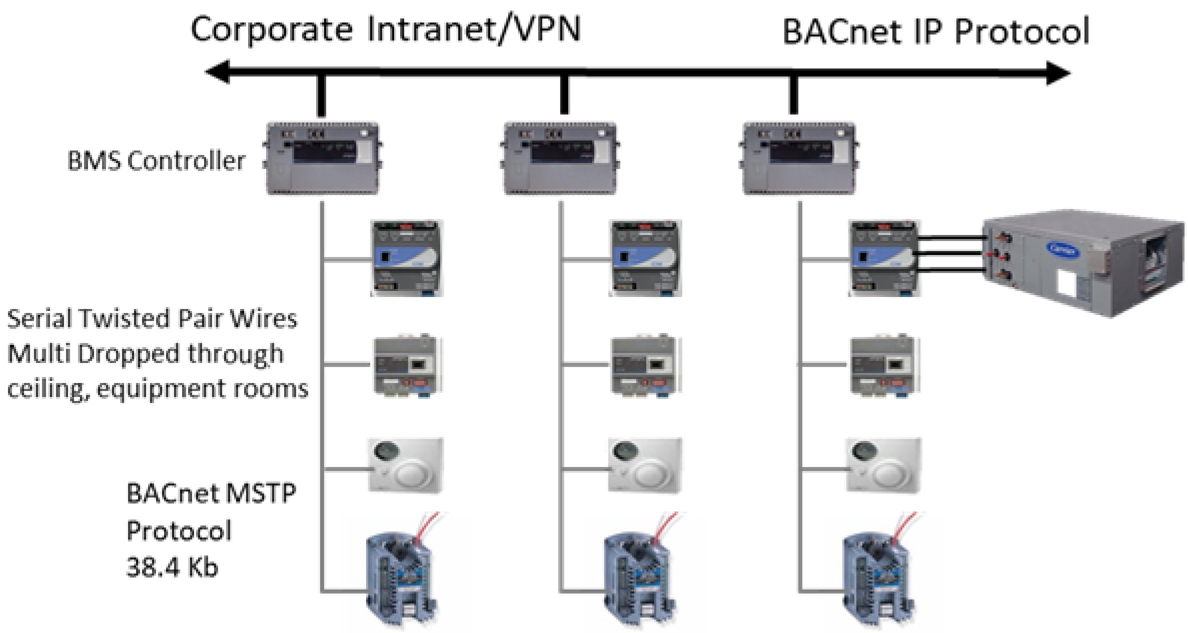

Figure 1 – Typical Sensor Network Connection

The integration device must transport that data to the servers running the application. Many companies already have intranets connecting their buildings and choose to simply route the building data via those existing networks. Some companies, based on their corporate policies, choose to install separate networks or virtual private networks just for building data. Some companies choose to procure a direct internet connection for each site and use that public internet connection to deliver data to the applications executing in the cloud or in a corporate data center. Ultimately, a path from sensor to the applications must be created. All of the above options can achieve successful results.

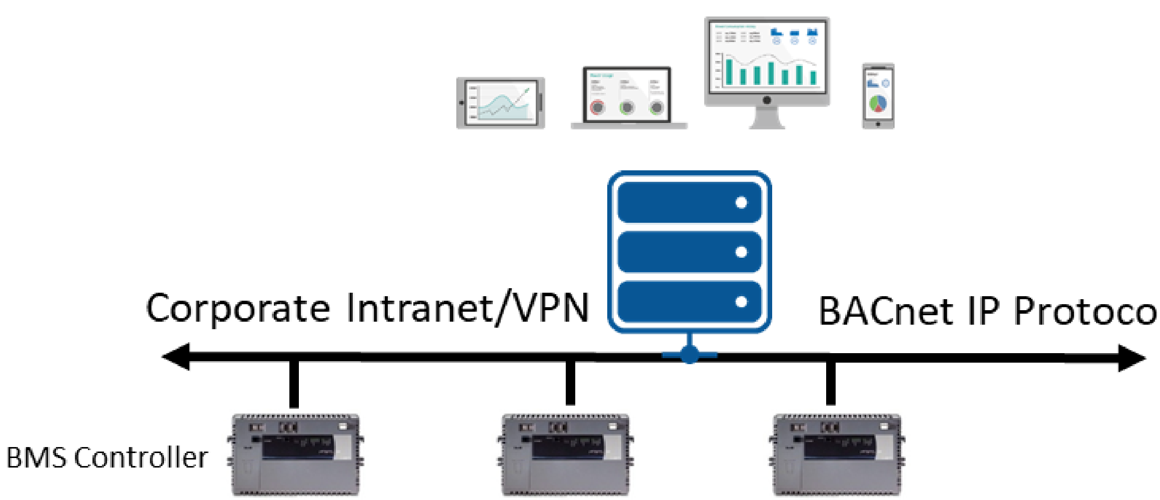

Figure 2 - On Premise Implementation

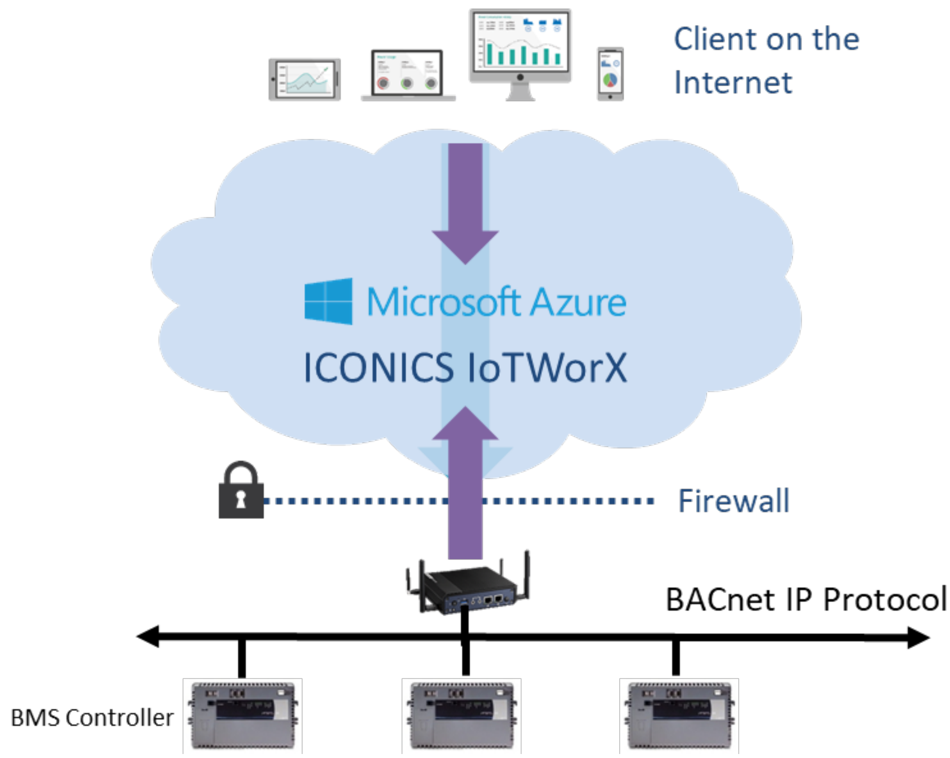

Figure 3 - Cloud Implementation

4. Open Protocols

As previously described, a path from the sensor/actuator producing the data to the applications must be achieved. However, this in itself is not sufficient. The data must be delivered in a format that applications from different vendors can be understood. This is achieved by utilizing open protocols. Listed below are open protocols that are commonly available in the building industry.

Even though open protocols are available, it is up to a company to insist that all equipment it purchases adheres to and communicates via these protocols. Many vendors still have proprietary protocols and if a customer does not insist on open standards, such proprietary ones will tend to be the default, resulting in a customer being “locked in” to the vendor for all future work.

Commonly used open protocols include the following. Energy Smart Building Readiness requires that all building operational data is made available using one or more of these protocols:

- **BACnet** – Specifically BACnet IP Annex J – This is the most widely used open IP protocol in the building industry.
- **OPC** – A protocol widely used in industrial automation. It’s also available from some building automation vendors.

- **OPC-UA** – A newer OPC protocol; Gradually being adopted by major industrial control vendors
- **Modbus TCP** – A very widely used protocol for electrical equipment and metering. This is a simple protocol and thus is also used by many auxiliary equipment vendors (air compressors, vacuum systems, power meters, etc.).
- **SNMP** – Simple Network Management Protocol – This a widely used protocol for IT equipment monitoring. As such, network equipment and data center equipment (routers, switches, servers, UPSs, PDUs) can be monitored on the IP network with this protocol.
- **AMQP** – An IoT internet protocol – Starting to appear in IoT monitoring gateways for smaller sites and devices to be monitored. This is a freeform protocol, so vendors must supply the data format.
- **MQTT** – An IoT internet protocol – Starting to appear in IoT monitoring gateways for smaller sites and devices to be monitored. This is a freeform protocol, so vendors must supply the data format.

All Building Automation Systems (BASs) must expose all system data and enable supervisory control through the Company IP network. Note that some BASs may require additional hardware or software to accomplish this.

Since a typical application can include BAS components from many vendors and such could have been installed by many different contractors:

1. The Facility Management Team should manage and issue for vendor implementation: All IP addresses, BACnet Device IDs, BACnet Device Object Names and Network Numbers, and must guarantee uniqueness throughout all Company buildings.
2. The BAS vendors, Meter vendors, equipment vendors must configure all control devices to utilize IP addresses, BACnet Device IDs, and Network Numbers as provided by the facility owner.
3. The facility owner must ensure that the configuration of routers for internal intranet communications and company firewalls for outside access are properly configured to allow the open protocols described above to transverse through from controller to application servers.

5. Interoperability

System interoperability standards greatly reduce the effort to achieve energy smart building applications as well as system usability and maintainability. The following guidelines are provided in terms of a system utilizing BACnet protocol, since this is the most widely used standard in buildings. However, the same principles apply to all of the standards applied.

Controllers shall expose all sensor inputs, position inputs, statuses, adjustable set points, maximum/ minimum settings, and command-able values to the IP Network via BACnet. At a minimum, all BAS parameters should be exposed when available from HVAC equipment as BACnet objects.

All analog objects (inputs and values) shall have a COV (change of value) Increment setting, greater than or equal to .5% of the range of the specific analog value. This value is set to avoid unnecessary network traffic.

A customer must ensure that all BACnet Device IDs across all systems, all equipment, all vendors and all network/subnets, are unique. Similar to IP addressing, the BACnet protocol requires uniqueness.

Object/Point Naming Standards – Customers are encouraged to require consistent and human readable Point and Property naming standards. This is not a requirement of the protocols, but an obvious need for usability and maintainability. This means that:

a) All points/objects defined in the BAS system shall be required to have a specific and unique BACnet Object Name property defined. (Object_Name is a standard BACnet property whose property ID is 77).
b) Object Names shall be defined per a standardized hierarchy such as the following:
   [Building Descriptor].[System Descriptor].[Equipment Descriptor].[Point Descriptor]
c) For each object, four (4) distinct descriptors shall be linked to form its unique object name:
   1. Building Descriptor *(e.g.: McCormick)*
      Designated by the Company
   2. System Descriptor *(e.g.: Cooling, Heating… etc.)*
      Defines the system type
   3. Equipment Descriptor *(e.g.: AHU101, VAV201… etc.)*
      Defines the equipment identifier
   4. Point Descriptor *(e.g.: MA_Temp, SA_Temp… etc.)*
      Defines the hardware/software type or function associated with this object

d) Point Descriptor (or property) should follow a company-wide standard naming convention across all devices and systems. For example:
    - Supply Air Temperature – The exiting air temperature from all air handling devices should always have a descriptor of – "SAT"
    - Outdoor Air Temperature – As measured at a point, and conveyed by all systems, should always have a descriptor or property name of "OAT"
    - Damper Positions – The current % open of all dampers; Should always have a property name of "POS"

e) Use alphanumeric characters. Spaces and special characters (with the expection of underscores) are not allowed. Each of the four descriptors must be bound by a period to form the entire object name. Reference the following section for an example of these descriptors.

6. Documentation

Critical to implementing an Energy Smart Building is gaining and conveying an understanding of the existing installed equipment and systems and the current programming of all systems. Ultimately, such knowledge can be obtained through reverse engineering and discovery, but at obvious cost. The following is a list of as-built documentation used in gaining an understanding of the buildings and defining advanced analytics and optimization programs.

- **Building Facts –** Current or historical information of a building.
  It should include, but not limited to:
    - Building Name
    - Building Code (if applicable)
    - Building Address
    - Building Categorization (if applicable)
    - Building area, if applicable, denote any useful categorization of area, i.e.:
        - Occupied area
        - Unoccupied area
        - Tenant occupied area
        - Owner occupied area
    - Building designed occupancy
    - Building occupancy schedule
    - Any Energy Models Available for the Building
    - Energy Consumption and Cost histories for all applicable utilities
    - Rate Models for all applicable utilities

- **Mechanical Schedules**
  - Such schedules shall list each item of equipment and all design parameters for such equipment such as horsepower, minimum/maximum airflows, etc. Such schedules should list every air handling device, every pump, chiller, heat exchanger, VAV, and FCU, for example.
  - These schedules shall identify each item of equipment that the customer desires to have monitored and analyzed by the system.
- **Building Control Final Control Submittals** – This shall be as provided by the BMS vendor, Lighting Control Vendor, Electric Controls/Metering Vendor, or Fire Systems Vendor (If Applicable). Such documents will typically include:
  - Control Drawings for each equipment and system
  - Sequence of operations narratives for each equipment and system
  - All BMS, Lighting, Electric, Metering control architecture drawings
- **Mechanical Drawings for all Systems** – (chilled water, hot water, domestics water, etc.), and all air handling flow.
- **Mechanical Layout Drawings** – showing the location of all equipment
- If floorplan dashboards are desired (to indicate locations of monitored equipment and space conditions), electronic (AutoCAD, Revit, etc.) drawings shall be provided. Such drawings shall include a clean layer, show all final spaces within the building and final devices providing air and thermostats that control each space.
- **Space Priority –** A document listing the priority of each space served by building control equipment. At a minimum, a listing of critical spaces should be provided. This is used when weighing the relative priority of a detected fault in the system.
- **Electrical One Line Diagrams**
- **Electrical Metering Diagrams**
- **Electrical Meter Lists** – Electrical Meter Lists shall describe, for each meter:
  - The Meter ID
  - The Meter address (as described below under point mapping files)
  - The engineering units and range of each data tag provided by the meter
  - The rollover value configured for the meters accumulator (for readings such as kWh and kVARh)
  - The Scope or Load monitored by the meter
- **Point Mapping Files** – Each point or object to be mapped into the building automation system shall be listed with, at a minimum:
  - The complete address used to access such data point. The address shall be in the format of the open protocol required, i.e., BACnet (Device and BACnet object name), Modbus IP. (IP Address, Modbus Device, and Register), OPC (complete OPC Item Ref).
  - A human readable description clearly describing the function of the data point
  - The engineering units of the data point

- **Control Systems Architecture Drawings** – Describing all connected controllers, their protocols, and addresses
- **Existing IP Network Architecture**
- **Building Equipment Asset Lists**
- **Work Order Histories**
- **IT Network Diagrams** – (physical and logical) showing all network and subnets on which building equipment is connected
- **Past Retro Commissioning Reports**

7. Key Performance Indicators

The key business performance indicators that the system will monitor, calculate and display should be defined. These metrics will be used to drive business decisions and all significant stakeholders should be involved in their selection and definition. The result should be a list of KPI equations and conceptual dashboard/report contents and layouts. Typical KPIs are in the areas of:

- **Energy**
    a. Energy Used – HVAC, Lighting, Plug
    b. Energy Reduction
    c. Lost Opportunity Estimate – Per Day, Week, Month – Estimated lost energy due to detected faults
- **Maintenance**
    a. Number of faults per week-month-year, and per building, discipline, etc.
    b. Number of work orders
    c. Average time to resolution for work orders and or faults
    d. Total uncomfortable occupied space hours per day-week-month
- **Comfort**
    a. A measure of how well the system maintains temperature and humidity setpoints
    b. Whether the building is at a comfortable temperature in time for the start of the business day
    c. Number of hot/cold calls for different areas of the building

8. Appendix A – Typical Properties Monitored for Typical HVAC Equipment

Following are typical properties monitored via any modern building control systems that should be available on the IP network, to all monitoring and analytics platforms. All are not applicable for all equipment. However, where applicable, monitoring of these parameters provides the ability to continuously commission or analyze such equipment for proper, efficient operation.

Air Handler Unit

Supply Air Temperature	Preheat Coil Leaving Temp	Return Fan Status
Supply Air Temperature Setpoint	Pre Heat Valve Position	Return Fan Command
Return Air Temperature	Humidity Enabled	Return Fan Speed
Outdoor Air Temperature	Humidity	Return Fan Speed Command
Outdoor Air Flow	Humidity Setpoint	Filter Differential Pressure
Outdoor Air Damper Position	Humidity Valve Position	Supply Air Static Pressure
Mixed Air Temperature	Occupied Status	Supply Air Static Pressure Setpoint
Mixed Air Temperature Setpoint	Supply Fan Status	Supply Air Flow
Cooling Coil Entering Temp	Supply Fan Command	Supply Air Flow Setpoint
Cooling Coil Leaving Temp	Supply Fan Speed	Supply Fan KW
Cooling Coil Valve Position	Supply Fan Speed Command	Return Fan KW
Heating Coil Entering Temp		
Heating Coil Leaving Temp		
Heating Coil Valve Position		

VAV

Zone Temperature	Air Flow CFM	Damper Position
Zone Temp Setpoint	Air Flow Set Point	Reheat Valve/Coil Command
Zone Temp Effective Setpoint	Maximum Occupied Air Flow	
Cooling Minimum Setpoint	Minimum Occupied Air Flow	
Heating Minimum Setpoint	Occupied Status	

FCU

Zone Temperature	Air Flow	Damper Position
Zone Temp Setpoint	Air Flow Set Point	Cooling Valve/Coil Command
Zone Temp Effective Setpoint	Minimum Occupied Air Flow	Fan Speed
Cooling Minimum Setpoint	Fan Status	Occupied Status
Heating Minimum Setpoint	Fan Command	Heat Valve/Coil Command
	Fan Speed Command	

Exhaust Fan

Fan Status	CO2	Differential Pressure
Fan Command	CO2 SetPoint	Differential Pressure SetPoint
Fan Speed		

Pump

Pump Status	Pump Speed	Pump KW
Pump Command	Pump Speed Command	
Pressure	Pressure Setpoint	

Chiller

Chilled Water Flow	Chiller Load	Chilled Water Diff Pressure
Chilled Water Return Temp	Chiller KW	Chiller Tons
Chilled Water Supply Temp	Chiller Speed	Isolation Valve Command
Condenser Water Return Temp	Chiller Speed Command	
Condenser Water Supply Temp	Chiller Status	
Chilled Water Setpoint	Chiller Command	

Cooling Tower

Condenser Water Supply Temp	Fan Command	Sump Temperature
Condenser Water Return Temp	Bypass Valve Command	Fan Speed
Condenser Water SetPoint		

Heat Exchanger

Supply Side Entering Water Temp	Load Side Entering Water Temp	Temperature Setpoint
Supply Side Leaving Water Temp	Load Side Leaving Water Temp	Valve Command

Boiler

Boiler Command	Steam or HW Supply Temp	
Boiler Status	Steam or HW Supply Temp Setpoint	
Boiler Firing Rate	Flue Temp	

ESB IO

Refrigeration

Refrigeration Cases

Ambient Temperature	Case Temperature	Refrigerate Valve Command	
Ambient Humidity	Case Temp Setpoint	Evaporator Pressure Regulator Valve Cmd - %	
Ambient Dewpoint	Defrost Command		
Door Heater Status	Defrost Status		
Door Heater Command	Fan Status		
Full Off Dewpoint	Fan Command		

Compressors

# Active Stages	Compressor Failure Alarm		
Status of each stage			
Suction Pressure			
Suction Pressure Setpoint			
Discharge Pressure			
Percent Used			

Condensers

Ambient Temperature			
Liquid Refrig Level			
Discharge Pressure			
Split Valve State			
Condenser Status			

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