

Supplementary Materials

Table S1: full table of our review of metadata schemas

The full table of our review of metadata schemas can be found in the following publicly accessible Google spreadsheet. This expanded table captures extensive details about the 40 schemas our review surfaced, including more information on their syntax and purpose. Links to publicly available repositories for each schema are also provided.

<https://docs.google.com/spreadsheets/d/1Ldx5iC0ua1Y55D3SwkQ5ImUbisGAFhXzB3RC4bCYJfU>

After proposing the use case and grounding it with the example Figure 5, we formulated competency questions (i.e., detailed interrogatives that allow to scope an ontology) and we evaluated the required concept that needs to be present in an ontology to answer these questions. The detailed concepts listed here were then summarized in Table 2 of the paper.

Table S2: Concepts required by Use Case 1: Energy Audits

Category	Competency questions	Required concepts and their features
Zones/Spaces	<ul style="list-style-type: none">- What is the building layout (Geometry, Floor Area)?- What is the space function breakdown for areas comprising > 20% of gross floor area?- What is the design or typical occupancy and use (hours/week & weeks/year) required for primary spaces?	<ul style="list-style-type: none">- Concept of Space<ul style="list-style-type: none">- Geometry- Floor area- Space Function- Composition of Spaces- Concept of Schedule- Concept of Occupancy
Envelope	<ul style="list-style-type: none">- What are the overall building envelope characteristics ?	<ul style="list-style-type: none">- Concept of Envelope Element<ul style="list-style-type: none">- Type of Envelope Element- Number of Windows- Window to Wall Ratio- Qualitative Envelope Type (metal stud w/brick veneer)
Building Systems and Equipment	<ul style="list-style-type: none">- What is the primary energy consuming systems, their efficiencies, capacities and remaining lifespan ?- What are the main electrical loads (lighting, plug, process) ?- What is the energy use, cost and its breakdown by fuel source (and end-use if available) ?	<ul style="list-style-type: none">- Concept of Equipment/End-use/Asset<ul style="list-style-type: none">- Type of equipment- Rated power draw- Rated efficiency- Rated capacity- Remaining lifespan- Concept of Meter/Submeter<ul style="list-style-type: none">- Energy, power, cost- Time Series of energy use (Utility bill, more granular data)- Breakdown by end-use

		<ul style="list-style-type: none"> - Concept of Unit of Measure (e.g., kWh, BTU, \$) - Aggregation of cost/energy values - Relationship between Equipment and Space - Relationship between Equipment and Meter
Control Devices	<ul style="list-style-type: none"> - What are the control technologies adopted for different systems (digital, pneumatic, etc.) ? - What are the configuration parameters (e.g., schedules and setpoints) for the control devices ? 	<ul style="list-style-type: none"> - Concept of Control Device <ul style="list-style-type: none"> - Control Device Technology - Concept of Schedule - Concept of Setpoint
Sensor/Actuator	<ul style="list-style-type: none"> - What is the actual average occupancy of a space ? - What are temperatures in different spaces ? (when required for estimating savings potential of certain EEMs for Level 2 or Level 3 audits.) 	<ul style="list-style-type: none"> - Concept of Sensor - Relationship between Sensor and Control Device - Relationship between Sensor and Equipment

Table S3: Concepts required by Use Case 2: AFDD

Category	Competency questions	Required concepts and their features
Zones/Spaces	<ul style="list-style-type: none"> - What is the building layout (Geometry, Floor Area)? - How do the HVAC/lighting zones relate to the layout ? 	<ul style="list-style-type: none"> - Concept of Space <ul style="list-style-type: none"> - Geometry - Floor area - Concept of Thermal/Lighting Zone
Envelope	-	-
Building Systems and Equipment	<ul style="list-style-type: none"> - What HVAC systems are used to condition the building (e.g., Chillers, AHUs, VAVs) ? - What lighting systems are used for illumination (e.g., luminaires, lamp/fixture)? - What is the lighting system architecture? - How are these systems linked to each other? - What are the different components of these systems (e.g., fans, dampers, sensors)? - How are these components layed out in each system (e.g., sequence of components and system layout) - What are the energy meters in the building ? - How to meter relate to systems or components ? 	<ul style="list-style-type: none"> - Concept of System (e.g., hot water loop, chilled water loop, metering infrastructure, lighting system) - Concept of Equipment <ul style="list-style-type: none"> - Rated power draw - Rated efficiency - Rated capacity - Concept of Lighting Device (e.g., luminaire) <ul style="list-style-type: none"> - Rated inputs - Rated outputs - Safe operating conditions - Concept of Meter/Submeter <ul style="list-style-type: none"> - Energy, power - Time Series of energy use - Concept of Unit of Measure (e.g., kWh, BTU) - Relationship between Systems, Equipment, Components - Relationship between Equipment and Zone - Relationship between Equipment and Meter

	- What is the relationship between an HVAC system and a Zone ?	
Control devices	<ul style="list-style-type: none"> - What are the devices controlling the operation of the HVAC ? - What are the inputs and outputs of these controllers (points) ? - Are these points monitored ? - What is their sampling time ? - Which points are connected to real sensors/actuators ? What is that relationship ? - Which inputs/outputs are virtual ? - What categories of virtual points are used ? - What types of virtual points are defined ? - What is the control logic (sequence) implemented in such devices ? 	<ul style="list-style-type: none"> - Concept of Control Device <ul style="list-style-type: none"> - Inputs and Outputs (Points) - Concept of Point <ul style="list-style-type: none"> - Physical and Virtual Points - Time Series of Points - Sampling time - Unit of Measure (e.g., °F, CFM) - Relationship between Control Device and Sensor/Actuator - Concept of Virtual Point <ul style="list-style-type: none"> - Concept of Setpoints - Concept of Command - Concept of Alarm - Concept of Control Sequence <ul style="list-style-type: none"> - Concept of Schedule
Sensor/Actuator	- Where are sensors deployed in spaces and systems (context) ?	Relationship between Sensor/Actuator and Zones Contextual Information: <ul style="list-style-type: none"> - Relationship to equipment - Relationship to location - Relationship to control devices, schedules, controllers

Table S4: Concept required by Use Case 3: Optimal Control

Category	Competency questions	Required concepts and their features
Zones/Spaces	In addition to Use Case 2: <ul style="list-style-type: none"> - What zones are in thermal contact with each other? - What is the orientation of the Building? 	In addition to Use Case 2: <ul style="list-style-type: none"> - Zone Adjacency - Building Orientation
Envelope	- What are the envelope properties of the different elements (e.g., Windows, Walls) ?	- Envelope Element Properties (estimated U-Value and R-value, Solar Heat Gain Coefficient for Windows)
Building Systems and Equipment	[Same as in Use Case 2]	[Same as in Use Case 2]
Control devices	In addition to Use Case 2: <ul style="list-style-type: none"> - Which control inputs can be overridden ? - What is the control interval of existing controllers (e.g., 5 min) ? - How do overrides interact with the existing logic ? 	In addition to Use Case 2: <ul style="list-style-type: none"> - Overridable points - Concept of Control Strategy (detailed)
Sensor/Actuator	In addition to Use Case 2: <ul style="list-style-type: none"> - How are occupancy sensors in the lighting system related to the zones of the 	In addition to Use Case 2:-Relationship between Sensor/Actuator and Zones

	HVAC system ? - What virtual or physical sensors capture weather conditions?	Concept of Context
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Table S5: Building models in five ontologies

We facilitated our analysis of BOT, SSN/SOSA, SAREF, RealEstateCore, and Brick Schema by taking the sample building in Figure 5 and modeling its various elements using each ontology. The five versions of the model are available in GitHub and capture the decisions of our team working to represent this example. The model files are available in GitHub Gist at:

<https://gist.github.com/qttierro/c7aa9817d41ce956fbfeb71622f8cad8>