



RESEARCH REPORT

Semantics for IT and OT Convergence in Commercial Real Estate

A map of the published and in-development standards addressing meaning across the building lifecycle, the overlaps between them, and the gaps they leave open.

Building Lifecycle Management Initiative



Contents

Contents	2
Executive Summary	3
Introduction	4
Problem Statement	4
Background and Context	5
The design and construction lineage	5
The building automation lineage	5
The real estate business lineage	6
The governance and regulatory lineage	6
Methodology	6
Analysis	7
6.1 Mapping the information landscape	7
6.2 Overlaying the efforts	9
6.3 Where the efforts overlap	10
6.4 Where the gaps are	12
6.5 Adoption: where it is real and where it is not	14
6.6 Trajectory	17
Findings	18
Pathways and Options	19
Recommendations	20
Conclusion	21
Works Cited	22
Appendix A: Glossary	25
Appendix B: Effort Register and Verification Notes	26
B.1 Effort register	26
B.2 Items requiring verification before operational or contractual reliance	26
B.3 Scope constraints	27
About BLMI	28
Disclaimer	28
AI Use Transparency	28

Executive Summary

Thirty-four standards, ontologies, data models, and regulatory schemas were assessed for this report. They come from more than twenty separate bodies: standards organizations, industry consortia, government agencies, and regulators, writing for different original purposes over roughly two decades. Appendix B lists all thirty-four and states the rule by which they were counted. This report maps where each one actually defines meaning, where they duplicate one another, and where they leave the lifecycle unaddressed.

Semantic standards are not what the industry is short of. The shortage is in how they are distributed: dense in two places, absent from a third. A design and construction cluster, anchored by IFC and its surrounding buildingSMART apparatus, is consolidating steadily. An operations and control cluster, comprising ASHRAE 223P, Brick, Project Haystack, RealEstateCore, and SAREF4BLDG, is converging rapidly and visibly. A third cluster covering the money, the lease, the ownership structure, and the asset register is fragmented, thinly governed, and, critically, has no evidenced technical contact with either of the other two.

That third absence is the sharpest result in this research. In February 2026, OSCRE International announced a strategic shift toward a relationship aware data model, illustrating it with the example that a system should understand that a pump is equipment within a room which is part of a building, and that a pump identifier and an asset tag are, in the announcement's own words, synonymous in a given context. That is, precisely and without overstatement, the problem Brick and ASHRAE 223P have been solving since 2018. The announcement cites neither of them. Reciprocally, the extensive published alignment work among ASHRAE 223P, Brick, RealEstateCore, and Project Haystack mentions no lease, no chart of accounts, no rent roll, and no ownership entity anywhere. Two communities are independently building the same equipment to space containment model in 2026, each citing none of the other's published work. Whether that reflects unawareness or a deliberate scoping choice cannot be determined from the public record; what the record shows is the absence of contact.

Four further conclusions follow from the evidence assembled here. First, convergence within the operations cluster is real but is running through shared people and shared federal funding rather than through any signed institutional agreement; no merger, alignment memorandum, or joint charter was found. Second, adoption is concentrated almost entirely in federally owned buildings, hyperscale corporate campuses, research universities, and large institutional office, and is essentially undocumented in healthcare, multifamily, retail, industrial, and life sciences. Third, the design to operations handover seam remains unbridged: COBie is losing owner demand on the published record, the one working group chartered to bridge building information modeling and operational tagging has produced no deliverable in three years, and every bridging study located is academic and reports no validated accuracy. Fourth, European law is on the verge of requiring machine readable end of life and circularity data at both the product and building level, while no building ontology models deconstruction, recovery, or disposal at all.

For BLMI, the implication is a familiar one, and it is consistent with the initiative's founding position. The gap here is translation rather than invention. The raw material for a coherent, lifecycle spanning information model already exists across the standards landscape. What does not exist is a published map of how the pieces relate, a convening venue where the operations community and the real estate business community can discover that they are solving the same problem, and practitioner guidance keyed to the lifecycle stage and asset class an organization actually occupies. Those three are within BLMI's charter. A thirtieth standard is not.

Introduction

Commercial real estate has spent roughly a decade discussing the convergence of information technology and operational technology. The conversation is usually framed as a networking and cybersecurity problem: how does a building control system safely reach an enterprise network, and who is accountable when it does. That framing is necessary and incomplete. Once the packets flow, a second and harder problem appears immediately, and it is a problem of meaning rather than transport.

A building automation system will happily deliver a value labelled AHU3_SAT_SP to an analytics platform. Nothing in that label tells the receiving system that the value is a supply air temperature setpoint, that it belongs to an air handling unit, that the unit serves floors four through seven of a specific building, that the building is held in a particular ownership entity, that the floors are leased to two tenants under different expense recovery structures, or that the unit is nineteen years old and scheduled for replacement in the next capital cycle. Every one of those facts exists somewhere in the organization. None of them travels with the value. Supplying that missing context is what a semantic model does.

This report examines the standards, ontologies, taxonomies, and data models that attempt to supply it. The scope is deliberately wider than the building automation layer where the term semantics is most often used. A commercial real estate organization does not experience the building lifecycle as a control problem. It experiences it as a continuous chain running from development through design, engineering, construction, commissioning, and into an operating period in which finance, ownership, leasing, asset inventory, maintenance, capital renewal, and performance disclosure all consume and produce information about the same physical objects, and eventually into deconstruction. A semantic landscape assessment that stops at the mechanical room describes a fraction of the problem.

Three questions organize what follows. Where does each effort actually define meaning across that lifecycle? Where do the efforts overlap, and is the overlap wasteful duplication or complementary layering? And where, after twenty years of standards development, does the lifecycle remain unaddressed?

This report builds on and does not repeat a prior BLMI landscape scan, published in July 2026, which examined eleven standards addressing location, space, and asset hierarchy in commercial real estate. That scan established that no single standard defines a complete hierarchy from portfolio to component, and that OSCRE International functions as an integration layer which incorporates other bodies' measurement and classification work rather than competing with it. Those conclusions are treated here as established and are extended into the operational and end of life dimensions the earlier scan did not cover.

Problem Statement

The cost of missing semantics is measurable, and the measurements are unflattering.

Lawrence Berkeley National Laboratory, drawing on the United States Department of Energy Smart Energy Analytics Campaign covering 104 organizations and more than 6,500 buildings, reports a median fault detection and diagnostics setup cost of approximately 9 US dollars per point and 13,000 US dollars per building, with recurring cost near 4 US dollars per point, against an average of roughly 1,655 building automation points per building. Configuration duration is described as running to several months, with data integration and management named explicitly as the cause. [1] That is the price, per building, of reconciling one vendor's point naming to one application's expectations. It is paid again for the next application, and again for the next building.

The handover seam performs worse. A survey of 284 facility managers and owners at mid-Atlantic United States universities, with 59 respondents, found that spreadsheets remain the dominant handover format, that computer aided design files remain the most used format in operations, that a quarter of respondents do not use the building information model at all after construction, that a majority spend a month or more reorganizing handover data before it is usable, and that 1.20 percent mandated COBie as

a deliverable. [2] An earlier peer reviewed analysis of five United Kingdom construction projects reported COBie record level error rates between 84 and 100 percent on three of the five, with the diagnosed root causes being process, ambiguity, and absent role allocation rather than schema deficiency. [3]

A separate longitudinal study of building information modeling to facility management delivery found that, in an owner's existing portfolio of 1,275 assessed assets, 73 percent carried no maintenance procedure information and more than half lacked maintenance manual location, warranty, or serial number. Its authors observe that the support provided by industry standards and guidelines remains limited even where ISO 19650 and COBie are nominally in play. [4]

These numbers describe a single underlying condition. The information needed to operate a building exists, is generated at considerable expense during design and construction, and then fails to arrive in a form operations can use. The industry response has been to write standards. The question this report addresses is whether the standards written so far, taken together, actually cover the ground.

Standards are not the scarce resource. The ones that exist were written for different purposes by bodies that do not talk to one another, and the seams between them are exactly where the lifecycle breaks.

Background and Context

Understanding why the current landscape looks the way it does requires separating four development lineages, because each produced a different kind of document, and the differences are routinely conflated in practice.

The design and construction lineage

buildingSMART International, formerly the International Alliance for Interoperability, has maintained the Industry Foundation Classes since the 1990s. IFC is a data schema: it specifies how the pieces of a digital building model relate so that software can read and write them consistently. IFC 4.3 was elevated to full international standard status as ISO 16739-1:2024 in March 2024, and extended scope beyond buildings to infrastructure. [5] Around it sit the buildingSMART Data Dictionary, a hosting service that gives terms stable resolvable identity and now holds more than 300 dictionaries as of August 2026; the Information Delivery Specification, which converts information requirements from prose into machine checkable rules; and COBie, an exchange format carrying facility, floor, space, and component data from construction into facility management at handover. [6][7][8] National frameworks, principally NBIMS-US in the United States, wrap this apparatus in owner facing process guidance, and the ISO 19650 series governs the information management process itself across six published parts.

The building automation lineage

A second lineage grew from the control systems side and has almost no shared history with the first. Project Haystack was founded as a community in 2011 and incorporated in 2014, originating as a tagging convention for building management system data. Brick Schema emerged from academic work at Carnegie Mellon, the University of California Berkeley, and elsewhere as a formal resource description framework ontology for building assets, points, and relationships. RealEstateCore was founded in 2017 by a consortium of Swedish property owners and research institutions. In 2018 the ASHRAE BACnet committee, Project Haystack, and Brick Schema announced a collaboration on a unified semantic modeling solution, and that collaboration became proposed ASHRAE Standard 223P. [9]

It is worth stating plainly, because it is frequently misreported: as of 31 August 2026, ASHRAE 223P is not a published standard. It completed an advisory public review in spring 2024 and a first formal public review between 27 June and 11 August 2025. [10][11] The National Institute of Standards and Technology, a participating agency, stated in February 2026 that comments had been addressed, that the committee vote for a second public review was pending, and that publication was expected in federal fiscal year 2026, which ends 30 September 2026. [12] No approval notice was located as of this report's

date. Contract language and procurement specifications that cite 223P generically are citing a document that does not yet exist in published form.

The real estate business lineage

A third lineage originates in leasing, valuation, transactions, and lending, and has no connection to either of the first two. OSCRE International maintains the Industry Data Model, a business and data exchange model developed over roughly two decades and made freely available in 2020, organized around more than 150 use cases and described as covering the asset lifecycle from development through demolition. [13][14] MISMO, a subsidiary of the Mortgage Bankers Association, maintains a commercial family including appraisal, financial operating statement, rent roll, and green utility data standards, shipped on a roughly semi-annual versioned release cadence. [15] BOMA International maintains the ANSI accredited Z65 floor measurement family, most recently the 2026 Mixed-Use Standard released in July 2026, and the RICS led International Property Measurement Standards provide a parallel global measurement hierarchy. [16]

The governance and regulatory lineage

A fourth group defines method rather than content. DAMA-DMBOK2 supplies enterprise data governance practice; its third edition is in development with a published target publication window of April to July 2027, meaning DMBOK2 remains the governing reference throughout the horizon of this report. [17] The ISO 55000 asset management series was revised in July 2024 and gained two directly relevant companions: ISO/TS 55010, guidance on aligning financial and non-financial functions in asset management, and ISO 55013, guidance on data asset management. [18] Increasingly, regulation is supplying de facto semantics where standards bodies have not. ENERGY STAR Portfolio Manager is the compliance mechanism for more than fifty United States jurisdictional building performance and benchmarking laws, and GRESB collects per building energy, emissions, water, and waste data against a typed asset data dictionary from more than a thousand real estate managers annually. [19][20]

These four lineages produce documents that are not interchangeable. A vocabulary standard fixes what words mean. A classification system establishes categories into which things are filed. A data schema specifies how digital objects relate. A measurement method fixes what counts as a boundary. A management system standard governs process. An ontology asserts machine reasonable relationships. Six different kinds of document, all colloquially described as standards, all frequently compared as though they were rivals when in most cases they are not.

Methodology

This assessment began from a supplied reference list of seven efforts: ASHRAE 223P, Project Haystack 5, Brick Schema, the buildingSMART trio of IFC, bSDD, and IDS, NIBS NBIMS-US and COBie, the NIST building digitization program, and DAMA-DMBOK2. That list is accurate as far as it goes and is weighted, understandably, toward design and building automation.

Because the research question concerns coverage and gaps rather than description, the corpus was deliberately widened to include efforts occupying lifecycle positions the supplied list left empty. Twenty-seven further efforts were added across four areas: the transactional, financial, and lease domain; the topology and internet of things ontologies; the classification systems; and the regulatory schemas that impose structure from outside the standards bodies. That gives a corpus of thirty-four. Counting rule: an effort is one row where a single body maintains it as one publishable thing, so a numbered family issued together (the ISO 55000 series, the classification systems built on ISO 12006) counts once, and the NIST and Department of Energy research programs are treated as context rather than as efforts and are excluded from the count. The complete register appears in Appendix B. An assessment restricted to the original seven would have found gaps that are artifacts of the list rather than of the industry.

Evidence was collected through primary source verification against standards body catalogs, government agency publications, peer reviewed literature, and organizational primary documents, with trade press and vendor material used only where no higher tier source was available and flagged where used. Four source tiers were applied, following the BLMI research configuration: standards bodies, peer reviewed work, and government agencies at the highest tier; industry bodies and professional associations second; quality trade press and analyst firms third; vendor content lowest.

Two categories of evidence deserve explicit treatment. First, several conclusions in this report rest on negative findings, that is, on the absence of any locatable evidence for a relationship or activity that would be expected to exist. Negative findings are labelled as such throughout and are not asserted as proof of absence. Second, a number of the primary documents in this landscape sit behind purchase or membership gates, including the full ISO texts and the internal schema detail of the OSCRE Industry Data Model. Where that limited verification, the limitation is disclosed rather than papered over. Appendix B carries a list of items requiring further verification before operational or contractual reliance.

A disclosure of interest is owed to the reader. BLMI was co-founded by IFMA and Autodesk in March 2025. Autodesk is a commercial participant in the design and construction half of the landscape assessed here. OSCRE International, whose governance composition and version transparency this report examines critically, is an IFMA Strategic Partner Association. This report nominates BLMI as a convener in one of its pathways. None of those relationships changed a finding, and all of them are the kind of thing a reader is entitled to weigh.

A methodological note on adoption. No survey exists that segments semantic standard adoption by commercial real estate asset class. The adoption assessment in Section 6.5 is therefore a reasoned synthesis from mandate evidence, published deployments, instrumentation data, and structural drivers. It is defensible, and it is inference. It is presented as such.

Analysis

6.1 Mapping the information landscape

Before the standards can be overlaid on anything, the ground beneath them needs describing. Figure 1 maps the building lifecycle as an information landscape: what information comes into existence at each stage, and what each stage needs from the ones before it.

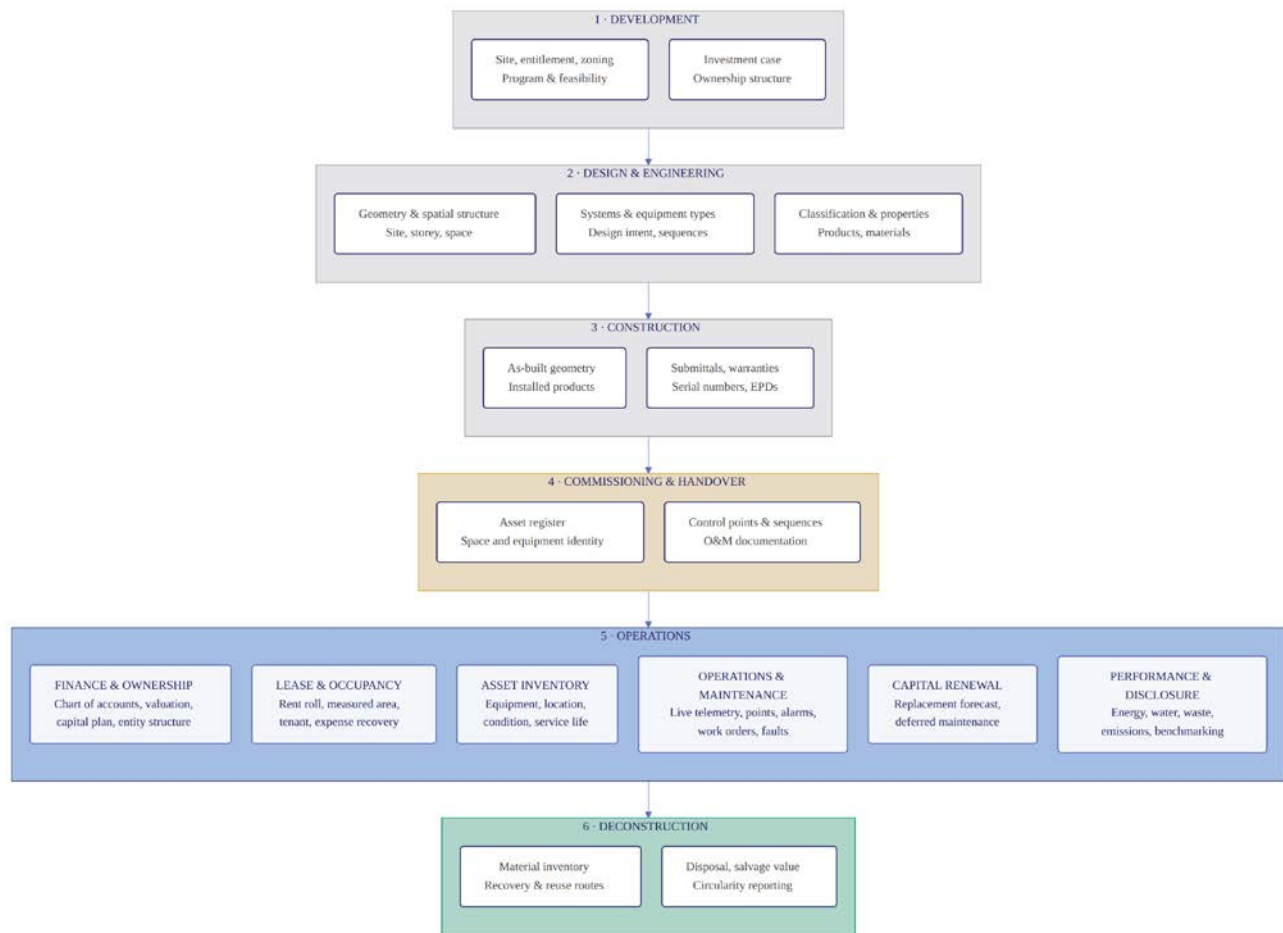


Figure 1. The building lifecycle as an information landscape. Operations is expanded because it is the stage where the largest number of distinct information domains coexist, and where they most often fail to reconcile.

Three properties of this landscape drive everything that follows.

Asymmetry. The lifecycle is asymmetric. Stages one through four are projects: they have a start, an end, a defined delivery team, and a contract that can compel information delivery. Stage five is not a project. It is a decades long operating period with rotating staff, changing ownership, successive software platforms, and no single contractual moment at which information quality can be enforced. Standards written for a project context transplant poorly into an operating context, which is a large part of why COBie has struggled.

Six operations, not one. Operations is not one domain but six, and they do not share a spine. The finance function knows a building as a cost center and an asset on a balance sheet. The lease function knows it as measured rentable area. The asset register knows it as a list of maintainable items. The control system knows it as a graph of equipment and points. The capital plan knows it as a replacement forecast. The disclosure function knows it as a set of annual consumption totals. All six are describing the same chiller. Only one of them, the control system, has a machine readable model of what a chiller is.

An orphan stage. The last stage has almost no information heritage. Deconstruction has never been a data rich activity because, historically, nothing downstream of it needed the data. Circular construction changes that assumption, and European regulation is now changing it faster than the standards landscape is responding.

6.2 Overlaying the efforts

Figure 2 places all thirty-four efforts on that landscape. A filled cell records where an effort's published scope makes a lifecycle stage a primary target. A lighter cell records partial or indirect coverage: the effort touches the stage through a subset of its model, through an adjacent standard it references, or through data it carries without defining. Blank means no coverage. Coverage marks record scope, not adoption depth; several efforts with wide marks here have very little field deployment behind them, which Section 6.5 addresses separately.

Figure 2 · Semantic Standards Coverage Overlaid on the Building Lifecycle
Each filled cell marks where an effort actually defines meaning. Vertical stacks are overlaps. Empty columns are gaps. Status as of 31 August 2026.

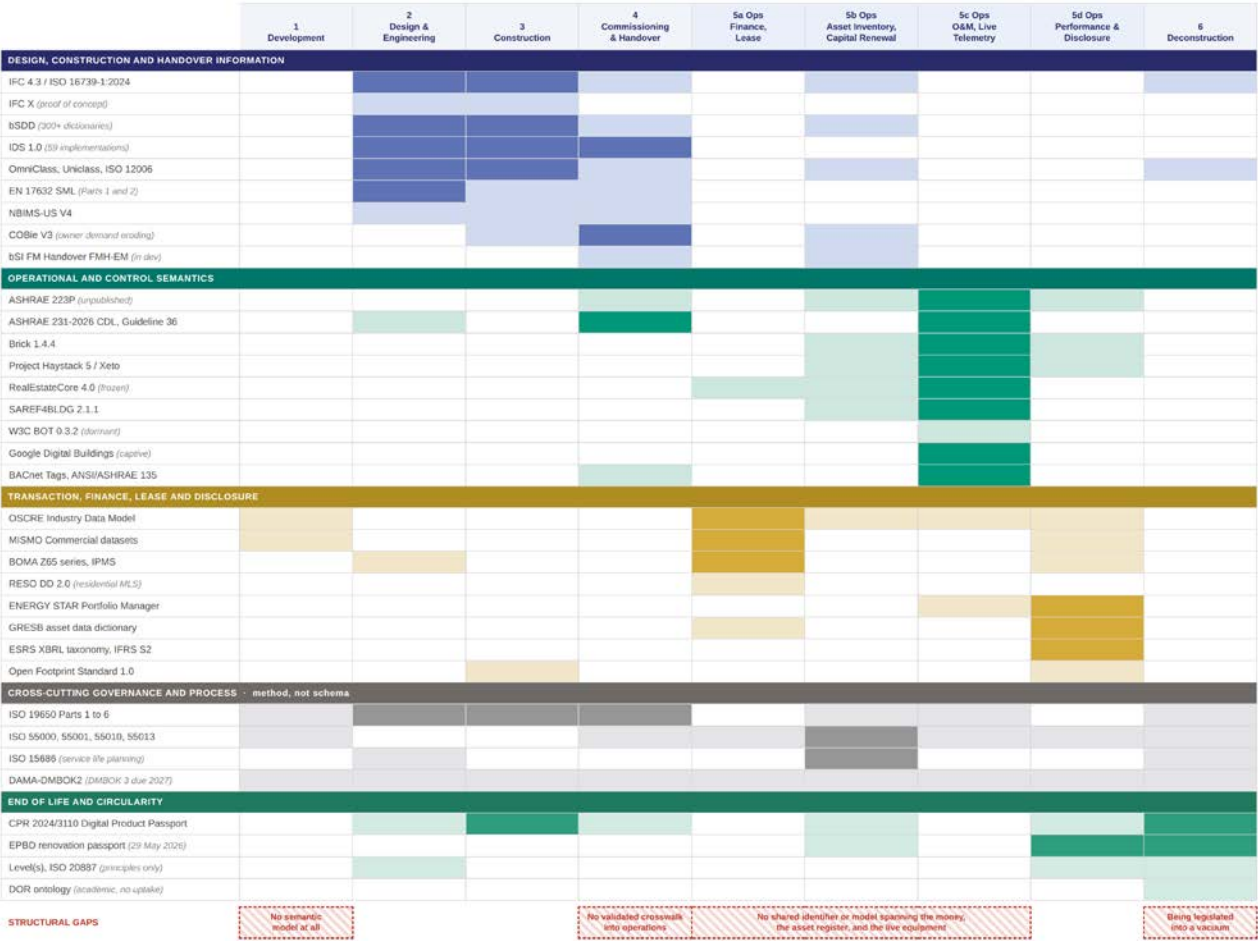


Figure 2. Semantic effort coverage overlaid on the building lifecycle. Vertical stacks of colour within a column are overlaps. Sparse columns are gaps. The structural gap band at the base marks the four points at which the lifecycle information chain breaks.

Read as a picture, the matrix says three things at a glance. The design and construction columns are densely populated and the efforts there are mutually referential. The operations and maintenance column is densely populated by a different family entirely. And the two ends of the lifecycle, development and deconstruction, are close to empty.

6.3 Where the efforts overlap

Overlap is not a single phenomenon, and treating it as one produces bad advice. Four distinct kinds appear in this landscape, and only one of them is genuinely wasteful.

Type 1: Real duplication within the operations cluster

Seven efforts model building equipment, control points, and spatial containment for operational purposes: ASHRAE 223P, Brick, Project Haystack, RealEstateCore, SAREF4BLDG, the W3C Building Topology Ontology, and Google's Digital Buildings Ontology. They answer the same question. An independent academic comparison surveying thirty building ontologies and evaluating four in depth concluded that Haystack and Brick have wider class hierarchies, giving better coverage at higher maintenance cost, while RealEstateCore and Google's ontology are deeper and more efficient but less discoverable, that significant unresolved semantic conflicts remain around points and measurements, and that there is no universal building ontology. [21]

This is the one overlap that is being actively resolved, and the resolution is worth describing precisely because it is often overstated. Brick and RealEstateCore announced a harmonization in August 2022, delivered as Brick 1.3 and RealEstateCore 4.0, with the joint statement explicitly preserving both as standalone projects under separate governance. [22] The practical outcome went further than the wording: from Brick 1.4.0 in 2024, the Brick download contains the Brick and RealEstateCore ontologies in the same file, and RealEstateCore's own repository states that its equipment and point hierarchies are sourced from the collaboration with Brick. Separately, Brick's reference schema was incorporated into the 223P draft, per the Department of Energy final report on the Brick program, and the 223P documentation publishes guidance on using 223 alongside Brick and RealEstateCore. [23] Project Haystack added resource description framework export in Haystack 5, and the Department of Energy award that funded the work states its purpose as making translation between schemas more reliable and bringing Haystack into alignment with 223P and Brick. [24]

Convergence in the operations cluster is real, but it is running through shared people and a shared funder rather than through institutional agreement. No merger, alignment memorandum, or joint charter among ASHRAE, the Brick Consortium, Project Haystack, and RealEstateCore was located. Anyone describing a formal merger is overstating the record.

Two mechanisms account for it. One individual leads Brick development, chairs the ASHRAE Semantic Interoperability Working Group that owns 223P, and was a listed member of the Project Haystack Xeto working group. And the United States Department of Energy Building Technologies Office funds Brick, Haystack, and 223P from a single program, roughly five million dollars cumulatively, with translation between the schemas named as a deliverable. [25] A single funder is, in practice, a stronger convergence mechanism than any memorandum. It is also a single point of failure, and the Department of Energy award specific to 223P concluded on 30 September 2025.

A market signal confirms that convergence has not yet arrived: schema translation between building ontologies is currently a commercial product category. At least one vendor open sourced a dedicated ontology alignment project with an application programming interface for automated translation between tagging models. Products exist to solve problems that persist.

Type 2: Unrecognized duplication across the cluster boundary

This is the most consequential overlap in the landscape, and it appears to be invisible to both parties.

In February 2026 OSCRE International announced a strategic shift beyond traditional data definitions toward an interconnected model that understands relationships between elements. The announcement's own worked example is that the system should comprehend that a pump is equipment within a room which is part of a building, and that a pump identifier and an asset tag are, in the announcement's own words, synonymous in a given context. [26] Equipment to space containment and identifier equivalence are the two foundational constructs of Brick, RealEstateCore, and ASHRAE 223P. The announcement references none of them.

The reciprocal check produces the same result. Across the published alignment literature of the operations cluster, including the Brick and RealEstateCore harmonization materials, the 223P guidance on using 223 with Brick and RealEstateCore, and the Department of Energy program documentation, no lease, chart of accounts, rent roll, operating statement, or ownership entity appears anywhere. Neither community's published record shows awareness of the other's work on the same construct.

This is reported as a negative finding after targeted searching, not as a claim about private roadmaps. It is nonetheless the clearest evidence in this research that the industry's semantic effort is not one effort.

Type 3: Complementary layering misread as competition

IFC and Brick are routinely compared as though an organization must choose. The evidence does not support the framing. A 2025 study mapping approximately 7,400 of 7,800 point labels at a Japanese technology center to Brick classes states the distinction directly: the IFC files included building architectural and spatial data, but they did not include sensor and actuator data. [27] A separate study converting building information models to Brick summarizes the same division as building information modeling excelling at geometry and Brick at operational semantics. [28] These are different layers of one stack, not rivals. The practical architecture is layered: information requirements and validation from ISO 19650 and IDS, geometry, spatial structure, and product identity from IFC and bSDD, classification from OmniClass or Uniclass, asset identity carried across handover, and an operational graph in Brick, Haystack, or 223P for live equipment, points, and control relationships.

Type 4: Different document types compared as though alike

The prior BLMI scan established this point for hierarchy standards and it holds across the wider corpus. BOMA Z65 and the International Property Measurement Standards are measurement methods. OmniClass and Uniclass are classification systems. IFC and Brick are schemas and ontologies. ISO 19650 and ISO 55001 are management system standards. DAMA-DMBOK2 is a body of practice. Each answers a different question about the same building. Apparent overlap at this level is usually an artifact of the comparison, not a defect in the standards.

6.4 Where the gaps are

Five structural gaps emerge from the overlay. Four are seams between clusters; one is an empty stage.

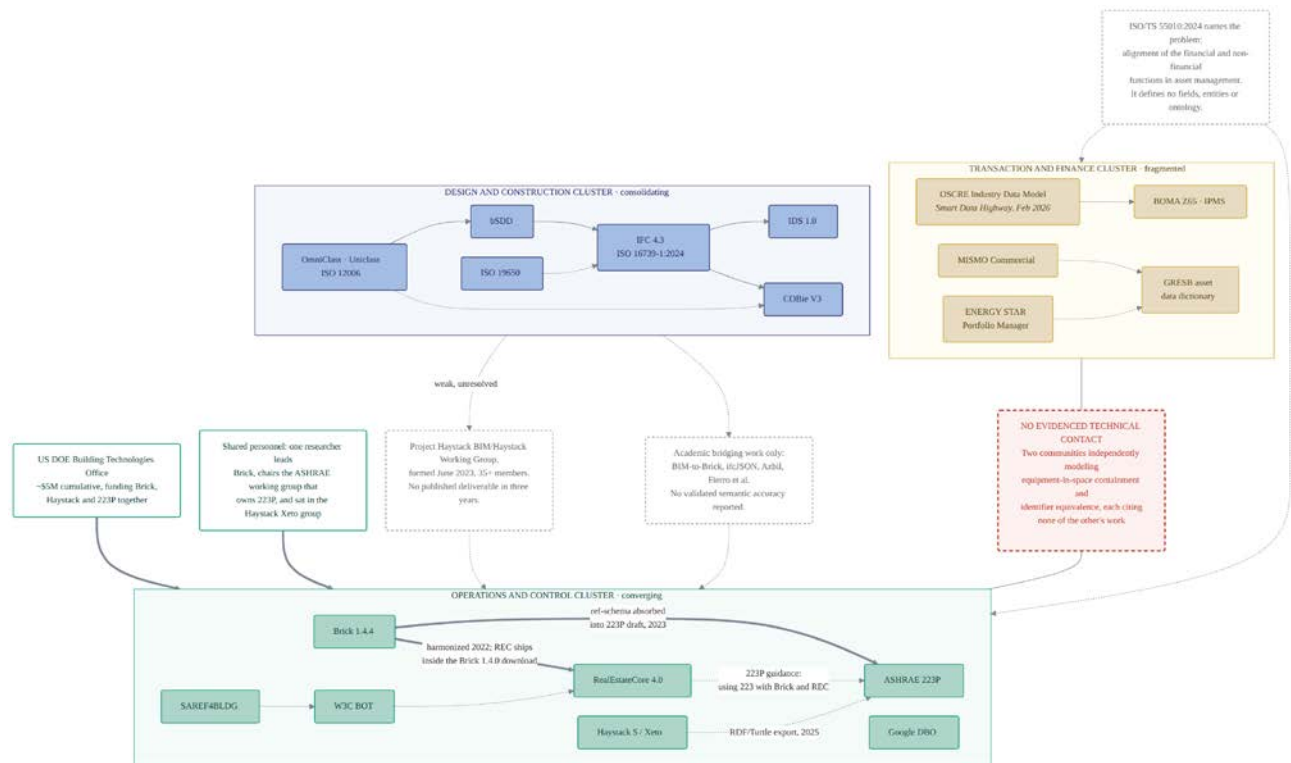


Figure 3. The connectivity map. Solid lines are evidenced technical alignment. Dashed lines are weak, exploratory, or unresolved. The marked void between the transaction cluster and the operations cluster is a negative finding: no technical contact between them was located.

Gap 1: The development stage has no semantic model

Site selection, entitlement, feasibility, and program definition generate the decisions that constrain everything downstream, and no effort in this corpus models them. OSCRE's Industry Data Model reaches into this territory in principle, its stated coverage running from development through demolition, but no published entity level detail for the development stage was locatable without membership access. The practical consequence is that the earliest and most consequential decisions about a building enter the information chain as documents rather than as data.

Gap 2: The handover seam has no validated crosswalk

This is the oldest known gap and it remains open. Three lines of evidence converge.

The incumbent is losing owner demand. COBie's position is deteriorating on the published record, and the evidence is now owner side rather than commentary. Transport for New South Wales, a major public asset owner, published a formal reasoned refusal to mandate COBie on five grounds: scope limited to buildings, insufficient evolution, redundancy with existing asset registers, missing coverage of asset owner, operations and maintenance contract, condition, remaining service life, and risk, and the observation that ISO 19650 does not mandate COBie. [29] The 1.20 percent mandate rate in the United States institutional survey cited earlier points the same way. buildingSMART itself established a COBie certification program in 2020 explicitly because of widespread inconsistency in the specification, enforcement, delivery, and use of COBie data. [30] It is worth being precise: COBie V3 shipped in 2023 as part of NBIMS-US V4 and is not abandoned by its publisher. What is eroding is owner demand.

The chartered bridge has produced nothing. Project Haystack chartered a BIM and Haystack working group in June 2023 with more than thirty-five members and the explicit scope of bridging IFC classes to

the Haystack convention. Discussion was still exploratory as of February 2025 and no consensus on formal bridging standards or publicly documented technical deliverable was located, roughly three years after formation. [31] No liaison, joint working group, or published mapping between buildingSMART International and Brick, ASHRAE 223P, Project Haystack institutionally, or RealEstateCore was located at all. Notably, the one bridging effort that has an organizational home sits inside Project Haystack, not inside buildingSMART.

Academic bridges only, with no validated accuracy. Every locatable bridging study is academic, and each reports the same obstacle. A building information model to Brick conversion of a Singapore research building produced 458 Brick objects and 1,219 relationships from 932 model instances in seventeen seconds, but its authors record that point names and attributes were not easily decodable by machines and that building management system labels lack consistency or rely on arbitrary naming conventions, and provide no accuracy metrics or ground truth validation. [28] A companion study frames its research problem in its title as generating a Brick model from imperfect building information modeling. [32] Not one published bridging study located here reports validated semantic accuracy.

Gap 3: The money and the machine do not connect

This is the gap Figure 3 marks as a void, and it is the finding this research would lead with.

No mature, governed, published effort mapping a commercial real estate financial, lease, or ownership data model to a building operational ontology was located. Four partial approximations exist, and characterizing each precisely matters more than listing them.

Candidate bridge	What it actually is	Why it does not close the gap
ISO/TS 55010:2024	Guidance on aligning the financial and non-financial functions in asset management.	The closest institutional framing of the problem anywhere in the corpus, and it defines no fields, entities, or ontology. It is management guidance, not a data model.
MISMO Commercial datasets	Financial operating statement standard designed to normalize across differing charts of accounts, plus rent roll and a green utility standard carrying building energy and water data into the lending flow.	Lender driven and multifamily weighted, with no equipment layer. Notable as one of the few artifacts that structurally crosses the finance and operations boundary at all.
OSCRE Smart Data Highway	An announced strategic direction toward relationship aware modeling, with a universal chart of accounts pilot behind it.	As of this report's date an announcement and one pilot, not a specification. If delivered as described it would be the bridge; it is not yet one.
GRESB asset data dictionary	A typed per building schema with enforced validation, collecting energy, emissions, water, waste, and ownership percentage from more than a thousand real estate managers annually.	The de facto bridge that actually moves data at scale, and it was not designed as one. Single purpose, annual snapshot rather than operational, and governed by a benchmarking organization rather than a standards body.

Table 1. The four partial bridges between the financial and operational information models, and the reason none of them closes the gap.

A structural observation reinforces the point. OSCRE's 2025 to 2026 board of directors is drawn from investment managers, owner-operators, an accounting firm, and technology providers, and carries no facilities management, building automation, or operational technology representation. [33] Governance composition tends to determine which problems a body can see.

The counterargument. The strongest counterargument deserves stating, because the report's central claim depends on answering it. A reader could reasonably object that the two clusters have good reasons to stay apart. They run on different clocks: a financial close is quarterly, a telemetry point is fifteen minutes. They model different kinds of identity: a legal entity is not a physical device, and conflating the two is how data models become unmaintainable. And a case can be made that the right place to join them is the application layer, where an integrated workplace management system already reconciles a

lease to a floor to a work order, rather than the ontology layer. Those objections are sound, and they justify keeping the models separate. They do not justify the absence of a mapping between them. A crosswalk asserting that this equipment record and that capital plan line refer to the same chiller costs neither community its independence, and it is the artifact that does not exist. The claim here is not that the models should merge. It is that nobody has published the translation between them.

Gap 4: No identifier persists through equipment replacement

A chiller replaced in year eighteen inherits the location, the served spaces, the maintenance history, and the capital plan line of the unit it replaced, and inherits none of them automatically in any model in this corpus. IFC assigns globally unique identifiers to model objects, but a replacement is a new object. Brick, Haystack, and 223P model the equipment currently present. COBie captures a handover snapshot. ISO 55000 supplies vocabulary for asset, asset system, and asset portfolio without prescribing identifier persistence. The academic literature has begun to address the identity through change problem, but no standard in this corpus solves it. In an asset class where hold periods exceed equipment service lives, that is not an edge case.

Gap 5: End of life is being legislated into a semantic vacuum

None of the building ontologies model deconstruction. Brick, Haystack, ASHRAE 223P, RealEstateCore, and Google's ontology all model operational assets and points; none carries deconstruction, material recovery, salvage, or disposal concepts. IFC carries material and quantity information usable for the purpose, but the material passport literature reports that specific IFC schema details remain underdeveloped in existing frameworks. [34] The only purpose built artifact located is an academic Decommissioning and Reuse Ontology with no evidence of adoption by any commercial tool, platform, or standards body.

Meanwhile the regulatory clock is running. The recast Energy Performance of Buildings Directive requires every European Union member state to establish a building renovation passport scheme by 29 May 2026. The passport is a voluntary instrument for building owners unless a member state decides otherwise, and its required content includes general information on options to improve product circularity and reduce whole life cycle emissions, with a Commission recommendation that member states use machine readable digital formats where feasible. [35] The Construction Products Regulation establishes the legal basis for a construction digital product passport whose mandated content includes end of life information, with environmental indicator obligations phasing through 2030 and 2032. [36] A machine readable circularity obligation is being created at both the product and the building level, and there is no agreed ontology behind either.

The sharpest defensible gap statement this research supports: European law is about to require structured end of life data from a landscape that has never modeled end of life at all.

6.5 Adoption: where it is real and where it is not

Coverage on paper and adoption in the field are different measurements, and the gap between them is wide. This section assesses the second.

The baseline: most buildings have nothing to model

The United States commercial building stock comprises roughly 5.9 million buildings and 96 billion square feet. Building automation for heating and cooling is reported in a small single digit percentage of those buildings but roughly a quarter of the floorspace, a figure drawn from the 2018 Commercial Buildings Energy Consumption Survey summary and flagged in Appendix B as requiring confirmation against the detailed tables before operational reliance. [37] The direction of the finding is not in doubt even if the precise percentages are: building automation is concentrated in large assets. Semantic modeling of building automation data is therefore, structurally, a large asset phenomenon. For most commercial buildings the question of which ontology to adopt does not yet arise, because there is no telemetry to model.

The honest negative

The most credible statement of the adoption gap comes from a source with no incentive to make it. The Center for the Built Environment at the University of California Berkeley, framing a Department of Energy funded project advocating Brick, wrote that Brick had not been used at scale outside of small ad-hoc applications, attributing this to a lack of tools, translators, and integration with existing time series databases. [38] That framing is project rationale rather than a current finding, and the project's 2023 final report is the more defensible citation for outcomes. [23] It is quoted here because it is a pro-Brick source stating the deployment problem plainly, and because no source located since supersedes it with a scaled commercial deployment count.

Adoption by sector and asset class

The following assessment is a reasoned synthesis. No survey segments semantic standard adoption by asset class, and readers should treat the ordering as defensible inference rather than measured data.

Sector or asset class	Adoption	Evidence and driver
Federal government, owned	Strongest	GSA Order ADM 7002.1 requires all building automation work to comply with the GSA Data Normalization for Building Automation Systems, whose standard tagging model is stated to be modeled after Project Haystack, and requires component naming per GSA COBie and national maintenance management requirements. Driver: single owner, long hold, statutory energy targets, centralized procurement.
Hyperscale technology campus	Strong but captive	Google built and open sourced its own Digital Buildings Ontology, reported as in use across its own portfolio. Microsoft publishes a DTDL rendering of RealEstateCore for Azure Digital Twins. Neither publishes portfolio counts. Driver: owner-occupier with in-house engineering capacity.
Higher education and research	Deep but experimental	Brick's academic origins and campus testbeds make higher education the richest source of published case material. Department of Energy reporting records 108 or more California buildings modeled in Brick and 50 or more on a research platform, figures dating from 2022 with no updated count located. Driver: research funding, not operations.
Large institutional office	Tooling yes, semantics no	A survey of more than a thousand senior corporate real estate decision makers reports that over 80 percent of large occupiers have adopted environmental sensors, data modeling tools, and predictive maintenance, while more than 60 percent must address fundamental technology issues before fully leveraging artificial intelligence and 81 percent report at least three existing systems not generating expected results. The missing layer is precisely the semantic one. [39]
Data centers	Instrumented, not semantic	Uptime Institute's 2025 survey of more than 800 owner-operators reports 84 percent tracking facility power and 74 percent tracking power usage effectiveness, both down year on year from 89 and 76 percent, against a small single digit percentage of commercial buildings having any building automation at all. The report contains no mention of data standards, ontologies, or semantic interoperability. Maturity here is metric discipline, not shared meaning. [40]
Healthcare	No evidence located	Despite hospitals carrying among the densest building automation point counts per square foot of any asset class, no citable evidence of Brick, Haystack, or 223P adoption in health systems was located. Searches returned clinical information interoperability, never building systems semantics.
Multifamily, retail, industrial, life sciences	No evidence located	No adoption evidence located in any of the four. Low automation point density in industrial and most retail makes the return on semantic normalization structurally weak. Life sciences is a plausible fit given existing regulated environmental monitoring data governance, but no linkage was verified.

Table 2. Adoption of building semantic standards by sector and asset class. Ordering is reasoned synthesis from mandate evidence, published deployments, and structural drivers; no segmented survey exists.

The artificial intelligence question

A reasonable executive question in 2026 is whether large language models make this whole problem go away by tagging points automatically. The published evidence says not yet. The most substantial published work located, from a major cloud provider's research group, applies retrieval augmented in-context learning to classify building management system points into Brick classes, and frames the difficulty concretely: 936 Brick point classes in the current version, insufficient model domain knowledge, and a heavy manual verification burden. [41] Its own stated contribution is reducing manual verification effort, not eliminating it, and its evaluation covers two buildings. Reported accuracy figures could not be independently retrieved during fact checking and are therefore not quoted here.

Assisted classification is not automation. It is manual tagging with a head start and a mandatory review pass, on a task where the consequence of a wrong classification is a silently incorrect analytic. Meanwhile a pattern worth naming has appeared in the vendor market: platforms advertising artificial intelligence point mapping that structures device and point ontology in minutes rather than weeks, while referencing only generic internal ontology classes and claiming no conformance to Brick, Haystack, or 223P, and publishing no accuracy figure or validation method. Automated mapping to a proprietary internal model, marketed as solving the interoperability problem, reproduces lock-in one layer up. Buyers evaluating these claims should ask which published ontology the output conforms to, and what the measured accuracy is.

6.6 Trajectory

Projecting which efforts prevail requires separating three questions that are usually merged: which effort is technically strongest, which has institutional backing, and which has a forcing function behind it. Technical quality is the weakest predictor of the three. The clearest illustration in this landscape is that IFC 2x3 TC1, published in 2007, remains an official release nineteen years later. Publication dates are not adoption dates.

Four forces are visible in the evidence, and they explain most of what follows.

Concentrated funding. Federal money is the single strongest convergence mechanism in the operations cluster, and its direction is not guaranteed. The Department of Energy award specific to ASHRAE 223P concluded on 30 September 2025.

Mandate beats merit. Where a mandate exists, adoption follows regardless of technical elegance. The GSA data normalization order, the more than fifty United States jurisdictions whose building performance or benchmarking laws use ENERGY STAR Portfolio Manager as the compliance mechanism, and the European Union renovation passport deadline are producing more structured building data than any voluntary standard.

Regulatory divergence. Regulatory momentum has split by jurisdiction. The European Union enacted an omnibus simplification in early 2026 that narrowed sustainability reporting scope and deferred timelines, while EFRAG committed to deliver an updated reporting taxonomy by December 2026. In the United States, the Securities and Exchange Commission proposed rescission of its 2024 climate disclosure rules in May 2026, with the comment period closing in August 2026 and the rules remaining stayed; no operative federal climate disclosure taxonomy exists. [42][43] European regulation is now the stronger forcing function by a wide margin.

Release discipline compounds. Efforts that publish dated, diffable releases accumulate trust and implementers. Efforts that do not are difficult to build on and difficult to assess. This distinction separates several otherwise comparable efforts below.

Trajectory	Efforts	Basis
Likely to prevail	IDS 1.0; IFC 4.3 and ISO 16739-1:2024; ETSI SAREF and SAREF4BLDG; ENERGY STAR Portfolio Manager; GRESB asset data dictionary; ASHRAE 223P conditional on publication	IDS is the momentum leader of the design cluster: version 1.0 final in June 2024 and 59 listed software implementations by mid-2026, though the register itself states these are vendor self-declared and uncertified. IFC 4.3 is consolidating rather than winding down, with IFC 4.4 targeting international standardization around 2028 per the same chapter report. SAREF is the only effort in the corpus to gain a formal European standards tier, with the first SAREF European Norm, ETSI EN 303 760, published in October 2024, development transferred to an ETSI technical committee, and SAREF4BLDG 2.1.1 released on 24 April 2025. Portfolio Manager gained its first congressionally mandated funding floor in 2026 alongside a transfer to the Department of Energy. GRESB is imposed by capital rather than committee. 223P is the standards-track answer for operational semantics and has government backing, and its prevailing is conditional on actually publishing.
Likely to persist in a defined niche	Project Haystack 5 and Xeto; Brick as substrate; BOMA Z65 and IPMS; Uniclass; BACnet Tags	Haystack retains by far the deepest commercial vendor bench in the corpus and a large installed base, and Xeto adds the schema rigour that tag-only approaches lacked; its future is as the production layer that translates into the standards-track model rather than as the standards-track model. Brick is winning the substrate contest even where it loses the branding contest: its reference schema sits inside the 223P draft and its download carries RealEstateCore. Floor measurement remains load bearing for lease economics and energy intensity alike and has no substitute. Uniclass is on a published quarterly cadence.
Likely to diminish	COBie; RealEstateCore as an independent ontology; W3C Building Topology Ontology; Google	COBie faces documented owner-side refusal, a 1.20 percent mandate rate in the one segmented survey located, and a successor project at its own publisher whose page does not mention it. RealEstateCore is organizationally alive but has published no ontology release since February 2023 while its equipment and point hierarchies migrated into Brick. The Building Topology Ontology's last release was in 2020 and its community group mailing list carried single-digit annual traffic

Trajectory	Efforts	Basis
	Digital Buildings Ontology; NBIMS-US; RESO for commercial purposes	through 2026. Google's ontology is active but captive, with no third-party adopter located. No publicly dated NBIMS-US output since the V4 launch in September 2023 was located, which is an argument from absence and should be verified directly with NIBS. RESO has a hard association mandate and real adoption, and it is residential: it has no lease administration, portfolio, or ownership semantics and should not be positioned as a commercial candidate.
Requires monitoring	IFC X; OSCRE Smart Data Highway; Microsoft digital twin direction; DAMA-DMBOK 3	What was called IFC 5 was reported as renamed IFC X at the buildingSMART Porto summit in March 2026 and repositioned as a parallel track to the IFC 4 series rather than its successor, with the public repository carrying no alpha or beta and an explicit warning that the schema will change. Anyone planning around it as a near-term deliverable is planning on air, and this specific point should be reconfirmed with buildingSMART International before it is relied upon. OSCRE's Smart Data Highway would be the bridge described in Section 6.4 if delivered as announced; it currently has one pilot behind it. Microsoft's Azure Digital Twins is not retired, but new investment is visible in a different Fabric-based product that references neither DTDL nor RealEstateCore, which is strategic drift rather than deprecation. DMBOK 3 has a published target window of April to July 2027.

Table 3. Projected trajectory. Basis is the dated evidence in Appendix B; the direction assessments are analytical judgment.

One projection deserves separating from the table because it is a conditional with a near date attached. If ASHRAE publishes 223P, the operations cluster acquires a standards-track anchor that procurement can cite, and the convergence already underway acquires an institutional home that does not depend on one funder and one individual. If it does not, the cluster continues to converge informally around Brick as substrate and Haystack as production layer, and the industry loses several years. As of this report's date, with roughly one month remaining in the fiscal year the participating federal agency forecast for publication and no approval notice located, that outcome is genuinely uncertain.

Findings

Finding 1: The commercial real estate semantic landscape resolves into three clusters rather than one effort. A design and construction cluster is consolidating, an operations and control cluster is converging rapidly, and a transaction and finance cluster is fragmented. Coverage is dense within clusters and thin at every seam between them.

Finding 2: No evidenced technical contact exists between the transaction and finance cluster and the operations and control cluster. OSCRE's February 2026 announcement describes equipment to space containment and identifier equivalence, the foundational constructs of Brick and ASHRAE 223P, and cites neither; the operations cluster's extensive alignment literature contains no lease, chart of accounts, rent roll, or ownership entity. This is reported as a negative finding after targeted searching.

Finding 3: Convergence within the operations cluster is real but informal. It runs through one individual who leads Brick, chairs the ASHRAE working group that owns 223P, and sat in the Project Haystack Xeto group, and through a single Department of Energy program funding all three. No merger, alignment memorandum, or joint charter was located. That structure is efficient and it is fragile.

Finding 4: ASHRAE 223P is not published as of 31 August 2026. It completed a first formal public review in August 2025; a participating federal agency forecast publication within federal fiscal year 2026, which ends 30 September 2026, and no approval notice was located. Its public model corpus consists of national laboratory models and control sequence examples, with no commercial building and no vendor product announcing support located.

Finding 5: The design to operations handover seam has no validated crosswalk. The one working group chartered to bridge building information modeling and operational tagging has produced no

publicly documented deliverable in three years, no liaison between buildingSMART and any operational ontology body was located, and every bridging study found is academic and reports no validated semantic accuracy.

Finding 6: Owner demand for COBie is eroding on the published record. A major public asset owner has published a formal reasoned refusal to mandate it; a segmented survey of United States institutional owners found a 1.20 percent mandate rate; its own publisher created a certification program in 2020 citing widespread inconsistency in delivery and use. COBie V3 is not abandoned by its publisher; what is eroding is demand.

Finding 7: No standard in the corpus provides an asset identifier that persists through equipment replacement. In an asset class where hold periods routinely exceed equipment service lives, maintenance history, capital planning, and operational analytics all depend on a continuity the models do not supply.

Finding 8: Deconstruction is modeled by no building ontology, while European law is creating machine readable end of life obligations at both product and building level, including a member state renovation passport deadline of 29 May 2026. The only purpose built end of life ontology located is academic with no evidenced adoption.

Finding 9: Adoption is concentrated in federally owned buildings, hyperscale corporate campuses, research universities, and large institutional office. No citable adoption evidence was located for healthcare, multifamily, retail, industrial, or life sciences. Data centers are highly instrumented and show no semantic standard adoption at all.

Finding 10: Regulation and capital markets are now producing more structured building data than voluntary standards are. ENERGY STAR Portfolio Manager is the compliance mechanism for more than fifty United States jurisdictional building performance and benchmarking laws, and GRESB collects per building data against a typed dictionary from more than a thousand fund managers annually. Neither is governed as a standard, and both have more real implementation behind them than several efforts that are.

Finding 11: Artificial intelligence assisted point tagging is real, improving, and not yet displacing manual work. The most substantial published work located evaluates two buildings against a 936 class label space and frames its own contribution as reducing rather than eliminating manual verification. Vendor claims of minutes rather than weeks generally reference proprietary internal ontologies and publish no accuracy figure at all.

Finding 12: Transparency practices differ sharply across the corpus and this materially affects assessability. Several bodies publish dated, versioned, diffable releases in multiple formats. At least one central effort publishes no version number, release date, or changelog for its model, which means it cannot be independently diffed over time and its progress cannot be verified by a non-member.

Pathways and Options

Four pathways are available to BLMI. They are distinguished along a single axis: the mechanism by which BLMI would help the industry act on what this research found, running from explaining the landscape, to guiding individual organizations through it, to convening the bodies that own it, to advocating ahead of a regulatory deadline. All four are consistent with BLMI's founding position that it synthesizes and advocates for existing industry standards rather than creating competing ones.

Pathway A: Publish and maintain the map. BLMI productizes the coverage overlay in Figure 2 as a maintained public reference: an effort register carrying scope, lifecycle coverage, current version, governance model, release cadence, and verification status, refreshed on a stated cycle. This requires no engagement from any standards body, creates no competing standard, and is immediately useful to any practitioner trying to work out what exists. Its limitation is that a reference does not close a gap; it makes gaps easier to see.

Pathway B: Publish adoption guidance by lifecycle stage and asset class. BLMI produces a decision framework advising which combination of efforts fits a given position: IFC, IDS, and a classification system for a design to handover program; a floor measurement standard and a business data model for lease administration; an operational ontology for a portfolio pursuing fault detection at scale. This is the most immediately actionable pathway for an organization making a near-term architecture decision. It requires the most original synthesis work and depends on Pathway A's groundwork.

Pathway C: Convene the seam. BLMI uses its neutral position to bring the operations semantics community and the real estate business data community into contact, on the specific and demonstrable basis that both are currently modeling equipment to space containment and identifier equivalence without reference to each other. This addresses the highest value gap in the report and matches BLMI's charter as an industry catalyst. Its success depends on institutional engagement outside BLMI's control and carries the longest and least certain timeline. Section 6.4 supplies the obvious objection to this pathway: the one working group chartered to bridge building information modeling and operational tagging has produced nothing publicly in three years. That precedent is worth taking seriously, and it differs from this pathway in two respects. It was a technical working group housed inside one party's governance, tasked with producing a mapping, which is the hardest possible first deliverable; and it operated within a single cluster rather than across the seam this report identifies. A convener whose first deliverable is a published comparison rather than a schema, and who belongs to neither party, is a different instrument attempting a different first step. That is an argument for sequencing Pathway C after Pathway A, not for abandoning it.

Pathway D: Advocate ahead of the circularity deadlines. BLMI surfaces the end of life gap publicly while European member state implementation is still forming, on the argument that a machine readable circularity obligation without an agreed model will produce twenty-seven incompatible national implementations. This is time bounded, differentiated, and aligned with BLMI's decarbonization and lifecycle positioning. It is also the pathway furthest from BLMI's current North American center of gravity.

The evidence points toward A and B together as the near-term direction, with C as the higher value follow-on that A and B earn the credibility to attempt. The reasoning is the same one the prior BLMI scan reached from different evidence: the industry is solving this problem through translation and combination rather than through a single unifying standard, and BLMI's comparative advantage is as an explainer and translator across bodies rather than as an organization with the standing to convene ISO, ASHRAE, buildingSMART, and OSCRE simultaneously. Pathway C becomes realistic once the map exists and the specific technical overlap has been demonstrated publicly, which is exactly what Pathway A produces.

Recommendations

- 1. Publish the effort register and coverage overlay as a maintained reference.** Thirty-four efforts, one page, with lifecycle coverage, current version, governance model, and release cadence. Refresh semi-annually. This is the lowest cost, highest immediate utility output available from this research and it requires no third party cooperation.
- 2. Surface the finance and operations overlap publicly and specifically.** The OSCRE pump-in-a-room example set beside the Brick and 223P containment model is a concrete, verifiable, non-accusatory demonstration that two communities are solving one problem. Publishing that comparison is the single highest leverage act this research supports, and it is what makes any subsequent convening credible.
- 3. Frame the handover seam as a process failure, not a schema failure.** The evidence consistently locates COBie's difficulties in ambiguity, absent role allocation, and inadequate client information requirements rather than in the specification. Owners should be directed toward machine checkable information requirements, which the Information Delivery Specification now makes practical, before they are directed toward any particular handover format.

4. Advise owners to specify a published ontology by name in procurement. Vendor claims of automated ontology mapping frequently reference proprietary internal models. Owners should require that output conform to a named published ontology, that the conformance be demonstrable, and that measured mapping accuracy be disclosed. Where ASHRAE 223P is specified, the exact public review or published edition should be cited rather than the designation alone.

5. Raise the persistent asset identifier problem with the asset management community. Identifier continuity through equipment replacement is unaddressed across the entire corpus and is not owned by any body. The ISO 55000 community, which already frames asset identity and now publishes guidance on aligning financial and non-financial functions, is the most plausible home for it.

6. Track the ASHRAE 223P publication decision as a near-term trigger. Whether 223P publishes by 30 September 2026 materially changes the advice BLMI should give about operational semantics. This is a binary, dated, checkable event and it warrants an explicit watch rather than a general awareness.

7. Treat publication status and version transparency as first class evaluation criteria. Practitioners routinely cite proposed standards as though published and unversioned models as though diffable. Any BLMI guidance should carry publication status, current version, and release date for every effort it names, and should say plainly where a body publishes none of these.

Conclusion

The commercial real estate industry does not lack semantic standards. Thirty-four of them address some part of the building lifecycle, most are competently made, and several are converging. What the industry lacks is a connection between them at the four seams where the lifecycle actually breaks: at the transition from development into design, at the handover from construction into operations, between the financial view of a building and the operational view of the same building, and at the point where a building is taken apart.

The most striking of those, and the one this research would put in front of the industry first, is the third. Two communities of serious people are independently building a model of equipment contained in a room contained in a building, and of the recognition that a pump identifier and an asset tag denote the same object. They are doing it in 2026, in public, each citing none of each other's work. The obstacle there is institutional geography rather than technology, and naming that kind of obstacle is what a neutral convening body is for.

The lifecycle perspective that gives BLMI its name earns its place here as an analytical instrument rather than a framing device: it is what makes the gaps visible at all. Any assessment scoped to building automation semantics would have found a converging, healthy field. Any assessment scoped to building information modeling would have found a consolidating one. Only an assessment that follows a building from entitlement to demolition, and that treats the money, the lease, the asset register, and the live equipment as parts of one chain, finds the seams. The seams are where the value is lost, and they are where the work remains.

Future research should close three specific items this assessment could not. Whether ASHRAE publishes 223P within its forecast window, which is checkable within weeks. Whether OSCRE's announced Smart Data Highway produces a specification and, if so, whether it references the operational ontologies. And what the European member states actually implement for renovation passports, because that will determine whether the circularity obligation arrives with a model behind it or without one.

Works Cited

- [1] Lin, G., Kramer, H., Nibler, V., Crowe, E., & Granderson, J. (2022). Building analytics tool deployment at scale: benefits, costs, and deployment practices. *Energies*, 15(13), 4858. Lawrence Berkeley National Laboratory. <https://www.mdpi.com/1996-1073/15/13/4858>
- [2] Mayo, G., McCuen, T., & Shelbourn, M. (2023). Building information modeling data handover from construction to operations. EasyChair Preprint. <https://easychair.org/publications/paper/7V86/open>
- [3] Alnaggar, A., & Pitt, M. (2019). Lifecycle Exchange for Asset Data (LEAD): a proposed process model for managing asset dataflow between building stakeholders using BIM open standards. *Journal of Facilities Management*, 17(5). <https://doi.org/10.1108/JFM-06-2019-0030>
- [4] Tsay, G. S., Staub-French, S., & Poirier, E. (2022). BIM for facilities management: an investigation into the asset information delivery process and the associated challenges. *Applied Sciences*, 12(19), 9542. <https://www.mdpi.com/2076-3417/12/19/9542>
- [5] International Organization for Standardization. (2024). ISO 16739-1:2024, Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries, Part 1: Data schema (2nd ed.). ISO. <https://www.iso.org/standard/84123.html>
- [6] buildingSMART International. (n.d.). buildingSMART Data Dictionary (bSDD). <https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/>
- [7] buildingSMART International. (2024). Information Delivery Specification (IDS), version 1.0. <https://www.buildingsmart.org/standards/bsi-standards/information-delivery-specification-ids/>
- [8] National Institute of Building Sciences. (2023). Construction to Operations Building Information Exchange (COBie) V3.0, in National BIM Standard-United States Version 4. <https://nibs.org/nbims/v3/cobie>
- [9] Project Haystack. (2018). ASHRAE's BACnet Committee, Project Haystack and Brick Schema collaborating to provide unified data semantic modeling solution. <https://marketing.project-haystack.org/project-haystack-media/press-releases>
- [10] ASHRAE. (2024, March 22). Standards Actions, Vol. XIII, Issue 62: Advisory public review of BSR/ASHRAE Standard 223P. <https://www.ashrae.org/technical-resources/standards-and-guidelines>
- [11] ASHRAE. (2025, June 27). Standards Actions, Vol. XV, Issue 26: First public review of BSR/ASHRAE Standard 223P, Semantic Data Model for Analytics and Automation Applications in Buildings. <https://www.ashrae.org/technical-resources/standards-and-guidelines>
- [12] National Institute of Standards and Technology. (2026, February 19). Building Digitization and Semantic Interoperability. <https://www.nist.gov/programs-projects/building-digitization-and-semantic-interoperability>
- [13] OSCRE International. (2026). How the Industry Data Model is organized. <https://www.oscre.org/Industry-Data-Model/How-the-Industry-Data-Model-is-organized>
- [14] Facility Executive. (2020, August 17). OSCRE providing industry open access to its real estate data standards. <https://facilityexecutive.com/oscre-providing-industry-open-access-to-its-real-estate-data-standards/>
- [15] MISMO. (2026). Commercial standards and resources. <https://www.mismo.org/standards-resources/commercial>
- [16] BOMA International. (2026, July 28). BOMA International releases 2026 Mixed-Use Standard after completed ANSI review process. <https://boma.org/boma-standards/>
- [17] DAMA International. (2026). DAMA-DMBOK 3.0 project. <https://www.damadmbok.org/project>
- [18] International Organization for Standardization, ISO/TC 251. (2024). ISO 55000:2024, ISO 55001:2024, ISO/TS 55010:2024 and ISO 55013:2024. <https://committee.iso.org/home/tc251>
- [19] US Environmental Protection Agency. (2023). What are building performance standards? ENERGY STAR policy brief. <https://www.energystar.gov/buildings/resources-topic/what-are-building-performance-standards>; and Facilities Dive. (2026, April 29). Map: tracking building performance standards across the US. <https://www.facilitiesdive.com/news/map-tracking-building-performance-standards-across-the-us/743214/>
- [20] GRESB. (2025, October 15). GRESB 2025 benchmarks reflect industry maturity and continued progress toward responsible investing; and GRESB API documentation, asset data dictionary. <https://www.gresb.com/> and <https://gresb.github.io/api-docs/>
- [21] Qiang, Z., Hands, S., Taylor, K., et al. (2026). A systematic comparison and evaluation of building ontologies for deploying data-driven analytics in smart buildings. *Energy and Buildings* / arXiv:2603.14374. <https://arxiv.org/abs/2603.14374v2>
- [22] Brick Consortium and RealEstateCore Consortium. (2022). Brick and RealEstateCore harmonization. <https://www.realestatecore.io/brickrec/> and <https://brick.andrew.cmu.edu/rec-brick-harmonization/>

- [23] Fierro, G., Roa, C., Raftery, P., Prakash, A., Pritoni, M., Paul, L., Wetter, M., Paulson, E., & Pepper, T. (2023). Skewering the silos: using Brick. Final technical report, US Department of Energy Award DE-EE0008681. Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/2025-05/skewering_the_silos.pdf
- [24] US Department of Energy, Building Technologies Office. (n.d.). Project Haystack: metadata for the masses. <https://www.energy.gov/cmei/buildings/project-haystack-metadata-masses>
- [25] US Department of Energy, Building Technologies Office. (n.d.). Semantic modeling and interoperability. <https://www.energy.gov/cmei/buildings/semantic-modeling-and-interoperability>
- [26] OSCRE International. (2026, February 24). OSCRE unveils vision for a Smart Data Highway to take real estate data standards to the next level. <https://www.prweb.com/releases/oscre-unveils-vision-for-a-smart-data-highway-to-take-real-estate-data-standards-to-the-next-level-302696018.html>
- [27] Teymourzadeh, M., & Nakazawa, S. (2025). A scalable and interoperable platform for transforming building information with Brick ontology. arXiv:2509.16259. <https://arxiv.org/pdf/2509.16259>
- [28] Vittori, F., Tan, C. C., Pisello, A. L., Chong, A., & Miller, C. (2023, 2025). BIM-to-BRICK: using graph modeling for IoT/BMS and spatial semantic data interoperability within digital data models of buildings. arXiv:2307.13197; Energy and Buildings. <https://arxiv.org/pdf/2307.13197>
- [29] Transport for New South Wales. (2022, December). Why not COBie. Digital Engineering standard DMS-SD-138, version 3.1. <https://www.transport.nsw.gov.au/system/files/media/documents/2023/Why-not-COBie-DMS-SD-138.pdf>
- [30] buildingSMART International. (n.d.). COBie Certified Professional programme: history. <https://cobiecert.buildingsmart.org/history/>
- [31] Project Haystack. (2023 to 2025). BIM/Haystack Working Group. <https://project-haystack.org/forum/topic/1071>
- [32] Li, X., Wang, Z., Fierro, G., Man, K., So, K., & Leung, M. (2024). Developing an automatic integration approach to generate Brick model from imperfect building information modelling. Journal of Building Engineering. <https://www.sciencedirect.com/science/article/abs/pii/S2352710224022654>
- [33] OSCRE International. (2025, August 8). OSCRE International announces 2025-26 board of directors. <https://www.prweb.com/releases/oscre-international-announces-2025-26-board-of-directors-302524649.html>
- [34] Senarathne, H. N. Y., Weerasinghe, N. P., & Zhang, G. (2025). Developing a standardized materials passport framework to unlock the full circular potential in the construction industry. Sustainability, 17(14), 6337. <https://www.mdpi.com/2071-1050/17/14/6337>
- [35] European Commission. (2026, January 13). Renovation passports: Commission issues guidance on implementation. Directive (EU) 2024/1275, Article 12 and Annex VIII. <https://build-up.ec.europa.eu/en/resources-and-tools/publications/renovation-passports-commission-issues-guidance-implementation>
- [36] European Parliament and Council. (2024, November 27). Regulation (EU) 2024/3110 laying down harmonised rules for the marketing of construction products and repealing Regulation (EU) No 305/2011. <https://eur-lex.europa.eu/eli/reg/2024/3110/oj/eng>
- [37] US Energy Information Administration. (2018). 2018 Commercial Buildings Energy Consumption Survey: building characteristics flipbook. https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS_2018_Building_Characteristics_Flipbook.pdf
- [38] Center for the Built Environment, University of California Berkeley. (2026, March 31). Skewering silos: using Brick. <https://cbe.berkeley.edu/research/skewering-silos-using-brick/>
- [39] JLL. (2025). Reality check: the true pace and payoffs of AI adoption in corporate real estate. Global Real Estate Technology Survey. <https://www.jll.com/en-us/insights/global-real-estate-cre-technology-survey>
- [40] Uptime Institute Intelligence. (2025). Global Data Center Survey 2025. <https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2025.Annual.Survey.Report.pdf>
- [41] Qian, Y., Zhang, X., Song, Y., Sokhandan, N., Marlowe, C., & Socolinsky, D. (2026). Brick-DICL: dynamic in-context learning for automated Brick schema classification. KDD RelKD 2026 workshop paper / arXiv:2606.17637. <https://arxiv.org/abs/2606.17637> Reported accuracy figures could not be retrieved during fact checking and are not cited in this report.
- [42] US Securities and Exchange Commission. (2026, May 29). SEC proposes rescission of climate-related disclosure rules. Press release 2026-49; Federal Register 91 FR 33296 (2026, June 3). <https://www.sec.gov/newsroom/press-releases/2026-49-sec-proposes-rescission-climate-related-disclosure-rules>
- [43] XBRL International. (2026, May 4). EFRAG's 2026 work programme puts XBRL taxonomy front and centre; Amendment Directive (EU) 2026/470. <https://www.xbrl.org/news/efrags-2026-work-programme-puts-xbrl-taxonomy-front-and-centre/>
- [44] ETSI. (2024 to 2025). SAREF portal, SAREF4BLDG extension version 2.1.1, and ETSI EN 303 760. <https://saref.etsi.org/saref4bldg/>

- [45] Open223 project. (2026, August 3). ASHRAE Standard 223P user documentation, ontology version 223p-1.0.0-ppr2.1. Community project, not endorsed by ASHRAE. <https://open223.info/>
- [46] Brick Consortium. (2025). Brick Schema resources and releases, version 1.4.4. <https://brickschema.org/resources/>
- [47] buildingSMART International. (2026). IDS software implementations register. Entries are vendor self-declared and uncertified. <https://technical.buildingsmart.org/ids-software-implementations/>
- [48] US General Services Administration. (2021, December 16). GSA Order ADM 7002.1, GSA Smart Buildings; and GSA Data Normalization for Building Automation Systems, version 2.3 (2018). <https://www.gsa.gov/directives/>
- [49] NBS. (2026, January 19). Uniclass January 2026 update. <https://www.thenbs.com/knowledge/uniclass-january-2026-update>
- [50] CEN/TC 442. (2022, 2024). EN 17632-1:2022 and EN 17632-2:2024, Building information modelling (BIM), Semantic modelling and linking (SML). Reference implementation at <https://github.com/Stichting-CROW/sml>
- [51] buildingSMART Deutschland. (2026, April 15). IFC-Roadmap nach Porto: Version 4.4 kommt, IFC 5 wird zu IFC X. Reporting the buildingSMART International Summit, Porto, March 2026. <https://www.buildingsmart.de/buildingsmart/aktuelles/ifc-roadmap-nach-porto-version-44-kommt-ifc-5-wird-zu-ifc-x>
- [52] buildingSMART International. (2026). IFC5-development repository. Preliminary examples only; no official alpha or beta release. <https://github.com/buildingSMART/IFC5-development>
- [53] Real Estate Standards Organization. (2023 to 2026). RESO Data Dictionary 2.0 and resource register. <https://dd.reso.org/>
- [54] The Open Group. (2026, June 2). The Open Group launches the Open Footprint Standard Edition 1.0. <https://www.businesswire.com/news/home/20260602260814/en/>
- [55] Building Lifecycle Management Initiative. (2026, July). Location, space, and asset hierarchies in commercial real estate: a landscape scan of formal standards. BLMI Research Department.

Appendix A: Glossary

ASHRAE 223P: A proposed ASHRAE standard defining a machine readable semantic data model for building automation and analytics applications, developed by the Semantic Interoperability Working Group of the BACnet committee. Proposed as of August 2026, not published.

bSDD (buildingSMART Data Dictionary): An online, application programming interface accessible service that hosts data dictionaries, classification systems, and property sets, giving each term a stable resolvable identifier that models can reference.

Brick Schema: An open resource description framework ontology that standardizes semantic descriptions of physical, logical, and virtual building assets and the relationships among them, so that applications and queries can move between buildings despite differing vendor naming.

COBie: Construction to Operations Building Information Exchange. A structured data exchange carrying facility, floor, space, system, component, and maintenance information from construction into a facility management system at handover.

Digital Product Passport: A machine readable record of a product's technical, environmental, and end of life information, established for construction products under the European Union Construction Products Regulation.

IDS (Information Delivery Specification): A buildingSMART standard expressing information requirements as machine checkable rules, so that a model can be automatically validated against what the owner asked for.

IFC (Industry Foundation Classes): An open, vendor neutral data schema for describing buildings and infrastructure digitally, standardized as ISO 16739-1. Version 4.3 is current.

Ontology: A formal, machine readable specification of the concepts in a domain and the relationships between them, expressed so that software can reason over it rather than merely store it.

OSCRE Industry Data Model: A business and data exchange model for commercial real estate maintained by OSCRE International, organized around use cases spanning leasing, portfolio management, transactions, and facilities operations.

Project Haystack: An open community and specification for tagging and modeling building operational data. Haystack 5 introduces Xeto, a schema language adding formal typing and validation, and adds resource description framework export.

RealEstateCore: A building ontology founded by a Swedish property owner consortium, harmonized with Brick in 2022 and distributed inside the Brick download since 2024.

SAREF4BLDG: The buildings extension of the ETSI Smart Applications Reference ontology. SAREF reached European Norm status in October 2024, the only effort in this corpus to hold a formal harmonized standard tier.

Semantic model: A representation that carries the meaning of data along with the data, so that a receiving system can determine what a value is, what object it belongs to, and how that object relates to others.

Taxonomy: A hierarchical classification scheme that organizes concepts into categories and subcategories. Narrower than an ontology, which also expresses non-hierarchical relationships.

Appendix B: Effort Register and Verification Notes

B.1 Effort register

Thirty-four efforts were assessed. The seven marked with an asterisk were supplied in the original reference list; the other twenty-seven were added during research to cover lifecycle positions the original list left empty.

Counting rule, stated so the total can be checked. One effort is one row where a single body maintains it as one publishable thing. A numbered family issued and revised together counts once, which is why the ISO 55000 series and the ISO 12006 based classification systems each occupy a single row. A separately published companion standard counts separately, which is why IDS is not folded into IFC. Research programs that fund and coordinate other bodies' work, principally the NIST building digitization program and the Department of Energy semantic modeling program, are treated as context and are excluded from the count; both are discussed in Section 6.3 because they are the mechanism of convergence, not an effort competing for adoption. The thirty-four rows below correspond one to one with the thirty-four rows in Figure 2.

Family	Count	Efforts assessed
Design, construction and handover	9	IFC 4.3 / ISO 16739-1:2024*; IFC X (in development); buildingSMART Data Dictionary*; Information Delivery Specification*; OmniClass, Uniclass and ISO 12006 (classification family); EN 17632 Semantic Modelling and Linking; NBIMS-US V4*; COBie V3*; buildingSMART FM Handover (FMH-EM)
Operational and control	9	ASHRAE 223P*; ASHRAE 231-2026 Control Description Language and Guideline 36; Brick Schema*; Project Haystack 5 and Xeto*; RealEstateCore 4.0; SAREF4BLDG; W3C Building Topology Ontology; Google Digital Buildings Ontology; BACnet Tags (ANSI/ASHRAE 135)
Transaction, finance, lease and disclosure	8	OSCRE Industry Data Model; MISMO Commercial datasets; BOMA Z65 series and International Property Measurement Standards; RESO Data Dictionary 2.0; ENERGY STAR Portfolio Manager; GRESB asset data dictionary; ESRS XBRL taxonomy and IFRS S2; Open Footprint Standard 1.0
Governance and process	4	DAMA-DMBOK2*; ISO 19650 Parts 1 to 6; ISO 55000, 55001, 55010 and 55013; ISO 15686
End of life and circularity	4	Construction Products Regulation (EU) 2024/3110 Digital Product Passport; EPBD renovation passport; Level(s) and ISO 20887; Decommissioning and Reuse Ontology (academic)
Total	34	Excludes the NIST and Department of Energy research programs, treated as context per the counting rule above.

The efforts come from more than twenty separate bodies, spanning international and national standards organizations (ISO, CEN, ETSI, ANSI accredited bodies), industry consortia (buildingSMART, Brick Consortium, Project Haystack, RealEstateCore, OSORE, MISMO, RESO, The Open Group), professional and trade associations (BOMA, RICS, NIBS, CSI, DAMA), government agencies (the United States Environmental Protection Agency and Department of Energy), capital market bodies (GRESB, EFRAG, the IFRS Foundation), a platform vendor publishing in the open (Google), the European Union legislature, and one university research group. That dispersion of authorship is the structural reason the landscape looks the way Figure 2 shows it.

B.2 Items requiring verification before operational or contractual reliance

This assessment discloses its limits rather than smoothing them over. The following items were used in the analysis at a confidence level below primary source confirmation, and should be verified directly before any operational, contractual, or published reliance.

Item	Issue	How to close
ASHRAE 223P publication	A participating federal agency forecast publication within federal fiscal year 2026; no ANSI approval notice was located as of 31 August 2026. A second public review draft is distributed by a community project without a corresponding ASHRAE Standards Actions listing.	Monitor ASHRAE Standards Actions directly through 30 September 2026.
IFC 5 renamed to IFC X	The rename and the parallel-track repositioning rest on a report from a buildingSMART national chapter. buildingSMART International's own English language page still uses IFC 5 language.	Confirm with buildingSMART International; obtain Porto Summit 2026 proceedings.
CBECs building automation percentages	Extracted from a graphical summary rather than the detailed data tables.	Pull the CBECs 2018 detailed tables from the Energy Information Administration.
NBIMS-US activity level	No publicly dated output was located since the V4 launch in September 2023. This is an argument from absence and does not establish dormancy.	Direct enquiry to the NIBS BIM Council.
OSCRE Industry Data Model version	No version number, release date, or changelog is published, so the model cannot be independently diffed over time.	Membership access, or direct enquiry to OSCRE.
Construction Products Regulation dates	Entry into force and application dates returned inconsistently across sources.	Read the consolidated EUR-Lex text of Regulation (EU) 2024/3110 directly.
Brick and Haystack deployment counts	The available Brick deployment figures date from 2022; Project Haystack publishes no adoption metrics at all.	Request current figures from the respective consortia.
Reported accuracy of AI assisted point classification	The results tables of the cited paper could not be retrieved from any available rendering during fact checking, so no accuracy figure is quoted in this report.	Retrieve the paper through institutional access and read its results section directly.
ISO/TS 55010 and 55013 content	Titles and scope confirmed from the technical committee page; normative text is paywalled and was not read.	Purchase the standards before relying on any characterization of their internal content.

B.3 Scope constraints

This assessment takes no position on which effort is superior to another and endorses no vendor or product, consistent with BLMI's neutrality mandate. Vendor platforms, computer aided facility management, integrated workplace management, and computerized maintenance management data models were excluded from scope by design; the corpus covers standards bodies, industry consortia, open ontologies, and regulatory schemas only. Several of the standards cited are under active revision, including the ISO 19650 series, and any operational or contractual use should confirm the current edition with the issuing body rather than relying on this report's summary.

About BLMI

The Building Lifecycle Management Initiative (BLMI) is a volunteer-led, not-for-profit initiative working at the intersection of Facility Management, Commercial Real Estate, PropTech, and Data Governance. BLMI advances a single foundational premise: that buildings generate valuable data across their entire lifespan (from design through deconstruction) and that the industry's persistent failure to preserve and transfer that data across ownership transitions, operational phases, and technology generations remains an industry-wide challenge the built environment has been slow to systematically address.

BLMI does not create new standards. Its role is synthesis and advocacy: connecting the work of established frameworks (IFMA, BOMA, CoreNet Global, OSCRE, ASHRAE, and USGBC) into a coherent lifecycle perspective, and translating that perspective into actionable guidance for the professionals who manage, own, and operate buildings at scale.

Publications are produced through a research and editorial process developed by domain practitioners and made freely available to the industry. To contribute, collaborate, or access the full research library, visit blmi.org.

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