



BuildingSync Implementation Guide Version 1.0.0

Robert Hendron and Michael Deru
National Renewable Energy Laboratory

**NREL is a national laboratory of the U.S. Department of Energy
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Nomenclature or List of Acronyms

BEDES	Building Energy Data Exchange Specification
HVAC	heating, ventilating and air conditioning
NREL	National Renewable Energy Laboratory
XML	extensible markup language

DRAFT

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1 Introduction

Energy audit data collection and reporting approaches differ widely between auditors and software tools, which makes it challenging to aggregate data or to make comparisons between audit results. BuildingSync® is a standardized language for commercial building energy audit data to facilitate data exchange between audit tools and data storage platforms. Using the schema ensures that data collected for a single building over time is consistent and comparable, that data from different buildings can be easily aggregated and compared for large-scale analysis, and that data can be transferred between a variety of software tools. Standardized data can also make it easier for building owners to integrate the information they receive in an energy audit into property management tools for later reference and reuse. Utilities or local governments that run energy audit programs may also find it easier to utilize the results of energy audits to spur energy efficiency improvements when those results are in a common format.

BuildingSync is a use case of the Building Energy Data Exchange Specification (BEDES), and as such it follows the BEDES standard energy data terminology (<http://energy.gov/eere/buildings/building-energy-data-exchange-specification-bedes>). BuildingSync was developed as an extensible markup language (XML) schema to capture the data relations and for ease of implementation with energy audit software development. BuildingSync was funded by the U.S. Department of Energy and developed by the National Renewable Energy Laboratory (NREL). The XML schema definition (XSD) file, an html version, a spreadsheet data definition file, and supporting documentation are available as free downloads (www.nrel.gov/buildings/buildingsync.html).

This Implementation Guide was written to provide context for the BuildingSync schema design and guidance for how to use the schema in common audit data management applications. We assume that users have a basic understanding of the purpose of XML schema definitions (XSD files), of how XML schema definition files are structured, and of common terminology associated with XML files. We further assume that users are familiar with commercial building design and the basic principles of energy auditing.

2 Relationship to Other Building Energy Data Taxonomies

BuildingSync was developed as an official use case of BEDES. It assembles the BEDES terms into a complete hierarchical schema for a specific application, in this case commercial building energy audits. BuildingSync is thus compliant with the BEDES data dictionary wherever overlapping terms appear. BEDES terms are sometimes building blocks for more complex terms in applications such as BuildingSync. In those cases, we developed new definitions consistent with the intent of the BEDES definitions. Numerous BuildingSync terms, such as geometry terms, cross-references, headings, and filters, are necessary for a logical and orderly hierarchical structure, but are not appropriate for BEDES, which is use case independent. The corresponding BEDES terms are, when appropriate, identified in the BuildingSync Data Dictionary that is included with the schema file.

BuildingSync includes all data fields necessary to generate a Commercial Building Energy Asset Score (<http://energy.gov/eere/buildings/commercial-building-energy-asset-score>). These terms

are highlighted in the BuildingSync Data Dictionary. In some cases, data would need to be transformed to map BuildingSync terms (which are based on BEDES) with corresponding Asset Score terms. This mapping may be automated by the Asset Score program, one of its partners, or a software developer in 2015, which would open the door to Asset Score calculation using BuildingSync XML files.

BuildingSync data terms cover the full range of ASHRAE energy audits from Preliminary Energy-Use Analysis to Level 3 (Detailed Analysis of Capital-Intensive Modifications). No strict rule set has been written for the data that should be collected at each level, but *Procedures for Commercial Building Energy Audits, Second Edition* (published by ASHRAE in 2011) provides general guidance. Based on this guidance, NREL has made recommendations for which the ASHRAE audit level generally corresponds to each data term in the BuildingSync Data Dictionary. These recommendations are by no means conclusive, and the building owner and auditor should define the range of data appropriate for the specific building being audited and the budget available for the project.

Many building energy data standards and schemas used by other programs (such as HPXML, Portfolio Manager, eProject Builder, Green Button, and Technology Performance Exchange) were leveraged for BEDES and BuildingSync, which were developed collaboratively, and reconciled before release. We endeavored to use the most important elements of these data structures with some of the same terms and definitions to ensure consistency within BuildingSync.

3 Versioning

NREL adopted [semantic versioning](#) for BuildingSync. The first public release of BuildingSync was version 1.0.0. The version number takes the form MAJOR.MINOR.PATCH. Major version numbers will be changed when the updated schema is no longer compatible with previous versions. Minor version numbers will be changed when the update is backward compatible (i.e., older BuildingSync XML documents are valid with the revised schema). Minor updates can include new elements and branches in the schema, but not changes to element names or data types. Elements or items in enumerated lists cannot be deleted. Patches are minor updates to correct bugs rather than improve the schema's functionality.

BuildingSync has no pre-established schedule for updates. Several patches or minor updates may be made during the first few months after release, as early adopters begin providing feedback. However, major updates would create significant disruption in the industry, and would be recommended only to correct major errors or to remain market relevant. No major updates are expected for at least a year.

4 Overall Structure

The BuildingSync schema organizes data logically and efficiently; it is intended to minimize repetition, backtracking, and hunting for the correct data fields. Many data structures used in audit software and energy databases were reviewed during the process of designing the BuildingSync schema, and an effort was made to maintain as much commonality as possible with current schema designs. Software and data platform developers will ultimately need to

implement the BuildingSync schema by either adding an import/export capability to their current schemas or by integrating the schema fully within their software programs.

A well-organized schema requires a balance between simplicity and efficiency. We attempted to use a logical hierarchical structure that minimizes the repetition of data fields at various levels and avoids irrelevant data combinations (such as combustion efficiency for a heat pump) that can contaminate a database. For example, all cooling systems include basic elements such as year installed, model number, and control strategy, which are defined at the cooling source level. But information such as chilled water supply temperature is relevant for chillers only, and supply air wet bulb temperature is important for evaporative coolers only. Another example is fenestration, where framing material is relevant for all fenestration types, but sill height is relevant for the window subcategory only. We therefore define fields at the highest possible level in the schema to minimize repetition in various branches and to ensure that the field is relevant for all lower level branches to avoid nonsensical data combinations. Striking that balance was an overriding philosophy that drove many decisions during the schema design phase.

Figure 1 shows the first tier of the BuildingSync schema. The following sections provide an overview of each primary data category.

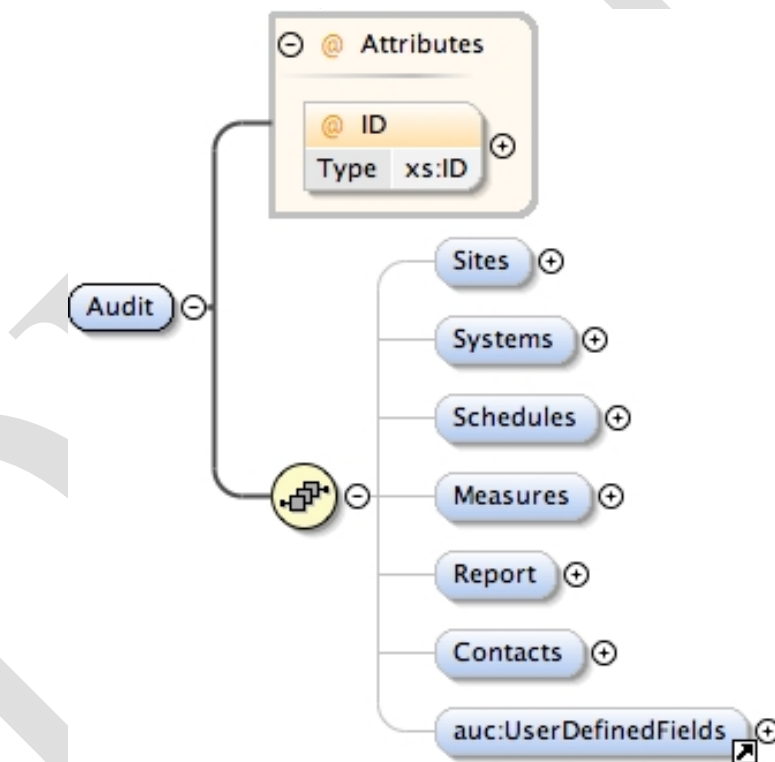


Figure 1. The first tier of the BuildingSync schema identifies major categories of audit data that may be included in a BuildingSync XML file.

4.1 Sites

The data recorded under “Sites” include the major characteristics of the building(s) being audited, such as the building name, function, climate zone, floor area, and number of stories. A single audit may cover several sites, each of which may include multiple buildings. Within each site a hierarchy of “premises” ranges from the entire site to a single room. This hierarchy (shown in Figure 2) establishes the necessary parent-child relationships between premises for complete understanding of the building design, but is not defined in BEDES.

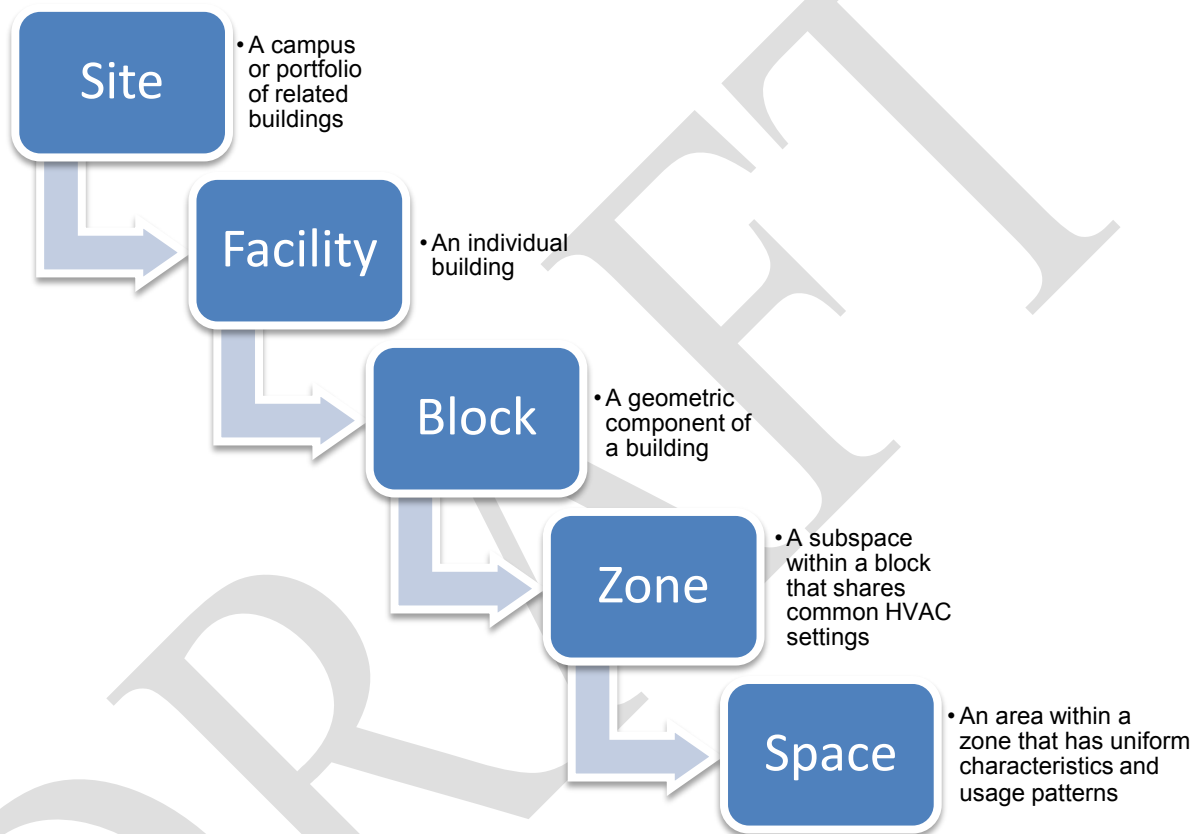


Figure 2. Parent-child relationships for various premise types at an audited site

4.2 Systems

Systems data include the specifications of all energy-related building components and equipment, such as windows, lighting, and heating, ventilating, and air conditioning (HVAC) systems. Figure 3 shows the categories of systems for which specifications can be included in the data set. Some systems, such as motors, fans, and HVAC, may be interconnected. In such cases, ID references are used to indicate that one system is a component of another system (see Section 4).

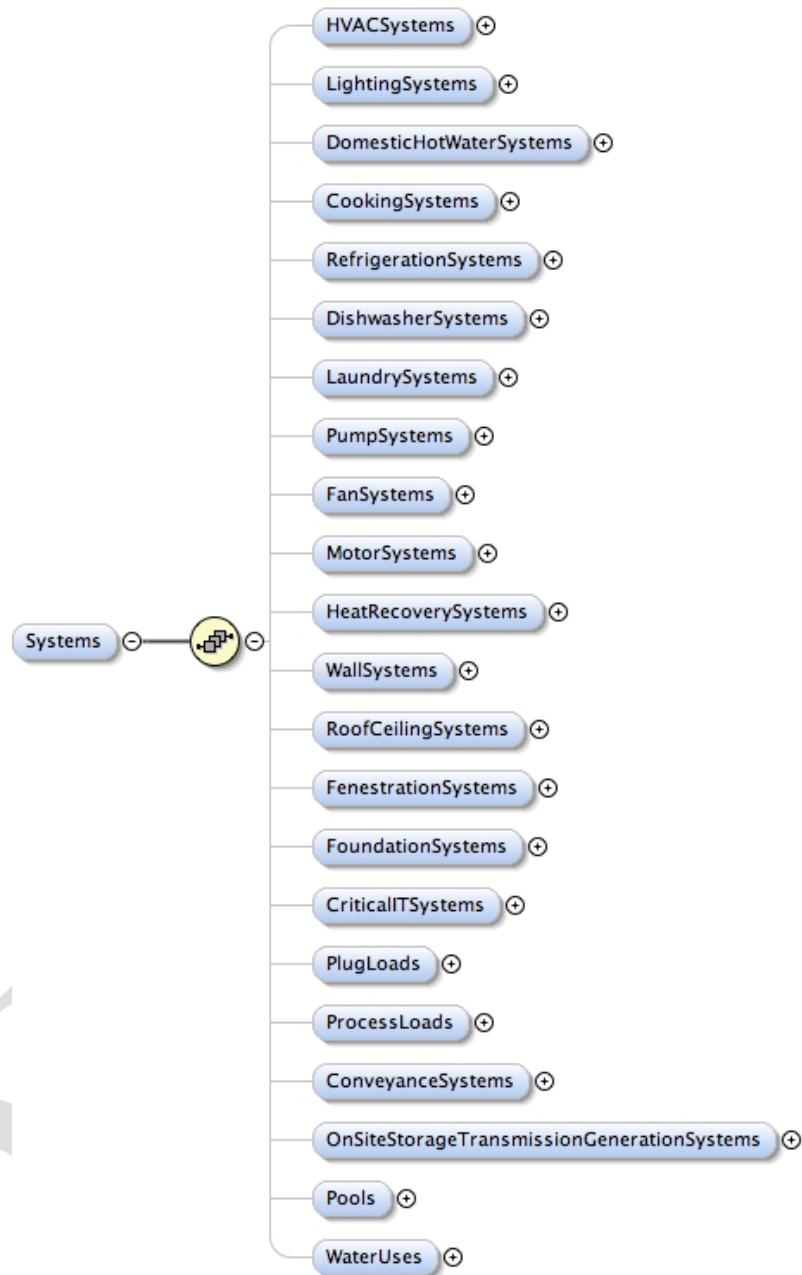


Figure 3. The major categories of systems in the BuildingSync schema

4.3 Schedules

BuildingSync uses schedules for a variety of purposes, but in most cases establishes hourly multipliers as a function of day types that are used to estimate partial loads for a system (power, energy, duty cycle) or space (occupancy, activity level). It does not use hourly schedules for thermostat settings, but uses a simplified approach to define them in the Zone section.

4.4 Measures

The energy efficiency measures included in BuildingSync were taken from those used in the Compliance Tracking System, which documents progress by federal agencies toward the requirements of the Energy Independence and Security Act of 2007. The 20 technology categories and approximately 100 measure descriptions are listed in Appendix C of the U.S. Department of Energy's *Guidance for the Implementation and Follow-up of Identified Energy and Water Efficiency Measures in Covered Facilities* (http://www1.eere.energy.gov/femp/pdfs/eisa_project_guidance.pdf). We made a few minor changes and additions to the Measures section of the BuildingSync schema to reduce duplication and include all common energy retrofit measures. For completeness we added two more technology categories: "Health and Safety" and "Uncategorized."

Data related to individual measures (such as installation cost, energy savings, and systems affected) are included in the Measures section. Packages of energy efficiency measures are treated as scenarios under the Report branch (see Section 4.5). Measure data do not include interactive effects between measures; packages should include such interactions. Energy savings and costs for packages are thus not necessarily the sum of the values for the individual measures that constitute the package.

4.5 Report

The Report section of the BuildingSync schema covers benchmarking results (billing data, annual energy and water use); analysis of recommended measures (energy savings, cost effectiveness); and general information about the audit (audit date, auditor qualifications).

When reporting energy use, a wide range of situations may be of interest, and the relevant data fields may be very different for each. To manage this, BuildingSync uses a variety of scenario types to identify the application of interest. Some of the more common scenarios are:

- Baseline measured actual energy use
- Baseline simulated weather normalized
- Equivalent code minimum building
- Post-retrofit (package of measures applied to the baseline building)
- Target building performance (net zero energy, 30% savings).

If energy savings will be reported, a second scenario must be identified as the reference case. This may be the actual building in its current state, or it may be a hypothetical scenario such as regional standard practice or a building representative of the existing stock.

BuildingSync provides many options for expressing energy use, depending on the purpose:

- Annual site or source energy use
- Fuel-specific energy use
- End-use breakdowns

- Monthly utility bills
- Submetered energy data at any time step.

4.6 Contacts

The Contacts section includes the basic contact information for individuals associated with the project. These contacts can be referenced from other sections of the schema to identify the key points of contact for the owner, auditing firm, property manager, occupants, or other relevant parties.

4.7 User-Defined Fields

User-defined fields are included at various levels throughout the schema to ensure that any uncommon fields that are important to a particular user, but unimportant or meaningless to other users, can be included in BuildingSync XML files without schema conflicts. As shown in Figure 4, user-defined fields are always in pairs; one field defines the name of the term, and the other provides the value. Both fields are free text.

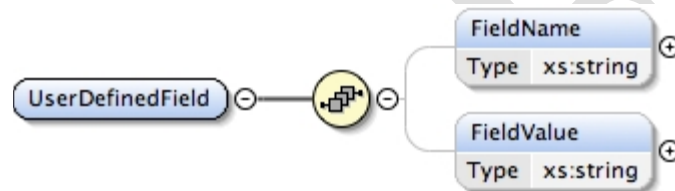


Figure 4. User-defined elements provide flexibility to include special data fields important to a narrow group of users only.

5 Data Properties

5.1 Metadata

Metadata are used to characterize the nature or source of a particular data element. A data attribute labeled “Source” is a metadata field associated with all data elements that have decimal or integer data types (see Figure 5). Text fields do not have the source attribute. Their purpose is to provide a sense of the reliability of the data point based on how the value was calculated or obtained. For example, the default value of efficiency or the product rating from a catalog may be quite different from the installed performance, especially after many years of operation.

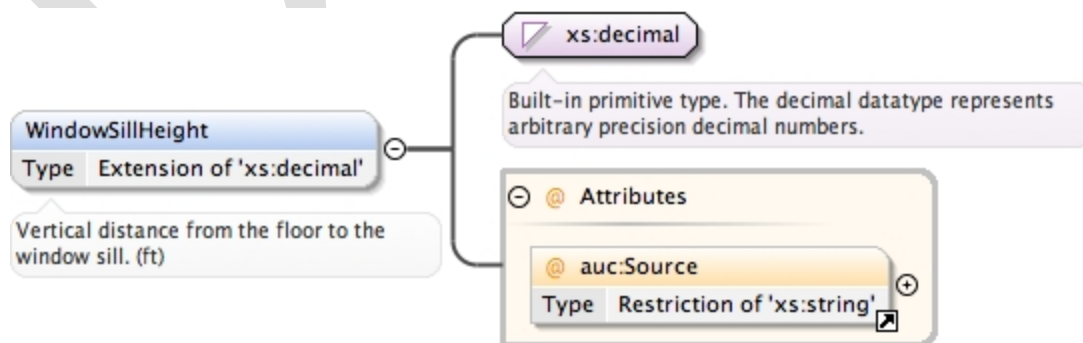


Figure 5. Metadata are applied as attributes to all numerical fields, and specify the source or method used to determine the value of the data field.

The following values of the source attribute are possible:

- Measured
- Calculated
- Default
- Product specification
- Drawing
- Building component library
- Utility bills
- Simulation
- Other.

5.2 Required Elements

Very few elements in the BuildingSync schema are mandatory, meaning they must have at least one occurrence in any valid BuildingSync XML file. Elements are required in the following situations:

- There must be at least one audit element. This is self-evident, because any audit data file must include some audit data.
- If a data heading such as “HVAC Systems” appears, at least one element of that type must be included in the XML file. This helps ensure an efficient and accurate query process, where the data categories included in a particular XML file are easily determined.
- ID references must be provided once a linkage is made between two elements, such as a space and a schedule, or a motor and fan. However, linkages are optional.

All other elements are optional in the BuildingSync schema. Individual program managers or building owners may customize BuildingSync by requiring certain key data fields that are important for their own needs. For example, a building owner may want annual energy savings and net present value to be reported for all energy efficiency measures. In such cases, the BuildingSync schema can be edited to make certain elements mandatory for compliance within the context of a particular project, which would still maintain compatibility with other BuildingSync XML files. However, the reverse would not be true. Making mandatory fields optional could result in files that aren't BuildingSync compliant. We feel that minimizing the number of required fields in BuildingSync is important, and defer decisions about the importance of specific data fields to the end user.

5.3 Data Types

Only a few data types are used in BuildingSync; all are standard XML types:

- Decimal (arbitrary precision)
- Integer
- String (either free text or selected from an enumerated list)
- Boolean (true or false)
- Gregorian year (CCYY)
- Gregorian month-day (--MM-DD)
- Gregorian calendar date (CCYY-MM-DD)
- Date and time (CCYY-MM-DDThh:mm:ss.sss)
- Time (hh:mm:ss.sss)
- ID and IDRef (used only for cross-referencing elements).

BuildingSync places no restrictions on data values beyond those inherent in the XML data type definitions. For example, text fields have no maximum length, decimals have no maximum value, and zip codes have no mandatory patterns. Where relevant, logical constraints are specified in the definition for each term, but are not enforced by the schema. Also, constrained lists nearly always have an “Other” option. We made this decision to maximize flexibility and avoid making assumptions about the limitations of future technologies. For example, most equipment efficiency ranges from 0 to 1, but this isn’t a hard constraint. A solar-assisted heating system can have an efficiency greater than 1, and a fireplace can have a negative efficiency if the heat lost by induced infiltration exceeds the heat added to the space. An individual user may impose data constraints for quality assurance reasons. Such constraints will not affect the validity of an XML file against the BuildingSync schema.

5.4 Global Types

5.4.1 Elements

Global elements are defined for data terms or groups of terms in BuildingSync that are repeated in a variety of contexts, such as quantity, primary fuel, and capacity. Global elements matter little to the end user, but developers can modify definitions or names of elements in later releases much more easily and with fewer errors, because each occurrence of the field is updated whenever the global element is changed.

5.4.2 Complex Types

Global complex types in BuildingSync are used to group logical subsets of data together, such as zone type, wall type, and motor type. This allows easier navigation across the schema, instead of having to drill down through multiple levels to access the more detailed data fields at lower levels. ID numbers are usually assigned at this level as well, making it easier to connect related elements.

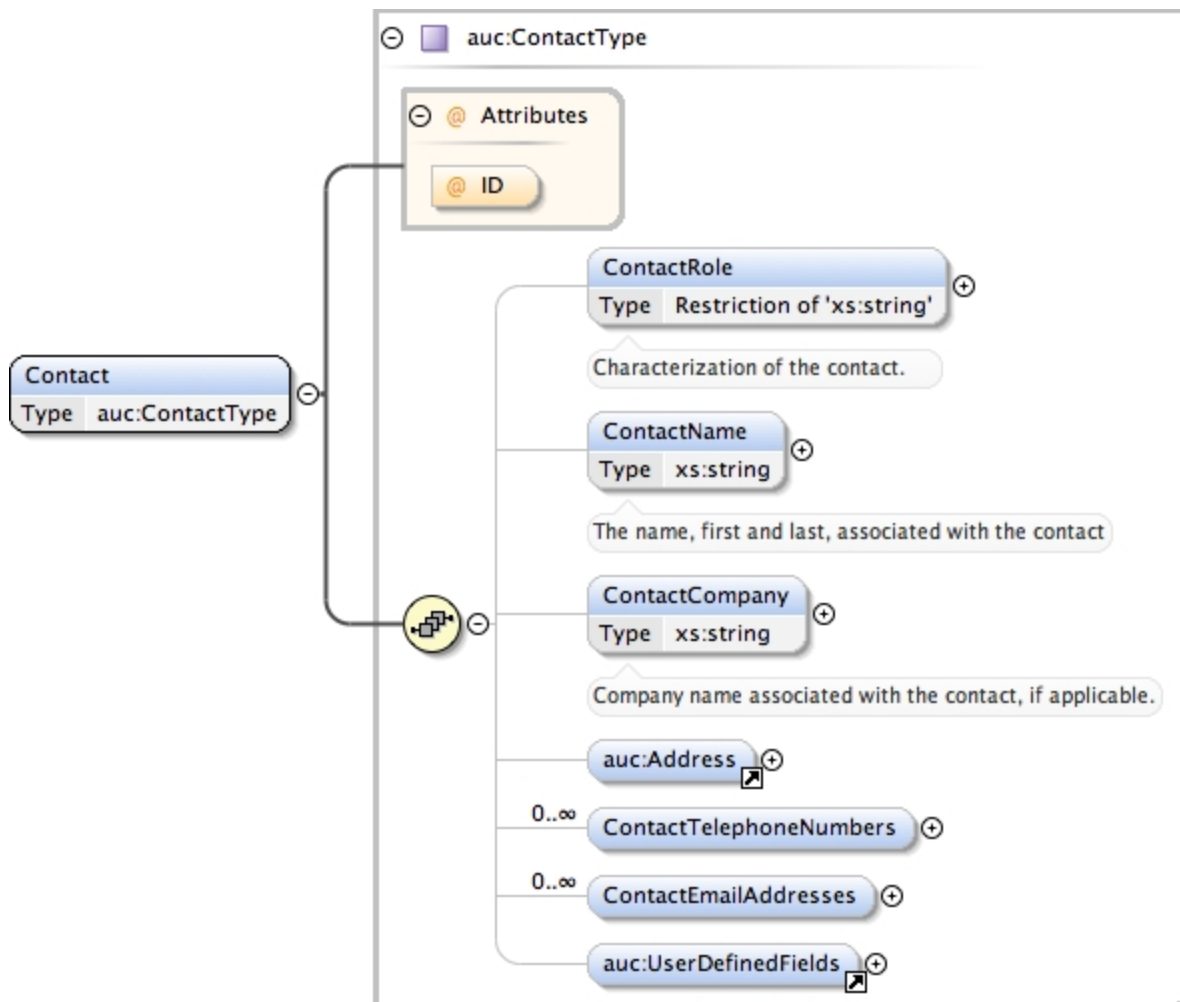


Figure 6. The global complex type labeled Contact, which includes several related elements and an ID number

5.5 Compositors

In most cases, child elements are associated with a parent element using the sequence compositor, which indicates that the child elements must occur in a particular order in the XML file. The child elements in a sequence are generally independent, and one or many may occur for each instance of the parent element.

The choice compositor is often used in BuildingSync to indicate that only one child element may occur. The choice compositor is useful when the relevance of lower branches is highly dependent on the type of building, system, or scenario under consideration. Figure 7 shows an example choice compositor applied in the context of lamp types. In this case, lamp length and start type are children of linear fluorescent, but neon lamp types have no child elements.

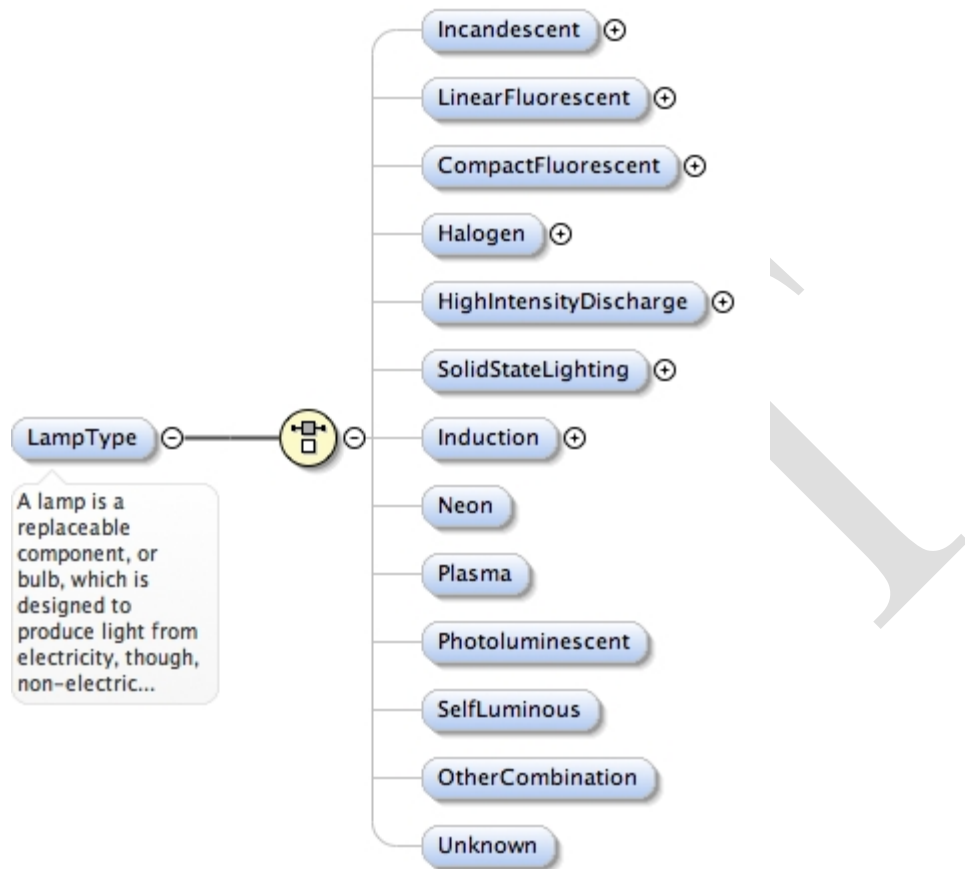


Figure 7. A choice compositor identifies the type of lamp used in a particular lighting system and narrows the list of child elements to those that are relevant.

The BuildingSync Data Dictionary uses enumerated lists to specify choice relationships. In general, software user interfaces should use a drop-down list regardless of whether the schema uses a choice compositor or a simple string element with an enumerated list restriction.

6 Conclusion

This guide provides an introduction to BuildingSync and basic guidance for software developers interested in using BuildingSync to standardize energy data collection, storage, and reporting. Flexibility, clarity, and efficiency were driving themes of the BuildingSync development process, resulting in a schema that is relatively straightforward to understand, navigate, and implement. More detailed information about XML syntax and schema design is available from online resources with links found on the [BuildingSync](http://www.buildingsync.org) website. Additional background information on BEDES (including documentation of the collaborative processes, authoritative references, and industry partners that supported BEDES and BuildingSync development) can be found at <http://energy.gov/eere/buildings/building-energy-data-exchange-specification-bedes>.