Enabling Interoperability through a Common Language for Building Performance Data

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ABSTRACT

While the availability of "big data" about building energy performance is increasing in response to market demands and public policies, the lack of standard data formats is a significant ongoing barrier to its full utilization. To overcome this barrier, the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL) developed the *Building Energy Data Exchange Specification* (BEDES). BEDES is designed to enable the exchange, comparison, and combination of empirical information by providing common terms and definitions for data about commercial and residential building's physical and operational characteristics, energy use, and efficiency measures. This paper describes the BEDES development process, scope, structure, and plans for implementation and ongoing updates. BEDES was developed based on a review of over 40 common data formats and an intensive working group process, which engaged stakeholders from State and local governments, energy-efficiency programs, and private sector products and service providers. The DOE Office of Energy Efficiency and Renewable Energy is committed to using BEDES for all relevant programs, grants, and tools, etc., in order to make its tools interoperable, reduce reporting burdens, and to make it possible to combine resulting datasets. Broader, voluntary adoption of BEDES will facilitate data sharing and exchanging among subsectors of the industry, and open a pathway for innovative analysis and technologies at relatively lower transaction costs, by reducing the time spent on data formatting and cleansing. This in turn will increase available information for decision-makers, and ultimately facilitate growth of the energy efficiency market.

Introduction

The Building Energy Data Exchange Specification (BEDES) is a dictionary of terms and definitions designed to facilitate the use and sharing of empirical building characteristics and energy performance data among software tools and data collection and analysis activities more easily, consistently, and at lower cost. BEDES enables analysis of measured energy performance of commercial and residential buildings, with definitions for building characteristics, equipment, efficiency measures, and energy use. By introducing a standard set of terms and definitions into the market, the creators of BEDES hope to overcome the significant ongoing barrier of data inconsistency, and to realize the full use of empirical information about building energy performance.

While BEDES was originally developed for use in the Buildings Performance Database (BPD) and other DOE tools, LBNL worked with stakeholders from the energy-efficiency industry to arrive at a set of common terms and definitions for a broader range of building energy performance data. Invited stakeholders participated in two working groups: technical and strategic. The technical working group focused on ensuring that the first iteration of the BEDES

fulfills three main use cases that were first identified through a scoping study conducted by the Peregrine Energy Group in collaboration with Raab Associates, discussed in further detail below. The strategic working group addressed the logistics of how BEDES would evolve over time to encourage continued adoption by the building sector.

Overview of Past Work

As noted above, BEDES was initially developed for DOE's Buildings Performance Database (BPD). The goal of the BPD is to hold hundreds of thousands of individual building records. The records come from various established public and private data collections, such as the U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) and Residential Energy Consumption Survey (RECS), the California Energy Commission's Commercial End-Use Survey (CEUS), EPA's ENERGY STAR Portfolio Manager, the Better Buildings Challenge, as well as large property management firms and energy-efficiency incentive programs around the country. The team at LBNL set out to define a common classification schema that would be used as the specification for the database structure, with the intent that the BPD would need to accept a wide array of data collected through diverse procedures. As the schema evolved to accept more datasets, it became increasingly clear that standardization of terms across the building sector was sparse.

In the anticipation of a flexible data schema, LBNL conducted a review of over 40 common specifications to determine the best structure, field categorizations, and fields to include and their respective definitions, data types, and units. This review was done under the single BPD use case, unlike the later effort to make BEDES functional for a variety of use cases. As a result, the scope was limited to enabling the collection of building data relevant to energy performance and savings-potential retrofit analysis.

An additional use case, closely related to BPD, is that of tracking and analyzing local benchmarking and disclosure programs, primarily using ENERGY STAR Portfolio Manager, audit and retro-commissioning reports, tax assessor data, land use data, etc. The DOE developed the Standard Energy Efficiency Data (SEED) Platform based on an expanded version of the schema used for the BPD in order to accept and combine data from that range of sources.

As the value of a common data exchange specification became apparent, the schema used by the BPD and the SEED Platform became the beta version of BEDES. To better guide the evolution of BEDES, LBNL worked with Peregrine Energy Groups and Raab Associates to conduct a scoping study to verify a need for a common language and most imperative uses cases. From there, LBNL invited building sector stakeholders, e.g., building owners, managers, designers, energy-efficiency program administrators, financiers, etc., to participate in technical and strategic working groups throughout the development of BEDES. Stakeholders participating in the technical working group were able to provide direct feedback to the LBNL team, as BEDES was developed in modules. It was through discussion in this working group that the LBNL team concluded that BEDES does not need to impose a structure, but rather simply provide a common language. In parallel, the strategic working group more clearly outlined the vision for BEDES going forward.

Three other efforts have pledged to develop schemas in compliance with BEDES, the Home Performance XML (HPXML), and DOE's Commercial Building Energy Asset Scoring Tool, and Home Energy Score. The team also worked to fully integrate the terms from ENERGY STAR Portfolio Manager (ESPM), given its widespread use across the U.S. In addition, two federal software tools, Compliance Tracking System (CTS) for EISA Section 432 Federal

building benchmarking and the eProjectBuilder, plan to utilize BEDES in the near future.

Vision for BEDES

One of the primary challenges to expanding the building energy-efficiency retrofit market is the lack of data on the actual energy performance, combined with the physical and operational characteristics, of commercial and residential buildings. This situation makes it difficult for building-level decision-makers to understand the drivers of variations in building performance, identify efficiency investment opportunities, and project the likely savings from investments. Moreover, the lack of empirical market data limits the ability of public sector actors to tailor the design and implementation of energy efficiency programs and policies to be most effective, given local market conditions and trends.

Recent technology, market, and policy drivers such as smart meters, energy performance disclosure laws, etc., are resulting in a rapid increase in the generation of data that could address these issues. But these data are still hard to access, aggregate, share and utilize because they are housed in many decentralized databases, and in different formats. Stakeholders consistently reported that they spend more time on data formatting and cleaning than they do on conducting analysis. The lack of standard data formats, terms, and definitions is a significant ongoing barrier to realizing the full utility of empirical information about building energy performance.

The DOE's vision is to facilitate the optimal operation of the energy efficiency market by nurturing development of a robust ecosystem of interoperable private and public data tools. BEDES helps achieve this vision by facilitating the utilization and sharing of empirical building energy performance data among software tools and data collection and analysis activities, more easily and consistently and at lower cost. BEDES is intended to be used in tools and activities that help stakeholders make energy efficiency investment decisions, track building performance, and implement energy efficiency policies and programs.

The goal for BEDES is to serve as a central "data dictionary" that a range of tools and platforms can either utilize or map to. A set of common data definitions and formats would increase interoperability among tools by mitigating the ambiguity and transaction costs associated with sharing and aggregating data. This ability would in theory lower the cost and increase the availability of products and services that utilize energy data. As a result, these products and services would achieve greater market penetration and deliver better information to decision-makers. This in turn would increase available information, lower transaction costs for decision-makers, and ultimately, facilitate growth of the energy efficiency market.

Technical Development Process

The initial scoping study identified a range of potential key users of BEDES, and described how they could use BEDES for their specific needs, called use cases. Table 1 shows the various user groups that could use BEDES for their specific use cases. Individuals from these user groups participated in the technical development process through the technical working group meetings convened by LBNL throughout the development phase.

Table 1. Description of BEDES user groups

Owners	Individuals with a stake or role in building operations, such as building owners, manager and tenants.
Implementers	Parties involved or interested in the design and construction of building aspects, such as energy auditors, architects and engineers, consultants, contractors, ESCOs, etc.
Administrators	Parties involved in the design, implementation, and evaluation of efficiency programs, such as utilities, program administrators, implementation contractors, program evaluators, PUCs, etc.
Public Entities	Federal agencies, states and cities as well as all parties that work for them, including regulators, foundations, institutes, etc.
Financiers	Parties with a financial stake in buildings, such as lenders, insurers, appraisers, and investors.
Researchers	Individuals who conduct analysis of building energy and characteristic data to inform activities of other stakeholders, such as researchers, academics, and advocates.
Developers	Parties that create databases, platforms, software, or guidelines that support the activities of the other stakeholders.

Key Specs and Mapping Process

The initial datasets that laid the foundation for BEDES were the California Commercial End-Use Survey (CEUS), the US DOE's two national datasets, the Commercial Building Energy Consumption Survey (CBECS), and the Residential Energy Consumption Survey (RECS), and ASHRAE's *Procedures for Commercial Building Audits*. As established comprehensive surveys on energy use in the California and national commercial sectors and for their widely recognized approach, both CEUS and CBECS were chosen as the primary sources for BEDES regarding commercial facility energy use and characteristics fields. Similarly, RECS supplemented the residential facility fields in BEDES. While the ASHRAE auditing guideline is not intended for surveying a dataset, LBNL felt it would provide the most standard terminology for BEDES fields relating to HVAC equipment.

The first challenge was developing a set of fields that would accommodate the three major contributors and an established HVAC data standard. From that founding exercise, the specification grew to accommodate each new data source that was acquired by BPD outreach efforts, as well as other established schemas that were identified. With this approach, the schema grew very quickly into a complex, highly detailed, rather messy document that was difficult to use and understand.

At this point, after several datasets from private building owners, energy efficiency incentive programs, and other sources had been adopted, the LBNL team decided it was time to rethink how best to accommodate any and all data sources. At the same time, other programs said that they expressed similar challenges and expressed interest in utilizing a uniform format.

To address this concern, the team conducted a market scoping study and developed three overarching use cases for the initial BEDES:

1. Energy-efficiency investment decision-making,
2. Building performance tracking, and
3. Energy-efficiency program implementation and evaluation.

Once these use cases were established, it became easier to decide which new fields should be accepted or rejected. First, and perhaps most importantly, it was necessary to define what roles BEDES did not intend to fill. In order to achieve the three uses cases described previously, BEDES does not intended to support data required for:

- Detailed energy simulation, e.g., using EnergyPlus modeling
- Building design and construction process, e.g., as in IFC
- Performance of individual components, e.g., specific pump or fan
- Building system controls, e.g., EMCS trend data
- Fault detection and diagnostics

We expect that future users of BEDES will develop their own use cases, and ideally, these would be made available on a BEDES website for others to use or modify for their own needs.

Structure

Because the initial organization of BEDES was based on the BPD organization, which is an implementation of a specific use case, the first BEDES documents included groupings of building characteristics and a hierarchical structure (specific data relationships) between data fields. There was also a prioritization of fields, defining which data would be required and which would be optional.

The complexity of the built environment and existing building datasets (energy and other), as well as the requirement for BEDES to have more universal application across many use cases, means that one set of data relationships will not work for all situations. After discussion with stakeholders, many of whom have developed their own data relationships based on how they would use the data, it was decided that BEDES should not imply any data relationships, hierarchy, or prioritization, and should instead be a technical dictionary of terms and definitions that are used in data sets. The data relationships would be defined, as needed, by the users of BEDES for their own individual specific use cases. This type of technical dictionary, based on terminology from standards and building energy efficiency practitioners, establishes a common language for describing data that can be used across data sets and implementation tools. In addition, mapping the technical dictionary terms between existing datasets allows the common definitions to be related while allowing implementations to keep their existing terminology.

Figure 1 illustrates how a user could construct a BEDES-compliant data set. The user can choose to be fully harmonized, in which case their implementation uses only BEDES terms and definitions. The user can also be partially harmonized with BEDES, in that they are using BEDES terms and definitions where they are needed for the specific use case, but they also use

other terms and definitions for areas not covered by BEDES. The third image in the figure illustrates that it is possible to definite mappings between terms and definitions in other formats and those in BEDES.

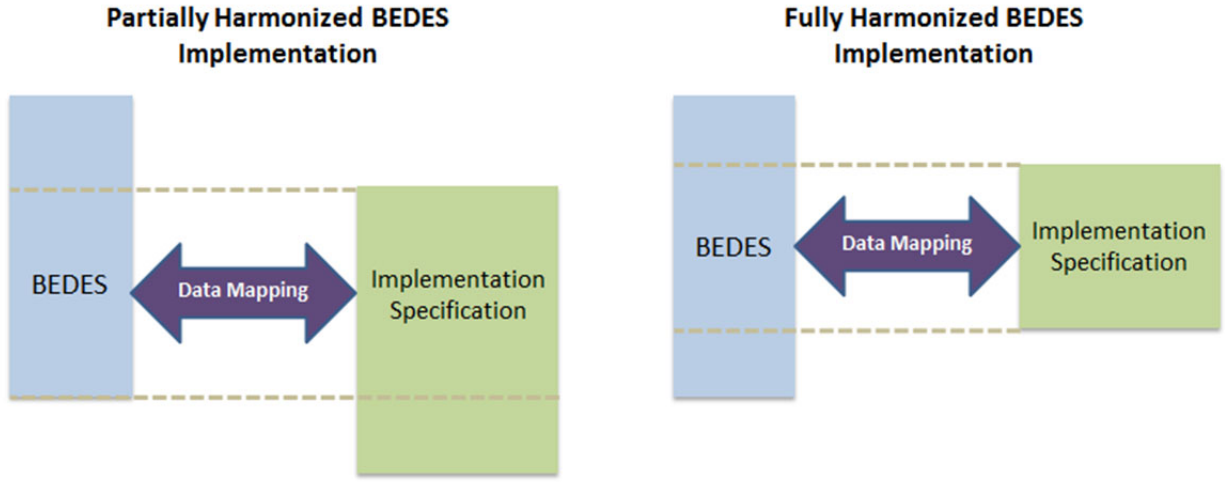

Figure 1. Harmonization with BEDES.

Figure 2 shows an example of a specification that is fully harmonized with BEDES, even though it does not use all of the BEDES terms. The user picked only the BEDES terms that were needed, and set up the relationship between those terms, grouping by Building, Energy Use and Systems, for their particular use case.

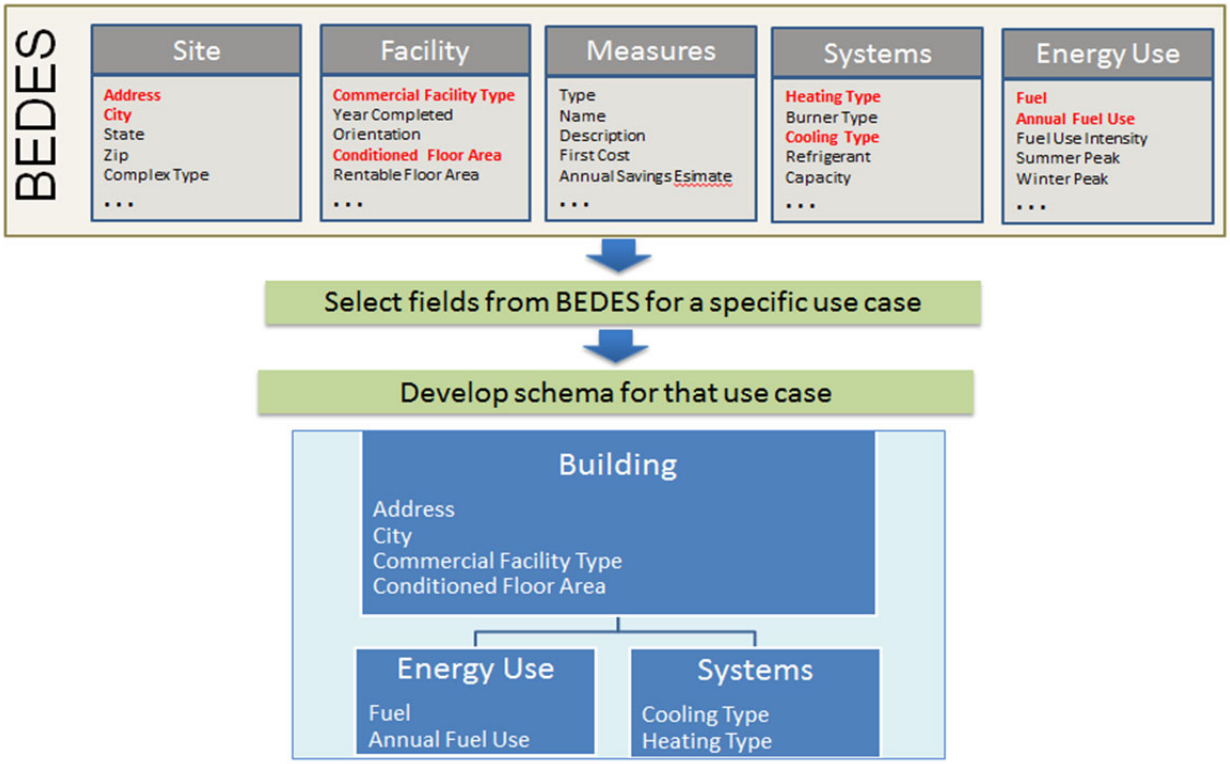

Figure 2. An example of a specification/schema that is fully harmonized with BEDES.

Strategic Development Process

Ideally, BEDES would be widely adopted as a standard reference across the U.S. building sector. Whether BEDES is adopted formally as a technical standard, e.g., by ANSI/ASTM, or becomes adopted through common usage, there are many issues about how it will be hosted, maintained, and updated.

Options for Hosting & Maintaining BEDES

There are several questions about how BEDES should be maintained and further developed, and who should best do it. We have identified the following as some of the tasks for the support, maintenance, and upgrading BEDES:

1. **Maintenance, error fixing, and periodic updates**. After the initial release of BEDES 1.0, there will need to be a process for providing maintenance, fixing user-identified errors, and periodic updates.
2. **User support**. Because BEDES is a reference for a diverse set of users, there will need to be a mechanism for answering user questions about how BEDES is to be used, and what is can and cannot do. Users will have questions about Use Cases and other issues on functionality.
3. **Upgrades and future development**, e.g., BEDES 2.0. There are several features that could be added to future versions of BEDES, e.g., ways that users can share their own schema, and use cases.
4. **Promotion and market engagement**. We see the need both for a plan for how to promote and engage market players, and to implement the plan.

We've identified different categories of entities that could host BEDES. These include:

1. **Non-profit organizations**. There may be the need to develop a new non-profit organization, dedicated to promoting the use and exchange of building energy performance data. Green Button and National Fenestration Rating Council (NFRC) are examples of federally funded activities that have spun off into their own non-profits.
2. **Standards organizations**. While technical standard organizations are often themselves non-profit organizations, e.g., ASHRAE, ANSI, ASTM, ISO, they are designed to adopt standards, and rely on others to update and support the standards [this could use some clarification]
3. **For-profit organizations**. For-profit organizations, e.g., Google, Microsoft, have explored providing energy-efficiency services and products for residential and commercial buildings, and might see the benefit in leading an industry-hosted standard for data exchange.
4. **Universities**. Several universities have active energy efficiency centers that might be interested in hosting BEDES e.g., CMU, ASU, UCD, etc.
5. **National Laboratories**. National Laboratories have a long history of developing and maintaining building energy databases and tools, and could host BEDES and support BEDES users. Labs that conduct work in this area include ORNL, NREL, PNNL, LBNL, NIST, and others.

6. **Federal Agencies**. Federal agencies such as DOE, EPA, GSA, DOD, Commerce, and many others, all have directives and policies that relate to collecting and analyze building energy data. DOE has already pledged to adopt BEDES across many of its programs to further facilitate the exchange and analysis of data, so maintaining compatibility with Federal tools is a priority.

To pursue the question of what type of organization could best host and maintain BEDES, we went through the exercise of identifying potential criteria for evaluating organizations/entities for hosting BEDES. We identified the following criteria:

1. **Accessibility**: Will the group provide access to BEDES by all interested users?
2. **Support:** Does the group have financial resources to maintain BEDES and future updates?
3. **Neutrality:** Does the group have special interests that would prevent it from being fair and impartial?
4. **Expertise:** Does the group have domain knowledge to support BEDES?
5. **Stability:** Does the group have a stable organization with relatively low-turnover in staff and support?
6. **Flexibility & Adaptability**: How fast could the group update versions, and how easily could it expand new use cases?
7. **Promotion & Market Engagement**: Does the group have expertise and experience in market engagement?

We asked our expert group to apply these criteria to each of the proposed host groups, and following their recommendations, have developed the following two scenarios:

Scenario #1: Open-source hosting. There was a great deal of support from the expert group for following an "open-source" model, in which the user community of building energy data practitioners and researchers would contribute their expertise and use cases, and the forum of users would determine best practices for updates and future functionality.

Scenario #2: Hybrid model. There was also a lot of interest in exploring whether the DOE and another public sector host, e.g., a national laboratory, would provide institutional support for a new non-profit that would host BEDES. Examples of this scenario include Green Button, which was developed by the National Institute of Standards and Testing (NIST) with support from the U.S. Department of Commerce, and then evolved into a non-profit.

We plan to further explore these two scenarios and pursue the option that appears best suited for achieving the BEDES vision.

Conclusions

Our work on BEDES has led us to the following conclusions that will guide the effort going forward:

1. BEDES should aim to "knit together" existing data formats in order to use established, effective definitions wherever possible. There are a series of existing data formats that

have already helped to standardize pieces of the puzzle, such as Green Button, Portfolio Manager, HP XML and others. BEDES will pull these together and focus on creating new data fields and formats only in areas with the least consistency, such as building equipment characteristics and energy conservation measures.

2. The goal of BEDES should strive to be a common data format for the building energy community, but it is not necessary to achieve 100% adoption. The range of programs, tools and guidelines that deal with empirical building energy data can use BEDES in several ways:

    a. Public policies and programs, and private software tools may choose to directly adopt BEDES
    b. In cases where policies, programs and tools use their own data formats, mappings to BEDES can facilitate translation among them
    c. BEDES can also be used to conduct activities that follow methodological guidelines, which do not prescribe a data format.

3. Establishing and updating "mappings" between BEDES and other data formats will be crucial to its success. The BEDES documentation should indicate the sources for individual fields, or note that a new field was created. Programs, policies and tools will also be able to use mappings to show where their fields align with or diverge from BEDES. An ongoing update cycle will be needed ensure that users of BEDES can provide input on changes and additions.

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