Improving Access to Foundational Energy Performance Data

Daniel Studer, William Livingood, and Paul Torcellini

Technical report prepared for the Federal Energy Management Program DOE/EERE

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Technical Report
NREL/TP-5500-61543
August 2014

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NATIONAL RENEWABLE ENERGY LABORATORY

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Prepared under Task No. FE14.3025

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Executive Summary

When stakeholders, individuals who influence energy consumption and the procurement of energy-consuming systems or technologies in the commercial building sector, seek out or are approached with products that claim to increase energy efficiency, they often find that they lack access to what are perceived as credible energy performance data. Therefore, even if a stakeholder determines that a product would likely provide an acceptable increase in efficiency, they often have difficulty convincing their management to move forward with a project because they cannot support the development of a quality business case.

To facilitate improved identification, storage, and sharing of foundational energy performance data, the U.S. Department of Energy funded the National Renewable Energy Laboratory to develop the Technology Performance Exchange™. The Technology Performance Exchange uses data entry forms to identify the intrinsic, technology-specific parameters necessary for a user to perform a credible energy analysis and includes a robust database to store these data. End users are able to leverage stored data to evaluate the site-specific performance of various technologies, support financial analyses with greater confidence, and make better informed procurement decisions.

To allow new technologies to be added over time, the Technology Performance Exchange was developed in two pieces. A Web-accessible nucleus acts as a software foundation, providing the services that any user would expect from an information portal. This core set of infrastructure accepts the overlay of technology categories via the development of data entry forms.

A combination of workflows and metadata are used to ensure that Technology Performance Exchange end users have enough context to decide for themselves whether uploaded data are credible. Before users can upload performance data, they must first register using one of three registration options. Each registration option has a unique set of permissions. Metadata, which provide additional information related to where product performance data originated, persist when product performance data are downloaded.

Many stakeholders are interested in adopting energy efficiency solutions in the built environment, but up to now have lacked the data to determine whether these solutions are cost effective. By providing a modular structure, a series of carefully constructed user workflows, an open and transparent set of processes, and a robust application programming interface, the Technology Performance Exchange improves the identification, storage, and sharing of foundational energy performance data across a range of building technologies, allowing end users to conduct more effective financial analyses. The ability to find, leverage, and share data in ways not formerly possible also opens many new collaboration pathways between data providers and consumers, enabling stakeholders to more efficiently and accurately predict the energy performance of specific building products and technologies, and more rapidly deploy cost-effective energy efficiency solutions.

Nomenclature

API	application programming interface
DEF	data entry form
DOE	U.S. Department of Energy
NREL	National Renewable Energy Laboratory
SME	subject matter expert
TPEx	Technology Performance Exchange
UI	user interface
VRF	variable refrigerant flow

Contents

Figures

1 Introduction

When stakeholders, individuals who influence energy consumption and the procurement of energy-consuming systems or technologies in the commercial building sector, seek out or are approached with products that claim to increase energy efficiency, they often find that they lack access to what are perceived as credible energy performance data. Therefore, even if a stakeholder determines that a product would likely provide an acceptable increase in efficiency, they often have difficulty convincing their management to move forward with a project because they cannot support the development of a quality business case.

This is not to say that energy performance data are not available. Generally, product manufacturers provide some level of energy performance data for their products. Sometimes these data are sufficient to support detailed building- and use-case-specific energy performance analyses. But for many technologies, this is not the case.

To facilitate improved identification, storage, and sharing of foundational energy performance data, the U.S. Department of Energy (DOE) funded the National Renewable Energy Laboratory (NREL) to develop the Technology Performance Exchange™ (TPEx™; NREL 2014b). The TPEx is a free, publically accessible Web-based portal that serves as a centralized repository for users to share and find product-specific energy performance data.

Composed of a single database that is accessible via an intuitive user interface (UI) and an application programming interface (API), the TPEx uses technology-specific data entry forms (DEFs) to identify "the minimum product-specific energy performance characteristics and other critical properties necessary to evaluate a product's energy performance" (Studer and Lee 2013). Currently, only parameters included in DEFs are accepted by the TPEx.

By independently identifying parameters, TPEx provides a level of assurance that the requested data parameters are those necessary to support a robust analysis. Because it also serves as a centralized repository, TPEx users can leverage data that have already been contributed to the TPEx to evaluate the site-specific performance of various products and technologies, conduct more effective financial analyses, and make better informed procurement decisions.

This paper first provides a brief overview of the TPEx followed by a discussion of how data identification, verification, and dissemination challenges were overcome. The specific workflows implemented to identify accepted energy performance characteristics and those used to provide open and transparent data exchange are detailed, along with the types of interactions the project is meant to support.

1.1 Improving Site-Specific Performance Predictions at Scale

Access to foundational energy data, intrinsic data not tied to a particular use case, is key to improving the efficiency of the built environment. The TPEx is focused on providing better access to this type of data, which is referred to as *performance data* in this document. Building owners and operators need performance data to identify and procure the most cost-effective technologies and products. Electric and gas utilities use performance data to qualify technologies for incentive programs and to set performance thresholds for product rebates.

Energy modelers require detailed performance data to accurately predict the impact of energy efficiency design decisions and strategies.

Oftentimes, this foundational data is provided via laboratory tests. While laboratory testing can provide very accurate performance data for specific operating conditions and assumed usage patterns, it does not necessarily reveal reliability, integration, or business productivity impacts. In addition, laboratory testing procedures assume usage patterns that may not mimic real-world behavior.

Alternatively, field demonstrations provide information on reliability, whole system integration, business productivity impacts, and insight into actual use patterns. However, energy performance results obtained via field demonstrations are not broadly applicable, largely because they involve a less controlled experiment, fewer sensors, and less accurate equipment than laboratory testing. More importantly, field demonstration results are specific to the building where the demonstration takes place and are extremely difficult to generalize to other buildings. It is challenging to draw general conclusions based on such efforts because many building and site parameters, which vary from building to building and site to site, have a substantial impact on the results.

Building simulation, however, provides a method to marry the benefits of laboratory testing and field demonstration, helping to mitigate individual limitations and lead to a robust and accurate performance prediction. As shown in Figure 1–1, by incorporating performance data obtained via laboratory testing with use patterns observed via field demonstration, building simulation offers a pathway to analyze the energy performance of technologies in a manner that accounts for building- and site-specific parameters, while still allowing for portfolio-wide analyses.

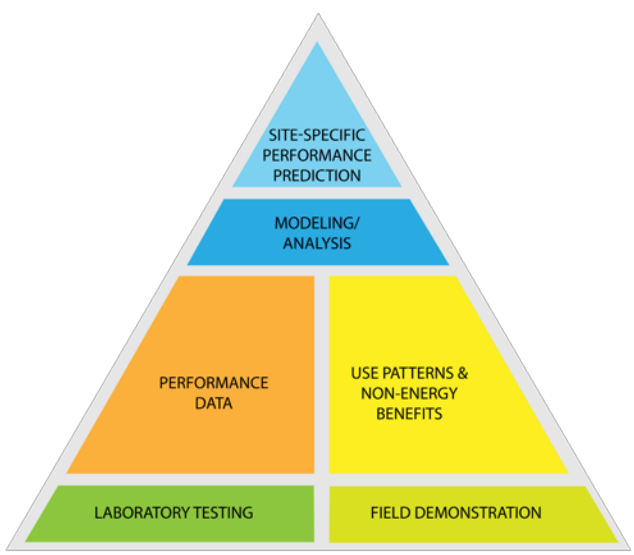

Figure 1–1 Illustration showing the relationship between laboratory testing, field demonstration, and modeling/analysis.

Credit: Marjorie Schott, NREL

As an example, consider variable refrigerant flow (VRF) systems. The site-specific performance of VRF systems can readily be analyzed using a variety of existing methods. However, due to the complexity of the technology, detailed input data are necessary to enable an accurate performance prediction that accounts for unique building characteristics and alternative VRF configurations. If comprehensive performance maps (Performance Data in Figure 1–1) for both the indoor and outdoor units are made available via laboratory test methods (e.g., load-based testing), or manufacturers' detailed, in-house component models, any potential system configuration can be analyzed using energy simulation.

Field demonstration data could then be used to strengthen the resulting prediction, as monitored field data for many operational characteristics (set points, occupancy patterns, lighting schedules, system response to internal/external temperatures, etc.) can be used to improve simulation inputs. Field demonstration results also offer a reality check by providing hard data on real-world operation, helping to verify that simulation results are reasonable.

The use of performance data *and* use pattern data to support and improve energy modeling results has been a driving factor in the design of the TPEx, which has been developed to support this integrated workflow. In fact, work sponsored by the Bonneville Power Administration has already linked the foundational energy performance data housed in TPEx to DOE's larger modeling ecosystem via the Building Component Library (NREL 2014a). While that work is not the topic of this paper, that effort is discussed at length in Studer et. al (2014).

2 Structure

Because the building technology landscape is dynamic, with new technologies and products being brought regularly to market, it is important to ensure that DOE, NREL, and external stakeholders can easily add new technologies and products to the TPEx. To allow new technologies to be added over time, the TPEx was developed in two pieces. First the core infrastructure was developed. This Web-accessible software nucleus acts as a foundation, providing the services that any user would expect from an information portal, including data indexing, search capability, user registration/account access, and data upload/download pathways.

This core infrastructure was built to accept the overlay of any number of technology categories via the development of DEFs. Defined as a "grouping of products whose energy performance can be predicted through the use of a common set of energy performance characteristics and other critical properties necessary to evaluate a product's energy performance" (Studer and Lee, 2013), adding a technology category to the TPEx enables product-specific energy performance data to be uploaded and shared. Energy performance characteristics in this sense are "product [properties] that a user can, in combination with installation-specific parameters and use patterns, use to predict the site-specific energy performance of that product" (Studer and Lee 2013).

This combination of a core infrastructure and technology-specific DEFs enables the TPEx to function as an expandable—but analysis platform agnostic—data clearinghouse. With a robust foundation on which to build, new technologies can be added as the appropriate energy performance characteristics are identified. That same core infrastructure also enables TPEx users to easily upload, share, find, and download product-specific energy performance data for any product that has been submitted to the exchange. As the goal of the TPEx is to foster improved access to energy performance data, there is no minimum performance requirement for products to be added to the TPEx; submitted data, products, and technologies are never rated or ranked.

2.1 Data Entry Form Development

Identifying exactly which energy performance characteristics are selected is a critical path item to ensuring that the minimum data needed to perform a credible energy analysis are made available to users. But because the term *credible energy analysis* can mean different things to different people, great care must be taken to ensure that the proper energy performance characteristics are identified. Therefore, a step-by-step process was developed to ensure that all DEFs are defined in a manner that supports robust analysis. At a high level, the process is (Studer and Lee, 2013):

1. An interested individual (the DEF developer) proposes a new technology category.
2. A TPEx subject matter expert (SME) reviews the proposed technology category.
3. If the technology category is approved, the DEF developer identifies a set of relevant evaluation tools on which the DEF will be based. If applicable, EnergyPlus (DOE, 2013) must be included in this set. Basing DEF development on one or more evaluation tools allows the engineering effort that went into tool development to be leveraged, and ensures a consistent and sufficient level of detail across DEFs.

4. For each identified evaluation tool from Step 3, the DEF developer creates a comprehensive list of the input fields necessary to analyze products within the specified technology category.
5. The DEF developer removes non product-specific input fields (sizing factors, control set points, etc.) from the comprehensive list.
6. For each remaining input field, the DEF developer identifies the foundational parameters that underlie each remaining input field. As an example, if an input field consisted of some sort of performance curve (e.g., heat pump capacity as a function of entering wet-bulb temperature), the DEF developer would identify the required performance map points that would be needed to construct that curve. Only measurable parameters should remain after this step. Note that after this step, the draft list of DEF parameters will be evaluation tool agnostic.
7. To prevent the inclusion of unwanted energy performance characteristics, the DEF developer removes any parameters identified as unnecessary (with justification). This step enables the DEF developer to exclude parameters that do not fit within the scope of the defined technology category or that have minimal or no impact on energy use.
8. To enable TPEx users to properly identify products that meet their own unique use cases, the DEF developer identifies applicable supplemental criteria. These supplemental criteria are not energy related, but are often critical to identifying the appropriateness of any given energy efficiency solution (e.g., color rendering index could be included in an electric lighting technology category).
9. Once the full list of energy performance characteristics and supplemental criteria is identified, the DEF developer specifies what and how the data must be collected. For each parameter, a narrative definition is created, IP and SI units are identified, the number of displayed decimal places are assigned, minimum and maximum allowed values are set, enumerations (if applicable) are specified, and performance map templates (if applicable) are drafted.
10. The DEF developer submits the draft DEF to a TPEx SME.
11. A TPEx SME reviews the draft DEF. If approved, the DEF is implemented on the TPEx. If rejected, the DEF developer must address all comments before returning to Step 10.

To date, individuals from multiple organizations have followed these steps to draft 17 DEFs, identifying 280 parameters (not including the points requested as part of applicable performance maps) in the process.

3 Data Provenance

Of paramount importance during the project was ensuring the credibility of the data housed in the TPEx. The idea of vetting uploaded performance data was dismissed because it would not be practical or sustainable for any entity to validate all uploaded data.

With no practical method to ensure data validity, an alternative was sought. The implemented solution deals with the issue of data credibility via a less traditional approach, using a combination of restricted workflows and metadata to ensure that TPEx end users can decide *for themselves* whether to trust the uploaded data.

3.1 Workflow Processes

Before TPEx users can upload performance data, they must first register using one of three registration options: *Manufacturer/Brand Owner*, *Third-Party Test Laboratory*, or *Contributing Evaluator*. (There is a fourth option: *Basic User*, but that user account type does not allow data uploads.) Registration as one of these three types requires association with an organization; all new organizations are reviewed and must be approved by an administrator for a user to contribute content to the TPEx.

Each registration option has a unique set of allowed permissions that define the actions a user associated with that registration type can execute. The use of numerous registration types (1) helps to prevent intentional misrepresentation (either through over- or understatements) of product performance; and (2) provides data source transparency that TPEx users can refer to when deciding whether to use posted data.

Before highlighting the main differences between the three registration options, it is worthwhile to differentiate between product data and performance data. To ensure that performance data (the parameters identified during DEF development) are useful, they are always associated with a specific product. The TPEx allows multiple users to contribute the same type of performance data for any particular product (e.g., numerous users could contribute the measured energy efficiency ratio for a specific rooftop unit). Because of this one-to-many relationship, product data (which consist of non-energy related items such as manufacturer, brand name, product line, model number, and UPC) are treated separately from performance data.

Currently, Manufacturers/Brand Owners are the only users who can add products (via product data) to the TPEx. However, when Manufacturers/Brand Owners upload product data, the "manufacturer" parameter is automatically set to the user's organization, meaning that Manufacturer/Brand Owner users can only add their own products. These users can also add performance data to the TPEx, but again due to workflow restrictions, they are only able to do so for products that users in their organization have contributed (e.g., user A from company X can only add performance data to their own company's products, which must have been contributed by company X members). Requiring that manufacturers upload their own products ensures that those organizations are aware that their products are housed in the TPEx and therefore helps to reduce the likelihood that the performance of those products will be misrepresented (or at least that such misrepresentations will go undetected).

Third-Party Test Laboratory users can add energy performance data to any product in the TPEx, provided their organization is accredited to measure the performance data being uploaded. Third-Party Test Laboratory users can indicate their organization's current accreditations so that other TPEx users can be assured that the data being provided are of high quality.

Contributing Evaluators, neutral organizations that do not have conflicts of interest related to the data they provide, can add energy performance data to any product in the TPEx. Contributing Evaluators generally consist of non-accredited organizations that have an interest in testing product performance, such as electric and gas utility technology demonstration programs, consulting firms, and even some private sector building portfolio owners/operators.

3.2 Metadata

To empower all TPEx users to make informed decisions about which, if any, performance data to use in product or technology energy analyses, the TPEx displays a host of additional information related to product performance data provenance. Referred to as *metadata*, the following information is displayed alongside each piece of performance data:

1. The name of the organization that uploaded the data.
2. The date the performance data were uploaded.
3. The data derivation method. Options are chosen from an enumerated list and associated with each data parameter (not just a dataset). The allowed options are:
    a. None
    b. Non-Measurable Physical Property/Design Criteria
    c. Self-Measured, Field
    d. Self-Measured, Laboratory
    e. Measured by Others, Field
    f. Measured by Others, Laboratory
    g. Calculated Using Self-Measured Field Data
    h. Calculated Using Self-Measured Laboratory Data
    i. Calculated Using Others' Measured Field Data
    j. Calculated Using Others' Measured Laboratory Data
    k. Reported by External Source, Derivation Unknown
    l. Calculated Using External Data, Derivation Unknown

    The derivation method options provide a means for users to designate whether performance data were obtained in a laboratory or a field setting. Consistency between laboratory and field measurements can help provide assurance that the data are credible.
4. The registration type of the contributing organization (Manufacturer/Brand Owner, Third-Party Test Laboratory, or Contributing Evaluator), denoted as a graphical icon.

When TPEx users download performance data from the site, the metadata are downloaded as well (whether the data are accessed through the UI or through the API). This ensures that TPEx users are able to make informed decisions about the information they choose to use in analyses, even if those data are not obtained directly from the TPEx (e.g., forwarded from a TPEx user to another individual, or accessed via a third-party data portal that references TPEx data). Figure 3–1 provides a visual representation of how metadata are displayed via the TPEx UI.

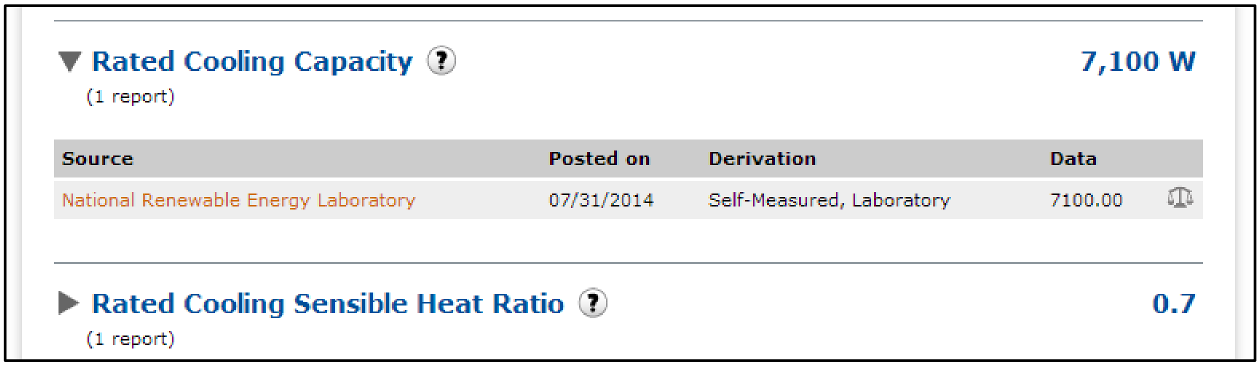

Figure 3–1 TPEx screenshot showing contributed energy performance data and its associated metadata (data source, posting date, and derivation method). The scales icon at the far right indicates NREL is registered as a Contributing Evaluator.

Credit: Daniel Studer, NREL

4 Data Accessibility

Because the TPEx is meant to be a mechanism through which energy performance data are actively shared, two mechanisms were created to facilitate easier data access: a Web interface (the UI) and an API. Figure 4–1 provides a graphical representation of how users interact with the TPEx.

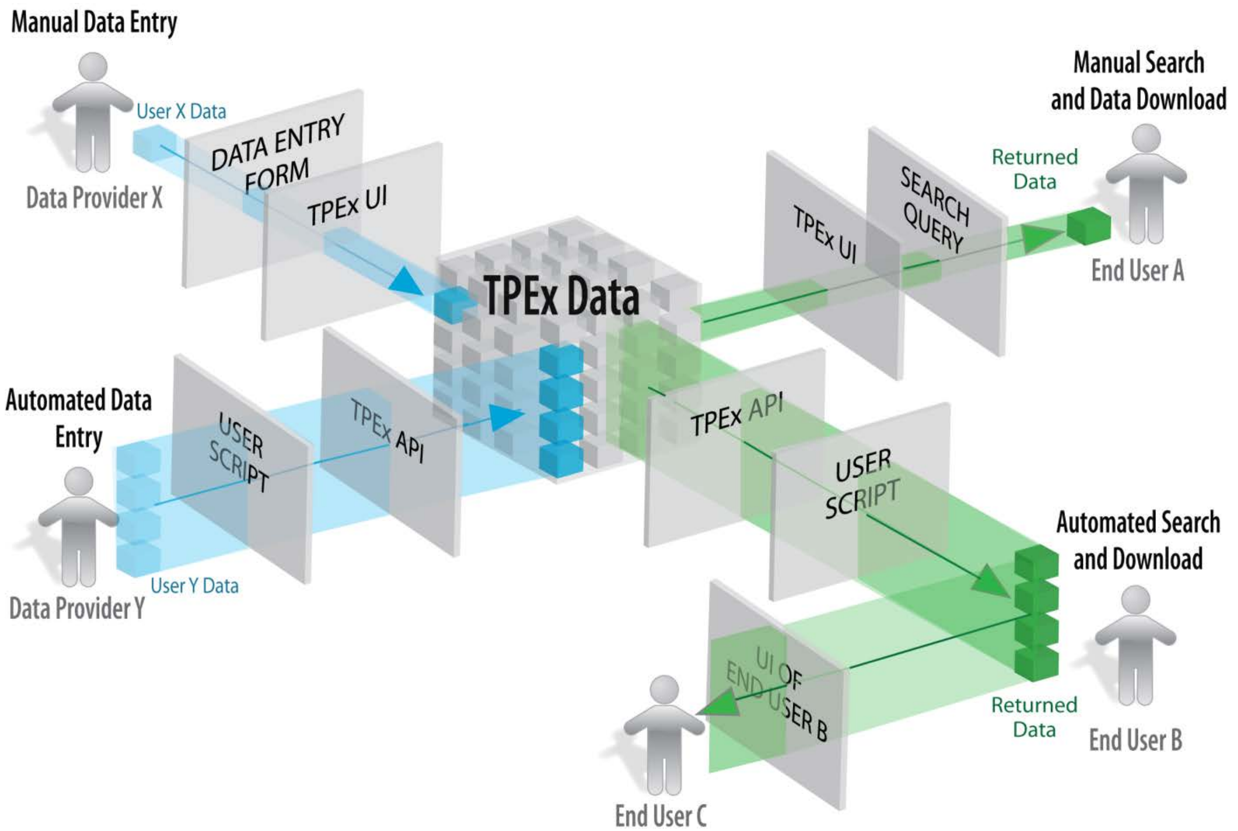

Figure 4–1 This diagram provides an overview of how TPEx end users contribute and access performance data: (a) directly via the UI, or (b) by accessing the TPEx API via user-created scripts. Note that the integration of TPEx data into third-party applications and databases (bottom right) is encouraged.

Credit: Marjorie Schott, NREL

4.1 Application Programming Interface

The TPEx API enables users to automate interaction with TPEx data. Using the TPEx API *search*, *download*, and *fields* resources, users can automatically query the TPEx database and download any or all performance and metadata for products of interest. TPEx users can also automate the upload of product and performance data (contingent on their registration type).

Additionally, interested parties can create their own, independent and custom-branded portals that interact with the TPEx via the API. For instance, organizations that support technology demonstration programs could use the API to link their vendor submission portal to the TPEx. This type of integration (illustrated by End User C in Figure 4–1) would allow the vendor submission portal to self-populate performance data for products already contained in TPEx, and even pull in performance data for similar products to provide performance context for evaluation staff.

4.2 Web Interface

The TPEx UI provides similar, though manual, capabilities to the TPEx API. Users can browse technology categories, search for products, and download energy performance and metadata all via the UI. However, two main features available through the TPEx Web interface are not available through the API: (1) users can easily track and maintain (edit, update, or delete) their product or performance data submissions as part of their account page; and (2) users can compare up to four products within any technology category side-by-side. This comparison feature is helpful if a user is investigating only a handful of products and desires an easy way to compare performance characteristics.

4.3 Stakeholder Interactions

The TPEx interface mechanisms (the UI and API) were developed to enable interested parties to use and share large amounts of relevant energy performance data. There are numerous reasons why an organization would be interested in either uploading or downloading data to/from the TPEx; the following sections detail a few of the interactions that the TPEx was designed to support.

4.3.1 Product Manufacturers

Product manufacturers sometimes face an uphill battle convincing potential customers that their products provide cost- and environmentally-friendly solutions to the customer's needs. Because the DEF development process ensures that the parameters that the TPEx accepts are identified in a systematic manner, the provision of energy performance data to the TPEx by manufacturers can help to assuage customer's product performance doubts. The TPEx API allows manufacturers to efficiently upload entire product catalogs, even if such data represent only a subset of the requested parameters.

4.3.2 Utilities

Many electric and gas utilities currently oversee or participate in technology field demonstrations as a means to assess technology energy performance. These programs are used to identify technologies that are likely to provide demand or energy reduction, but common practices make it difficult to share test results with other utilities in a meaningful way. Although project summary reports and aggregated analyses are published and shared, innate differences between utility service territories (climate, generation mix, demand profiles, prevalence of building type, etc.) often preclude the rote application of demonstration results from one utility to another.

Use of the TPEx's standardized structure to share measured foundational energy performance data (i.e., characterized product performance) provides a mechanism through which multiple utilities can collaborate to avoid duplication of effort and reduce total project time and cost. By co-sponsoring field testing efforts, or by using an alternative round-robin style technology demonstration approach to increase the number of examined technologies, utilities can leverage a common set of measured data and then apply utility-specific characteristics (weather data, region-specific usage patterns, etc.) to the data during the evaluation process.

4.3.3 Energy Modelers

By providing a central, standardized repository for evaluation tool-agnostic energy performance data, the TPEx promises to reduce the time currently required to find input data. And because of the robust DEF development process used to identify allowed parameters, the TPEx increases the likelihood that *required* input data will be available, reducing the need for modelers to make estimates or use rules-of-thumb.

Additionally, use of the API allows energy modelers to automate data queries, data aggregation/synthesis, and even the translation of foundational energy performance data into actionable energy modeling code syntax. This approach is currently being pursued by the Bonneville Power Administration, which is sponsoring work to automate the translation of products within specific technology categories into publically accessible EnergyPlus input objects (Studer et. al, 2014).

Streamlined access to relevant and detailed energy modeling input data coupled with the ability to quickly use that data will help energy modelers accurately identify the most cost-effective strategies, technologies, and products for their clients, increasing the market uptake of energy efficient solutions.

5 Conclusion

Many stakeholders are interested in adopting energy efficiency solutions in the built environment, but lack the data to determine with a high degree of confidence whether these solutions are cost effective for their particular application. With stakeholders often unable to identify whether particular products make fiscal sense, and unable to support conclusions with the level of confidence needed to advance projects to deployment, many otherwise cost-effective (and energy-efficient) projects remain unimplemented.

Designed to provide a mechanism through which data providers and data consumers can interact, the TPEx uses a modular structure, a series of carefully constructed user workflows, an open and transparent set of processes, and a robust API to improve the identification, storage, and sharing of foundational energy performance data across a range of building technologies. Acting as a freely accessible public repository and clearinghouse for product-specific energy performance data, the TPEx enables stakeholders to find, leverage, and share data in ways not formerly possible, opening new collaboration pathways, and enabling them to conduct more effective financial analyses and make better-informed procurement decisions.

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