Accessorizing Building Science: A Web Platform to Support Multiple Market Transformation Programs

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ABSTRACT

As demand for improved energy efficiency in homes increases, builders need easily accessible information on building science measures, installation information, energy codes, and technical requirements for labeling programs. The Building America Solution Center (BASC) is a U.S. Department of Energy website containing hundreds of expert guides designed to help residential builders and other stakeholders access energy efficiency measures for new and existing homes. Users can package measures with other media such as images and architectural drawings, to customize and archive content. BASC content provides technical support to market transformation programs such as ENERGY STAR. This approach has also been adapted for the Better Buildings Residential Program.

BASC uses Drupal, an open source content management platform, to combine a variety of media in an interactive manner to make information easily accessible. Developers designed a unique taxonomy to organize and manage content. That taxonomy was translated into web-based modules that allow users to rapidly traverse structured content with related topics and media. This paper presents information on the current design of BASC and the underlying technology used to manage the content. In this paper, we explore features, such as "Field Kits" that allow users to bundle and save content for quick access, along with the ability to export PDF versions of content. Finally, we will discuss development of mobile applications, and a visualization tool for interacting with the Building Science Publications tool that allows the user to dynamically search the entire Building America Library.

Introduction

The Building America Solutions Center (BASC) is a U.S. Department of Energy (DOE) web application funded by the Building America program and developed at the Pacific Northwest National Laboratory (PNNL). BASC is designed to offer fast, online access to expert guidance on hundreds of high-performance construction topics developed by Building America Teams. The website gives users the tools to create personalized collections of content, called Field Kits, to take information to the jobsite. Furthermore, BASC was designed to:

- Help residential builders and contractors install efficiency measures in new and existing homes,
- Give users fast access to the information they need to perform high-performance residential construction, renovation, and to improve the energy efficiency of buildings,
- Provide information in a simple, user friendly manner, and
- Allow users to access materials via a mobile application, even when internet access may not be available.

The core organization of content in BASC is formatted as guides. BASC currently contains over one hundred expert guides and supporting material including images, computer aided design (CAD) files, references, case studies, presentations, and videos. Each guide provides eight tabs of information; a scope of work, full description and tips for installation, climate considerations, training images, presentations and videos, code and program compliance, case studies, plus other external information related to the topic. The overall objective of the guides is to provide detailed information on how to install, how to specify, and how to verify performance of high-performance building science measures.

In addition to guides, BASC provides content browsing and search capabilities, allowing users to access information within the database. BASC promotes community involvement and allows registered users to provide direct feedback on content and submit new content to the site.

Technology Overview

BASC is a publicly available, web-based application. PNNL developed the website using Drupal, an open source, database-driven, content management system (CMS). Drupal provides a robust, reusable, and powerful platform that has been widely adopted by the U.S. federal government (Drupal Association 2014). PNNL has previously built applications for DOE and other government organizations using open source technology (Corley et al. 2011; Gorton et al. 2012; Livingston et al. 2012; Madison et al. 2012). Drupal, as with many other open source platforms, operates on a modular design, allowing developers to easily add on functionality and features to the core application. Therefore, functionality described in this document will fit into one of three categories:

1. Derived from core (or original) Drupal capability,
2. Derived from modules created by the Drupal community that are available for public consumption, reuse, and customization, and
3. Built from the ground up by PNNL.

Drupal can be deployed into a wide variety of environments, however for BASC, we have chosen to deploy the application onto a RedHat Linux server, running Apache, PHP, and MySQL. Drupal's core file structure is stored mostly as PHP files on the webserver, configuration and content are stored in the database, and access to the website is governed through a standard firewall and SSL protocol. We also take advantage of a continuous build system that pulls from a series of code repositories, managed by Git, allowing us to rapidly develop, test, and push updates into our production Drupal environment using a common codebase that is shared among multiple projects at PNNL.

This continuous build system takes code stored in the Git repositories and merges core code from the Drupal community, applies patches and modifications made by our larger development team, and then makes project specific customizations for BASC. This allows BASC to take advantage of the larger scale Drupal development being done both in the community and at PNNL, while still having its own customized look, feel, and functionality. It also enables our development team to build new features in a development environment, thoroughly test these features in a test environment, and then 'build' them to our production environment. As new features are checked into the repository, the build system can deploy these changes to our other environments.

As described previously, BASC has a variety of types of content (e.g., guides, case studies, images), each of which are built from a unique template. Using Drupal's application programming interface, we have created a content entity representative for each of these content types. A content type, by default, handles content entry via a web form, storage in a database, a permission schema to control who can create/edit/view the content, and basic rendered views for the content.

Users with content creation access use a collection of fields on user friendly web forms to populate the database. While Drupal does not support true semantic markup, these fields do produce a collection of 'linked data' and common data structures that can be reused throughout the site (Corlosquet et al. 2009), making searching and querying significantly simpler for the user. In essence, PNNL developers designed the content entities to re-use fields whenever possible, making it easier for users to compare disparate content through a common structure. The most commonly reused fields in BASC relate to our taxonomy, or classification system(s), which will be described in more detail in the organizing content section of the paper.

Organizing Content

Content is just one example of customizable entities that Drupal supports. Taxonomy, which provides the outline for content organization, is also a definable and customizable entity within Drupal. Through the taxonomy system, site administrators can define vocabularies, which contain taxonomy terms that inform varying types of website navigation. Sometimes, a vocabulary is a well-structured, pre-defined list of terms, such as an energy efficiency program checklist. This type of organization is often referred to as a categorization system. Other times, a vocabulary is simply a container for content editors and authors to fill with terms in a free tagging fashion, such as broader building science categories (air sealing, water management, indoor air quality, etc.). This method is similar to the concept of a folksonomy (Gruber 2007), a method of socially creating a vocabulary, which has arisen thanks in part to blogging and social media like Delicious and Twitter. As content is created, tags are applied to content that inform specific types of taxonomy organization. If an existing vocabulary term (tag) is entered, the form within Drupal will autocomplete to indicate its existence. This is one way Drupal automatically applies categories to content that is similar or belongs to the same higher-level category. If Drupal does not recognize the vocabulary term, a new tag is created and made available for future use.

On BASC, all of the content is tagged with a common set of taxonomy terms that act as content filters, or categories. Examples of these types of tags include climate zone (Pacific Northwest National Laboratory 2010); construction types, such as new, existing; programmatic checklists such as ENERGY STAR; and building components such as roof, foundation, and walls. As new content is developed and added to Drupal, these taxonomy terms allow the content to be organized and categorized in the same fashion, ensuring that content from different sources, authors, and types is consistent. This allows content to be easily searched by users, and ensures that even content with limited text-based content (e.g., images) still will have enough metadata to be returned in searches.

Content Navigation and Access

BASC content navigation includes five primary forms once the user enters the homepage. This includes navigating by Building Component, Program Checklists, Building Science

Publications, Content Browsers, and Search. Enhancing content with taxonomy and other metadata has a significant impact on the methods that can be used to locate that content once published on the website. Traditional, full text search has become standard in a Google-powered world. However, full text search is only an effective method of finding content if a user manages to perfectly capture the text string that they are searching for, or if there are synonyms defined well enough to correlate what the user is looking for with existing content. While effective on a broad Internet search, this technique of searching can be limiting within the context of a single website. Google and other search engines have much wider ranges of data to correlate user searches, and can much more easily take a user's search and find related/correlating information (Bowman et al. 2001). While BASC does take advantage of full text search, it is not our preferred method of aiding users in finding content. By providing traditional text search and then supplementing that with four additional navigational infrastructures, the BASC development team aims to provide multiple paths into the content, enabling users to locate their content without requiring a single, set path through the application. It also alleviates the need for the user to hit on the perfect search phrase to locate the material they are trying to find. These search options are discussed below.

Navigation Methods

Exploration and discovery of relevant content is an approach users often prefer when browsing large repositories of data. Often users may not know the exact resources they are seeking and therefore cannot confidently describe and find those resources using traditional search strings. In other instances, users may successfully find relevant content but seek to confirm that no better or alternative solutions exist. Lastly, some users prefer a discovery approach where all the resources are presented in a manner facilitating the filtering and exclusion of unwanted content ultimately resulting in the information they are seeking. BASC provides several avenues to support this discovery mechanism of search, many of them utilizing the taxonomy terms that are applied to the content.

By Building Component

This tool allows users to browse through guides based on how it is categorized as a component to a house. Selecting a component leads to a more specific sub-selection, which leads directly to all of the guides on the website that match that component/sub-component relationship.

By Program Checklists

This tool allows users to find guides that relate specifically to the ENERGY STAR, Version 3 programmatic checklists (Figure 1). These checklists are presented using a simple expanding/retracting accordion widget. As users drill down into the accordion widget, BASC queries the database to locate content that has been associated with the ENERGY STAR taxonomy. The BASC team is currently developing DOE's Challenge Home Checklists, which will mirror functionality and layout of the ENERGY STAR checklists. In the future, more checklists will be developed to support other programs and existing homes.

Thermal Enclosure System Rater Checklist (TES)

TES 1. High-Performance Fenestration

TES 2. Quality-Installed Insulation

TES 3. Fully-Aligned Air Barriers

TES 4. Reduced Thermal Bridging

    TES 4.1. Insulated ceilings with attic space, Grade I insulation extends to exterior wall at CZ 1-5: ≥ R-21; CZ 6-8: ≥ R-30

    TES 4.2. Slabs on grade in CZ 4 and higher, 100% insulated to ≥ R-5 as specified by 2009 IECC and aligned with thermal boundary of walls

    TES 4.3. Insulation beneath attic platforms ≥ R-21 in CZ 1-5; ≥ R-30 in CZ 6-8

    TES 4.4. Reduced thermal bridging at above-grade walls separating conditioned from unconditioned space

        TES 4.4.1. Continuous rigid insulation, insulated siding, or combination of the two; ≥ R-3 in Climate Zones 1 to 4, ≥ R-5 in Climate Zones 5 to 8

        TES 4.4.2. Structural Insulated Panels (SIPs)

        TES 4.4.3. Insulated Concrete Forms (ICFs)

        TES 4.4.4. Double-wall framing

        TES 4.4.5. Advanced framing, including all of the items below:

            TES 4.4.5a. All corners insulated ≥ R-6 to edge

            TES 4.4.5b. All headers above windows & doors insulated ≥ R-3 for 2x4 framing or equivalent cavity width, and ≥ R-5 for all other assemblies (e.g., with 2x6 framing)

            TES 4.4.5c. Framing limited at all windows & doors to one pair of king studs, plus one pair of jack studs per window opening to support the header and sill

            TES 4.4.5d. All interior / exterior wall intersections insulated to the same R-value as the rest of the exterior wall

            TES 4.4.5e. Minimum stud spacing of 16 in. o.c. for 2x4 framing in all Climate Zones and, in Climate Zones 5 through 8, 24 in. o.c. for 2x6 framing unless otherwise specified

TES 5. Air Sealing

HVAC System Quality Installation Contractor Checklist (HVAC/C)

HVAC System Quality Installation Rater Checklist (HVAC/R)

Water Management System Builder Checklist (WMS)

Figure 1. ENERGY STAR Checklist. Items in red indicate a link to content, and items in black indicate higher level checklist themes that do not translate into a checklist line item.

By Content Type

This method of searching is not based on the taxonomy, instead it is based on the type of content such as images, CAD files, references, and case studies. Users are able take advantage of faceted browsing (Stefaner 2009), similar to that found on common e-commerce sites such as Amazon or eBay when browsing content. Faceted browsing allows the user to make selections from the boxes on the right side of the screen and drill down into content based on their selections to more easily find articles that meet their search parameters. Figure 2 presents a faceted search example of the image gallery.
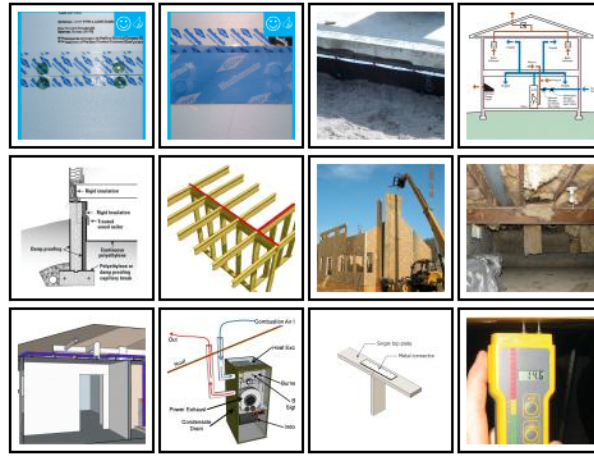
Figure 2. BASC image gallery.

The content browsers also attempt to route the user to content as rapidly as possible. The image gallery (pictured in Figure 2 above) provides previews of the images, which expand into larger versions with additional information when the user clicks on them. The case studies browser page (pictured in Figure 3 below) has links directly into the case study attachment, preventing the user from having to open another webpage before they are able to download the document.

Figure 3. Case study browser.

By Building Science Publications

The Building Science Publications tool (as seen in Figure 4) contains content from the Building America Library. Primarily, it provides visual methods for users to explore the content, focusing primarily on the dates of publication and various taxonomies used in BASC. These attributes of the publications are presented through the visual interface of the Scalable Reasoning System (SRS) framework (Dowson et al. 2009; Best et al. 2012). SRS is a modular analytic framework developed at PNNL that facilitates the development of analytic pipelines to retrieve, process, model, and visualize information through a widget-based web framework. SRS subscribes to the Drupal database, accessing the same content that the rest of BASC does, ensuring that any updates to the BASC content are immediately reflected in the Building Science Publications application.

Figure 4. Building science publications.

Categorical properties of the publications, represented via Drupal taxonomy, are presented through a faceted browser allowing users to interactively scan and filter the publications based on properties of interest. One method of filtering is typically through this faceted search interface that presents users with the full set of possible values for each facet, including content type, author, authoring organization, construction type, and application climate. Users can quickly scan, select, and filter the content based on those facets they are interested in.

The date of publication is also important for users particularly when they may be seeking content that is the most current, or are interested in understanding the history of when content around a particular topic or technology was released. Temporal summarization and filtering is supported through the publication date histogram. For cases where users need to only focus on publications from a specific time period, the basic interface provides for the selection of a date range.

Finally, the tree map representation (as seen in Figure 4) of the taxonomy serves as a visual table of contents, both organizing the data into meaningful groups while also conveying the volume of publications related to any given part of the taxonomy structure. Users can interactively select and then drill into a high level grouping that subsequently filters the publications and then organizes the remaining documents into the next tier of the taxonomy.

By Mobile Device

While this section has primarily focused on the type of content the user might be accessing and the methods the Solution Center provides to facilitate this access, we cannot ignore that modern users are no longer guaranteed to be on desktop with large monitors or laptops with high definition screens. One goal of BASC that will aid users in the field is to ensure the website works with the same level of quality and convenience, no matter what type of device a user accesses it from. BASC has been specifically customized to take advantage of responsive design, changing the site's layout, content, and style based on the width of a user's device screen.

A typical Drupal website has a primary layout (known as a skin) and uses a principal stylesheet, customized for specific browsers (e.g., Internet Explorer) and modules (e.g., layout for an image gallery). A Drupal site enhanced with responsive design uses a technique called a media query to take note of the pixel (px) width (resolution) of the screen of the device that is viewing the website. The BASC Drupal skin has multiple layouts, based on the possible widths of common devices. BASC supports a standard desktop/laptop layout at least 980px wide, a tablet layout between 750px and 980px (Figure 5), and a smartphone layout that is less than 750px. The smartphone layout will continue to respond down to screens around 300px wide, and will maintain that width for devices smaller than 300px.
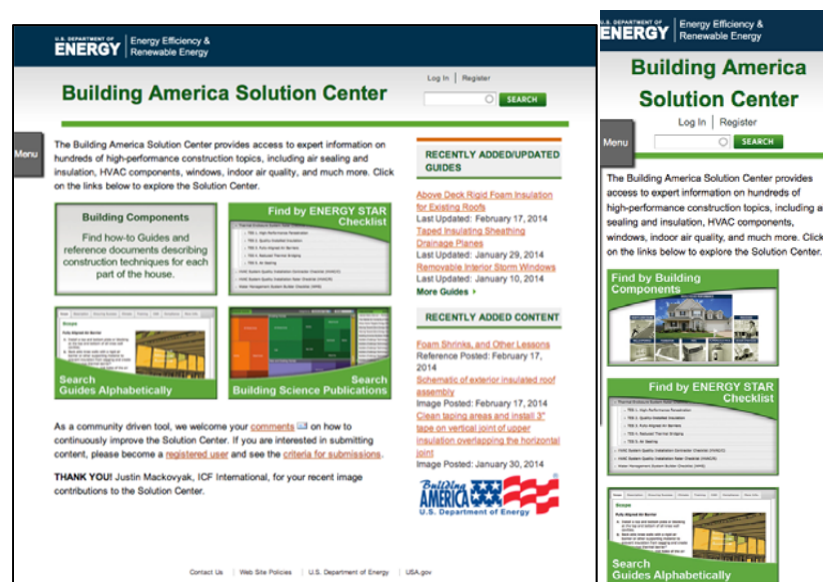

Figure 5. BASC at tablet resolution (left) and smartphone resolution (right).

As the width of the screen is reduced, some graphic elements are left out of the lower-resolution layout. To consolidate space in the horizontal width of the site, the left menu becomes a simple button that toggles the visibility of the menu when tapped, instead of taking up valuable

screen real estate. Other elements on the page rearrange so that they are more vertically oriented, ensuring that even at the smartphone resolution, the user is not forced to repeatedly scroll horizontally, or zoom in/out in order to view all of the content.

Saving Content

BASC contains a significant amount of information; there are over 110 CAD files, 1,400 images, and 111 guides. Despite the many methods of searching for content, many returning users will want rapid access to this material, meaning that even the most efficient of searches will become repetitive. BASC allows registered users to customize content, saving folders of images, CAD files, and guides for fast, easy access each time they visit the site. Additionally, PDF and print functionality is available for each guide, allowing the user to download and save or print the guides regardless of whether they are logged in or not.

Field Kits

The Field Kit customization tool allows users to bookmark content within BASC. Each user has the ability to create multiple field kits, with customized names. Then, as they browse the website, they are able to add content to their field kits for quick retrieval. Field kits can be generic, allowing a user to store all content they are interested in within a single location, or they can be customized to property locations, jobs, or areas of interest (see Figures 6).
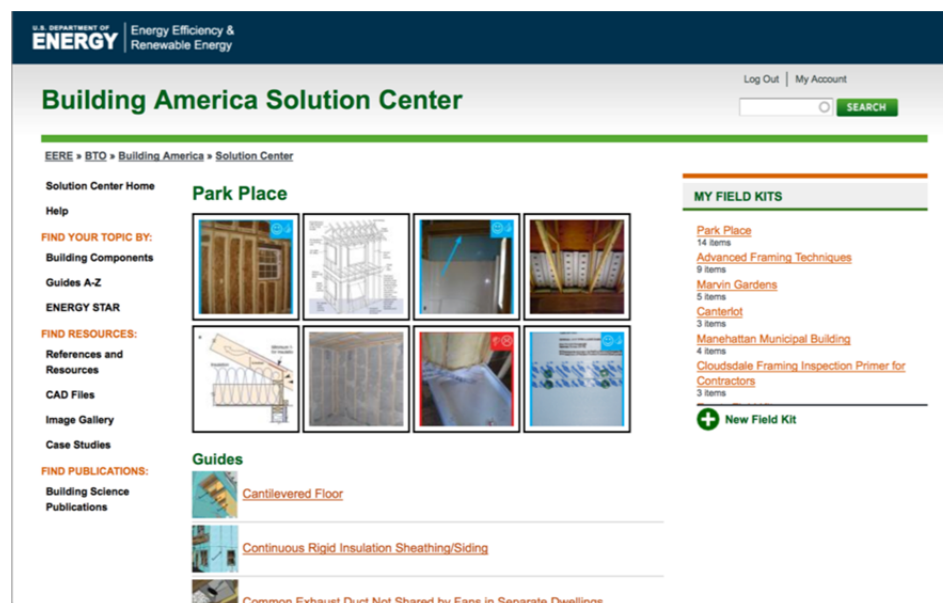

Figure 6. Summary of content that has been flagged for an example Field Kit.

Field kits are an artifact of BASC and not the user's browser bookmarks. Because of this, the user can log into BASC from any device and then access their saved content without having to transfer bookmarks. This is particularly useful when the user visits BASC from a mobile device or from a computer that is not their typical workstation (e.g., a client's device).

Mobile Access to Field Kits

BASC content is designed to facilitate projects at building and build sites around the country. High resolution images, videos, and other content available from a website can be difficult to download in the field. Internet connections are notably varied based on location, and not all builders have access to laptops with cell access at a build site. To ease these issues, Solution Center developers have created mobile applications that will run on Android or iOS devices.
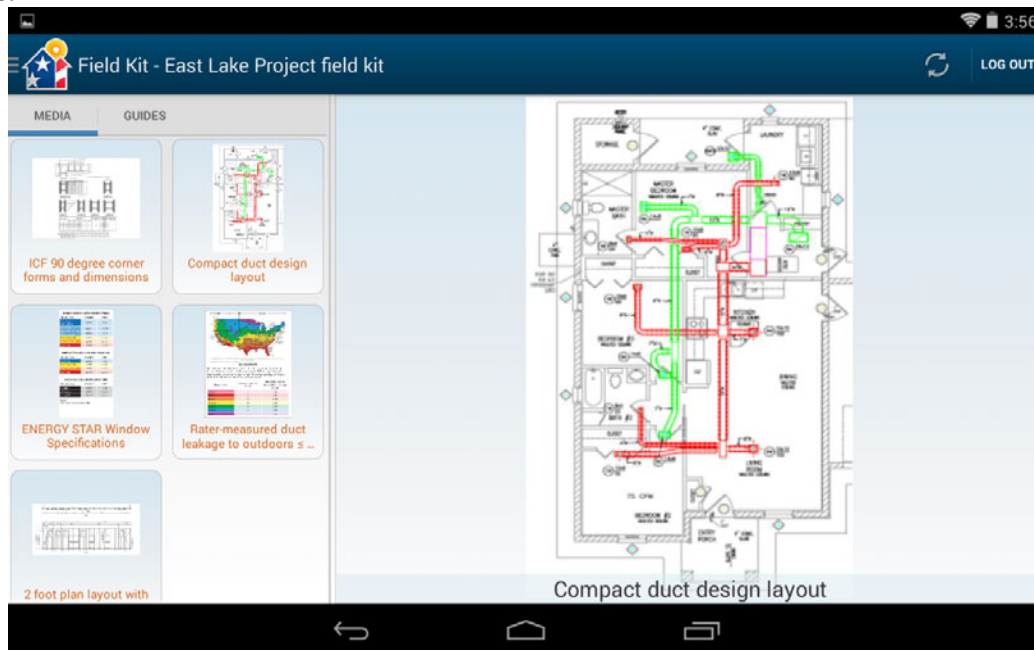

Figure 7. Sample field kit as seen on the Android application.

Drupal still acts as the principal CMS for BASC, however the mobile application has its own local database for offline data storage. Once a user has an account on BASC and they have created at least one field kit, that user is able to synchronize that field kit to the mobile device. The guide and all relevant content is downloaded to the device and made available from that device's internal storage instead of via an internet connection, allowing the user to access downloaded field kits regardless of whether they have internet access.

While fundamentally similar to the responsive design developed into the BASC skin, the major difference with the mobile applications and the responsive version of the BASC website is that the applications do not run in the device's browser(s) and do not require any internet connection, beyond the occasional synchronization back to the Drupal database. When content is updated on the live site, users are able to re-synchronize their device to ensure that the most current version of the content is on the mobile device.

Exporting Content

While many users today have access to smartphones or tablets, not all users do, or have consistent access to an Android or iOS device. As such, printing and saving offline copies of materials still have value to many users. To support this use case, BASC has taken advantage of the Drupal Print module that allows us to dynamically generate PDFs on demand of guides for

our users. This functionality is available to users, regardless of whether they are logged into their user account.

This method of generating PDFs is particularly effective with a CMS, given the ease of updating the web content. It ensures that newly rendered PDF versions of our content is always up-to-date.

User Information

Initial reaction to BASC has been very positive. BASC recently won a DOE Innovation Award (Department of Energy 2013), establishing it's place as one of "46 diverse industry leaders bringing the best in energy efficient building technologies and design to new and older homes and helping households save money" (Department of Energy 2013).

We have also seen tremendous interest from the community, with roughly a quarter million page views from four thousand unique users. Of those four thousand users, over five hundred have registered for accounts, enabling the creation of field kits and the bookmarking of content for use in the field.

Conclusion

BASC provides the building science community with a robust resource containing proven performance research in an easily accessible format. BASC users represent a wide variety of stakeholders within residential energy efficiency, from builders to raters and researchers. Using a Drupal platform, BASC allows users to access and customize content specific to their needs and uses. Users are encouraged to provide input, feedback, and submit content for upload to BASC, in an effort to produce a rich repository of information about building science measures.

While the content behind BASC is of primary focus to users, it is only easily accessible due to a well thought-out development plan and execution. The mobile applications that sync and interact with Drupal and responsive designed Drupal skin are the first such developed at PNNL. The technology used throughout BASC, from the server environment, to the user interface, to Drupal itself, continues to mature and evolve, leading our team to new and exciting technologies that are benefiting BASC users and stakeholders.

Acknowledgements

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