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Web Services that Foster Innovation in Buildings Energy Analysis Tools

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ABSTRACT

Software tools have long played an influential role in buildings energy efficiency markets, becoming increasingly pervasive with the advent of personal computers. Early disk-based tools faced considerable limitations in the ease and cost of distribution and version control. Subsequent web-based tools reached far larger audiences, but remained limited to the scope and user-interfaces devised by isolated tool developers. The current frontier is defined by the advent of 'web services' enabling any number of tool developers to design user interfaces powered by independent and common "back end" sets of models and data. This technology fosters greater internal consistency of methods across tools, reduces barriers to market entry, and stimulates innovation and a more diverse field of third-party tools that inexpensively extend a given set of analytics to serve a greater diversity of audiences and purposes. The Lawrence Berkeley National Laboratory has made two energy-analysis methodologies have been made available as web services for residential (Home Energy Saver) and non-residential (EnergyIQ) markets. Early third-party applications of these services include tools for home energy auditors using mobile devices, building inspector training, carbon-footprint calculators, Weatherization Assistance Program auditing, and consumer-focused energy decision-making. The experience provides a strong illustration of how publicly funded R&D can enable private-sector innovation.

Introduction

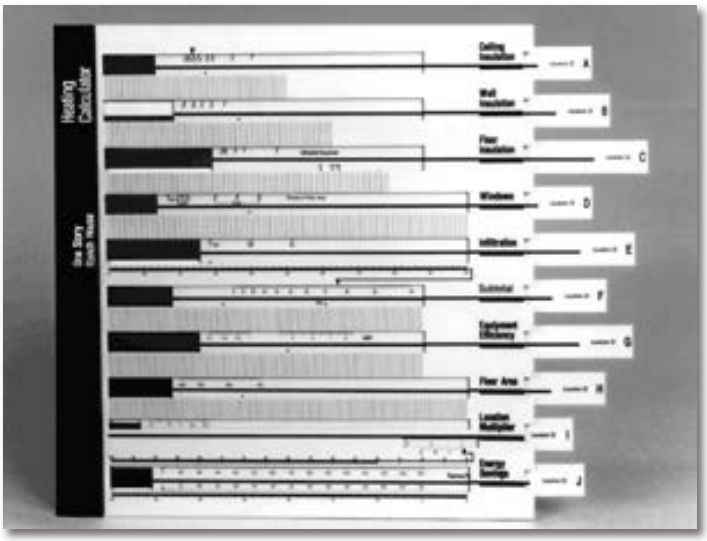
The evolution of buildings energy software has followed that of software and computing more generally: a progression from massive code libraries running slowly on room-sized and heavily air-conditioned "mainframe" computers, to the personal computer and, most recently to "cloud-based" platforms where software becomes a service accessed through the Internet rather than possessed in myriad duplicate, mixed-versioned disks on end-users' computers. Meanwhile user interfaces have evolved from tedious and sometimes inscrutable "command-line" interactions on hardwired desktop terminals to efficient and sometimes even elegant graphical user interfaces running on mobile wireless devices.

Early building simulation tools were computationally intensive yet analytically primitive. Few people—primarily research scientists—had access to them (Leighton *et al.,* 1978; Birdsall *et al.,* 1990).[1] Eventually the larger engineering firms and others from the private sector gained access. Simplistic "take-offs" (e.g., nomographs, such as that in Figure 1) or lookup software operating in pseudo-simulation mode (Huang *et al.,* 1987) were developed based on large numbers of parametric runs on mainframe machines, enabling non-specialists to obtain

[1] During 1975, the U.S. Energy Research and Development Administration (ERDA, which later became the U.S. Department of Energy), and the California Energy Commission (CEC) agreed that a comprehensive building energy analysis computer program was needed to develop and support energy efficiency standards. LBNL initiated a joint project with two other national laboratories—Los Alamos National Laboratory (LANL) and Argonne National Laboratory (ANL)--to develop the Cal-ERDA code, later to become DOE-1 and then DOE-2. LBNL based DOE-2 on algorithms developed by ASHRAE and methods from earlier programs like NECAP, NASA's Energy Cost Analysis Program, and TWO-ZONE, a residential analysis program developed by LBNL (Mills 1993).

approximated assessments. Later, as personal computers gained sufficient power, these applications moved to the desktop with dedicated user interfaces. However, these user interfaces remained cryptic, and output often files took the form of stacks of printouts that had to be manually combed for the relevant data. Later, investments were made in graphical user interfaces and the tools became accessible to progressively broader user audiences.

Figure 1. Nomographic home-energy "slide rule", based on thousands of parametric simulation model results, circa 1985



The disk-based distribution paradigm persisted, which limited uptake and posed inevitable barriers to adoption stemming from the capacity of the user's computer, compatibility of operating systems, and skill/time on the part of the user. Users also had to be patient, initially waiting hours for results (depending on the complexity of the underlying building).

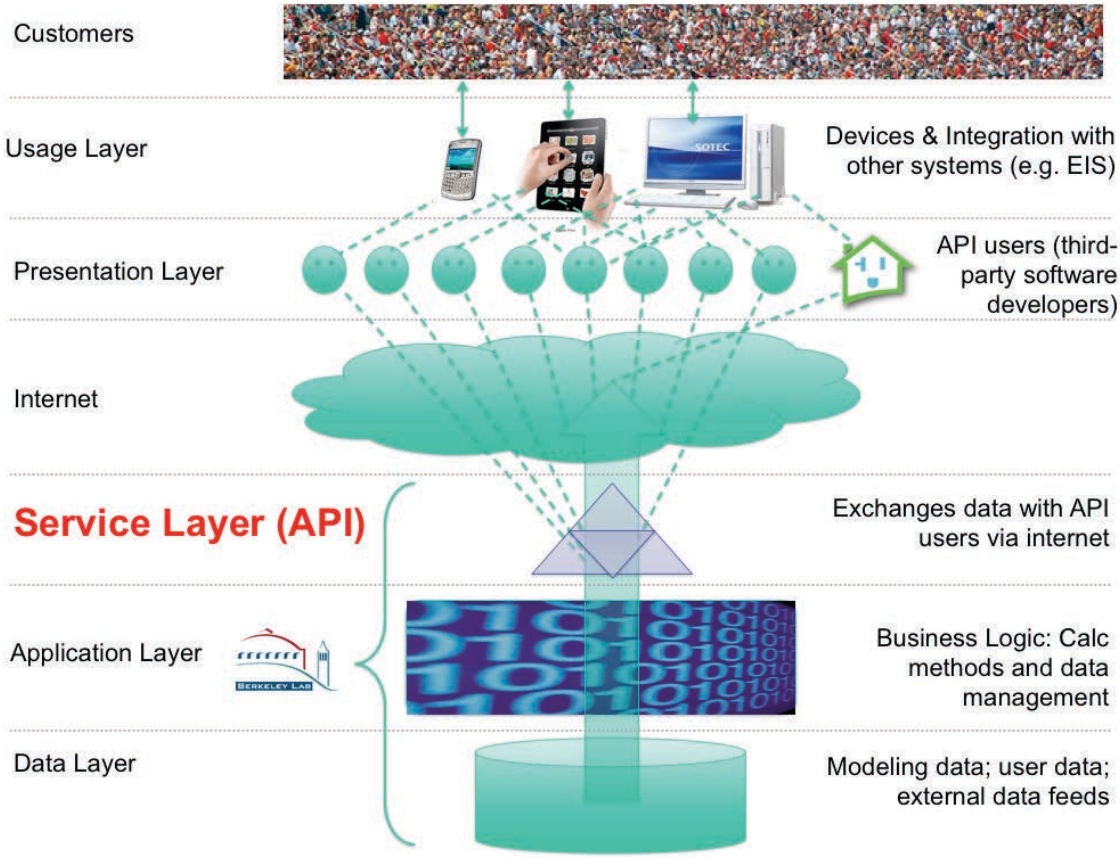
In the mid-1990s, the Home Energy Saver (HES) became the first whole-house residential energy simulation tool (combining DOE2.1E with other algorithms to encompass all energy end uses) to be purpose-built for the Internet using a full graphical user interface with "user-friendly" input syntax and output reports (Mills 1997). Now, users anywhere on the Internet (even consumers) had access to a residential simulation tool that would run in essentially real-time. Later, a web-based energy benchmarking tool for non-residential buildings—EnergyIQ—was developed by Lawrence Berkeley National Laboratory (LBNL). Thanks to centralized web hosting of these systems, updates were instantaneously and inexpensively deployed to all users.

Because single GUIs were the only modes of access to these tools, there remained bottlenecks to tailoring the applications to a myriad of use cases. These barriers were removed with the advent of web services and "APIs" (or Application Programming Interfaces).

Web Services and APIs

A web service is a system of data exchange methods made available by a "host" computer offering a service to "client" computers located elsewhere on the Internet. APIs are the exact protocols through which the host and client communicate (Figure 2). Strict syntax, format, and other rules must be adhered to by the client when submitting inputs to the host, which returns the results back to the client, essentially in real time. The client is then free to further organize, format, and otherwise present the results to customers via customized user interfaces, without the burden of developing the back-end algorithms, calculation software, or hosting infrastructure.

Figure 2. Web services in context of back-end functionality (data, business logic) and downstream programmers ("API License") and end users



Looking at the web service from a high level, the system architecture is divided into layers. At the base of the system (bottom of the diagram) is the *Data Layer*. The Data Layer contains databases and external data services that used in calculations.

Sitting directly above the data layer is the *Application Layer*. The Application Layer contains assorted libraries of software elements ("code libraries") and is the heart of the system. The "business logic", i.e., the rules that govern how the system operates resides in the code libraries in the application layer. When people think about software, they are usually thinking about the code libraries in the application layer. In fact, this is just one part of the broader enterprise.

Sitting above the application layer is the *Service Layer*. The Service Layer manages third-party interactions with the underlying applications and data. External systems interface with this system through the Internet via *web services*, which are a type of application programming interface or API. Users (API "clients") are given a unique key, which grants them access to the services and defines their usage rights once they have joined the system. Key-holders can use the entire system or pick and choose particular elements that are of interest. Any number of developers and websites can be supported on top of a given API.

Websites created by third-party API clients reside in the *Presentation Layer*, directly above the Service Layer. This is where the end-user interfaces (web sites) are developed and hosted by the ultimate clients of the web service.

And finally, sitting at the top of this structure, is the most important layer; the *Usage Layer*, which is populated by end users. APIs allow developers to create user interfaces for any type of end-user device (desktop computer, smart-phone, abacus, etc.).

Market Deployment

Building energy software lends itself particularly well to an API-based deployment strategy, supported via public goods research and development. This is due to the considerable level of subject-matter expertise needed to develop tools, computing power required, the value of methodological consistency, and the disadvantageous relationship between the high cost of development and market entry and the low potential for revenue from providing such services to end users such as engineers or consumers. Another key motivation for APIs in energy software is that it is virtually impossible to have a single GUI that "does it all". Different use cases (as defined by user type, goals, and skill level) demand different user interfaces.

From a public policy perspective, it is important to seek appropriate levels of standardization and quality assurance in energy analysis, especially with the increasing ease with which user interfaces can be developed and deployed by entities that may lack the necessary qualifications. The presence of over 600 building energy software tools[2] suggests that many developers have ploughed similar ground, with the result that end-users are faced with offerings that do not always give internally consistent results. Web services make it possible to maintain (and even increase) the variety of tools—different user interfaces tailored to different audiences or purposes—while achieving a higher degree of internal consistency, common data, etc., on the back end. In the case of an application like the Home Energy Scoring Tool for home asset rating (Bourassa *et al.,* 2012)—where very highly prescribed data and algorithms must be consistently employed to obtain a statutory Score, the API makes it possible—and even attractive—for a variety of software developers (public and private alike) to integrate the functionality into their existing applications. Public goods sponsorship of web services also helps ensure that the resources remain available long-term in an otherwise turbulent energy software marketplace.

LBNL has developed what are, to our knowledge, the first web services for buildings energy modeling, based on the calculation methods and data underpinning their Home Energy Saver (residential operational energy simulation), Home Energy Scoring Tool (residential asset-based rating), and EnergyIQ (non-residential energy benchmarking) (Mills and Mathew 2008, Mathew and Mills 2008) (Figure 3).[3] It is worth noting that these LBNL-based user interfaces employ the web services in exactly the same fashion as done by third-party developers.[4]

The Home Energy Saver service is a whole-building residential energy simulation environment, using state-of-the-art data and models to support the Federal energy mission by helping to build national recognition of energy efficiency programs and enabling consumers to quantify the energy savings and environmental benefits that can be achieved by improving the energy efficiency of their particular home. The system calculates energy consumption by end use, for the entire household, and estimates energy bills and greenhouse-gas emissions based on

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[2] See http://apps1.eere.energy.gov/buildings/tools_directory/ While some are specialized, a significant proportion are regarded as whole-building analysis tools.

[3] Engineering documentation: Home Energy Saver suite - https://sites.google.com/a/lbl.gov/hes-public/ | EnergyIQ - https://sites.google.com/a/lbl.gov/energyiq/

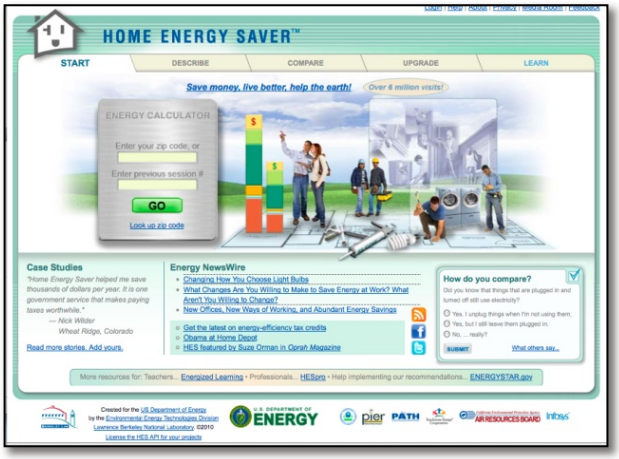
[4] Full API documentation is provided here: https://developers.buildingsapi.lbl.gov/

end use consumption, and a comparison of consumption to a "typical" household and subsequent recommendations for bill reduction. The system is highly accurate (Parker *et al.,* 2012).

The *EnergyIQ* service is an "action-oriented" energy-benchmarking tool for non-residential buildings that uses whole building and system-level benchmarking results to identify potential energy efficiency actions. Users can select peer groups for comparison from different datasets, including the California Commercial End Use Survey (CEUS) and the national Commercial Building Energy Consumption Survey (CBECS). Users benchmark energy use, costs, greenhouse-gas emissions, and building features and display results using a variety of metrics and graphical and tabular formats. In addition to cross-sectional benchmarking (comparison to peer buildings), users can also conduct longitudinal benchmarking i.e. tracking the performance of an individual building or portfolio over time.

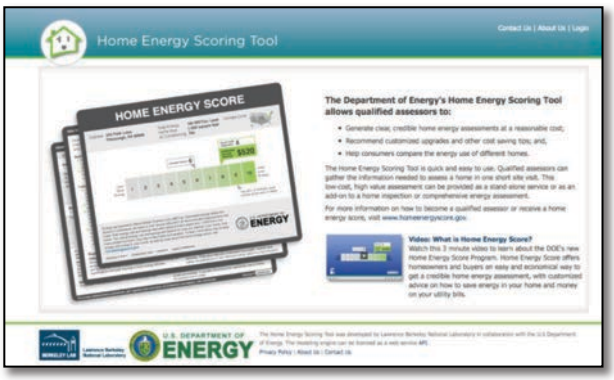
Figure 3a-d. Four web-based energy analysis tools providing web services for third-party software developers

(a) Home Energy Saver
http://hes.lbl.gov
(Mills 1997)



(b) Home Energy Saver Pro
http://hespro.lbl.gov

(c) Home Energy Scoring Tool
http://homeenergyscore.lbl.gov
(Bourassa *et al.,* 2012)



(d) EnergyIQ
http://energyiq.lbl.gov
(Mills *et al.,* 2008)

This new software deployment paradigm also ameliorates concerns occasionally expressed about "competition" between public- and private-funded buildings energy software initiatives. (The distinction is not black-and-white given that private software developers routinely receive funding from public sources, e.g., ratepayer funds via energy utilities.) The availability of APIs is now enabling private-sector energy software developers to obtain market advantages and reduced business risk based on R&D that would be unaffordable if self-financed. A good API drastically reduces the cost of market entry for software developers. Rather than independently investing large sums (hundreds of thousands to millions of dollars) in developing software (and underlying databases and hosting infrastructure) from scratch, entrepreneurs using the APIs can leverage existing engineering methods, data, and IT infrastructure. This, in turn, enables these parties to focus far more quickly on defining the unique parts of their offering, i.e., the user interface and positioning of the tool within their broader business strategy.

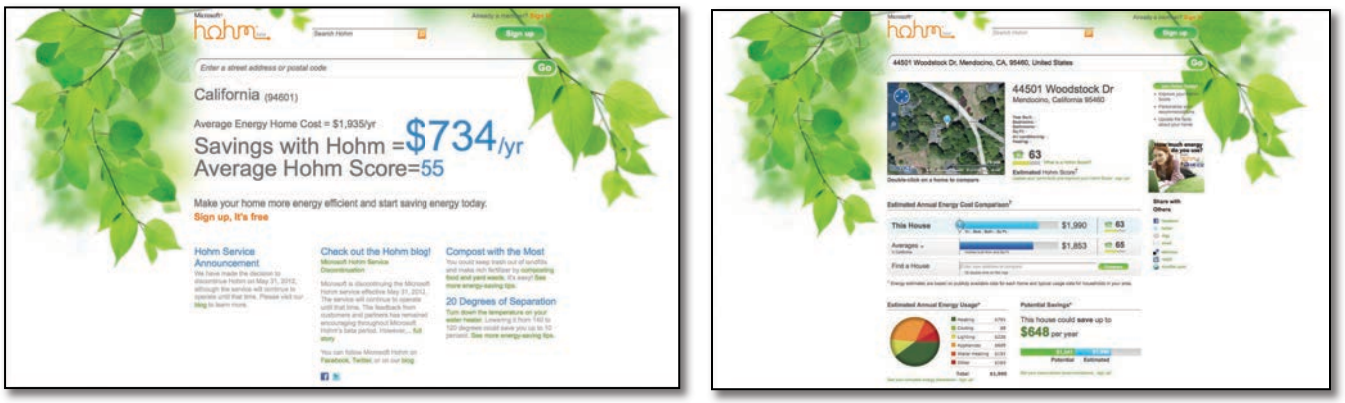
While the shift from LBNL's disk-based energy assessment tools to web-based applications increased the user base from hundreds to millions, the availability of APIs promises to create yet another major increase in users. Implementations could range from tiny "widgets" filling a few square inches on a web page or smartphone to fully featured energy auditing tools. While the services support a whole-house assessment, third-party web service users may be interested in specialized applications (e.g., appliance selection or lighting calculators), which can be "powered' by tapping the relevant elements of the comprehensive API. For LBNL, this extends the analytical frameworks embodied in the Home Energy Saver and EnergyIQ web sites well beyond their own user interfaces. For example, within the first year of launching the HES API, customers of third-party user interfaces collectively doubled overall usage of the system.

First-Generation Implementations by Third-Party Software Developers

Within the first year of their availability, more than 50 entities—ranging from private companies, to nonprofit and educational organizations, to governmental agencies and laboratories—have become users of the HES and EnergyIQ APIs, and more than 100 additional entities have formally registered into the system as potential users. Examples of specific third-party implementations follow:

Microsoft's *hohm* project (Figure 4) was the first third-party website to utilize the Home Energy Saver methods. While it did so before the APIs were available and thus employed a much more labor-intensive programmatic implementation, the end result was the same: a third-party calculator utilizing the HES methods behind the scenes.

Figure 4. Microsoft *hohm*



Using the HES API, Envirolytics developed the first iPhone implementation of the web service (Figure 5).[5] Users flip through a short set of input pages tailored for a Smartphone's screen-size and ergonomics. The App is tailored for consumer use.

Figure 5. iViro's "App" using the HES, designed for iPhone

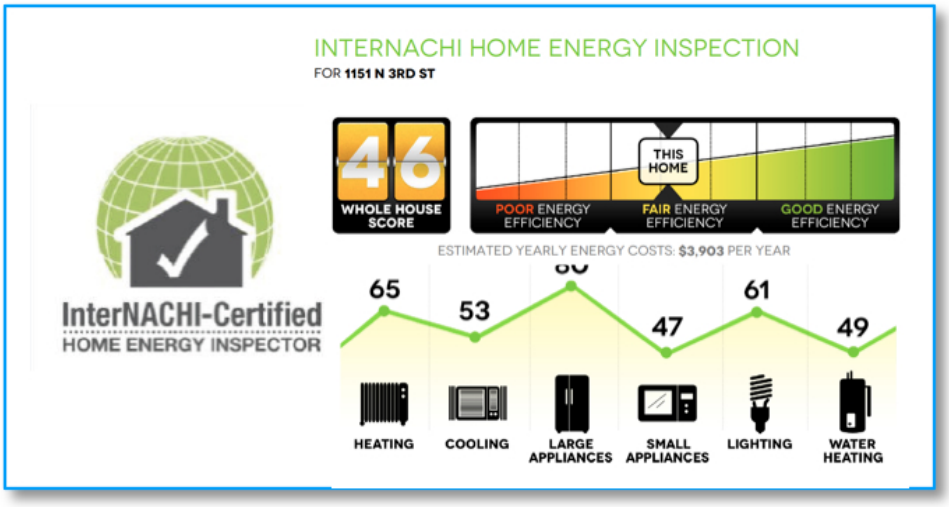
Wattzon[6] has used the HES API to develop their own consumer-oriented web calculator (Figure 6), which analyzes baseline energy use, benchmarks the home against similar homes, and formulates an energy savings plan. The tool is used as a lead-generator for retrofit projects.

Figure 6. Wattzon consumer-focused home energy calculator utilizing the HES API

The International Association of Certified Home Inspectors (InterNACHI) describes itself as the world's largest, non-profit building inspection association. InterNACHI has used the HES API (Figure 7) to develop an energy calculator that their member inspectors can use to advise prospective homebuyers.

[5] See http://itunes.apple.com/us/app/iviro-home-energy-analysis/id462910127?ls=1&mt=8#
[6] See http://www1.wattzon.com/

Figure 7. InterNACHI's tool for home inspectors



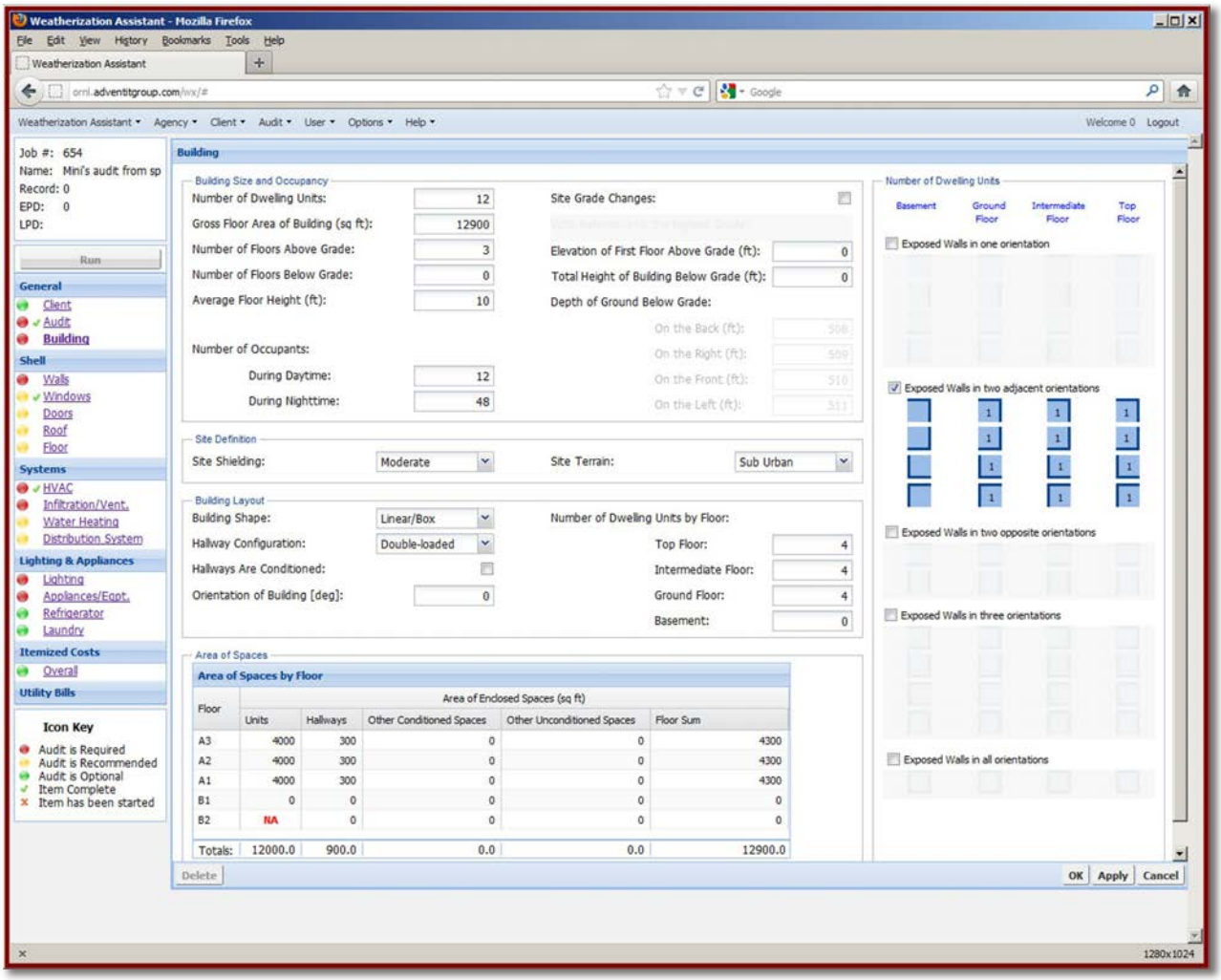
The Minnesota Center for Energy and Environment is developing mobile versions of the Home Energy Scoring Tool (Figure 8), adapted to the limitations of smaller screen size and new features such as data export to CSV file and download to DropBox web service. The tools run on multiple platforms: iOS (iPhone, iPad) and Android (Phone, Galaxy Tab) versions. Qualified home assessors approved by the U.S. Department of Energy (DOE) will have access to the tool.

Figure 8. MNCEE mobile implementation of the Home Energy Scoring Tool

In support of DOE's Weatherization Assistant Program, Oak Ridge National Laboratory is deploying a new tool to rigorously model energy use and savings in multifamily buildings (Figure 9).

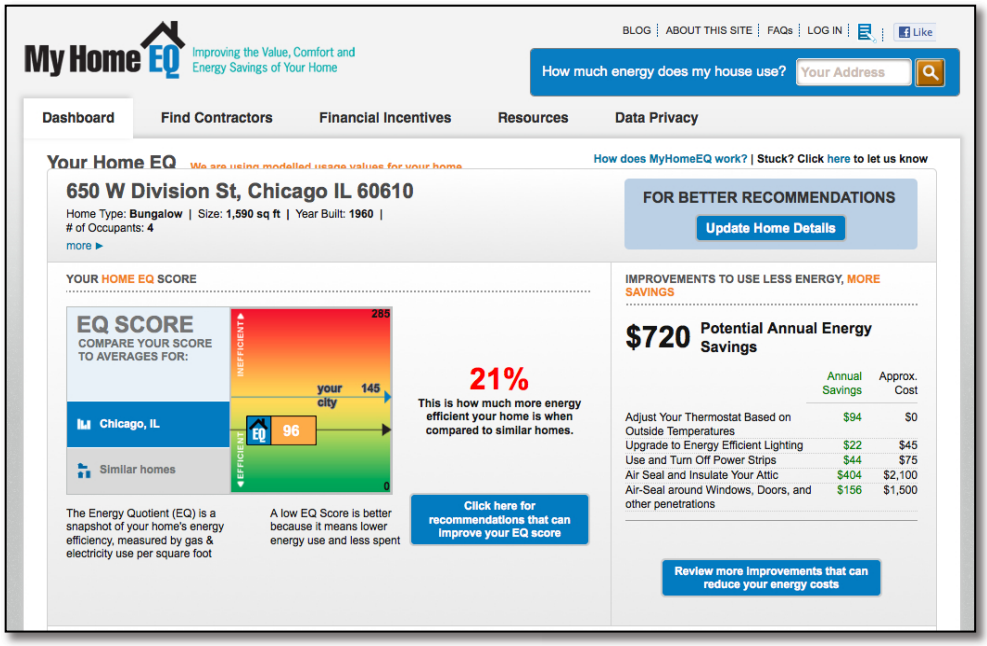
In support of this goal, the Home Energy Saver API has been expanded to model multifamily buildings, and used to power the HVAC and water-heating portions of this tool (Malhotra *et al.,* 2012). The initial version will support central hot water systems and distribution and low-rise building types, with central HVAC and high-rise building types to follow.

Figure 9. Weatherization Assistant multifamily tool prototype using HES API



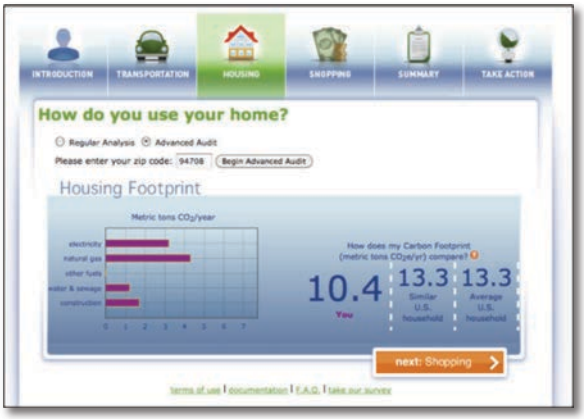
The MyHomeEQ website (Figure 10), produced by a spinoff of the Center for Neighborhood Technology, provides a home energy calculator for Northern Illinois that generates a home rating and provides lead-generation for home performance contractors.

Figure 10. MyHomeEQ web calculator



The CoolCalifornia project of the California Air Resources Board (Figure 11) computes carbon footprints for homes and businesses and provides customized recommendations for saving energy.[7] The service is integrating the HES API for household energy use and the EnergyIQ API for non-residential building energy use, together with analytics and data from other sources. The HES API is used to provide the option of an "advanced audit" calculation, with more input flexibility and specificity than the highly simplified "regular" approach. The results are combined with those from other facets of the user's lifestyle (transportation, consumption) for a combined carbon footprint.

Figure 11. CoolCalifornia carbon-footprint calculator



[7] See http://www.coolcalifornia.org

Additional implementations of the HES and EnergyIQ APIs under development by other licensees include a consumer-facing tool to be imbedded in a utility website, consumer-facing websites which cities will require being used by homeowners as part of a rebate-application process and financing programs, and addition of the Home Energy Scoring tool functionality to existing third-party energy calculators. Another is in development that will match consumers and contractors for upgrade projects.

Caveats

APIs are, by definition, an Internet phenomenon and thus the services provided by them are web-based. Access issues associated with the "digital divide" thus apply here, as with all Internet-based initiatives. A corollary issue is that the provider of the APIs can become a bottleneck in terms of capacity to support simultaneous users, uptime, security, debugging, etc. However, these are issues that any website faces and the methods of managing those risks are well established.

By making it easier for non-specialists to develop energy tools, it is important to beware of a potentially unproductive proliferation of applications based on APIs. In the special case of the Home Energy Scoring Tool, for example, the US DOE is establishing a quality assurance process to ensure that third-party user interfaces and their results are in keeping with the underlying initiative to promote a consistent basis for home energy scoring across the country. We have developed a unique set of APIs have for this use case. However, use of the Home Energy Saver and EnergyIQ APIs is not proscribed in this fashion, as evidenced by the diversity of uses illustrated in this paper.

APIs need to be flexible in order to support innovation and a diversity of uses. Within the HES APIs, for example, is an extensive set of default values enable third-party developers to simplify their user interfaces by skipping inputs that they do not need users to provide, e.g., in the case of do-it-yourself audits for consumer audiences.

Future Directions

A key trend is the notion of "Mashups,"[8] referring to the hybridization of multiple web services to create new and more useful implementations of the original information. The Home Energy Saver has ventured into this domain by integrating location information APIs (through Google Maps) with carbon footprint data produced via the HES API (Figure 12).

More in-depth applications could take the form of integrating end-use energy APIs and renewable energy equipment APIs to facilitate the analysis of Zero Net Energy homes, integration of individual-home models and macro-scale models for energy policy applications, or coupling of energy analyses with financial calculators e.g., for computing home mortgages.

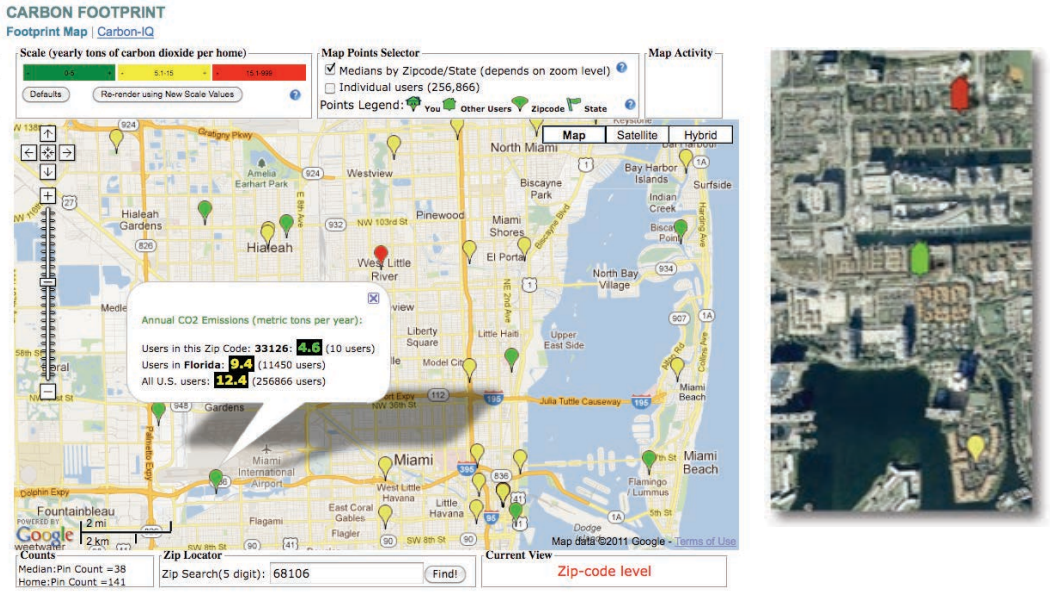
For non-residential buildings, many Energy Information Systems (EIS) vendors have expressed strong interest in incorporating EnergyIQ's action-oriented benchmarking analytics into their dashboards. EIS systems are typically integrated with utility meters and are used to track energy use and costs. Most EIS vendors offer basic analytics such as energy baselining, but do not include cross-sectional benchmarking or identification of efficiency opportunities. AN API link with EnergyIQ could significantly enhance an EIS's existing functionality with a

[8] See http://en.wikipedia.org/wiki/Mashup_(web_application_hybrid)

relatively low level of effort. For users that are already invested in a particular EIS this is especially attractive because they can access this functionality without having to acquire or learn new software.

Utility programs can use EnergyIQ APIs to integrate benchmarking functionality into existing programmatic tool-suites. Tools used for energy audits can incorporate action-oriented benchmarking functionality to improve pre-screening of efficiency opportunities – again without auditors having to acquire and learn new software.

Figure 12. Mashup of Google Maps API and the Home Energy Saver API to visualize carbon footprint by zip code and individual homes (right)



Conclusions

APIs and web services are powerful new technologies in the computer software arena. Applications for buildings energy analysis are providing new opportunities for software developers to create increasingly innovative analytical and marketing tools for a variety of audiences. Web services reduce barriers to market entry for buildings energy software developers and stimulate innovation and support the creation of a more diverse field of third-party tools that inexpensively extend a given set of analytics to serve different audiences and purposes.

Acknowledgments

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