Automating Energy Modeling, In Principal and In Practice

Chris Baker, The Weidt Group
David B. Goldstein, Natural Resources Defense Council
Charles Eley, Eley Consulting

ABSTRACT

The Commercial Energy Service Network (COMNET) is a quality assurance initiative to standardize building energy modeling, by creating consistent baselines relative to various energy codes and standards. COMNET extends and supports existing systems for assessing and rating the energy efficiency of new commercial and multifamily buildings in the United States. In 2010, COMNET anticipated the need for a standard in energy modeling. This standard needed to include default operating characteristics and automated generation of baseline models for purposes such as building asset rating and labeling. This paper discusses the principals and goals of COMNET and lessons learned from applying the COMNET Modeling Guidelines and Procedures (MGP) to an online energy modeling tool for the Massachusetts Department of Energy Resources Asset Rating Pilot. The COMNET MGP was created to increase the accuracy and confidence in energy modeling. It provides standard operating assumptions to be used with the ASHRAE 90.1 Appendix G modeling protocol. It also requires that baseline models be automatically generated so that authorities approving the energy models only need to verify that the design model was input correctly. The COMNET standard was used in the creation of Asset Rater, an online energy modeling application for the Massachusetts Department of Energy Resources (DOER) Asset Rating Pilot Study. This study, called Asset Rater™, created and calibrated models of 11 existing buildings using ASHRAE Guideline 14, and an "as-operated" Energy Use Intensity (EUI) was calculated. The COMNET MGP values for typical schedules, equipment power densities and other operational parameters were substituted for the actual operational parameters so the buildings could be compared with normalized operations. This paper will discuss which parts of COMNET worked well for Asset Rater, and which could be improved.

Introduction

Energy modeling is a valuable tool for identifying cost effective ways to reduce the energy consumption in buildings, and to compare and rank efficiency among different buildings. Standardizing quality assurance (QA) and quality control (QC) processes in energy modeling is critical to the confidence of architects, engineers, owners and investors. Currently the application of QA and QC processes varies widely from firm to firm and even within firms. COMNET has been the industry's most comprehensive step to address issues of QA and QC to date. This paper discusses the creation of COMNET; lessons learned in one application's use of COMNET and suggested next steps for QA and QC in energy modeling.

COMNET

COMNET MGP is a quality assurance guideline focusing on energy models that are being used to predict commercial building energy performance. These models are used for the purposes of code compliance, energy ratings, and incentive/recognition programs. The scope of COMNET aligns with ASHRAE Standard 90.1 and 189.1 by applying to all building types, except low-rise residential.

Why COMNET Was Developed

The motive for COMNET springs, on one hand, from the success of the California Alternative Calculation Method (ACM)[1], and on the other, from the problems at the national level, in both the U.S. and elsewhere, of not having a standard procedure for energy modeling.

In the mid-1980s, California moved from fixed energy budgets look-up tables of required maximum Energy Use Intensity (EUI) to custom energy budgets. With the new procedure, which has subsequently been incorporated in Standard 90.1 and virtually all other energy codes that have a performance procedure, two models are created. The proposed design model represents the building that is proposed for construction. This model includes all the energy efficiency features that are significant to performance. The energy performance of the proposed design is then compared to the performance of a baseline building which is similar to the proposed design in most respects, but is upgraded or downgraded to be in compliance with the prescriptive standards. Buildings can comply with the energy code by showing that the design uses less energy than a similar building with attributes set to the prescriptive requirements. As noted, this fundamental approach has been incorporated in the Energy Cost Budget (ECB) and Performance Rating Method (PRM) in Standard 90.1.

Prior to the development of the California ACM, energy modeling in most jurisdictions[2] was unstructured. Energy modelers were able to tweak objective model inputs such as performance curves in the proposed design while leaving those inputs unchanged in the baseline building, causing just about any building to comply with the standard. It was not realistic to expect code officials to be experts in energy modeling and to catch these little and often subtle differences between the proposed design and the baseline building.

Simulated energy performance using essentially the same procedures used for energy code compliance is also used in a number of other contexts described below. In all of these cases, the modeled results can be considered building asset ratings. Asset ratings rate the physical attributes of the building based on standard levels of energy service and operations and maintenance practices. This allows a potential new occupant to a building to compare different buildings evenly.

Asset ratings face the same problems as code compliance, and more. Nationally, the problem of unstructured procedures is compounded by the many forums in which asset ratings or asset-rating-like modeling is used; energy code compliance, LEED® points, and promotion of a building by using expressions such as “25% below ASHRAE90.1-xxxx”. For the case of code compliance, there is limited use of the performance path in those states that enforce versions of

1 The California ACM is a detailed specification for software used for code compliance in the state. It requires that the software automatically generate the baseline building, apply fixed and restricted inputs to both the baseline building and the proposed building, generate standard compliance reports, and meet minimum standards for accuracy.

2 Several utility incentive programs include modeling procedures and guidelines.

ASHRAE 90.1. This limitation is due in part to the challenge of code officials being able to enforce code properly, as we noted was the case in California in the 80s, and in part to the expense of doing such a calculation. The calculation requires time to set the model inputs both for the proposed design and for the baseline building.

There are several other important uses of the performance approach to code compliance, including:

- Compliance with LEED, and obtaining LEED credits for beyond-code energy savings
- Compliance with the requirements of IRS Code Section 179[3] for tax deductions for efficient buildings
- Demonstration of whole-building savings for utility programs such as Savings By Design[4]
- Use in the ENERGY STAR® Target Finder program

In the early 1990s, several members of the 90.1 ECB project committee suggested that a document similar to the California ACM be developed as part of Standard 90.1. This proposal was not accepted by ASHRAE, both at the project committee level and the Board leadership. One of the concerns was the amount of ongoing effort it would take to create and maintain such a document. In a sense, COMNET is the manifestation of the early vision of the ECB project committee[5], but with a broader scope that includes software accreditation, standard reporting of results, and automation of the software procedures. Because of developments during the dozen years following ASHRAE's decision not to pursue this path, the COMNET initiative has also developed as a response to the desire for harmonization of rating standards. This occurred initially in the North American market, but ideally on a global level, where anecdotal evidence suggests that many asset rating systems give unsatisfactory results for the real estate industry.

One of the significant problems with code compliance and programs that are based on exceeding code minimum is that the baseline is different for different codes, and it frequently changes (Eley 2009). When someone claims that a building is 30% better than code, the first question should be, "Which code?" and the second, "Which version of the code?" Standard 90.1 is under a program of monthly or bi-monthly maintenance and changes. California and other state codes are updated on a regular cycle of three to four years.

To address this problem, a stable scale has been proposed called the Zero Energy Performance Index (zEPI) (Eley 2009 and Eley 2011). zEPI was incorporated in the IgCC[6] in 2013. ASHRAE Standard 90.1 is considering a proposal to adopt a similar stable scale to achieve many of the benefits of zEPI (Rosenberg 2013). The ASHRAE proposal would set the baseline for the performance rating method at a level similar to the prescriptive requirements of ASHRAE 90.1-2004. This is already the U.S. Department of Energy's baseline for code monitoring.

Establishing a stable baseline has many advantages. The same energy analysis could be used for multiple purposes. Software developers could get off the treadmill of trying to keep up

---

3 This tax deduction expired at the end of 2013 but is being considered for reinstatement.

4 Savings By Design is a program operated by the California investor owned utilities that provides a monetary incentive to building owners and designers to construct buildings that exceed minimum code requirements.

5 Charles Eley is the primary author and technical editor of the COMNET MGP. David Goldstein was one of the originators of the COMNET project. Both served on SSPC 90.1 during the time when the *ECB Compliance Supplement* was being discussed and when a draft was actually developed. This draft served as one of the starting points in the development of the COMNET MGP.

6 IgCC is the International Green Construction Code.

with changes to the prescriptive requirements and instead invest in automating the process to comply with COMNET specifications. Code officials and program evaluators would have more confidence in the results. Greater energy efficiency and energy savings would eventually result.

What COMNET Does

COMNET's vision is that its *quality assurance program* be widely used and accepted as the most technically credible and reliable procedure for evaluating the energy performance of nonresidential and high-rise residential buildings. COMNET is intended to support compliance with building energy codes, green building ratings, government and utility programs, and asset ratings.

COMNET's mission is to build consensus among software developers, rating authorities and energy modelers, and through this process, develop and maintain a quality assurance program that consists of the following elements:

- Process for accreditation of energy modeling software that implements:
  - Detailed specification for energy analysis software (MPG)
  - Automation of baseline building generation (required by the MGP)
  - Control of neutral variables (required by the MGP)
  - Generation of standard output reports in both text and electronic formats (required by the MGP)
- Continued review and quality assurance of accredited energy modeling software
- Updates and enhancements to the MGP along with requirements for re-accreditation of energy modeling software
- Development and maintenance of the COMNET portal through which all COMNET accredited energy analysis would pass. The portal quality assurance component would:
  - Make basic and automated quality assurance checks for every COMNET energy analysis
  - Select certain COMNET energy analyses for detailed quality assurance checks by qualified engineers. The sampling size and procedure would be modified to suit the desired level of confidence and budget
- Official interpretations on how the MGP specification applies
- Periodic internal quality audits to identify the extent to which the COMNET documented procedures are followed and the effectiveness of current processes, per ISO 9000
- Credentialing and/or training of energy modelers who participate in the COMNET quality assurance process.

Through dozens of meetings with energy modelers, builders, environmentalists and design professionals, the stakeholders reached consensus on which inputs are allowed to change. All other inputs would be held constant or kept neutral between the proposed design and the baseline building. Some inputs were *neutral independent*, which means that they are fixed at a certain level, with no consideration of the proposed design. Other inputs were *neutral dependent*, which means that they are the same between the proposed design and the baseline building, but the input is dependent on the proposed design. Examples of neutral independent inputs are schedules of operation, thermostat schedules, etc. Examples of neutral dependent inputs are floor area, wall area, and building configuration.

COMNET also requires software to automatically generate the baseline building and to automatically apply the neutral independent and neutral dependent inputs to both the baseline building and the proposed design. This significantly reduces the time required to evaluate a building for the intended purpose and to prepare the necessary documentation.

The challenges facing COMNET are greater than those facing the California standardization effort. California has but one standard and set of modeling rules. COMNET, by contrast, supports multiple baseline building specifications and different purposes. To be used as a compliance tool for Standard 90.1, the procedures must be consistent with the ECB, but LEED and other green building standards use the PRM. Federal tax credits use version 2001 as the baseline, but LEED uses 2007 and now 2010 as a baseline. The Design to Earn ENERGY STAR procedures do not use a modeling baseline and have other restrictions on its use.

To address these issues, the COMNET MPG supports multiple purposes. The MGP content lives within an on-line content management system (CMS) where users can select the purpose that is relevant to them and the content is then filtered to show just what is relevant. The CMS also enables users to make comments about the requirements to help the COMNET technical committee make the material more clear and correct errors. When new purposes are developed, these are available for review within the CMS, where reviewers can post their public review comments and where technical committee members can review and respond to these comments.

Asset Ratings and Operational Ratings

There are two common building energy rating systems, operational ratings and asset ratings. Operational ratings, such as ENERGY STAR, rate the energy consumption of a building including the influence of the occupants and operations, but usually normalizing for weather and hours of occupancy. Asset ratings attempt to isolate the physical attributes of the building such as its envelope, heating and cooling systems, lighting systems, and controls and standardize the level of energy service (including weather) and operations and maintenance (O&M) practices (Goldstein 2014). Both ratings are valuable, because they highlight different aspects of energy performance. In the often cited analogy, asset ratings are akin to miles-per-gallon (MGP) ratings for cars, and operational ratings are akin to your actual consumption of gasoline based on your driving habits.

Operational ratings are useful for comparing the energy consumption of a portfolio of similar buildings. However, with just an operational rating it is unclear how much of the energy performance is due to the level of energy service demanded by occupants, or quality of O&M practices or how much is due to the energy efficiency of the building assets. Careful O&M and low levels of energy use due to diligent occupants who turn off lights when there is sufficient daylight can result is an excellent operational rating even in a building with poor energy efficiency assets. Conversely, a high level of energy use (see Figure 3 for an illustration) may yield a high operational rating no matter how efficient the building and its O&M are. This limits the usefulness of operational ratings for real estate decisions that need to focus on the building assets.

Figure 1. Example of high level of energy services.

Asset ratings on the other hand account for the occupants and operations and rate only the physical attributes of the building based on standard levels of energy services and O&M practices. This allows a potential new occupant to a building to compare different buildings evenly.

Operational and asset ratings are both useful independently, but when used together they can provide even more information. By comparing the two ratings, a building owner can see if they need to focus on operational changes or make capital investments to improve energy efficiency. While not ratings, the Energy Services Index and O&M Index have been proposed as a way to isolate the impact of these factors (Goldstein 2014).

NEEP and DOER Asset Rating Pilot Project

Several organizations, including The Massachusetts Department DOER, the Northeast Energy Efficiency Partnership (NEEP), and the U.S. Department of Energy (DOE) have been interested in developing ways to isolate the energy performance of building assets independently of the occupants and operation, an essential requirement of asset ratings. DOER and NEEP issued an RFP and selected three organizations to develop pilot studies to develop and test asset ratings. As one of the three phase-one pilot studies The Weidt Group developed an energy modeling web-application called Asset Rater.

Process

The DOER provided key attributes that would typically be available for a building from an ASHRAE Level 1 Audit walk-through as inputs for each of 11 pilot buildings as well as 12 months of utility consumption data. The web-application Asset Rater used these limited inputs and created DOE-2 models of the buildings. The initial energy modeling results by end use were then compared with the end uses derived from their utility bills and a PRISM (Reichmuth and Turner 2010) disaggregation to estimate the portion of energy that is heating, cooling, and internal loads. The disaggregated end-use energy provided clues about the unknown building values that needed refining for model calibration. We were then able to approach the model calibration simultaneously and iteratively from three different directions to estimate the unknown values:

1. Match the derived end-use energy as closely as possible
2. Match the total annual consumption for each fuel as closely as possible
3. Reduce the mean bias error and the root mean square deviation to within acceptable limits.

The scope of the study did not include a site visit to confirm the estimates for heating, cooling, internal loads and calculated unknown values for each fuel type.

Asset Rater then took the building model with the as-operated schedules and automatically substituted the operational values from COMNET and created a unique benchmark building based on an ASHRAE 90.1-2007 Appendix G baseline building. The building and its subsystems were then rated as a ratio of their energy consumption divided by their benchmark energy consumption as shown in Equation 1.

Equation 1

$$Asset\ Rating = \frac{Building\ EUI\ with\ COMNET\ Operations}{Benchmark\ EUI\ with\ COMNET\ Operations}$$

The pilot study was limited to office buildings, but this method allows dissimilar building types to be compared. A building with an asset rating less than 1.0 is already performing well and will have less potential for additional savings from capital investments than a building with an asset rating of 1.5 or greater.

Individual Building Asset Scores

This section provides a graphical *Asset Rater* Report for a sample building. It graphs the Asset Index and provides Asset Model EUI for:

- Site energy for each end-use
- Site energy use for each fuel type used in the building
- Total site and source energy

An Index value less than 1.0 indicates efficient asset with low improvement potential, and a value higher than 1.0 indicates improvement potential for the asset. The overall Asset Index is 1.33 based on the total source energy.

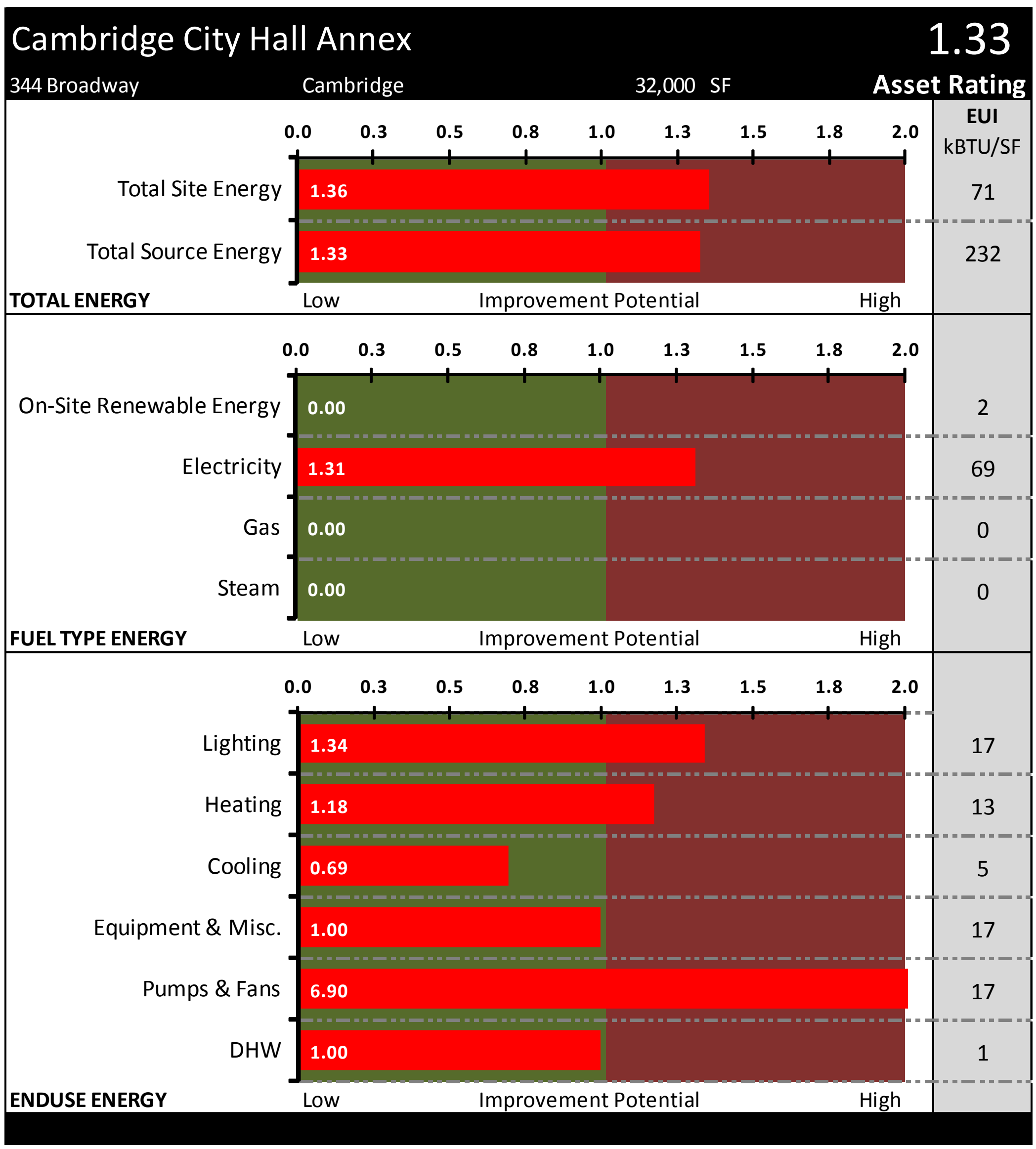

Figure 2. Individual building asset scores.

Figure 2 below shows how the buildings ranked with different metric systems, with 1 being the best building by that metric, and 11 being the lowest performing. If all of the methods agreed, there would be consistent color banding rows for each building. The fact that there is not consistent color banding indicates that there are differences when comparing the metrics. The benchmark ratio in the table below is the ratio of the building's energy use divided by that of its benchmark.

	As-Operated Site EUI Rank	As-Operated Source EUI Rank	Asset Model Site EUI Rank	Asset Model Source EUI Rank	Benchmark Ratio Site EUI Rank	Benchmark Ratio Source EUI Rank
Building 1	2	7	1	5	6	6
Building 2	11	5	11	6	10	8
Building 3	10	10	9	10	9	9
Building 4	1	3	7	9	2	2
Building 5	5	2	10	8	11	11
Building 6	4	1	2	1	1	1
Building 7	6	4	6	3	5	4
Building 8	8	9	5	4	7	7
Building 9	9	11	8	11	8	10
Building 10	3	8	3	7	4	5
Building 11	7	6	4	2	3	3

Figure 2. EUI ranks.

This chart illustrates why isolating the effects of the asset from the operations and occupants is important. If investment decisions were made strictly based on the relative EUI of a building, investments may be misallocated. The buildings with the greatest potential are the buildings that are using more than their benchmarks. The EUI may be greater because of an expanded data center, a new cafeteria, or other high energy use space that has only limited savings potential. This supports many of the ideas explored in Goldstein 2014 specifically that asset and operational ratings will vary for a building because of differences in operations and energy use.

The Value of Asset Ratings

Asset ratings are important for two reasons. First, they allow a building operator to evaluate energy efficiency assets with standard energy use and O&M. Comparing how an individual building performs with an asset rating versus an operational rating can provide insight into whether energy performance would improve more from capital investments or from operational improvements such as staff training or commissioning. A building with a poor asset score and a good operation score would see more improvement with capital investments. A building with a good asset score but poor performance score would improve more with attention on operational and energy use issues. Furthermore, when such comparisons are performed on a more systematic basis and compiled, they can provide an analytic basis for updates to the requirements in the COMNET MGP so that it better predicts average metered energy consumption.

Second, when there is a real estate transaction such as a lease or sale of a building, that transaction will only leave the asset in place. A new owner or tenant may find that a building with a great operational rating performs poorly when occupants require a higher level of energy service or are less diligent about turning off lights and behaving efficiently. Asset ratings remove those variables and allow a fair comparison of the physical attributes of the building. Figure 2 demonstrates this difference: Building 4 has the lowest As-Operated Site EUI, but with standard operating conditions, it drops to ninth of eleven. Similarly, Building 6 has the best asset rating, but only a middling as-operated site EUI.

How Asset Rater Pilot Project Used COMNET

Although Asset Rater addressed existing buildings and the three purposes of COMNET are all focused on new buildings there were several aspects of COMNET that were used directly by our application, and many other parallels between COMNET concepts and concepts applied in Asset Rater.

Much of what Asset Rater used directly from COMNET was the vetted operational assumptions in Appendix B of COMNET. These assumptions include temperature set points, schedules, plug loads, ventilation rates and others. By having assumptions for these that were established by an independent third party, we saved a significant amount of time and effort by not having to scrutinize these assumptions. Several of these values are not new to COMNET, but having them all in a single place simplifies the discussion rather than referring to the 90.1 User's Manual, ASHRAE Handbooks, ventilation standards and other sources.

Many of the principals we used to develop Asset Rater have parallels to COMNET. For instance, we did not specifically test Asset Rater with the acceptance criteria that COMNET establishes for the ASHRAE Standard 140 tests of simulation engines, but we did use DOE2, a simulation engine that has been previously vetted against Standard 140.

Asset Rater also used standardized modeling procedures to translate the inputs into DOE2 input files and automatically generated a baseline building that is compliant with Standard 90.1-2007 Appendix G. We did this using an internally developed web-service that allowed us to specify simple inputs and derived a typical building with those attributes. This means that regardless of who is operating the tool the building components were modeled the same way. By programming the modeler's judgments on how to model the building components we eliminated the variation that can emerge from different modelers using different techniques to represent a building.

Where the Asset Rater Diverged From COMNET

A large reason Asset Rater Pilot project diverged from COMNET requirements is it has a different purpose than the three original purposes for COMNET. All three of those purposes involve new construction with complete construction documents. It is important that COMNET codifies how energy performance is calculated at that milestone because that is when a building is deemed compliant with the energy code as well as when the savings beyond the energy code of the design are calculated. However, this is only one brief moment in the life of a building, and energy modeling is useful both before and after this moment. The value of modeling to inform design throughout the process has long been recognized and is beginning to be set into code by efforts such as the proposed ASHRAE Standard 209 Energy Simulation Aided Design for Non Residential Buildings.

Asset Rater in particular was developed for existing buildings and to only require a basic walk through of a building to establish the inputs. This means that we needed to use typical air handler assignments, make assumptions about wall insulation when not known, and in other ways create a lower fidelity representation of the building than would be required for COMNET purposes. Because the model was lower fidelity many of the building description inputs required by COMNET were algorithmically derived for Asset Rater.

Asset Rater did not require the building description details that regulators envisioned for COMNET because Asset Rater in this pilot phase was only going to be used by a handful of expert users. If Asset Rater is developed for public use, we will likely include input checks to make sure non-expert users are submitting rational inputs.

Conclusions

Industry wide agreement on QA and QC will provide more consistent energy modeling, and with the automation of consistent baseline generation, modeling will be cheaper with no compromise (and most likely an increase) in accuracy. Reviewing those models will also take less time and be more cost effective thanks to automatically generated baselines and a standard reporting schema. An important step to getting more software developers to automate the generation of baselines will be the adoption of a fixed baseline. A fixed baseline will allow the investment to be amortized over more than the current three year code cycle.

COMNET has been a step forward in QA and QC for energy modeling. The next step is to update the standard based on the lessons learned by software developers as they work to apply COMNET to their applications. This will allow the use of COMNET in a wider range of software. Wider adoption will lead to more feedback, refinement and hopefully even wider adoption until COMNET certified energy modeling software becomes standard across the industry.

Acknowledgements

The Weidt Group would like to acknowledge NEEP and DOER, under who provided funding and oversight to the Asset Rater pilot.

References

COMNET, 2014, Modeling Guidelines and Procedures, C. Eley Technical Editor, available at www.comnet.org/mgp.

Eley, C. et. al., 2009, Rethinking Percent Savings, The Problem with Percent Savings and the New Scale for a Zero Net-Energy Future, published and funded by Southern California Edison, July 22, 2009.

Eley, C. and R. Higa, K. Goodrich, D. Rauss and John Arent, 2011, Rethinking Percent Savings – The Problem with Percent Savings and zEPI: The New Scale for a Net Zero Energy Future, ASHRAE Transactions, 2011, Vol. 117, Part 2.

Goldstein, D. and C. Eley, 2014, A Classification of Building Energy Performance Indices, Energy Efficiency Magazine, DOI 10.1007/S12053-013-9248-0.

Reichmuth and Turner 2010. *A Tool for Efficient First Views of Commercial Building Energy Performance*, Proceedings of ACEE Summer study on Energy Efficiency in Buildings, Pacific Grove, CA, August 2010.

Rosenberg, M. and C. Eley, 2013, A Stable Whole-Building Performance Method for Standard 90.1, ASHRAE Journal, May, 2013.