Setting Whole-Building Absolute Energy Use Targets for the K-12 School, Retail, and Healthcare Sectors

Matt Leach, Eric Bonnema, Shanti Pless, and Paul Torcellini,
National Renewable Energy Laboratory

ABSTRACT

Careful goal setting is required to design and construct high-performance buildings. Percent savings goals are popular and can be effective but depend heavily on an often theoretical baseline case against which savings are measured. Specification of whole-building absolute energy use intensity targets can help designers and owners ensure that the desired level of performance for a project is achieved. Some benefits of whole-building absolute energy use intensity targets are that they:

- Provide a directly measureable target that enables clear and straightforward determination of energy performance success
- Compel design and construction teams to realize energy performance goals by explicitly including energy targets in contractual documents
- Emphasize the importance of capturing whole-building energy use, as opposed to a subset of building energy uses required for compliance with building codes or certification programs

This paper helps owners' efficiency representatives to inform executive management, contract development, and project management staff as to how specifying and applying whole-building absolute energy use targets for new construction or renovation projects can improve the operational energy performance of commercial buildings. The absolute energy use targets developed for the 50% series of *Advanced Energy Design Guides*, which promote the use of economically replicable, industry-vetted, energy efficiency strategies, are emphasized. Sector-specific absolute energy use targets that account for sector-wide programmatic variation are presented for K-12 schools, medium- to big-box retail stores, and large hospitals.

Benefits of Whole-Building Absolute Energy Use Targets

The value of whole-building absolute energy use targets has been demonstrated through real-world application (Brown et al. 2010; Pless et al. 2011). The following section highlights ways in which the specification of such targets increases the likelihood that pitfalls associated with the specification of traditional energy performance targets can and will be avoided.

Importance of a Clearly Defined Goal

A clearly defined energy performance goal brings focus to a project. When energy performance is defined in terms of a percent savings goal, significant analysis is typically required to translate that goal into a specific energy use target. Establishing a baseline requires assumptions that allow significant individual interpretation. Even with the best of intentions, generating a baseline that accurately represents the project can be time consuming; the subjective nature of this process (especially as it relates to defining quantities not governed by codes or standards, such as plug and process loads [PPLs]) can also easily be exploited to game rating or certification procedures. Whole-building absolute energy use targets provide clear energy performance goals that leave no room for interpretation.

Importance of Goal Verification

Building energy performance is rarely measured (using utility bills or installed metering); most commonly, an energy model representing the final low-energy design is used to determine percent savings over the baseline model. Energy modeling is extremely valuable for defining energy use targets, predicting building performance throughout the design and construction process, and setting end-use energy budgets, but the inherent differences between simulation and reality make it impossible for energy modeling results to fully represent the actual building. Thus, occupied building energy use must be measured to determine if energy performance goals have been met. Specification of whole-building absolute energy use performance targets shifts the focus of performance verification away from energy modeling and towards building measurement; whole-building absolute energy use can be measured with utility bills, allowing for simple and straightforward verification of energy performance goals.

Importance of Capturing Whole-Building Energy Use

A primary limitation of traditional goal setting, which typically measures performance against the requirements of a prevailing building code or recognized national standard (such as ASHRAE Standard 90.1), is that such goals address only a subset of the energy-using building systems (typically neglecting PPLs, realistic operational schedules, etc.). Depending on the application, nonregulated loads, such as PPLs, can dominate energy use, and must be understood and controlled to meet energy performance goals (Brown et al. 2010). Specification of whole-building absolute energy use targets necessitates that all energy-using building systems are considered and reflected in energy performance goals.

Consideration of whole-building energy use will often foster discussions that focus on often-overlooked energy use implications. Evaluation of whole-building energy use requires that the term *whole-building* be defined. We define whole-building as the building and its immediate site. We also define energy targets with respect to site energy, as opposed to alternative energy use metrics such as source energy or carbon emissions.

Importance of Maximizing Project Resources

Specific and measurable energy use intensity goals, as opposed to prescriptive design requirements, allow for design flexibility and encourage innovative, cost-effective, and integrated design strategies. Specifying a whole-building absolute energy use goal alleviates the need to create and maintain a baseline energy model; this allows the design team to focus all resources on developing the low-energy design. To further maximize resources, the project can be defined such that the design and construction team is awarded bonus fees when it reaches the whole-building absolute energy use target (Pless et al. 2011).

Tailoring Whole-Building Absolute Energy Use Targets to Project Parameters

Determining a project's achievable energy performance level requires a complete understanding of where and how the building will use energy. The next section highlights key parameters that influence energy use, and provides guidance on how those parameters should inform the energy target selection process.

Defining Key Project Parameters

The following project parameters have a particularly strong impact on energy use and should be considered with particular care.

- **Building function:** Buildings are designed for the functions they will facilitate, and different building functions have different energy use characteristics. Retail buildings, for which merchandise display is a key function, typically have large lighting loads. Office buildings typically have high computing loads, and often require dedicated data centers. Some buildings may be considered as hybrids of other, single-function types (e.g., a hospital with medical offices). Functions such as electric vehicle charging stations and exterior lighting, which may be exterior to the building but still included in the immediate building site, must be included.
- **Climate:** Envelope and ventilation loads, and the effectiveness of many efficiency strategies, vary with climate; for example, natural ventilation is most effective in mild climates. Energy performance of buildings with lower surface-area-to-volume ratios or lower outdoor airflow requirements is less affected by climate.
- **PPLs:** These vary with building function and can have a substantial impact on whole-building energy use.
- **Hours of operation:** Operating requirements can differ between night and day. Cooling loads are larger during the day, whereas heating loads (in the absence of temperature setback) are larger during the night. For exterior spaces, lighting equipment is typically used only at night. Strategies that require solar energy or daylight are beneficial only during the day. And some strategies require spaces to be unoccupied when employed (e.g., night economizing to cool thermal mass). Accordingly, hours of operation can significantly affect how a building uses energy and which strategies can effectively reduce energy use.
- **Occupancy:** Occupancy dictates ventilation requirements. Occupants can also be a significant source of internal loads, both sensible and latent. Understanding occupancy densities and patterns is critical for system sizing and control schemes. Buildings with significant variations in occupancy must have systems that are designed to operate efficiently over a wide range of loading conditions.
- **Service level:** Building energy use is strongly tied to the level of service for which a building is designed. Requirements for comfort and indoor air quality should be clearly defined. Certain space types may have unique conditioning requirements; for example, grocery sales areas are often maintained at a lower-than-normal dew point to reduce refrigerated case loads and prevent condensation.

- **Specialty space types:** Some buildings have specialty space types, such as data centers or laboratories, with unique loads. Characteristics of such space types are often project specific and can be difficult to define. Accordingly, specialty space types often require separate energy use analysis.

Using Project Parameters to Focus the Target Selection Process

When specifying whole-building absolute energy targets for a project, it is wise to survey standard and best practices for the applicable building type. Case studies of projects demonstrating best-in-class efficiency provide insight into what can be achieved. Survey of the existing stock of a building type establishes typical energy use and provides context for best-in-class performance.

Significant information is available to inform the specification of whole-building absolute energy use targets (50% *Advanced Energy Design Guide* (AEDG) series, Commercial Buildings Energy Consumption Survey (CBECS), High Performance Buildings Database, ENERGY STAR® Target Finder, portfolio data, local building utility data, etc.); the challenge is filtering those data to extract the most applicable information. Defining key parameters and seeking out comparison data and target-setting recommendations according to compatibility with those parameter definitions can focus the target selection process and enable better-informed decision making.

Using Subsystem Targets

Specialty space types may require separate analysis to determine subsystem targets. For example, a large, dedicated, data center represents a specialty space type that is very different from typical office building space types; data centers are typically thermally isolated from other space types and require dedicated heating, ventilation, and air-conditioning (HVAC) equipment and strategies. Accordingly, it may be useful to isolate the data center from the rest of the building and analyze it separately, seeking out case studies that highlight efficiency strategies specific to data centers. Wet and dry laboratories, commercial kitchens, surgery suites, and indoor swimming pools may also require this type of analysis.

Specialty space types may have unique energy performance metrics. For example, data center performance is measured with respect to power usage effectiveness, a ratio of total data center power consumption to computational power production.

Specifying Whole-Building Absolute Energy Use Targets

This section presents varying approaches to using building parameter definitions and available resources to specify aggressive and achievable whole-building absolute energy use targets. Each approach follows the same basic steps:

1. **Define project parameters:** All parameters that affect energy use should be defined; especially those that have a particularly strong impact on energy use.
2. **Survey applicable resources:** These will vary by project. For many projects, comparable industry best practice case studies will be available. For owners with a large portfolio of buildings that share a prototypical design, extensive measured data may be available for nearly identical projects. For projects that are more unusual, possibilities may include

high-level comparison against a building type at the national or local level, piece-wise comparison of building sections designed for distinct functionality, and increased reliance on energy modeling to predict the energy use implications of project-specific parameter definitions.

3. **Select goal reference and specify target:** Ideally, targets should be set based on technical and economic feasibility. In this respect, the whole-building energy use that the target represents is important, not the reference point against which it is measured. Reference points can provide context for energy goals, however; a target of "30% better than the previous building" likely has more meaning than the whole-building energy use that such a target represents (in kBtu/ft^2, for example).

Many resources may be applicable, and the design team will have to weigh options to select a reference point on which the target will be based. For example, many reference points may be available to an owner with a portfolio of buildings that share a prototypical design: comparable best practice projects for similar buildings, Retail AEDG energy targets, mean portfolio performance, best practice portfolio performance, ENERGY STAR Portfolio Manager, and CBECs data for the appropriate building type.

The following subsections focus on Step 3.

Specifying Whole-Building Absolute Energy Use Targets According to Industry Best Practice

Industry projects demonstrating best practice may be excellent reference points for energy use target setting. Best practice performance should be identified and targeted any time it is cost effective or otherwise justifiable (e.g., corporate image boost). Potential issues associated with this approach may include:

- Best practice projects that align with the key parameter definitions of a project cannot be identified;
- Best practice projects that align with the key parameter definitions of a project do not align with the project budget; and
- Best practice projects cannot be identified that achieve the level of performance desired by the design team.

The K-12 School, Retail, and Large Hospital AEDGs provide guidance for specifying whole-building absolute energy use targets to achieve 50% savings beyond ASHRAE Standard 90.1-2004 (ASHRAE 2004); 50% AEDG energy use targets represent industry-vetted, economically replicable absolute reference points for industry best practice. Another resource for best practice is the High Performance Buildings Database.

Specifying Whole-Building Absolute Energy Use Targets According to Portfolio Performance

An owner may have a portfolio of buildings that share a prototypical design; building design may vary somewhat by climate and functionality, but is similar for many projects. In such cases, portfolio energy performance data are invaluable, as they provide options for selecting a reference point for energy use target setting. Such data enable an owner to determine typical performance and compare it to that for the most and least energy-efficient buildings in the portfolio. Poor performers represent straightforward opportunities for improvement; top performers represent what is possible with the current prototype design and reference points for efficiency improvements. These data can be used to validate or reject efficiency strategies, highlight opportunities for improvement, and illustrate a path of continuous improvement.

The greatest benefit of comparing a building to other buildings in a portfolio is that the resulting comparison projects have nearly identical project parameter definitions. The biggest downside is that it tends to perpetuate the design status quo. The top-performing buildings may fall short of industry best practice in a number of respects; considering examples of best practice throughout the industry as a whole may shed light on design deficiencies and encourage forward thinking. ENERGY STAR Portfolio Manager compares building energy use to CBECS data and assigns efficiency scores that define individual building energy performance with respect to the CBECS dataset. The score of the top-performing buildings establishes a context for portfolio performance and defines the gap between current design and industry best practice.

Using High-Level Sector Data to Specify Whole-Building Absolute Energy Use Targets

For some projects, comparable industry best practice projects may not be identifiable and portfolio-based comparisons may not be possible. In such cases, high-level sector data sources such as CBECS and ENERGY STAR Target Finder may be used to inform target setting. Such sources can provide a high-level look at energy use across a sector and for a certain location. Sector-average energy performance incorporates the performance of buildings of varying vintages and typically does not match performance characteristics of compliance with current codes and standards; such high-level data are useful to establish context for project goals, but cannot typically be benchmarked against project-specific parameter definitions to the extent required to ensure whole-building absolute energy use targets are achieved.

Using Energy Simulation to Specify Whole-Building Absolute Energy Use Targets

If a project cannot be accurately characterized using industry best practice case studies, portfolio data, or high-level sector data, annual whole-building energy simulations can be used to specify absolute whole-building energy use targets. A detailed whole-building energy model can accurately capture any and all project-specific features and provide accurate energy use predictions that can be used to specify achievable, aggressive targets. The downside to energy modeling is that it is resource intensive and requires simulation expertise. Ideally, it should be used to supplement best practice case studies and/or portfolio data and be used to explore the impact of project-specific parameters that are not sufficiently characterized by other sources.

Using Absolute Energy Targets throughout a Project to Improve Energy Performance

An energy performance goal must be considered during each stage of a project, starting with the proposal and continuing through commissioning to building occupancy and operation. All design and construction decisions should be considered for their energy performance implications. This section highlights the ways whole-building absolute energy use targets can be used to increase the probability of energy performance success at various stages.

This section also details how energy modeling can be used to ensure that whole-building absolute energy use targets represent energy performance goals and can ultimately be achieved during building operation. Annual whole-building energy modeling represents the most comprehensive way to combine all aspects of building design that affect energy use into a holistic analysis of whole-building energy use.

Case studies of similar projects are valuable resources for specifying these targets. They can be used to select efficiency strategies and to predict a likely range of energy use based on similarity to a proposed design. A case study is rarely fully compatible with the set of parameters definitions for a given project, however. Energy modeling can be used to bridge this gap by facilitating project-specific evaluation of efficiency strategies identified through a case study survey.

Team Selection Stage

Selecting a design and construction team is critical to project success. If the owner or the owner's efficiency representatives can establish whole-building absolute energy use targets before the team is selected, team members are much more likely to be selected for their ability to reach the performance goal within the specified budget.

In a design-build scenario, including whole-building absolute energy use targets in the request for qualifications frees respondents from prescriptive design requirements and encourages innovative, cost-effective solutions. Willing and positive team participation to help meet energy performance requirements can be further encouraged via a voluntary incentive program that offers an award fee of 2%-3% of the total contract fee. This can be especially valuable during commissioning and warranty periods because it gives the design team a financial stake in identifying and addressing performance issues (Pless et al. 2011).

Using energy modeling to inform the team selection process can have significant benefits. Although approximate energy use goals based on case study research may be minimally sufficient to characterize the design problem at the team selection stage, energy modeling can be used to focus energy use goals by accounting for project-specific parameter definitions. Contractual inclusion of whole-building absolute energy use targets requires accurate energy use predictions that carefully consider all building energy uses. Greater confidence in predictions allows for more aggressive targets, and comprehensive whole-building energy modeling (energy simulation, thermal bridging calculations, daylighting modeling, natural ventilation modeling, thermal storage modeling, renewable generation calculations, specialty space type modeling, etc.) results in the most accurate predictions (Hirsch et al. 2011). Energy modeling can also be used to evaluate applicants' proposed design solutions. And because energy modeling is useful throughout the project, this capability should be an important applicant evaluation criterion.

Early Design Stage

Traditional goal-setting exercises tend to neglect energy uses not governed by the relevant building code or certification process. Because whole-building absolute energy use targets apply to all energy uses in a building, the process of specifying aggressive energy performance goals using these targets often identifies a wider range of energy use considerations.

The early design phase provides an opportunity to identify and understand efficiency opportunities for often-overlooked programmatic energy uses. Key examples include space planning, equipment organization, and operational schedules. For example, space layout considerations can affect design flexibility later. Designing an office space to prevent exposure to direct sunlight can alleviate elevated perimeter conditioning requirements and allow radiant cooling solutions to be considered.

It is important to understand the distribution of energy use types (loading type, operational schedule, etc.) throughout a building. Zoning spaces according to similarities in energy use type allows for the consolidation of HVAC equipment, reducing first costs and operation and maintenance costs. When considered during the early design stage, such issues can be resolved appropriately and cost effectively; as the design process progresses, potential solutions become less viable.

Energy modeling should be used in the early design stage to determine the extent to which whole-building absolute energy use targets need to inform the design of the building form (Hirsch et al. 2011). Architectural decisions can be made to ensure that building orientation, massing, and layout contribute to the achievement of energy goals, often at no additional fixed or life cycle cost. Many efficiency strategies, such as daylighting, thermal mass distribution, natural ventilation, and solar shading, require integration with the building envelope and structure. By using energy modeling to evaluate and incorporate these simple and passive strategies into the early design, a design team can significantly improve the probability that targets can be met within budget (Pless et al. 2012). Incorporating strategies that require integration with the building envelope and structure becomes progressively more difficult and expensive as a project progresses (Pless et al. 2011). During the early design stage, energy modeling can also be used to answer questions about efficiency strategies as they relate to energy use targets. Is daylighting necessary? What types of HVAC systems can I use to reach my goals?

Construction Stage

During construction, the impact of change orders on the overall energy budget should be carefully considered. Where they significantly impact energy use goals, they should be reevaluated.

Construction contractors are typically unaware of energy performance goals, but whole-building absolute energy use targets can be written into contracts to provide contractors a financial incentive to help a project reach its energy performance goals.

As-Built Stage

Once design decisions are finalized and the building is constructed, all the necessary information is available to finalize end-use energy budgets. To be useful, these budgets must be realistic and take into account all operational details that affect energy use. Whole-building absolute energy use targets are a valuable reference during the specification of end-use energy budgets; the summation of these budgets should be no greater than the whole-building energy use target. An added benefit of this exercise is that the careful scrutiny required may highlight potential operational issues that would otherwise be overlooked (e.g., sequences of operation as they relate to system interactions).

As construction is completed, energy models should be updated to reflect any discrepancies between the final design and the constructed building. In particular, installed equipment power draws (including parasitic) should be measured and used to update energy model inputs (Hirsch et al. 2011). PPLs are notoriously difficult to predict and can have a significant impact on achieving an energy use target. Understanding installed loads and specifying energy model inputs accordingly can inform how associated control strategies may need to be updated to ensure that the PPL end-use energy budget will be met. As-built energy models should also reflect any differences between shop drawings and original plans, as well as the results of commissioning and testing and balancing.

As-Operated Stage

Once the building is operational, end-use energy budgets can be used to inform the control sequence commissioning process and to fine tune control schemes. The owner can compare actual end uses to energy budget allowances (using real-time, submetered data), to identify and reconcile discrepancies between design and operation: set points can be updated to match actual (as opposed to predicted) occupancy patterns; operation sequences can be modified to improve synergy between strategies such as economizing, natural ventilation, and supply air temperature control.

Energy models should be updated to reflect any changes made to control schemes or operational schedules during the control sequence commissioning process. Measured data should ultimately be used to evaluate the success of a project with respect to whole-building absolute energy use targets, but the final state of whole-building energy models should also be evaluated. Energy modeling results should be compared to measured whole-building and system-level (submetered) energy use data; discrepancies should be investigated and opportunities for improving modeling inputs should be identified. Lessons learned can inform future energy modeling efforts and improve the accuracy with which whole-building absolute energy use targets and end use energy budgets can be specified.

Comparing actual end use to energy budget allowances requires measurement and verification. Real-time, submetered data are required, and dashboards and displays designed to facilitate data analysis are strongly recommended.

AEDG Whole-Building Absolute Energy Use Targets

The U.S. Department of Energy has partnered with professional societies (ASHRAE, AIA, USGBC, and IES) to develop a series of AEDGs to provide cost-effective, industry-vetted recommendations for achieving energy performance that goes well beyond the minimum requirements of commercial building codes. The AEDGs offer a prescriptive path for design teams (building owners, architects, designers, engineers, and builders) to achieve significant energy savings without intensive calculations or complex analyses outside the scope of their normal practices. The initial series of six AEDGs provided recommendations for achieving energy savings of 30% beyond ASHRAE Standard 90.1-1999 (ASHRAE 1999); the series covered small office buildings, small retail buildings, K-12 school buildings, and small warehouse and self-storage buildings. A new series of AEDGs provides recommendations for achieving energy savings of 50% beyond ASHRAE Standard 90.1-2004 (ASHRAE 2004); AEDGs for small and medium office buildings, K-12 school buildings, medium to big box (20,000 to 100,000 ft^2) retail buildings, and large hospitals have all been published. These provide a prescriptive path to 50% savings as well as a performance-based path; in particular, these AEDGs contain guidance for setting whole-building absolute energy use targets. This section highlights the merits of those energy targets, describes the methodology behind their development, and provides guidance on their applicability.

Merits of AEDG Whole-Building Absolute Energy Use Targets

Much as the AEDG prescriptive paths are designed to simplify the path to economically replicable, industry-vetted savings, the AEDG energy use targets are designed to simplify the process of setting whole-building absolute energy use targets. The AEDG energy use targets are whole-building, absolute targets that align with 50% savings beyond current commercial building code (ASHRAE Standard 90.1-2004). Specifying AEDG whole-building absolute energy use targets and following the prescriptive recommendations of the 50% AEDGs (which have been demonstrated to meet or exceed the AEDG energy use targets) represents a clear, easy-to-follow path to specifying and achieving whole-building energy use targets that reflect industry best practice in energy efficiency.

The design team should not feel obligated to follow the prescriptive recommendations of the AEDGs; the prescriptive path represents one way, but not the only way, to achieve industry best practice energy performance. Specification of whole-building absolute energy use targets gives the design team the freedom to reach the performance goal with an approach that best fits the overall goals and constraints (including those not related to energy performance) of the project.

Because they embody the knowledge required to set practical, aggressive energy performance targets, specification of AEDG whole-building absolute energy targets can eliminate the majority of analysis that may otherwise be required to specify energy performance goals. In particular, because the AEDG energy targets are defined in terms of absolute energy performance (in kBtu/ft^2, rather than with respect to a theoretical baseline), they can be specified without the need for a baseline energy model. A design team can specify an absolute energy target based on the corresponding AEDG energy target and then focus analysis efforts towards achieving industry best practice energy performance rather than trying to define a reference point against which to measure performance.

Development of AEDG Whole-Building Absolute Energy Use Targets

The whole-building absolute energy use targets for the 50% AEDG series were developed in accordance with the following approach:

1. If possible, start with the DOE Commercial Reference Building model (Deru et al. 2011) that corresponds to the AEDG building type; this model is minimally compliant with ASHRAE Standard 90.1-2004. Where the Reference Building model did not sufficiently represent common practice for a building type, the AEDG project committee developed and approved an alternative model.
2. Update the Reference Building model according to the AEDG project committee's expert guidance; special care is given to aspects of the model not prescribed by ASHRAE Standard 90.1-2004, including schedules and unregulated PPLs. The goal is to develop a model that accurately captures typical (common practice) whole-building energy use for the relevant building type.
3. Simulate the industry-vetted model across a set of 16 climate zones that fully represent the variations in the eight DOE climate zones (Briggs et al. 2003). Benchmark modeling results against available sector data (e.g., CBECS) and project committee. Make necessary corrections to model inputs and resimulate. Iterate until results are in line with sector data and industry expectations for baseline energy performance by climate zone.

4. Set climate-specific absolute targets representing 50% savings beyond ASHRAE Standard 90.1-2004 by halving baseline whole-building energy performance results. Confirm through whole-building energy simulation and case study survey (including committee member projects) that 50% savings targets are feasible and representative of industry best practice energy performance.

The following sections present the 50% AEDG energy use targets for K-12 school buildings, medium to big box retail buildings, and large hospital buildings; guidance on target applicability is provided and case-specific variations in approach are explained.

AEDG Whole-Building Absolute Energy Use Targets for K-12 Schools

This AEDG is intended to provide user-friendly, "how-to" design guidance and efficiency recommendations for elementary, middle, and high school buildings (ASHRAE 2011). The mission of a K-12 school building is to facilitate education; school buildings are designed accordingly, and energy-saving measures must not compromise this fundamental goal. The measures recommended by the 50% AEDG for K-12 school buildings are intended to avoid compromising, and to complement whenever possible, the delivery of educational services.

For this analysis, two building types were modeled (primary and secondary schools) and two sets of climate-specific, whole-building absolute energy use targets for 50% savings beyond ASHRAE Standard 90.1-2004 were developed (Table 1 and Table 2).

Whole-building absolute targets are supplemented with key end use energy targets (PPLs, lighting systems, and HVAC systems). Although the end use targets need not be met to achieve the whole-building target, these targets provide guidance as to how energy use is likely to be distributed throughout a K-12 school building; they can also inform end use energy budgets.

Programmatic requirements are relatively constant for a given school type (primary or secondary); accordingly, the AEDG whole-building and end use energy targets for K-12 school buildings are likely to apply reasonably well to most K-12 school building projects. The AEDG energy targets do not take into account the energy use of specialty space types such as indoor swimming pools, wet labs (e.g., chemistry), dirty dry labs (e.g., woodworking and auto shops), or other unique spaces with extraordinary heat or pollution generation. Such space types should be analyzed separately; their predicted energy use can be combined with the AEDG targets to determine an area-weighted, whole-building energy use target that correctly reflects all project energy uses.

Table 1. Primary School AEDG Absolute Energy Use Targets

Climate Zone	Plug/Process (kBtu/ft^2·yr)	Lighting (kBtu/ft^2·yr)	HVAC (kBtu/ft^2·yr)	Total (kBtu/ft^2·yr)
1A	11	6	20	37
2A			20	37
2B			20	37
3A			15	32
3B-CA			8	25
3B			14	31
3C			10	27
4A			19	36
4B			15	32
4C			15	32
5A			22	39
5B			17	34
6A			27	44
6B			22	39
7			30	47
8			45	62

Table 2. Secondary School AEDG Absolute Energy Use Targets

Climate Zone	Plug/Process (kBtu/ft^2·yr)	Lighting (kBtu/ft^2·yr)	HVAC (kBtu/ft^2·yr)	Total (kBtu/ft^2·yr)
1A	8	7	21	36
2A			21	36
2B			21	36
3A			18	33
3B-CA			10	25
3B			17	32
3C			13	28
4A			22	37
4B			18	33
4C			19	34
5A			25	40
5B			21	36
6A			31	46
6B			26	41
7			34	49
8			48	63

AEDG Whole-Building Absolute Energy Use Targets for Medium to Big Box Retail

This AEDG is intended to provide user-friendly, "how-to" design guidance and efficiency recommendations for retail stores (ASHRAE 2011). Retail buildings are designed to facilitate the delivery of goods and services to the public; energy-saving measures must not compromise this fundamental goal. That stated, energy costs are typically the second-highest operating expense for retailers; implementing cost-effective energy-saving strategies has a direct and significant impact on profitability and is an essential part of a successful retail business.

Two building types were modeled for this analysis: medium box (40,000 ft^2) and big box (100,000 ft^2). Programmatic requirements can vary greatly from application to application. A high-end retailer may use significant high-wattage accent lighting to display merchandise with a particular style; a discount retailer may use little or no accent lighting. Similarly, an electronics retailer may have significantly higher installed PPLs than a clothing retailer. Because installed equipment load (including accent lighting and PPLs) can vary significantly according to project-specific requirements, AEDG energy targets were determined for a range of installed equipment loads. Energy targets are provided for two levels of baseline plug load requirements: Low and High, representing whole-building average installed plug load densities of 0.5 W/ft^2 and 0.7 W/ft^2, respectively. A general merchandise store would be a typical low-plug load case, whereas a dedicated electronics store would be a typical high-plug load case. Within each category of installed plug loads, energy targets are provided for three levels of baseline accent lighting requirements: (1) little or no accent lighting (Low), with a value of 0.0 W/ft^2; (2) a typical level of accent lighting (Med), 1.6 W/ft^2 for sales areas; and (3) a high level of accent lighting (High), representative of retail applications with specialty accent lighting requirements, such as jewelry sales, with a value of 3.9 W/ft^2, the maximum allowed for sales area by ASHRAE Standard 90.1-2004. Energy targets for 50% savings beyond Standard 90.1-2004 are presented in Table 3 and Table 4.

Table 3. Medium-Box Retail Energy Use Targets for 50% Savings

Climate Zone	Energy Use Intensity (kBtu/ft^2·yr)					
	Low-Plug			High-Plug		
	Low Accent	Med Accent	High Accent	Low Accent	Med Accent	High Accent
1A	42	58	81	45	61	85
2A	41	56	77	44	59	80
2B	37	53	75	40	56	79
3A	38	51	70	40	53	73
3B-CA	31	46	67	34	49	69
3B	36	50	72	38	53	75
3C	29	43	61	32	45	64
4A	39	51	68	41	53	70
4B	36	50	70	39	53	72
4C	33	44	61	35	47	63
5A	40	50	65	42	52	67
5B	36	49	67	39	51	69
6A	43	53	66	45	54	68
6B	39	50	65	41	52	67
7	44	52	63	46	54	65
8	56	61	69	57	62	71

Table 4. Big-Box Retail Energy Use Targets for 50% Savings

Climate Zone	Energy Use Intensity (kBtu/ft²·yr)					
	Low-Plug			High-Plug		
	Low Accent	Med Accent	High Accent	Low Accent	Med Accent	High Accent
1A	42	58	82	45	62	85
2A	41	56	77	44	58	80
2B	38	54	77	41	57	80
3A	35	49	69	38	52	72
3B-CA	30	45	66	33	48	69
3B	34	49	71	37	52	74
3C	28	41	61	30	44	63
4A	37	49	66	39	51	68
4B	34	48	68	37	51	71
4C	31	43	60	33	45	62
5A	38	49	64	40	51	66
5B	35	47	66	37	50	68
6A	41	51	64	43	52	66
6B	37	48	63	39	50	65
7	42	50	62	44	52	63
8	53	58	67	54	60	68

AEDG Whole-Building Absolute Energy Use Targets for Large Hospitals

This AEDG is intended to provide user-friendly, "how-to" design guidance and efficiency recommendations for large healthcare buildings (ASHRAE 2012). For healthcare applications, patient considerations (outcome, safety, and overall quality of experience) trump all cost and energy savings benefits. No efficiency strategy that would risk patient, staff, or visitor health is recommended by the 50% AEDG for large hospitals; on the contrary, strategies that reduce this risk are emphasized.

For this analysis, a single, 427,000 ft^2 building was modeled; climate-specific, whole-building absolute energy use targets for 50% savings beyond ASHRAE Standard 90.1-2004 are presented in Table 5.

Whole-building absolute targets are supplemented with key end use energy targets (plug and process equipment, lighting systems, and HVAC systems). Although the end use targets need not be met to achieve the whole-building target, they provide guidance as to how energy use is likely to be distributed throughout a large hospital building; they can also inform end-use energy budgets.

Table 5. Large Hospital Energy Use Targets for 50% Savings

Climate Zone	Plug/Process Loads ($kBtu/ft^2 \cdot yr$)	Lighting ($kBtu/ft^2 \cdot yr$)	HVAC ($kBtu/ft^2 \cdot yr$)	Total ($kBtu/ft^2 \cdot yr$)
1A	38	18	67	123
2A			68	124
2B			63	119
3A			62	118
3B:CA			55	111
3B			55	111
3C			55	111
4A			65	121
4B			50	106
4C			55	111
5A			65	121
5B			50	106
6A			68	124
6B			54	110
7			67	123
8			81	137

Applicability of Whole-Building Absolute Energy Use Targets

Specifying these targets requires detailed knowledge of where and how energy will be used. This section highlights some scenarios in which whole-building absolute energy use targets may be difficult to specify.

Projects with Specialty Space Types

Because specialty space types tend to be project specific and have unique programmatic requirements, it can be difficult to find points of comparison to inform energy use goal setting. When comparison points cannot be found, energy modeling informed by a best-in-class technology survey is a viable approach to establishing energy use targets.

Projects with Difficult-To-Define Operational Parameters

For some projects, operational parameters may be difficult to define before occupancy. Consider a cafeteria, for example. Accurately predicting customer occupancy patterns may be impossible, and because cafeteria energy use has a strong correlation with occupancy density, accurately predicting overall cafeteria energy use may be difficult. Design teams can still strive to maximize the energy performance of such projects, but initial energy use targets may need to be less aggressive than desirable.

Conclusions

The design and construction of high-performance buildings requires careful goal setting. Percent savings goals are popular and can be effective, but depend heavily on the definition of an often theoretical baseline case against which savings are measured. Whole-building absolute energy use targets provide straightforward, easily understood, and directly measureable performance goals that focus on realized building performance rather than comparison to a theoretical baseline. Defining the energy performance goal for a project using whole-building absolute energy use targets results in a specific and measureable, holistic goal and promotes innovative, cost-effective design and construction solutions. Achieving an energy performance goal requires consideration of that goal during each project stage, starting with the proposal and continuing through building occupancy and operation. Setting aggressive targets requires careful consideration of project-specific parameters and a complete understanding of where and how energy is used in the building. There are many ways to determine whole-building absolute energy use targets, but all require following the same basic steps: (1) define project parameters, (2) survey applicable resources, and (3) select goals and specify targets. Specifying whole-building absolute energy use targets can help designers and owners ensure that the project's desired performance goal is achieved.

References

ASHRAE. 1999. ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Ga.

ASHRAE. 2004. ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Ga.

ASHRAE, AIA, IESNA, USGBC, and DOE. 2011. Advanced Energy Design Guide for K-12 School Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Ga.

ASHRAE, AIA, IESNA, USGBC, DOE (2011). Advanced Energy Design Guide for Medium to Big Box Retail Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Ga.

ASHRAE, AIA, IESNA, USGBC, DOE (2012). Advanced Energy Design Guide for Large Hospitals: Achieving 50% Energy Savings Toward a Net Zero Energy Building. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Ga.

Briggs R. S., R. G. Lucas, and Z. T. Taylor. (2003). "Climate Classification for Building Energy Codes and Standards: Part 1 - Development Process." ASHRAE Transactions 109(1):109-121.

Brown, K., A. Daly, J. Elliot, C. Higgins, and J. Granderson. (2010). "Hitting the Whole Target: Setting and Achieving Goals for Deep Efficiency Buildings." In Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, Calif.

Deru, M.; Field, K.; Studer, D.; Benne, K.; Griffith, B.; Torcellini, P.; Liu, B.; Halverson, M.; Winiarski, D.; Rosenberg, M.; Yazdanian, M.; Huang, J.; Crawley, D. (2011). U.S. Department of Energy Commercial Reference Building Models of the National Building Stock. NREL/TP-5500-46861, National Renewable Energy Laboratory, Golden, Colo.

DOE. (2005). "Map of DOE's Proposed Climate Zones." Retrieved July, 2010, from www.energycodes.gov/implement/pdfs/color_map_climate_zones_Mar03.

Hirsch, A., S. Pless, R. Guglielmetti, P. A. Torcellini, D. Okada, and P. Antia. (2011). "Role of Modeling When Designing for Absolute Energy Use Intensity Requirements in a Design-Build Framework: Preprint." NREL/CP-5500-49067. National Renewable Energy Laboratory, Golden, Colo.

Pless, S., P. Torcellini, and D. Shelton. (2011). "Using an Energy Performance Based Design-Build Process to Procure a Large Scale Low-Energy Building: Preprint." NREL/CP-5500-51323. National Renewable Energy Laboratory, Golden, Colo.

Pless, S., P. Torcellini, and P. Macey. (2012). Controlling Capital Costs in High Performance Office Buildings: 15 Best Practices for Overcoming Cost Barriers in Project Acquisition, Design, and Construction. NREL/TP-5500-54978. National Renewable Energy Laboratory, Golden, Colo.