using energy modeling
TO INCREASE PROJECT VALUE

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Creating an energy model and cost profile early in the design process—using lightweight tools and resources, such as energy use intensity data, Department of Energy commercial benchmark model data, photovoltaic and solar thermal sizing tools, and ASHRAE, Core Performance, and other energy codes—can provide direction to the Building Team and generate consensus around an energy-efficient design that saves time and money.

Energy modeling is familiar to most Building Teams involved with green building projects or those that are applying for utility financial incentives. This course explores how to increase project value through energy modeling and shows how to identify the most viable energy strategies for your project. It details why it is important to conduct energy modeling during early design, and how to conduct quick payback and net present value analyses.

Energy modeling is a process that allows project stakeholders to understand the predicted energy use and energy cost for a building's operational phase before it is actually built. It involves creating a thermodynamic computer model that mimics a building's energy need, given the fluctuating external weather, the occupants' usage patterns and functions in the space, and the energy used by building systems such as lighting and air-conditioning.

The outcome of the energy-modeling process will allow the building's stakeholders to weigh the long-term cost impact of design decisions and arrive at an energy-efficient design that has a positive cash flow over time. More importantly, such a process guides Building Teams in creating a robust energy strategy for the project that aligns with the overall project goals and feeds into the project's retail marketing and long-term valuation strategy.

The most successful energy strategy has three attributes:

1. It should push the boundaries of the owner's and project team's aspirations while demonstrating successful payback over time.
2. It should have the backing of all project stakeholders.
3. It should align with the project's overall sustainability goal.

The best time in the design process to maximize all three attributes is in the Schematic Design stage. During SD, the design and ownership team members are in a highly collaborative mode. The design is not yet set in stone—there is room for creativity and change. The budget is somewhat flexible and provides an opportunity to shift costs between different building components.

This creates a valuable opportunity for the Building Team and the owner to develop a cutting-edge energy strategy that aligns with the project's overall sustainability goal and thereby creates a personal stake for everyone to see the strategy succeed.

By front-loading the energy-modeling process to create an energy strategy for the project, individual energy measures tend not to get deleted as the design progresses. The selected energy measures become a tightly knit set that complement each other with a pre-established understanding of the first cost and payback involved.

Compare this to compliance modeling, which typically starts at the Construction Drawings stage, is very reactive, and tends to adopt a scarcity approach to find incremental energy savings.

With SD energy modeling, compliance modeling can be used as a method to backcheck strategy achievement and demonstrate compliance with codes or to utilities for financial incentives. In addition, compliance modeling will become less arduous, since a basic model would already be available that can then be updated during 100% Construction Documents for submission to the appropriate entity.

Note: Compliance energy modeling is generally conducted at the end of the design stage to demonstrate the design energy-cost savings compared to the local energy code or other standard energy codes such as ASHRAE.

LEARNING OBJECTIVES

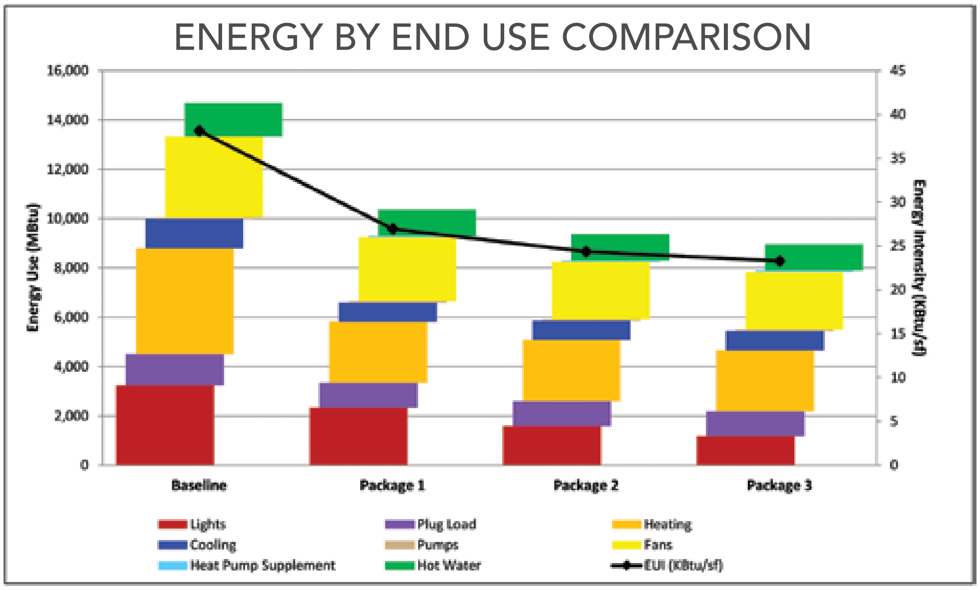
After reading this article, you should be able to:

+ EXPLAIN the basic concept of energy modeling as a process that allows project stakeholders to understand the predicted energy use/energy cost of a building before it is actually built.
+ DISCUSS three attributes of a successful project energy strategy, including pushing the owner's and project team's aspirations while demonstrating successful payback over time.
+ DESCRIBE how to create a project's energy-use profile using a variety of available options.
+ LIST the key factors to be considered in setting up an effective request for proposals for an energy-modeling bid.

THE 9 STEPS TO EFFECTIVE SD-LEVEL ENERGY MODELING

In order to create a highly effective energy strategy, the Building Team and the owner must first determine if the energy strategy for the project should include any predetermined energy goals, such as a specific energy-savings target for utility incentives or code compliance, green building certification, or the owner's marketing strategy. The process can then be broken down into nine steps:

1. Create the project's energy use profile. Creating the energy use profile will highlight where the building's highest energy-impact areas are. For example, in an office building, the plug loads and cooling energy use are usually the major end uses; however, if a building has a large public/private garage, the garage lighting can represent as much as 10-15% of overall project energy use.



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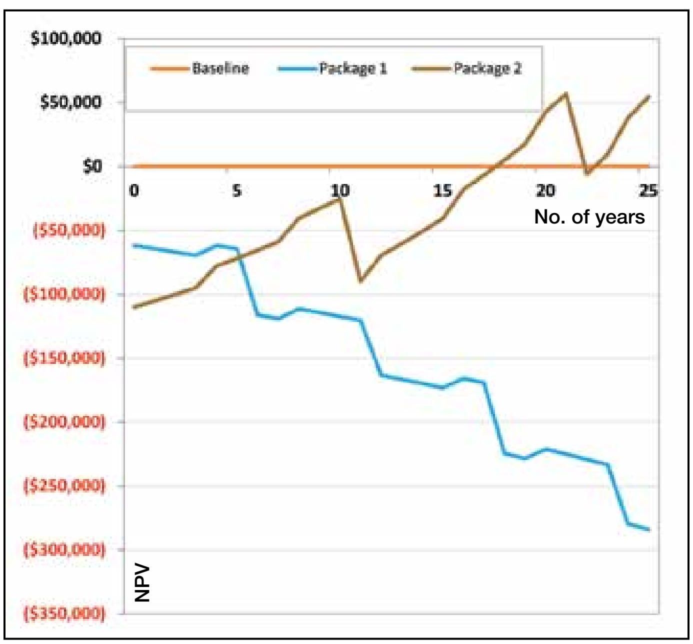
Bar graphs show absolute energy use and energy intensity for three ECM packages vs. a baseline. Together, the three packages can reduce project energy intensity from 38 KBtu/sf to 23 KBtu/sf.

2. Identify energy conservation measures (ECMs) for the major end uses. Review the energy profile to identify the project's two or three major end uses, which may vary depending on the building program.

Then research energy conservation measures applicable to these major end uses. It is very important to develop a list of ECMs that your Building Team can use as a starting point for brainstorming an energy strategy for the project. The DOE and its Office of Energy Efficiency & Renewable Energy (EERE) provide good resources for ECMs that apply to different building types. You should also review case studies on the USGBC website to gain insights into proven measures that are being used currently. See Resources at www.BDCnetwork.com/EnergyModeling/Resources for specific links.



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Net present value of two ECM packages over a 25-year period vs. a constant baseline package. Package 2 has twice the initial cost but begins to achieve payback in year 17, while Package 1 never achieves payback.

3. Calculate the savings for each ECM. Use spreadsheet calculations or energy modeling to determine the energy savings for each ECM. Apply energy-cost data published by the U.S. Energy Information Administration (EIA) or obtain applicable tariff rates published by the local utility to calculate energy cost savings for each ECM. Also calculate the greenhouse gas impact of each measure using the GHG emissions for utility grids published by EIA and consolidated by Energy Star in a quick reference table.

4. Create ECM packages. Using energy-cost savings and level-of-effort and cost-to-implement ECMs, designate each ECM as "low-hanging" or "advanced." Set up the analysis findings into stacked packages that build on top of each other. A low-hanging package would include all the low-cost ECMs that are within easy reach for the team to implement; an advanced package would include all the higher-cost ECMs that are cutting edge or beyond what is deemed usual practice.

Next, identify each ECM based on who would benefit from that particular ECM's savings. ECMs that obtain savings in owner-operated areas—corridors, lobbies, garages—would fall under "Owner ECMs"; those benefiting tenant energy bills—Energy Star appliances, reduced lighting power demand in tenant spaces—would fall under "Tenant ECMs."

5. Conduct the payback analysis for each package. Obtain first-cost information for each measure, and calculate life cycle payback for each low-hanging and advanced package. To do this, you will have to conduct life cycle payback and net present value calculations.

Life cycle payback is a methodology that can help you select the most cost-effective design alternative over a particular time frame. The methodology addresses not only typical owner concerns of design effectiveness and construction cost, but also reflects future costs associated with maintenance and operations and product replacement. Life cycle payback looks at the value of a capital project or procurement decision over time, thereby overcoming the limitations of first-cost analysis.

Net present value is the future amount of money that has been discounted to reflect its current value. NPV calculations for ECMs should take into account the first-cost investment, energy cost savings over time, yearly utility rate increases, operations and maintenance escalation, and future replacement costs.

A life cycle payback calculation differs from simple payback in that the latter just looks at the first cost investment and replacement cost.

NPV provides a more accurate picture of the expected payback by taking into account such factors as the future value of money, fluctuations in the cost of energy or labor, and the effect of alternate investments in place of investing in the selected ECMs.

A number of online NPV and life cycle payback calculators are available. (See www.BDCnetwork.com/EnergyModeling/Resources.) While the online calculators have default values for the following parameters, it is best to customize these values for each project.

Discount rate: This is the expected rate of return for an alternate investment instead of investing in the selected ECM—3.5% is a good value to use. However, we recommend checking with the project owner for the exact discount rate to be used in the NPV analysis. Owners with high-risk investments may use a higher discount rate. Federal and state projects may use a lower discount rate, since their investments are usually low risk and hence will have a lower rate of return.

Utility rate increases: The U.S. EIA is a helpful source for utility escalation rates for various fuel types.

O&M escalation: The Bureau of Labor Statistics' Producer Price Index is a good source for changes in the rate of O&M labor costs over future years.

Analysis period: Owners of self-occupied buildings—universities or hospitals, for example—will typically use a range between 20 and 30 years for the NPV analysis period, whereas developers of speculative office buildings will use a much shorter analysis period,

how to create AN ENERGY-USE PROFILE

Depending on the desired accuracy and available level of effort, the following options can be used to create your project's energy-use profile:

Low effort, low accuracy – Use the energy use index published by Energy Star Target Finder (http://1.usa.gov/19NLPGc) for the 50% median to determine the base building electricity and natural gas use.

Low effort, medium accuracy – The DOE's Energy Efficiency and Renewable Energy Building Technologies Office has created standard DOE reference models for various building types and climates that Building Teams can use as a starting point for their analysis: http://1.usa.gov/1bi9pWU.html. The end-use chart can be created using the results of the simulation captured in the html file located within the appropriate zip file.

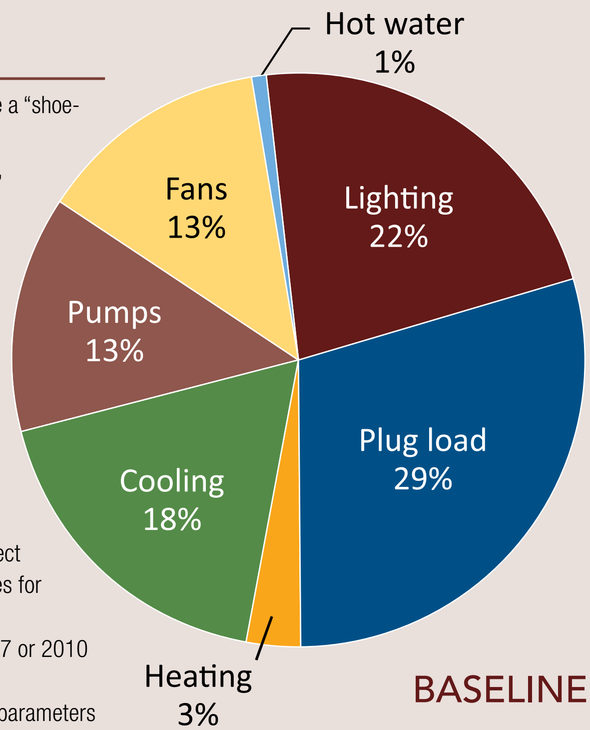
Medium effort, higher accuracy – Update the DOE reference models to match project specifications. While you will need advanced Energy Plus user capability to update the building area or the building shape, other factors such as the weather data file, glazing area, occupant density, and lighting power can be easily updated to match project design. The energy model will report the predicted energy by each end use.

High effort, high accuracy - Create a "shoebox" energy model using basic building program information such as floor area, number of floors, and orientation. Additional information required to complete the shoebox includes floor height, window-to-wall ratio, lighting power density, equipment power density, basic HVAC system type, domestic hot water system type, and site lighting density.

See the AIA's Energy Modeling Guide, Section 7, for a detailed energy-model inputs checklist. When information is not available in the project documents, use the following resources for default values:

- Local code or ASHRAE 90.1-2007 or 2010 standard prescriptive requirements
- DOE reference model, modeling parameters
- A Handbook for Planning and Conduction Charrettes for High Performance Buildings, Tables G-1 to G-18, at: http://www.nrel.gov/docs/fy09osti/44051.pdf

Once the shoebox model is set up, run it, using the applicable weather file. Create the energy-use profile using the annual-energy-by-end-use information calculated by the energy-modeling software.



TOTAL ENERGY COST: $482,570/YR
UNIT ENERGY COST: $2.20/SF/YR

The energy end use chart for a 220,000-sf high-tech office building in New York City with a 25,000-sf underground garage and 15,000 sf of ground-floor retail. Plug loads are the largest energy end use, followed by lighting and cooling energy end use.

3 ECM PACKAGES VS. BASELINE

	Annual Energy Use (MBtu)	% Energy Savings	Energy Use Index (KBtu/sf)	Annual Energy Cost ($)	Annual Energy Cost ($/sf)	% Energy Cost Savings	LEED EAc1 Points
Baseline	48,221	n/a	53.1	1,366,462	1.50	n/a	n/a
Package 1	32,663	32%	36.0	1,122,692	1.24	17.8%	5
Package 2	31,470	35%	34.6	1,080,736	1.19	20.9%	7
Package 3	31,220	35%	34.4	1,071,940	1.18	21.6%	7

at most 10 to 15 years. It's important for you to ask the project owner for the preferred analysis period for your project.

6. Present your findings to the entire team. Publish a findings report with your recommended energy goal and ECM packages. Include your findings on energy cost savings and payback periods. List any points for energy savings in LEED, Green Globes, or other rating systems. Identify the applicable number of points and include in the information set provided to the owner and design team as part of the energy study.

USGBC, LEED NCv2009 Rating System: http://www.usgbc.org/Docs/Archive/General/Docs5546.pdf

Green Globes, New Construction: http://www.thegbi.org/assets/pdfs/Green-Globes-NC-Technical-Reference-Manual-v1.2.pdf

7. Finalize your energy strategy to meet the project's energy goal. Conduct a mini-charrette with the entire team (including the owner, if possible) to finalize the project's energy goal and strategy. Focus on the level of effort for each ECM, available technologies and their level of adoption in the market, specific products (by brand and model), and maintenance and installation barriers. Track which ECMs get buy-in from the team and which are deemed too innovative or difficult to pursue, and why.

8. Incorporate your recommended strategies in the project design. Publish the final strategy memo showing the list of agreed-upon ECMs and the cumulative energy savings. Also indicate if the project energy goal is achievable, along with the expected payback in years.

Then convert the agreed-upon ECMs into actionable design specifications. For example, an ECM to achieve 0.12 W/sf lighting in the garage might be specified as "Use LED or T8 fixtures in the garage to achieve 0.12 W/sf lighting power density."

Finally, create an energy story writeup that can be included in the project's sales documents.

9. Complete your compliance modeling. At 50% CDs or at the end of the construction drawings stage, use the project documents to complete the compliance modeling for the project to backcheck the strategy and determine if you have achieved the project energy goal.

Once your SD energy modeling is complete, required modeling for the rest of the project should be a much simpler undertaking. In brief, the scope involves:

• DD level – Update the energy model and any hand calculations based on selected ECMs

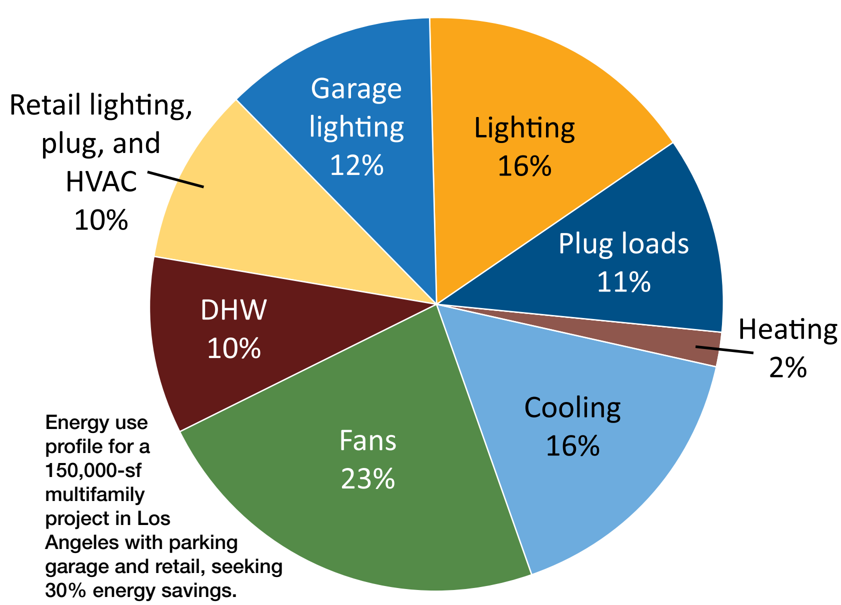
• CD level – Build a full-fledged energy model, complete compliance modeling, and documentation

• Start/end of construction – Backcheck to correct for any changes in the design

HOW ENERGY MODELING TO INCREASE VALUE WORKS IN A REAL PROJECT

To see how this process works in the real world, let's walk through a typical case—a 150,000-sf multifamily residential project in Los Angeles with a two-level, 120,000-sf underground garage, a 15,000-sf retail component (grocery store) on the ground floor, and a goal of 30% energy savings.

CASE STUDY: SD ENERGY USE PROFILE



Energy use profile for a 150,000-sf multifamily project in Los Angeles with parking garage and retail, seeking 30% energy savings.

To understand the project's energy use profile, the team used eQUEST energy modeling software to simulate the project's predicted energy use and end-use profile. We used ASHRAE 90.1-2007 assumptions and the Energy Star Multifamily High Rise (MFHR) Program Requirements to fill in missing design information.

Major end uses with opportunities for energy reduction were in the apartment and garage lighting, apartment cooling, and fan energy use.

The team identified the following Owner ECMs (in green) and Tenant ECMs (in blue) for major end uses:

Apartment lighting: To achieve a 35% lighting power density reduction compared to ASHRAE 90.1-2007 in corridors and public spaces, we called for lighting motion sensors in the apartment corridors and Energy Star–qualified light fixtures for all hard-wired lights, corridor lighting, and public areas.

Garage lighting: To achieve deep savings here (<0.12 W/sf), we recommended using lighting motion sensors in the garage.

Cooling and fan energy use: ECMs included a high-efficiency building envelope—a roof with a U-value of 0.03, an exterior wall with a 0.04 U-value, glazing with a center-of-glass U-value of 0.3, and a wall assembly with a 0.48 U-value.

Other cooling and fan energy use ECMs included air-source heat pumps in dwelling units; 100% heat-recovery OA units with direct-expansion cooling and gas heating to provide conditioned outside air to corridors and directly to apartment units (with ventilation air disconnected from heating/cooling); WiFi-enabled thermostat controls for dwelling units; Energy Star–qualified exhaust fans in dwelling unit bathrooms; and VFD fans with CO control in the garage.

To create the ECM packages, the above ECMs were segregated into Tenant and Owner ECM packages based on first cost and level of effort. Savings from Owner ECMs (below, in green) can be built into the life cycle analysis for the owner; savings from the Tenant ECMs (below, in blue) can be leveraged as unique selling features for potential clients.

We then calculated the combined savings from the two packages, which achieved a total energy savings of 31%. Thus, the design met its energy goal.

Finally, we converted the recommended strategies into design inputs:

- Use R30 rigid insulation for the roof, R19 batt insulation for the walls, and Solarban 60 or equivalent glazing with thermally broken metal frames and fiberglass spacers.
- For the apartment corridor lighting, have 20% of lamps stay on all the time, make 80% on an occupancy-sensor trigger.
- In the garage, use LED or T8 lighting, with dual lamps on separate circuits, to achieve the 0.12 W/sf lighting power density.
- Specify air-source heat pumps with a minimum SEER 15 rating.
- Specify the following sequence for CO sensors in the garage:
  - <35 ppm – fans off
  - >50 ppm for more than 3 minutes – low-speed fan
  - >150 ppm for more than 3 minutes – high-speed fan

MAKING THE CASE FOR EARLY DESIGN ENERGY MODELING

As we have seen, conducting energy modeling at the Schematic Design phase of a project adds substantial project value by allowing the Building Team to identify the energy conservation measures with the most impact, and requiring the least effort. This process also helps script a comprehensive energy story for the project that can be used to gain client buy-in and in the project's marketing efforts.

Early-stage analysis allows owners to identify additional budget for ECMs or to trade budget between building components to achieve an overall efficient building at the same cost. It creates an opportunity to implement one or two cutting-edge technologies to build the case for future projects. It gives owners sufficient time to do test studies and undertake site visits to gather intelligence around

some tips for conducting an effective ENERGY MODELING ASSESSMENT

An inherent difficulty of energy modeling at the Schematic Design stage is that, other than basic floor layout, floor areas, floor-to-floor height, and maybe some conceptual information on the building elevation and exterior finish materials, only a limited amount of project information is available—almost nothing on such crucial factors as the lighting technology, proposed lighting power density, or HVAC system type or performance parameters.

However, several good resources are available to fill this information gap:

- The ASHRAE 90.1 standard has prescriptive requirements for lighting, HVAC system type, and performance parameters.
- Information on occupancy densities and plug load densities are available in the ASHRAE 90.1 Users manual.
- The Energy Star multifamily standard has recommended lighting and equipment load information for multifamily building types

We recommend that you set up a central location to collect and document all the relevant project information and assumptions before starting the energy analysis. It is also important to get buy-in from the design team and owner regarding the design assumptions. This process will highlight obstacles to pursuing certain ECMs. The USGBC LEED EAc1 Input table is an excellent tool to gather and document assumptions (http://bit.ly/1dUMeWV).

There is also the matter of "directional" versus "absolute" results. Given the great number of unknowns the Building Team faces, it should be understood that the result from SD energy modeling can only be directional. It shows the trend or the level of magnitude, rather than absolute results.

For example, when analyzing daylighting as a viable ECM in an office building, the savings may range from 1% to 5%, depending on the project location and spce layout. A project in Seattle with an open-office configuration located on the interior of the floor plate with walkways at the perimeter will likely show very low savings compared to an office building in Phoenix with open offices in the perimeter. It is this range of impact combined with the payback analysis discussed on pp. 47-48 that shows the viability of a particular ECM.

Be aware, too, that while there is a wide range of energy strategies that can be analyzed for a project, it is not possible to analyze the impact and viability of each measure. Fortunately, there is a lot of research available (at www.BDCnetwork.com/EnergyModeling/Resources) with recommendations on the most viable ECMs for different project types. This information can be used as a quick starting point for the energy analysis.

As a rule of thumb, experience shows that it is best to select 6-8 ECMs to analyze. Again, before modeling these measures, it is good practice to include the ECMs selected for analysis as part of the input assumptions and circulate to the Building Team for buy-in and comments. This affords the whole team the opportunity to add any project specific-measures to the list of ECMs.

—*Thulasi Narayan*

how to set up an EFFECTIVE ENERGY-MODELING BID

To find a capable energy-modeling provider, you need to create a comprehensive request for proposals.

Your RFP should clearly state the client's energy-performance aspirations for the project—for example, "30% energy savings compared to local code," or "achieve net-zero energy use." It should also provide any information that could guide the selection of energy-reduction strategies, such as local emission laws prohibiting on-site cogeneration plants, or a client's goal to provide superior indoor air quality to occupied spaces, using MERV 13 filtration.

Your RFP should go on to summarize any directions or decisions that have emerged from prior research and proffer a list of deliverables (and a timeline for each of them). Ensure that separate requirements for SD-level modeling and compliance modeling are called out in the RFP, with anticipated delivery timelines. Having tight compliance modeling deadlines will put the energy modeler on the alert to pick up much of the compliance modeling in the SD stage.

Provide as much information as possible as to when the basic floor plate and space-zoning matters will be finalized. These are key components in determining when to move the energy model to an advanced stage. Changes to the floor plate and space zoning after this stage will result in costly rework of the model set-up.

Another important aspect of the energy-modeling exercise, especially in the SD stage, is to understand the first-cost and payback information for various energy conservation measures. The RFP should identify the members of the ancillary support team that would be available to assist the energy modeler in pricing out both first costs and O&M costs for selected ECMs; this will shorten the timeline for completing the net present value and payback calculation. The general contractor is usually a good source of information for first costs. Listing the members of the support team and their scope of assistance in the RFP will prevent any double-counting in the energy modeler's fee estimates.

Earning incentives for energy efficiency is another key aspect that ties into the payback analysis. Highlight who will be responsible for the conducting the research to identify and obtain such incentives: Will the energy modeling firm be in charge? Or will this task fall to another Building Team member, who will then feed the information to the energy modeler? The latter approach will guard against double-counting in the fee estimate.

systems or technologies that may be unfamiliar to them. Finally, SD energy modeling establishes a path to success for achieving a project's energy goal. +

> EDITOR'S NOTE

*This completes the reading for this course. To earn **1.0 AIA CES HSW learning units**, study the article carefully and take the 10-question exam posted at* **www.BDCnetwork.com/EnergyModeling.**

environmental design AIA CES MODULE

*Pass this exam and earn **1.0 AIA CES HSW learning units**. You must go to* **www.BDCnetwork.com/EnergyModeling** *to take the exam.*

1. Which of the following is NOT AN ATTRIBUTE of a successful building project energy strategy:
A. It should wait until the design is in 50% CDs (Construction Documents) to model energy performance.
B. It should push the boundaries of the owner's and project team's aspirations while demonstrating successful payback over time.
C. It should have the backing of all project stakeholders.
D. It should align with the project's overall sustainability goal.

2. According to the expert information provided in this course, the garage lighting for an office building with a large public/private parking garage can represent about HOW MUCH OF THE OVERALL PROJECT ENERGY USE?
A. Less than 5%
B. 5% to less than 10%
C. 10-15%
D. More than 15%

3. TRUE or FALSE: When analyzing daylighting as a viable energy conservation measure, an office building in Seattle with an open office configuration on the interior of the floor plate and walkways at the perimeter likely will have MUCH HIGHER ENERGY SAVINGS than an office building in Phoenix with open offices in the perimeter.
A. TRUE B. FALSE

4. Which of the following ELEMENTS SHOULD BE INCLUDED in a Request for Proposals (RFP) from energy-modeling service providers?
A. The RFP should clearly state the client's energy-performance goals for the project, such as "achieve 30% energy savings vs. local code."
B. The RFP should provide information on when the basic floor plate will be finalized.
C. The RFP should provide any information that could impact the selection of energy-reduction strategies, such as a local prohibition against the use of an on-site cogeneration plant.
D. All of the above

5. According to the expert information provided in this course, the BEST TIME TO BEGIN OPTIMIZING the energy strategy for a new building project is at the start of which phase:
A. Schematic Design
B. Design Development
C. Construction Documents
D. Construction Contracts Administration

6. An economic methodology that can help you select the MOST COST-EFFECTIVE DESIGN ALTERNATIVE over a particular period of time—including future costs for operations and maintenance and product replacement—is called:
A. Business case analysis
B. Simple payback
C. Annualized cost
D. Life cycle payback

7. Net present value (NPV) calculations for energy conservation measures (ECMs) in a building project SHOULD TAKE INTO ACCOUNT all of the following EXCEPT:
A. Energy cost savings over time
B. Interest rate forecasts
C. Future utility rate increases
D. First-cost investment

8. As a rule of thumb, how many ECMs (energy conservation measures) should be analyzed as part of the SD (Schematic Design) energy modeling process?
A. 1-2
B. 6-8
C. 2-15
D. As many as possible

9. Owners of self-occupied buildings (e.g., universities, hospitals) will typically use WHAT TIME PERIOD for the life cycle payback analysis of the project?
A. Less than 10 years
B. 10-19 years
C. 20-30 years
D. More than 30 years

10. Which of the following SHOULD NOT BE CONSIDERED in finalizing your strategy to meet the project's energy goal?
A. Technologies with a low level of adoption in the marketplace
B. Maintenance and installation barriers for technologies
C. The level of effort to implement each energy conservation method (ECM)
D. Specific recommended products or systems (by brand and model)