

Energy Analysis and Design

Donald Prowler, FAIA

Architects who can offer combined expertise in energy-related design factors and traditional architectural systems are in a unique position to meet the needs of energy-conscious clients.

Summary

ENERGY ANALYSIS AND DESIGN SERVICES

Why a Client May Need These Services

- ▶ To improve long-term operating costs
- ▶ To achieve energy conservation
- ▶ To achieve energy self-sufficiency
- ▶ To meet legislated energy requirements

Knowledge and Skills Required

- ▶ Knowledge of building thermal and energy systems
- ▶ Knowledge of energy-efficient building design factors
- ▶ Ability to perform energy load and use analyses
- ▶ Familiarity with comfort concepts
- ▶ Knowledge of energy codes and standards

Representative Process Tasks

- ▶ Define energy targets
- ▶ For renovations, profile existing conditions
- ▶ Conduct energy analysis throughout design process
- ▶ Analyze alternative HVAC configurations
- ▶ Conduct economic analysis of building design and system alternatives

Energy efficiency in buildings is achieved through a combination of design concepts, technologies, and operational strategies. These work together to reduce the consumption of energy derived from finite sources such as oil, gas, and coal. Depending on the set of design precepts used, energy-efficient design has also been labeled “energy-conscious,” “passive,” or “bioclimatic.” To be successful, energy-efficient buildings must also provide for the functional, environmental, and comfort needs of occupants.

In order to ensure that energy goals are achieved, the energy implications of design decisions must be evaluated at each project phase. For energy retrofit projects, the effectiveness of a full range of site and building design modifications, as well as insulation, HVAC, and lighting retrofits, is evaluated.

Following the 1973 Middle East oil embargo, fuel scarcity and high oil prices prompted the U.S. Department of Energy (DOE) to propose mandatory nationwide building energy performance standards. The embargo was lifted, oil prices came down, and the standards never took effect. Nonetheless, the research DOE sponsored to support the proposed regulations dramatically advanced knowledge of the energy performance of buildings, stimulated advances in the development of energy-conserving building materials and renewable energy strategies, and encouraged the development of sophisticated energy analysis tools. Much of this research was conducted for DOE by the AIA Research Foundation, the former research arm of the AIA.

In the late 1970s low-energy design concentrated on achieving the lowest possible energy consumption. Today the emphasis is on whole-building performance, and energy conservation objectives are balanced with issues such as occupant control and comfort and indoor air quality. Some architecture and engineering firms have a strong commitment to energy resource optimization and view it as a leading design consideration and directive. Others, while acknowledging that energy efficiency is a desirable end, do not see it as a central determinant of building form. These firms are usually content to postpone energy considerations until late in the design process, when improvements are limited to alternative heating, ventilating, and air-conditioning (HVAC) and lighting selections. At that point in the process, major opportunities for energy savings are likely to have been missed.

CLIENT NEEDS

Energy efficiency is a major component of environmentally conscious or sustainable building design. Different client types find energy-efficient design attractive for a variety of reasons, perhaps most commonly to reduce operating costs. Corporate image objectives motivate some clients, particularly those in businesses related to environmental concerns.

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Other clients need energy self-sufficiency, either because of a remote location (for example, a resort in a less-developed country) or a strategic need to reduce reliance on outside energy sources (military bases, hospitals). Government regulations and building codes regarding building performance also have a part in driving the market for building energy consulting services. An increasing number of clients are concerned with the overall environmental impact of their buildings and the health of building occupants.

Reduced operating costs. A major reason clients need energy-efficient design, whether for a new building or for a retrofit project, is to reduce facility operating costs. Large government, institutional, and corporate clients who own and occupy their buildings throughout the building life cycle have the strongest motivation for reducing operating costs. Owners of buildings with high energy consumption—such as malls, hospitals, college campuses, military bases, and factories—are also especially motivated to reduce energy costs.

The federal government is the world's largest consumer of building energy. In 1994 President Clinton issued an executive order challenging federal building managers to reduce the energy consumption of federal buildings by 30 percent by the year 2005 and to "incorporate energy efficiency, renewable energy, and passive solar design when it is technically and economically feasible." Many states have similar policies on the books. At the local level, school boards often have adopted energy cost reduction programs.

Meeting code requirements. Most building codes have energy requirements. Where prescriptive options limit design flexibility, designers can offer alternative methods to achieve equivalent performance. In this case, performance prediction modeling programs must be used to demonstrate performance.

Running the complex performance analysis programs required for larger buildings (such as DOE 2.2) is a service some consultants provide for building owners or other designers. In addition to validation that performance-based standards have been met, clients often need energy analysis to justify utility rebates or to evaluate the benefits of alternative fuel sources. In many parts of the country utility load reduction incentive programs have been the primary stimulant for the energy consulting market. Utility deregulation, however, has destroyed many of these incentive programs in recent years.

Conducting an energy performance analysis is a way to evaluate the relative energy performance of alternative designs, in both new and existing buildings. For example, the effect of optimizing glazing selection, moving windows from one facade to another for passive solar heating or improved daylighting; or installing dimmable ballasts can be carefully evaluated and compared.

SKILLS

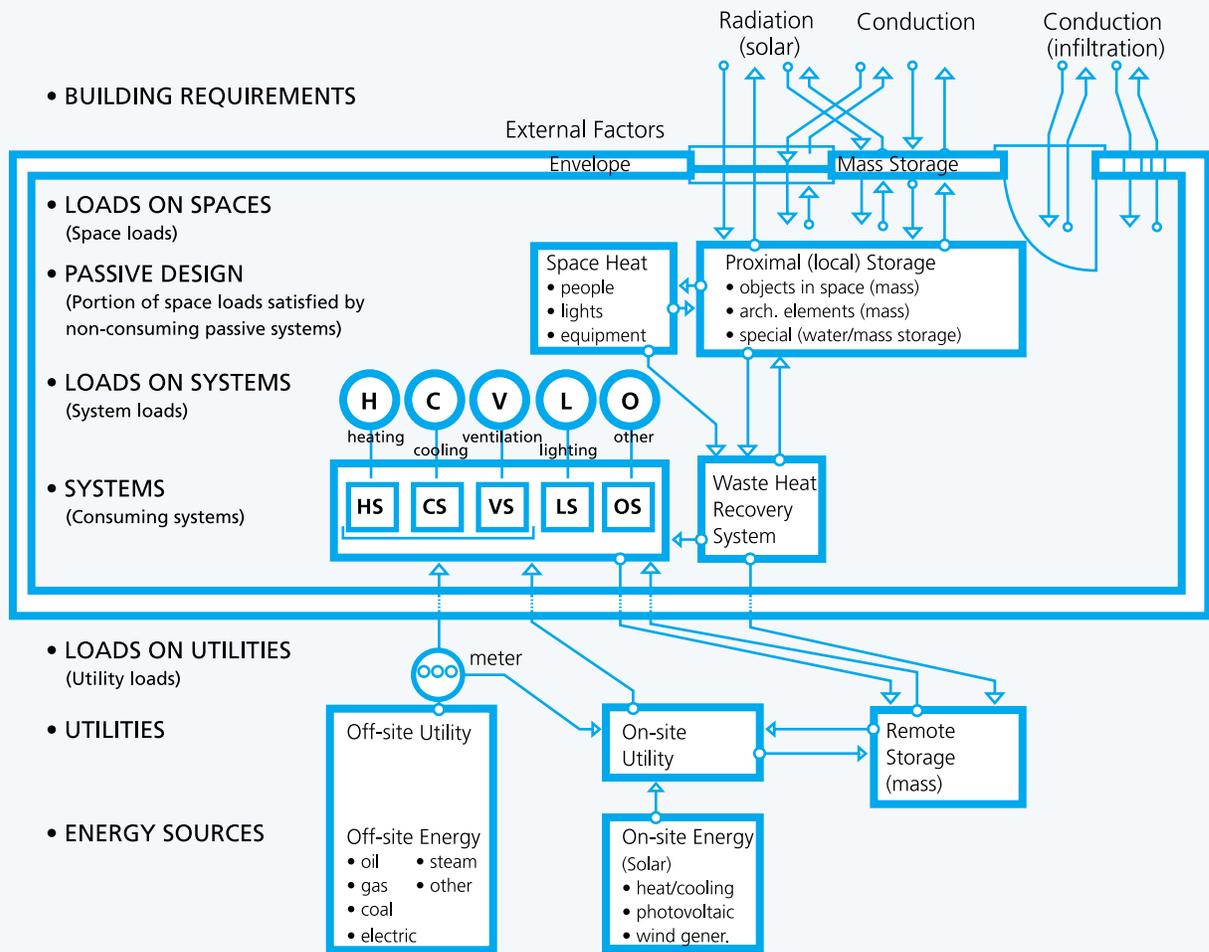
Offering low-energy analysis and design services requires competence in the design of daylighting, passive solar, and mechanical systems and familiarity with current energy products and technologies, such as high-performance glazing, low-energy lighting, and HVAC controls. Fundamental to energy-efficient design are a thorough knowledge of the thermal principles of heat gain and loss through materials and an understanding of building occupant comfort concepts.

Firms offering energy analysis services should also be familiar with load analysis and energy analysis programs. For smaller projects such as warehouses, small offices, or individual residences, some architects choose to run energy analysis programs in-house. Quick, design-based, climate- and program-specific energy software such as Energy-10, Building Design Advisor, or Energy Scheming can be used during the programming phase to establish energy targets and later during the schematic design phase to study energy options. Full analyses of larger buildings are often outsourced to energy analysis consultants unless a firm develops a specialty in energy analysis.

A working knowledge of ASHRAE energy standard 90.1, including its performance options, is useful for projects involving design of larger nonresidential buildings. The comparable code for federal projects is 10 Code of Federal Regulations (CFR) 435. For residential projects, the Model Energy Code has been incorporated into the building standards of most jurisdictions.

Related disciplines. For larger projects involving an architect-engineer team, it is essential for the entire team to be knowledgeable about energy issues. As well, superior

Building Energy Flow Diagram



This diagram is a composite illustration showing the sources of energy loads (external and internal) for a building along with the building systems that consume and modulate energy. The diagram also shows possible off-site and on-site energy sources.

Adapted from Donald Watson, FAIA, ed., *The Energy Design Handbook* (1993)

building performance is easier to achieve if the entire team is prepared to work together throughout the design process. Along with mechanical or electrical engineers, larger projects often involve energy, computer analysis, or code compliance specialists.

Related services. Competence in energy-efficient design and analysis can help a firm perform better and be more marketable in related areas such as general building design services, programming, commissioning, and facility management. Firms with expertise in energy analysis can easily broaden their services to include sustainable design and energy monitoring.

PROCESS

The scope of services involved in energy-efficient design is determined by the type of energy efficiency clients require and how much money they have budgeted for this element of architectural design. Energy analysis services ideally will pay for themselves in operating cost savings. One suggested rule of thumb is to spend as much as one year's expected energy savings for energy analysis studies of a new building design. Of course, analysis of demonstration or prototype projects may cost more.

In new office design, for example, it is economically realistic to reduce energy costs from 30 to 50 percent below national averages if an optimal mix of energy-efficient design strategies is applied to the design. Part of energy analysis services can be to help clients deter-

APPROPRIATE INVESTMENTS FOR ENERGY ANALYSIS SERVICES IN NEW CONSTRUCTION OR MAJOR RENOVATION PROJECTS*

ENERGY USE TYPE	INVESTMENT (\$/FT ²)		
	SMALL BUILDINGS (0-20,000 SQ. FT.)	MEDIUM BUILDINGS (20,000-1,000,000 SQ. FT.)	LARGE BUILDINGS (1,000,000 SQ. FT. AND ABOVE)
Moderate energy users (includes single-family residences, housing, and warehouses)	\$0.35 to \$0.25	\$0.25 to \$0.15	\$0.15 to \$0.05
High energy users (includes offices, factories, and service centers)	\$0.40 to \$0.30	\$0.30 to \$0.20	\$0.20 to \$0.10
Very high energy users (includes laboratories and hospitals)	\$0.45 to \$0.35	\$0.35 to \$0.25	\$0.25 to \$0.15

* This table adjusts the rule of thumb for building size and energy use characteristics. As buildings get larger, there is an economy of scale, so it is not necessary to expend as much money per square foot.

Source: "Procuring Low-Energy Design and Consulting Services" on the Federal Energy Management Program Web site at www.eren.doe.gov/femp/techassist/low_energy.html.

mine appropriate investment levels. The accompanying table shows some rules of thumb for appropriate investments in energy analysis services according to building size and intensity of energy use (per square foot of conditioned space). Note that these costs are for analysis studies only; additional construction costs may be associated with the energy features.

Steps Involved in Providing This Service

Based on the level of effort, energy-efficient analysis and design services might include the following packages of deliverables for a project involving design of a new office building.

Modest effort: 3 to 15 person-days (less than \$10,000). At this level of effort, services might include the following:

- Attendance at a preliminary meeting and presentation of results at a second meeting
- Definition of energy targets (in both dollars and Btus per square foot) during programming by running a design-phase analysis tool such as Energy-10
- Coordination with the project architect or manager to use similar tools during the early phases of design to study energy impacts of schematic building envelope and massing alternatives, including such options as daylighting, night cooling, passive solar heating, and glazing optimization
- In one- or two-zone buildings, analysis of a limited number of simplified HVAC configurations
- Provision of a brief, written final report summarizing recommendations.

Intermediate effort: 3 to 12 person-weeks (between \$10,000 and \$40,000). At this level, services might be expected to include the following:

- Attendance at regular meetings during the design and design development phases
- Definition of energy targets (in both dollars and Btus per square foot) during programming
- Cooperation with the project architect or manager during early phases of design to run DOE2.1E, Blast, or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including such options as daylighting, shading, lighting controls, and glazing optimization
- Ongoing coordination with the project architect or manager throughout the design process

- Analysis of alternative HVAC configurations, including controls and distribution options, during design development
- Economic analysis of building design and systems alternatives, including life cycle costs or discounted paybacks
- Provision of a comprehensive, written final report summarizing recommendations

Large effort: 2 to 6 person-months (more than \$40,000). At this level, services might include the following:

- Attendance at regular meetings throughout the project
- Definition of energy targets (in both dollars and Btus per square foot)
- Operation of DOE2.1E, Blast, or an equivalent hour-by-hour simulation tool during early phases of design to study schematic building envelope and massing alternatives, including such options as daylighting, shading, lighting controls, and glazing optimization
- Ongoing coordination with the project architect or manager throughout the design process
- Ongoing energy analysis of the evolving design to inform the designers of the energy implications of design alternatives
- Analysis of a significant number of alternative HVAC configurations, including controls and distribution options
- Comprehensive economic analysis of building design and systems alternatives, including life cycle costs or discounted paybacks (many federal agencies require analysis of at least three alternative HVAC systems on a life cycle basis)
- In some cases, writing or compilation of a building commissioning handbook
- In the case of major renovation projects, physical tests of existing conditions such as infiltration, thermography, and equipment efficiency studies
- Higher-order prediction studies such as physical daylight study models of prototypical office spaces or computational fluid dynamic models of convective flows in atriums
- Teaming with utility companies to analyze utility interface issues such as off-peak ice thermal storage and other peak-shaving and peak-shifting strategies
- Monitoring and profiling of actual building performance (see the topic Energy Monitoring [19.3])
- Intermediate reports and a comprehensive final report, as appropriate

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The AIA provides a contract document designed especially for alternative architectural services.

B102–2007, Standard Form of Agreement Between Owner and Architect without a Predefined Scope of Architect’s Services.

AIA Document B102–2007 is a standard form of agreement between owner and architect that contains terms and conditions and compensation details. B102–2007 does not include a scope of architect’s services, which must be inserted in Article 1 or attached as an exhibit. Special terms and conditions that modify the agreement may be included in Article 8.

The separation of the scope of services from the owner/architect agreement allows users the freedom to append alternative scopes of services.

AIA Document B102–2007 replaces and serves the same purpose as AIA Document B141–1997 Part 1.

For more information about AIA Contract Documents, visit www.aia.org/contractdocs/about

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