

Design Process

IN MARCH 1971 VISIONARY ARCHITECT MALCOLM WELLS published a watershed article in *Progressive Architecture*. It was rather intriguingly and challengingly titled “The Absolutely Constant Incontestably Stable Architectural Value Scale.” In essence, Wells argued that buildings should be *benchmarked* (to use a current term) against the environmentally regenerative capabilities of wilderness (Fig. 1.1). This seemed a radical idea then—and remains so even now, over 30 years later. Such a set of values, however, may be just what is called for as the design professions inevitably move from *energy-efficient* to *green* to *sustainable* design in the coming decades. The main problem with Wells’ “Incontestably Stable” benchmark is that most buildings fare poorly (if not dismally) against the environment-enhancing characteristics of wilderness. But perhaps this is more of a wakeup call than a problem.

As we enter the twenty-first century, *Progressive Architecture* is no longer in business, Malcolm Wells is in semiretirement, mechanical and electrical equipment has improved, simulation techniques have radically advanced, and information exchange has been revolutionized. In broad terms, however, the design process has changed little since the early 1970s. This should not be unexpected, as the design process is simply a structure within which to

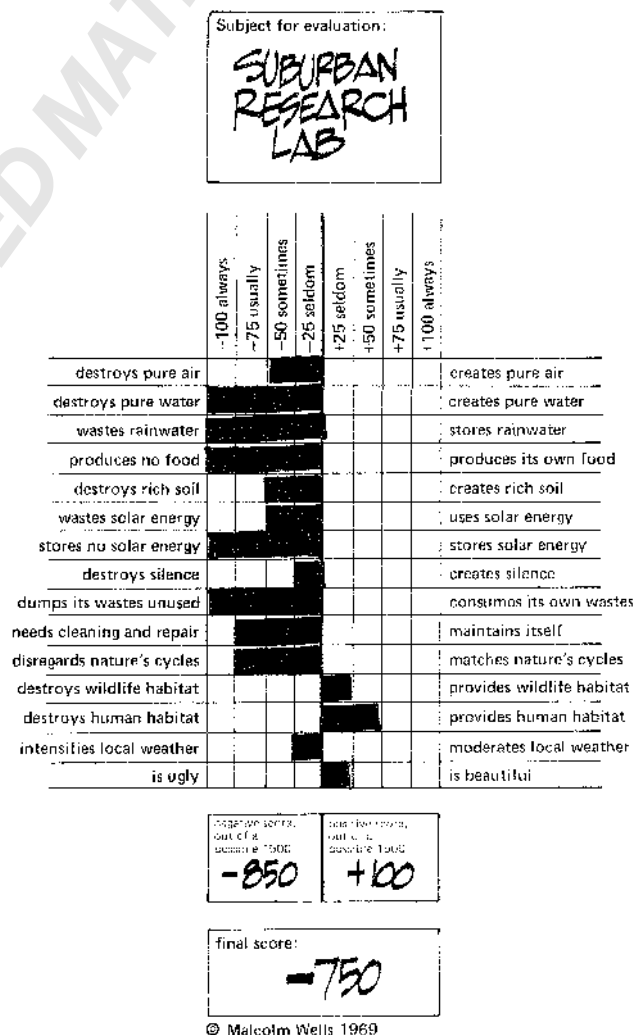


Fig. 1.1 Evaluation of a typical project using Malcolm Wells’ “absolutely constant incontestably stable architectural value scale.” The value focus was wilderness; today it might well be sustainability. (© Malcolm Wells. Used with permission from Malcolm Wells. 1981. *Gentle Architecture*. McGraw-Hill, New York.)

develop a solution to a problem. What absolutely must change in the coming decades are the values and philosophy that underlie the design process. The beauty of Wells' Value Scale was its crystal-clear focus upon the values that accompanied his design solutions—and the explicit stating of those values. To meet the challenges of the coming decades, it is critical that designers consider and adopt values appropriate to the nature of the problems being confronted—both at the individual project scale and globally. Nothing less makes sense.

1.1 INTRODUCTION

The design process is an integral part of the larger and more complex building procurement process through which an owner defines facility needs, considers architectural possibilities, contracts for design and construction services, and uses the resulting facility. Numerous decisions (literally thousands) made during the design process will determine the need for specific mechanical and electrical systems and equipment and very often will determine eventual owner and occupant satisfaction. Discussing selected aspects of the design process seems a good way to start this book.

A building project typically begins with pre-design activities that establish the need for, feasibility of, and proposed scope for a facility. If a project is deemed feasible and can be funded, a multiphase design process follows. The design phases are typically described as conceptual design, schematic design, and design development. If a project remains feasible as it progresses, the design process is followed by the construction and occupancy phases of a project. In fast-track approaches (such as design-build), design efforts and construction activities may substantially overlap.

Predesign activities may be conducted by the design team (often under a separate contract), by the owner, or by a specialized consultant. The product of predesign activities should be a clearly defined scope of work for the design team to act upon. This product is variously called a *program*, a *project brief*, or the *owner's project requirements*. The design process converts this statement of the owner's requirements into drawings and specifications that permit a contractor to convert the owner's (and designer's) wishes into a physical reality.

The various design phases are the primary

arena of concern to the design team. The design process may span weeks (for a simple building or system) or years (for a large, complex project). The design team may consist of a sole practitioner for a residential project or 100 or more people located in different offices, cities, or even countries for a large project. Decisions made during the design process, especially during the early stages, will affect the project owner and occupants for many years—influencing operating costs, maintenance needs, comfort, enjoyment, and productivity.

The scope of work accomplished during each of the various design phases varies from firm to firm and project to project. In many cases, explicit expectations for the phases are described in professional service contracts between the design team and the owner. A series of images illustrating the development of the Real Goods Solar Living Center (Figs. 1.2 and 1.3) is used to illustrate the various phases



Fig. 1.2 The Real Goods Solar Living Center, Hopland, California; exterior view. (Photo © Bruce Haglund; used with permission)

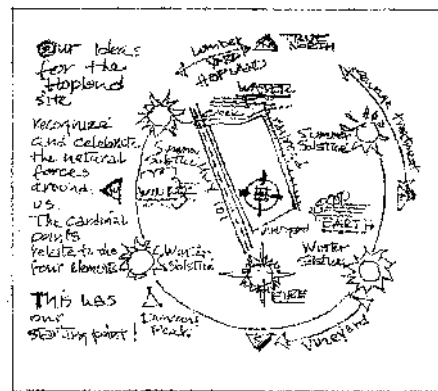


Fig. 1.3 Initial concept sketch for the Real Goods Solar Living Center, a site analysis. (Drawing by Sim Van der Ryn; reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation.)

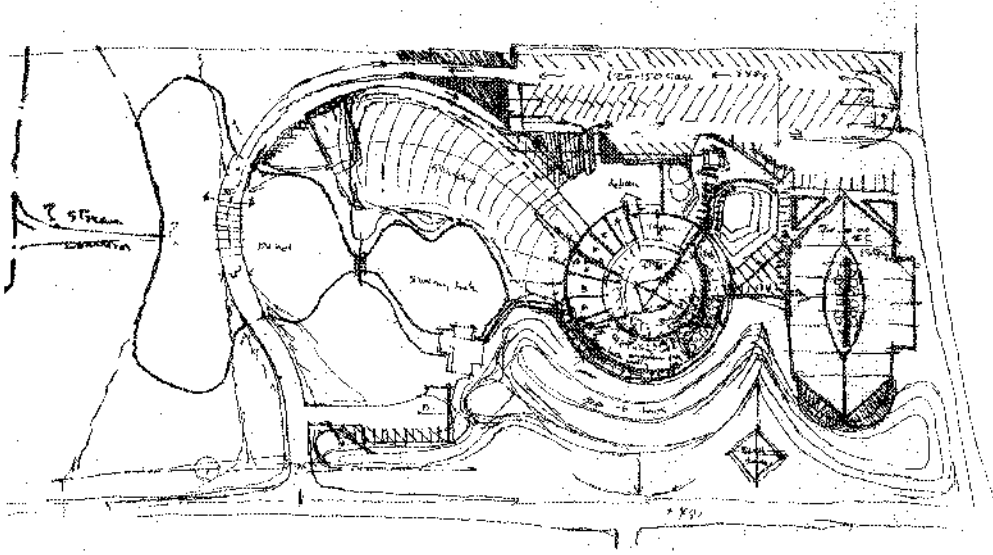


Fig. 1.4 Conceptual design proposal for the Real Goods Solar Living Center. The general direction of design efforts is suggested in fairly strong terms (the “first, best moves”), yet details are left to be developed in later design phases. There is a clear focus on rich site development even at this stage—a focus that was carried throughout the project. (Drawing by Sim Van der Ryn; reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation.)

of a building project. (The story of this remarkable project, and its design process, is chronicled in Schaffer et al., 1997.) Generally, the purpose of conceptual design (Fig. 1.4) is to outline a general solution to the owner’s program that meets the budget and

captures the owner’s imagination so that design can continue. All fundamental decisions about the proposed building should be made during conceptual design (not that things can’t or won’t change). During schematic design (Figs. 1.5 and 1.6), the

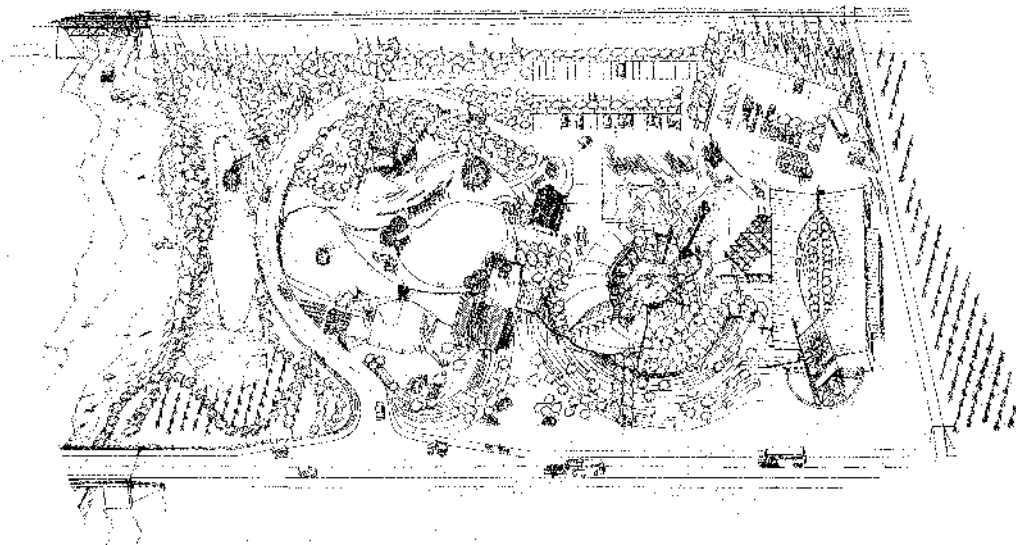


Fig. 1.5 Schematic design proposal for the Real Good Solar Living Center. As design thinking and analysis evolves, so does the specificity of a proposed design. Compare the level of detail provided at this phase with that shown in Fig. 1.4. Site development has progressed, and the building elements begin to take shape. The essence of the final solution is pretty well locked into place. (Drawing by David Arkin; reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation.)

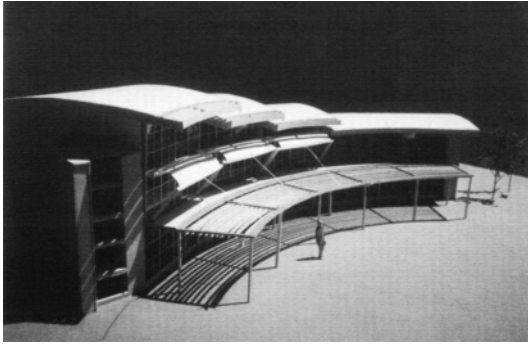


Fig. 1.6 Scale model analysis of shading devices for the Real Goods Solar Living Center. This is the sort of detailed analysis that would likely occur during design development. (Photo, model, and analysis by Adam Jackaway; reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation.)

conceptual solution is further developed and refined. During design development (Fig. 1.7), all decisions regarding a design solution are finalized, and construction drawings and specifications detailing those innumerable decisions are prepared.

The construction phase (Fig. 1.8) is primarily in the hands of the contractor, although design decisions determine what will be built and may dramatically affect constructability. The building owner and occupants are the key players during the occupancy phase (Fig. 1.9). Their experiences with the building will clearly be influenced by design decisions and construction quality, as well as by maintenance and operation practices. A feedback loop that allows construction and occupancy experiences (lessons—both good and bad) to be used by the design team is essential to good design practice.

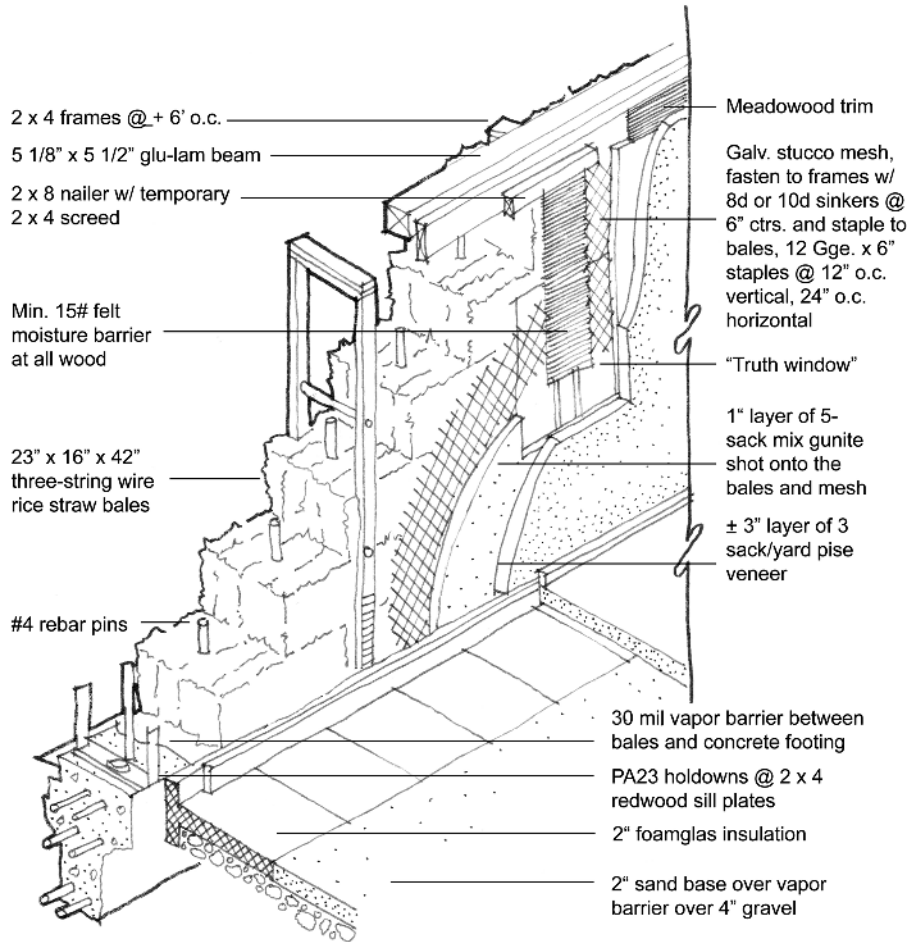


Fig. 1.7 During design development the details that convert an idea into a building evolve. This drawing illustrates the development of working details for the straw bale wall system used in the Real Goods Solar Living Center. Material usage and dimensions are refined and necessary design analyses (thermal, structural, economic) completed. (Drawing by David Arkin; reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation. Redrawn by Erik Winter.)



Fig. 1.8 Construction phase photo of Real Goods Solar Living Center straw bale walls. Design intent becomes reality during this phase. (Reprinted from *A Place in the Sun* with permission of Real Goods Trading Corporation.)

1.2 DESIGN INTENT

Design efforts should generally focus upon achieving a solution that will meet the expectations of a well-thought-out and explicitly defined design intent. Design intent is simply a statement that outlines the expected high-level outcomes of the design process. Making such a fundamental statement is critical to the success of a design, as it points to the general direction(s) that the design process must take to achieve success. Design intent should not try to capture the totality of a building's character; this will come only with the completion of the design. It should, however, adequately express the defining characteristics of a proposed building solution. Example design intents (from among thousands of possibilities) might include the following:



Fig. 1.9 The Real Goods Solar Living Center during its occupancy and operations phase. Formal and informal evaluation of the success of the design solution may (and should) occur. Lessons learned from these evaluations can inform future projects. This photo was taken during a Vital Signs case study training session held at the Solar Living Center. (© Cris Benton, kite aerial photographer and Professor, University of California–Berkeley; used with permission.)

- The building will provide outstanding comfort for its occupants.
- The building will use the latest in information technology.
- The building will be green, with a focus on indoor environmental quality.
- The building will use primarily passive systems.
- The building will provide a high degree of flexibility for its occupants.

Clear design intents are important because they set the tone for design efforts, allow all members of the design team to understand what is truly critical to success, provide a general direction for early design efforts, and put key or unusual design concerns on the table. Prof. Larry Peterson, former director of the Florida Sustainable Communities Center, has described the earliest decisions in the design process as an attempt to make the “first, best moves.” Strong design intent will inform such moves. Weak intent will result in a weak building. Great moves too late will be futile. The specificity of the design intent will evolve throughout the design process. *Outstanding comfort* during conceptual design may become *outstanding thermal, visual, and acoustic comfort* during schematic design.

1.3 DESIGN CRITERIA

Design criteria are the benchmarks against which success or failure in meeting design intent is measured. In addition to providing a basis against which to evaluate success, design criteria will ensure that all involved parties seriously address the technical and philosophical issues underlying the design intent. Setting design criteria demands the clarification and definition of many intentionally broad terms used in design intent statements. For example, what is really meant by *green*, by *flexibility*, by *comfort*? If such terms cannot be benchmarked, then there is no way for the success of a design to be evaluated—essentially anything goes, and all solutions are potentially equally valid. Fixing design criteria for qualitative issues (such as *exciting*, *relaxing*, or *spacious*) can be especially challenging but equally important. Design criteria should be established as early in the design process as possible—certainly no later than the schematic design phase. As design criteria will define success or failure in a

specific area of the building design process, they should be realistic and not subject to whimsical change. In many cases, design criteria will be used both to evaluate the success of a design approach or strategy and to evaluate the performance of a system or component in a completed building. Design criteria might include the following:

- Thermal conditions will meet the requirements of ASHRAE Standard 55-2004.
- The power density of the lighting system will be no greater than 0.7 W/ft².
- The building will achieve a Silver *LEED*® rating.
- Fifty percent of building water consumption will be provided by rainwater capture.
- Background sound levels in classrooms will not exceed RC 35.

1.4 METHODS AND TOOLS

Methods and tools are the means through which design intent is accomplished. They include design methods and tools, such as a heat loss calculation procedure or a sun angle calculator. They also include the components, equipment, and systems that comprise a building. It is important that the right method or tool be used for a particular purpose. It is also critical that methods and tools (as means to an end) never be confused with either design intent (a desired end) or design criteria (benchmarks).

For any given design situation there are typically many valid and viable solutions available to the design team. It is important that none of these solutions be overlooked or ruled out due to design process short-circuits. Although this may seem unlikely, methods (such as fire sprinklers, electric lighting, and sound absorption) are surprisingly often included as part of a design intent statement. Should this occur, all other possible (and perhaps desirable) solutions are ruled out by direct exclusion. This does not serve a client or occupants well and is also a disservice to the design team.

This book is a veritable catalog of design guidelines, methods, equipment, and systems that serve as means and methods to desired design ends. Sorting through this extensive information will be easier with specific design intent and criteria in mind. Owner expectations and designer experiences will typically inform design intent. Sections of the book that address fundamental principles will provide

TABLE 1.1 Relationships Between Design Intent, Design Criteria, and Design Tools/Methods

Issue	Design Intent	Possible Design Criterion	Potential Design Tools	Potential Implementation Method
Thermal comfort	Acceptable thermal comfort	Compliance with ASHRAE Standard 55	Standard 55 graphs/tables or comfort software	Passive climate control and/or active climate control
Lighting level (illuminance)	Acceptable illuminance levels	Compliance with recommendations in the <i>IESNA Lighting Handbook</i>	Hand calculations or computer simulations	Daylighting and/or electric lighting
Energy efficiency	Minimal energy efficiency	Compliance with ASHRAE Standard 90.1	Handbooks, simulation software, manufacturer's data, experience	Envelope strategies and/or equipment strategies
Energy efficiency	Outstanding energy efficiency	Exceed the minimum requirements of ASHRAE Standard 90.1 by 25%	Handbooks, simulation software, manufacturer's data, experience	Envelope strategies and/or equipment strategies
Green design	Obtain green building certification	Meet the requirements for a LEED gold rating	LEED materials, handbooks, experience	Any combination of approved strategies to obtain sufficient rating points

assistance with establishment of appropriate design criteria. Table 1.1 provides examples of the relationship between design intent, design criteria, and tools/methods.

1.5 VALIDATION AND EVALUATION

To function as a knowledge-based profession, design (architecture and engineering) must reflect upon previous efforts and learn from existing buildings. Except in surprisingly rare situations, most building designs are generally unique—comprising a collection of elements not previously assembled in precisely the same way. Most buildings are essentially a design team hypothesis—“We believe that this solution will work for the given situation.” Unfortunately, the vast majority of buildings exist as untested hypotheses. Little in the way of performance evaluation or structured feedback from the owner and occupants is typically sought. This is not to suggest that designers do not learn from their projects, but rather that little research-quality, publicly shared information is captured for use on other

projects. This is clearly not an ideal model for professional practice.

(a) Conventional Validation/Evaluation Approaches

Design validation is very common, although perhaps more so when dealing with quantitative concerns than with qualitative issues. Many design validation approaches are employed, including hand calculations, computer simulations and modeling, physical models (of various scales and complexity), and opinion surveys. Numerous design validation methods are presented in this book. Simple design validation methods (such as broad approximations, lookup tables, or nomographs) requiring few decisions and little input data are typically used early in the design process. Later stages of design see the introduction of more complex methods (such as computer simulations or multistep hand calculations) requiring substantial and detailed input.

Building validation is much less common than design validation. Structured evaluations of occupied buildings are rarely carried out. Historically, the

most commonly encountered means of validating building performance is the post-occupancy evaluation (POE). Published POEs have typically focused upon some specific (and often nontechnical) aspect of building performance, such as way-finding or productivity. Building commissioning and case studies are finding more application as building validation approaches. Third-party validations, such as the LEED rating system, are also emerging.

(b) Commissioning

Building commissioning is an emerging approach to quality assurance. An independent commissioning authority (an individual or, more commonly, a team) verifies that equipment, systems, and design decisions can meet the owner's project requirements (design intent and criteria). Verification is accomplished through review of design documents and detailed testing of equipment and systems under conditions expected to be encountered with building use. Historically focused upon mechanical and electrical systems, commissioning is currently being applied to numerous building systems—including envelope, security, fire protection, and information systems. Active involvement of the design team is critical to the success of the commissioning process (ASHRAE, 2005).

(c) Case Studies

Case studies represent another emerging approach to design/construction validation and evaluation. The underlying philosophy of a case study is to capture information from a particular situation and convey the information in a way that makes it useful to a broader range of situations. A building case study attempts to present the lessons learned from one case in a manner that can benefit other cases (future designs). In North America, the Vital Signs and Agents of Change projects have focused upon disseminating a building performance case study methodology for design professionals and students—with an intentional focus upon occupied buildings (à la POEs). The American Institute of Architects has developed a series of case studies dealing with design process/practice. In the United Kingdom, numerous case studies have been conducted under the auspices of the PROBE (post-occupancy review of building engineering) project.

1.6 INFLUENCES ON THE DESIGN PROCESS

The design process often appears to revolve primarily around the needs of a client and the capabilities of the design team—as exemplified by the establishment of design intent and criteria. There are several other notable influences, however, that affect the conduct and outcome of the building design process. Some of these influences are historic and affect virtually every building project; others represent emerging trends and affect only selected projects. Several of these design-influencing factors are discussed below.

(a) Codes and Standards

The design of virtually every building in North America will be influenced by codes and standards. *Codes* are government-mandated and -enforced documents that stipulate minimum acceptable building practices. Designers usually interface with codes through an entity known as the *authority having jurisdiction*. There may be several such authorities for any given locale or project (fire protection requirements, for example, may be enforced separately from general building construction requirements or energy performance requirements). Codes essentially define the minimum that society deems acceptable. In no way is code compliance by itself likely to be adequate to meet the needs of a client. On the other hand, code compliance is undisputedly necessary.

Codes may be written in prescriptive language or in performance terms. A *prescriptive* approach mandates that something be done in a certain way. Examples of prescriptive code requirements include minimum R-values for roof insulation, minimum pipe sizes for a roof drainage system, and a minimum number of hurricane clips per length of roof. The majority of codes in the United States are fundamentally prescriptive in nature. A prescriptive code defines means and methods. By contrast, a performance code defines intent. A *performance* approach states an objective that must be met. Examples of performance approaches to code requirements include a maximum permissible design heat flow through a building envelope, a minimum design rainfall that can be safely drained from a building roof, and a defined wind speed that will not damage

a roof construction. Some primarily prescriptive codes offer performance “options” for compliance. This is especially true of energy codes and smoke control requirements in fire protection codes.

Codes in the United States are in transition. Each jurisdiction (city, county, and/or state, depending upon legislation) is generally free to adopt whichever model code it deems most appropriate. Some jurisdictions (typically large cities) use home-grown codes instead of a model code. Historically, there were four model codes (the *Uniform Building Code*, the *Standard Building Code*, the *Basic Building Code*, and the *National Building Code*) that were used in various regions of the country. There is ongoing movement to development and use of a single model *International Building Code* to provide a more uniform and standardized set of code requirements. Canada recently adopted a major revision to its *National Building Code*. Knowledge of the current code requirements for a project is a critical element of the design process.

Standards are documents that present a set of minimum requirements for some aspect of building design that have been developed by a recognized authority (such as Underwriters Laboratories, the National Fire Protection Association, or the American Society of Heating, Refrigerating and Air-Conditioning Engineers). Standards do not carry the weight of government enforcement that codes do, but they are often incorporated into codes via reference. Standards play an important role in building design and are often used by legal authorities to define the level of care expected of design professionals. Typically, standards have been developed under a consensus process with substantial opportunity for external review and input. *Guidelines* and *handbooks* are less formal than standards, usually with less review and/or consensus. *General practice*, the least formalized basis for design, captures the norm for a given locale or discipline. Table 1.2 provides examples of codes, standards, and related design guidance documents.

(b) Costs

Costs are an historic influence on the design process and are just as pervasive as codes. Typically, one of the earliest and strictest limits on design flexibility is the maximum construction budget imposed by the client. First cost (the cost for an owner to acquire the

keys to a completed building) is the most commonly used cost factor. First cost is usually expressed as a maximum allowable construction cost or as a cost per unit area. Life-cycle cost (the cost for an owner to acquire and use a building for some defined period of time) is generally equally or more important than first cost, but is often ignored by owners and usually not well understood by designers.

Over the life of a building, operating and maintenance costs can far exceed the cost to construct or acquire a building. Thus, whenever feasible, design decisions should be based upon life-cycle cost implications and not simply first cost. The math of life-cycle costing is not difficult. The primary difficulties in implementing life-cycle cost analysis are estimating future expenses and the uncertainty naturally associated with projecting future conditions. These are not as difficult as they might seem, however, and a number of well-developed life-cycle cost methodologies have been developed. Appendix I provides basic information on life-cycle cost factors and procedures. The design team may find life-cycle costing a persuasive ally in the quest to convince an owner to make important, but apparently expensive, decisions.

(c) Passive and Active Approaches

The distinction between passive and active systems may mean little to the average building owner but can be critical to the building designer and occupant. Development of passive systems must begin early in the design process, and requires early and continuous attention from the architectural designer. Passive system operation will often require the earnest cooperation and involvement of building occupants and users. Table 1.3 summarizes the identifying characteristics of passive and active systems approaches. These approaches are conceptually opposite in nature. Individual systems that embody both active and passive characteristics are often called hybrid systems. Hybrid systems are commonly employed as a means of tapping into the best aspects of both approaches.

The typical building will usually consist of both passive and active systems. Passive systems may be used for climate control, fire protection, lighting, acoustics, circulation, and/or sanitation. Active systems may also be used for the same purposes and for electrical distribution.

TABLE 1.2 Codes, Standards, and Other Design Guidance Documents

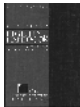
Document Type		Characteristics	Examples
Code		Government-mandated and government-enforced (typically via the building and occupancy permit process); may be a legislatively adopted standard	Florida Building Code; California Title 24; Chicago Building Code; International Building Code (when adopted by a jurisdiction)
Standard		Usually a consensus document developed by a professional organization under established procedures with opportunities for public review and input	ASHRAE Standard 90.1 (<i>Energy Standard for Buildings Except Low-Rise Residential Buildings</i>); ASTM E413-87 (<i>Classification for Rating Sound Insulation</i>); ASME A17.1—2000 (<i>Safety Code for Elevators and Escalators</i>)
Guideline		Development is typically by a professional organization, but within a looser structure and with less public involvement	ASHRAE Guideline 0 (<i>The Commissioning Process</i>); IESNA <i>Advanced Lighting Guidelines</i> ; NEMA LSD 12-2000 (<i>Best Practices for Metal Halide Lighting Systems</i>)
Handbook, design guide		Development can vary widely—involving formal committees and peer review or multiple authors without external review	IESNA <i>Lighting Handbook</i> ; ASHRAE <i>Handbook—Fundamentals</i> ; NFPA <i>Fire Protection Handbook</i>
General practice		The prevailing norm for design within a given community or discipline; least formal of all modes of guidance	System sizing approximations; generally accepted flashing details

Image Sources: code—used with permission of the International Code Council; standard—used with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers; guideline and handbook—used with permission of the Illuminating Engineering Society of North America; general practice—used with permission of John Wiley & Sons.

Acronyms: ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers; ASME = American Society of Mechanical Engineers; ASTM = ASTM International (previously American Society for Testing and Materials); IESNA = Illuminating Engineering Society of North America; NEMA = National Electrical Manufacturers Association; NFPA = National Fire Protection Association.

(d) Energy Efficiency

Some level of energy efficiency is a societally mandated element of the design process in most developed countries. Code requirements for energy-efficient building solutions were generally instituted as a result of the energy crises of the 1970s and have been updated on a periodic basis since then. As with all code requirements, mandated energy efficiency levels represent a minimum performance level that is considered acceptable—not an optimal performance level. Such acceptable minimum performance has evolved over time in response to changes in energy costs and availability and also in response to changes in the costs and availability of building technology.

In the United States, ANSI/ASHRAE/IESNA *Standard 90.1* (published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, cosponsored by the Illuminating Engineering Society of North America, and approved by the American National Standards Institute) is the most commonly encountered energy efficiency benchmark for commercial/institutional buildings. Some states (such as California and Florida) utilize state-specific energy codes. Residential energy efficiency requirements are addressed by several model codes and standards (including the *International Energy Code*, the *Model Energy Code*, and ANSI/ASHRAE *Standard 90.2*). Appendix G provides a

TABLE 1.3 Defining the Characteristics of Passive and Active Systems

Characteristic	Passive System	Active System
Energy source	Uses no purchased energy (electricity, natural gas, fuel oil, etc.)—example: daylighting system	Uses primarily purchased (and nonrenewable) energy—example: electric lighting system
System components	Components play multiple roles in system and in larger building—example: concrete floor slab that is structure, walking surface, and solar collector/storage	Components are commonly single-purpose elements—example: gas furnace
System integration	System is usually tightly integrated (often inseparably) with the overall building design—example: natural ventilation system using windows	System is usually not well integrated with the overall building design, often seeming an add-on—example: window air-conditioning unit
Passive and active systems represent opposing philosophical concepts. Design is seldom so straightforward as to permit the exclusive use of one philosophy. Thus, the hybrid system. Hybrid systems are a composite of active and passive approaches, typically leaning more toward the passive. For example, single purpose, electricity-consuming (active) ceiling fans might be added to a natural ventilation (passive) cooling system to extend the performance of the system and thus reduce energy usage that would otherwise occur if a fully active air-conditioning system were turned on instead of the fans.		

sample of energy efficiency requirements from *Standard 90.1* and *Standard 90.2*.

Energy efficiency requirements for residential buildings tend to focus upon minimum envelope (walls, floors, roofs, doors, windows) and mechanical equipment (heating, cooling, domestic hot water) performance. Energy efficiency requirements for commercial/institutional buildings address virtually every building system (including lighting and electrical distribution). Most energy codes present a set of prescriptive minimum requirements for individual building elements, with an option for an alternative means of compliance to permit innovation and/or a systems-based design approach.

Technically speaking, *efficiency* is simply the ratio of system output to system input. The greater the output for any given input, the higher the efficiency. This concept plays a large role in energy efficiency standards through the specification of minimum efficiencies for many items of mechanical and electrical equipment for buildings. *Energy conservation* implies saving energy by using less. This is conceptually different from efficiency but is an integral part of everyday usage of the term. Energy efficiency codes and standards include elements of conservation embodied in equipment control requirements or insulation levels. Because of negative connotations some associate with “conservation” (doing without), the term *energy efficiency* is generally used to describe both conservation and efficiency efforts.

Passive design solutions usually employ renewable energy resources. Several active design solutions, however, also utilize renewable energy forms. Energy conservation and efficiency concerns are typically focused upon minimizing depletion of non-renewable energy resources. The use of renewable energy sources (such as solar radiation and wind) changes the perspective of the design team and how compliance with energy efficiency codes/standards is evaluated. The majority of energy efficiency standards deal solely with on-site energy usage. Off-site energy consumption (for example, that required to transport fuel oil or natural gas, or the losses from electrical generation) is not addressed. This site-based focus can seriously skew thinking about energy efficiency design strategies.

(e) Green Building Design Strategies

Green design considerations are increasingly becoming a part of the design process for many buildings. Green design goes well beyond energy-efficient design in order to address both the local and global impacts of building energy, water, and materials usage. Energy efficiency is a key, but not self-sufficient, element of green design. The concept, broadly called “green design,” arose from concerns about the wide-ranging environmental impacts of design decisions. Although there is no generally accepted concise definition of *green*, the term is

typically understood to incorporate concern for the health and well-being of building occupants/users and respect for the larger global environment. A green building should maximize beneficial impacts on its direct beneficiaries while minimizing negative impacts on the site, local, regional, national, and global environments.

Several green-design rating systems have found wide acceptance as benchmarks for design. These include the U.S. Green Building Council's LEED system (*Leadership in Energy and Environmental Design*) and an international evaluation methodology entitled GBTool. Somewhat similar rating systems are in use in the United Kingdom and Canada. The LEED system (Fig. 1.10) presents a palette of design options from which the design team can select strategies appropriate for a particular building and its context. Amassing points for selected strategies provides a means of attaining green building status—at one of several levels of achievement, via a formal certification procedure. Prerequisite design strategies (including baseline energy efficiency and acceptable indoor air quality) provide an underpinning for the optional strategies.

The emergence of green building rating systems has greatly rationalized design intent and design criteria in this particular area of architecture. Prior to the advent of LEED (or GBTool), anyone could claim greenness for his/her designs. Although green design is entered into voluntarily (no codes currently require it, although a number of municipalities require new public buildings to be green), there are now generally accepted standards

against which performance can be measured. Appendix G provides an excerpt from the LEED green building rating system.

(f) Design Strategies for Sustainability

Unlike green design, the meaning of “sustainability” in architecture has not yet been rationalized. The term *sustainable* is used freely—and often mistakenly—to describe a broad range of intents and performances. This is unfortunate, as it tends to make sustainability a meaningless term—and sustainability is far too important a concern to be meaningless. For the purposes of this book, sustainability will be defined as follows (paraphrasing the Brundtland Commission): *Sustainability involves meeting the needs of today's generation without detracting from the ability of future generations to meet their needs.*

Sustainability is essentially long-term survival. In architectural terms, sustainability involves the survival of an existing standard of living into future generations. From an energy, water, and materials standpoint, sustainability can be argued to require zero net use of nonrenewable resources. Any long-term removal of nonrenewable resources from the environment will surely impair the ability of future generations to meet their needs (with fewer resources available as a result of our actions). Because sustainability is so important a concept and objective, the term should not be used lightly. It is highly unlikely that any single building built in today's economic environment can be sustainable (yielding no net resource depletion). Sustainability



(a)



(b)

Fig. 1.10 (a) The Jean Vollum Natural Capital Center, Portland, Oregon. A warehouse from the industrial era was rehabilitated by Ecotrust to serve as a center for the conservation era. (b) LEED plaque on the front façade of the Vollum Center. The plaque announces the success of the design team (and owner) in achieving a key element of their design intent. (Photos © 2004 Alison Kwok; all rights reserved.)

at the community scale is more probable; examples, however, are rare.

(g) Regenerative Design Strategies

Energy efficiency is an attempt to use less energy to accomplish a given design objective (such as thermal comfort or adequate lighting). Green design is an attempt to maximize the positive effects of design while minimizing the negative ones—with respect to energy, water, and material resources. Sustainable design is an attempt to solve today's problems while reserving adequate resources to permit future generations to solve their problems. Energy efficiency is a constituent of green design. Green design is a constituent of sustainable design. *Regenerative design* steps out beyond sustainability.

The goal of energy efficiency is to reduce net negative energy impacts. The goal of green design is to reduce net negative environmental impacts. The goal of sustainability is to produce no net negative environmental impacts. The goal of regenerative design is to produce a net positive environmental impact—to leave the world better off with respect to energy, water, and materials. Obviously, if design for sustainability is difficult, then regenerative design is even more difficult. Nevertheless, there are some interesting examples of regenerative design projects, including the Eden Project in the United Kingdom and the Center for Regenerative Studies (Fig. 1.11) in the United States. Both projects involve substantial site remediation and innovative design solutions.



(a)

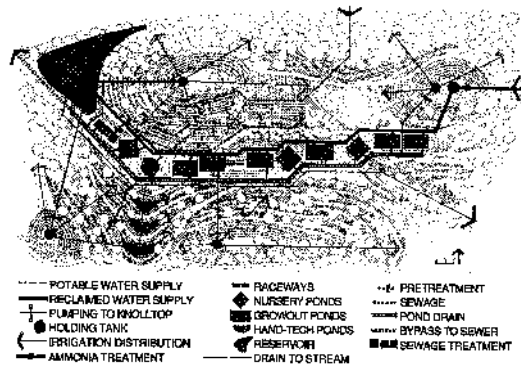
1.7 A PHILOSOPHY OF DESIGN

From a design process perspective, the operating philosophy of this book is that development of appropriate design intent and criteria is critical to the successful design of buildings and their mechanical and electrical systems. Passive systems should generally be used before active systems (this in no way denigrates active systems, which will be necessary features of almost any building); life-cycle costs should be considered instead of simply first cost; and green design is a desirable intent that will ensure energy efficiency and provide a pathway toward sustainability. Design validation, commissioning, and post-occupancy evaluation should be aggressively pursued.

John Lyle presented an interesting approach to design (that elaborates upon this general philosophy) in his book *Regenerative Design for Sustainable Development*. The following discussion presents an overview of his approach. The strategies provide design teams with varied opportunities to integrate site and building design with components and processes. Those strategies most applicable to the design of mechanical and electrical systems are presented here. This approach guided the design of the Center for Regenerative Studies at the California Polytechnic State University at Pomona, California (Fig. 1.11).

(a) Let Nature Do the Work

This principle expresses a preference for natural/passive processes over mechanical/active processes.



(b)

Fig. 1.11 (a) The Center for Regenerative Studies (CRS), California Polytechnic State University–Pomona. (b) Site plan for the CRS. It's not easy being regenerative—the highlighted elements relate only to the water reclamation aspects of the project. (Photo © 2004 Allison Kwok; drawing from Lyle, John Tillman. 1994. *Regenerative Design for Sustainable Development*. John Wiley & Sons, Inc., New York.)



Fig. 1.12 Letting nature do the work—via daylighting. Mt. Angel Abbey Library, Oregon, designed by Alvar Aalto. (Photo by Amanda Clegg.)

Designers can usually find ways to use natural processes on site (Fig. 1.12), where they occur, in place of dependence upon services from remote/nonrenewable sources. Smaller buildings on larger sites are particularly good candidates for this strategy.

(b) Consider Nature as Both Model and Context

A look at this book reveals a strong reliance upon physical laws as a basis for design. Heat flow, water flow, electricity, light, and sound follow rules described by physics. This principle, however, suggests looking at nature (Fig. 1.13) for biological, in addition to the classical physical, models for design. The use of a Living Machine to process building wastes as opposed to a conventional sewage treatment plant is an example of where this strategy might lead.

(c) Aggregate Rather Than Isolate

This strategy recommends that designs focus upon systems and not just upon the parts that make up a



Fig. 1.13 Consider nature as a model. Plants provide water treatment and generate biomass in an aquacultural pond at the Center for Regenerative Studies, Cal Poly–Pomona. (Photo © 2004 Alison Kwok; all rights reserved.)

system—in essence, seeing the forest through the trees. The components of a system should be highly integrated to ensure workable linkages among the parts and the success of the whole. An example would be optimizing the solar heating performance of a direct gain system comprised of glazing, floor slab, insulation, and shading while perhaps reducing the performance of one or more constituent parts (Fig. 1.14).

(d) Match Technology to the Need

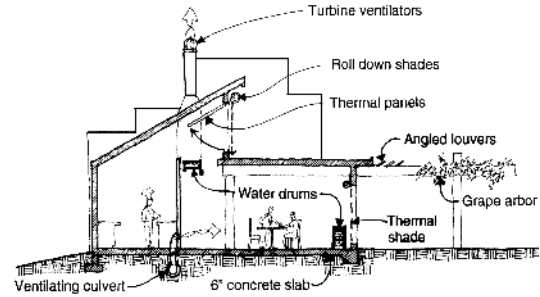
This strategy seeks to avoid using high-grade resources for low-grade tasks. For example, it is obviously wasteful to flush toilets with purified water, but perhaps less obviously wasteful (but equally a mismatch) to use electricity (a very-high-grade energy form) to heat water for bathing. The corollary to this strategy is to think small, think simple, and think locally (Fig. 1.15).

(e) Seek Common Solutions to Disparate Problems

This approach requires breaking out of the box of categories and classifications. An understanding of systems should lead to an increased awareness of systems capabilities—which will often prove to be multidisciplinary and multifunctional. Making a design feature (Fig. 1.16) serve multiple tasks (perhaps mechanical, electrical, and architectural in nature) is one way to counteract the potential problem of a higher first cost for green or sustainable design features. Solutions can be as simple and



(a)



(b)

Fig. 1.14 Aggregating, not isolating. (a) The Cottage Restaurant, Cottage Grove, Oregon. (b) This section through the restaurant illustrates the substantial integration and coordination (aggregation) of elements typical of passive design solutions. (Photo by G.Z. Brown; drawing by Michael Cockram; © 1998 by John S. Reynolds, A.I.A., all rights reserved.)

low-tech as using heat from garden composting to help warm a greenhouse.

(f) Shape the Form to Guide the Flow

The most obvious examples of this strategy are solar-heated buildings that are shaped (Fig. 1.17) to gather winter sun or naturally ventilated buildings shaped to collect and channel prevailing winds. Daylighting is another obvious place to apply the “form follows flow” strategy, which can have a dramatic impact upon building design efforts and outcomes.



Fig. 1.15 Match technology to the need. Sometimes it's the simple things that count. (Photo © 2004 Alison Kwok; all rights reserved.)



Fig. 1.16 Seek common solutions. The “atrium” of the Hood River County Library, Hood River, Oregon, provides a central hub for the library, daylighting, views (spectacular), and stack ventilation. (Photo © 2004 Alison Kwok; all rights reserved.)

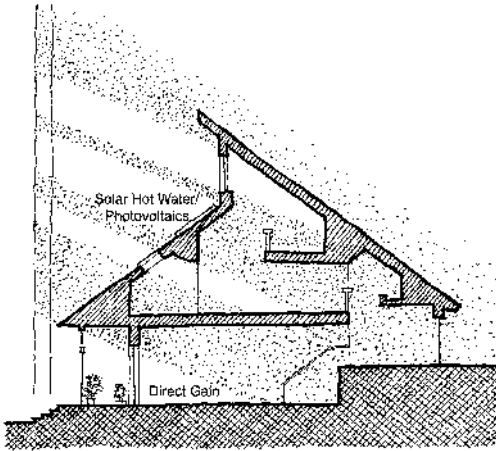


Fig. 1.17 Shaping the form to the flow. Using a “band of sun” analysis as a solar form giver (see Chapter 3 for further details). (Redrawn by Jonathan Meendering.)

(g) Shape the Form to Manifest the Process

This is more than a variation on the adage “If you’ve got it, flaunt it.” This strategy asks that a building inform its users and visitors about how it works both inside and out (Fig. 1.18). In passive solar-heated

and passively cooled buildings, much of the thermal performance is evident in the form of the exterior envelope and the interior space, rather than hidden in a closet or mechanical penthouse. Prof. David Orr of Oberlin College addresses this issue succinctly by asking “What can a building teach?”

(h) Use Information to Replace Power

This strategy addresses both the design process and building operations. Knowledge is suggested as a substitute for brute force (and associated energy waste). Designs informed by an understanding of resources, needs, and systems capabilities will tend to be more effective (successfully meeting intent) and efficient (meeting intent using less energy) than uninformed designs. Building operations informed by feedback and learning (Fig. 1.19) will tend to be more effective and efficient than static, unchangeable operating modes. Users of buildings can play a leading role in this approach by being allowed to make decisions about when to do what in order to maintain desired conditions. Reliance on a building’s users is not so much a direct energy saver—most controls use very little power—as it is an education. A user who understands how a building receives and conserves heat in

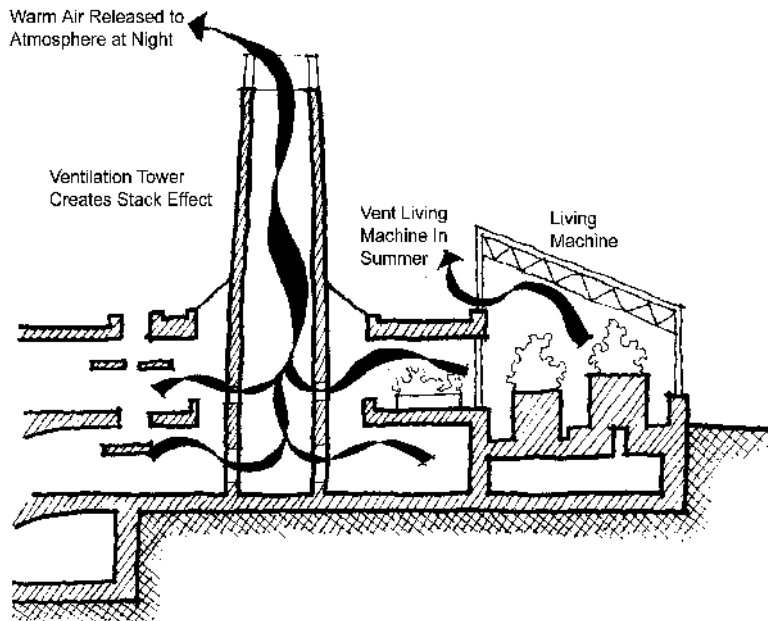


Fig. 1.18 Shaping the form to the process. Stack effect ventilation is augmented by the building form in this proposal for the EPICenter project, Bozeman, Montana. (Courtesy of Place Architecture LLC, Bozeman, Montana, and Berkebile Nelson Immenschuh McDowell, Architects, Kansas City, Missouri. Redrawn by Jonathan Meendering.)

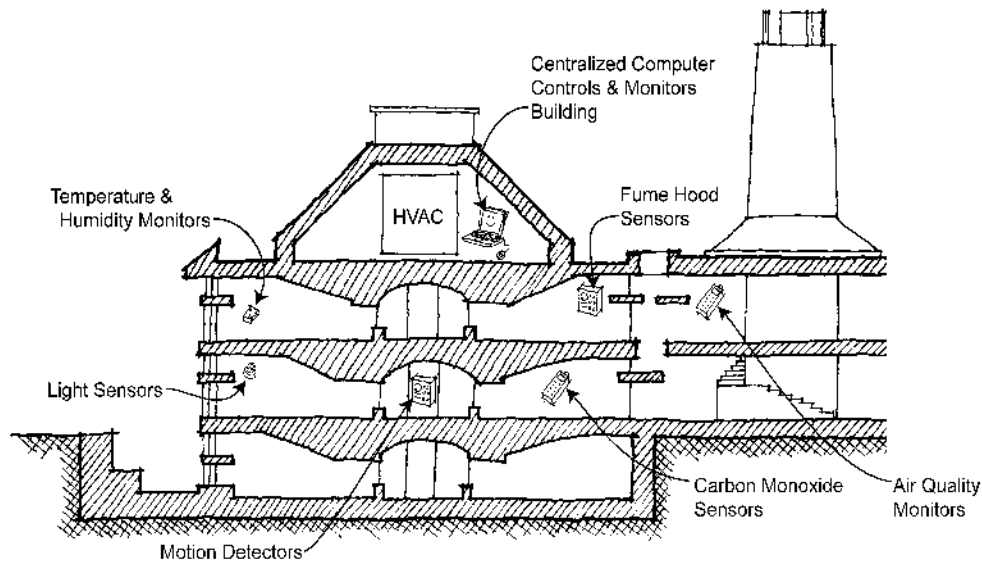


Fig. 1.19 Use information to replace power. Section showing intelligent control system components for the proposed EPICenter project, Bozeman, Montana. (Courtesy of Place Architecture LLC, Bozeman, Montana, and Berkebile Nelson Immenschuh McDowell, Architects, Kansas City, Missouri. Redrawn by Jonathan Meendering.)

cold weather is likely to respond by lowering the indoor temperature and reducing heat leaks. Furthermore, some studies of worker comfort indicate that with more personal control (such as operable windows), workers express feelings of comfort across a wider range of temperatures than with centrally controlled air conditioning.

(i) Provide Multiple Pathways

This strategy celebrates functional redundancy as a virtue—for example, providing multiple and separate fire stairs for emergency egress. There are many other examples, from backup heating and cooling systems, to multiple water reservoirs and piping pathways for fire sprinklers, to emergency electrical and lighting systems. This strategy also applies to climate–site–building interactions in which one site-based resource may temporarily weaken and can be replaced by another (Fig. 1.20).

(j) Manage Storage

Storage is used to help balance needs and resources across time. Storage appears as an issue throughout this book. The greater the variations in the resource

supply cycle, the more critical storage management becomes. Rainwater can be stored in cisterns, balancing normal daily demands for water against variable monthly supplies. The high variability of wind-generated electricity output can be managed with hydrogen storage, providing a combustible fuel

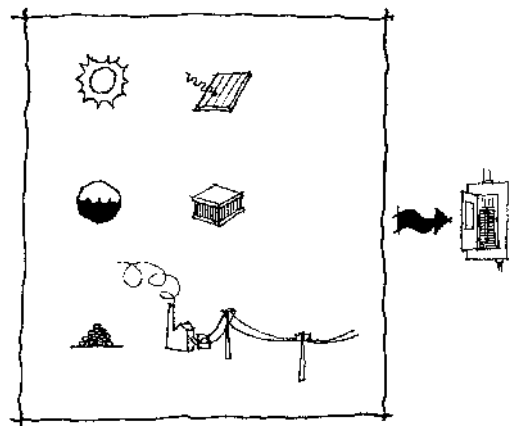


Fig. 1.20 Providing multiple pathways. Three distinct sources of electricity are projected in this conceptual diagram for the proposed EPICenter project, Bozeman, Montana. (Courtesy of Place Architecture LLC, Bozeman, Montana, and Berkebile Nelson Immenschuh McDowell, Architects, Kansas City, Missouri. Redrawn by Jonathan Meendering.)

that can be drawn on at a rate and time independent of wind speed.

On sunny winter days, a room's excess solar energy can be stored in its thermally massive surfaces (Fig. 1.21), to be released at night. On cool summer nights, *coolth* (the conceptual opposite of heat) can be stored in these same surfaces and used to condition the room by day. Most storage solutions will strongly impact building architecture.



Fig. 1.21 Manage storage. A concrete floor and barrels located high along the north wall provide thermal storage (for both heating and cooling) in the Cottage Restaurant, Cottage Grove, Oregon. (Photo by G.Z. Brown.)

1.8 CASE STUDY—DESIGN PROCESS

Gilman Ordway Campus of the Woods Hole Research Center

PROJECT BASICS

- Location: Falmouth, Massachusetts, USA
- Latitude: 41.3 N; longitude: 70.4 W; elevation: near sea level
- Heating degree days: 6296 base 65°F (3498 base 18.3°C); cooling degree days: 425 base 65°F (236 base 18.3°C); annual precipitation: 45.5 in. (1156 mm) (degree day data are for East Wareham; rainfall is for Woods Hole)
- Building type: remodeled and new construction; commercial offices and laboratory
- Building area: 19,200 ft² (1784 m²); four occupied stories
- Completed February 2003
- Client: Woods Hole Research Center
- Design team: William McDonough + Partners (and consultants)

Background. The Gilman Ordway Campus of the Woods Hole Research Center includes both new construction and extensive remodeling of a venerable old house to provide office and laboratory facilities. This recently opened building has generated a lot of interest. The clients are quite pleased with the facility and are using it as a vehicle to promote awareness of the environment and green design. The Research Center won an American

Institute of Architects/Committee on the Environment (AIA/COTE) Top Ten Green Project award and was recently the site of an Agents of Change POE training session. (The discussion that follows was extracted from information provided by William McDonough + Partners and the Woods Hole Research Center.)

Context. The work of the Woods Hole Research Center is focused upon the related issues of climate change and defending the world's great forests. When a new headquarters was considered, it was decided that the facility should reflect the Research Center's core values, support its research and education mission, and provide a healthy environment for building occupants and the outside world. Fund-raising was a major issue for this project and substantially impacted the design process and scheduling. Perhaps the most valuable lesson to be learned from this project is the inestimable value of perseverance and the benefit that a clearly enunciated set of objectives (design intent and criteria) can provide in seeing a donor-supported project through to completion.

Design Intent. The Woods Hole Research Center project sought to demonstrate that a modern building

can “harmonize with a habitable earth” while providing a healthy, comfortable, and enjoyable workplace. Enhanced productivity and job satisfaction for employees was a key intent, as was far-beyond-code-minimum energy performance. In addition, the building was to serve as a teaching tool, providing an exemplar of a thoughtful approach to energy production and use, water quality and conservation, site design, and materials selection.

Design Criteria and Validation. The aggressive energy performance criteria set by the client and design team required the use of ENERGY 10 computer simulations and the ongoing services of an energy systems consultant. Interestingly, this same strong energy-related design intent allowed the retention of critical mechanical system elements during an extensive value engineering phase that cut approximately 15% from the construction budget. The owner retained an independent authority for building commissioning.

Key Design Features

- Extensive daylighting throughout the building
- Operable windows throughout the building
- An exceptionally tight and carefully detailed building envelope featuring triple-glazed windows and Icynene foam insulation (also an air barrier)

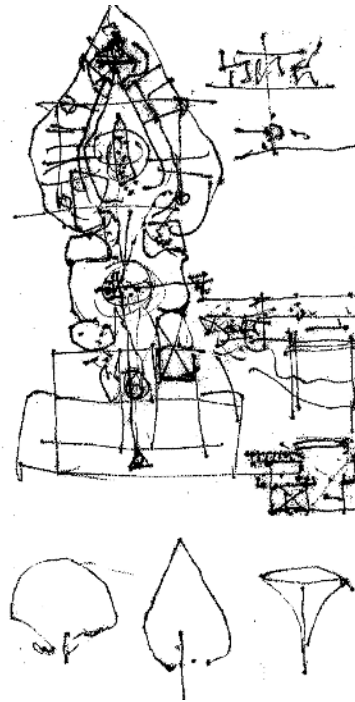


Fig. 1.22 Initial concept sketch for the Woods Hole Research Center (WHCR)—the “leaf.” This is an exceptional example of a conceptual design phase product. (© William McDonough + Partners; used with permission.)

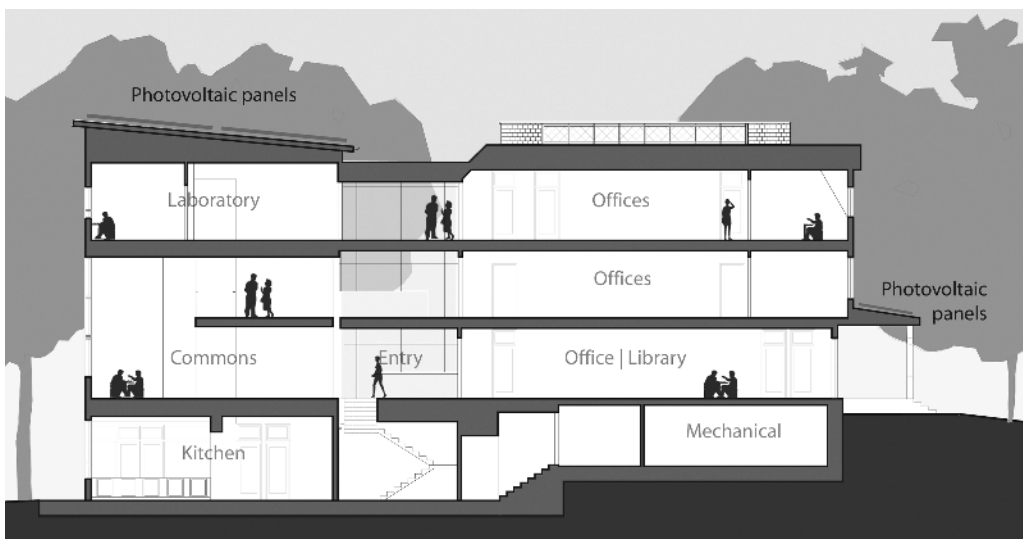


Fig. 1.23 Schematic design phase section through WHCR showing spatial organization and photovoltaic array locations. (© William McDonough + Partners; used with permission.)

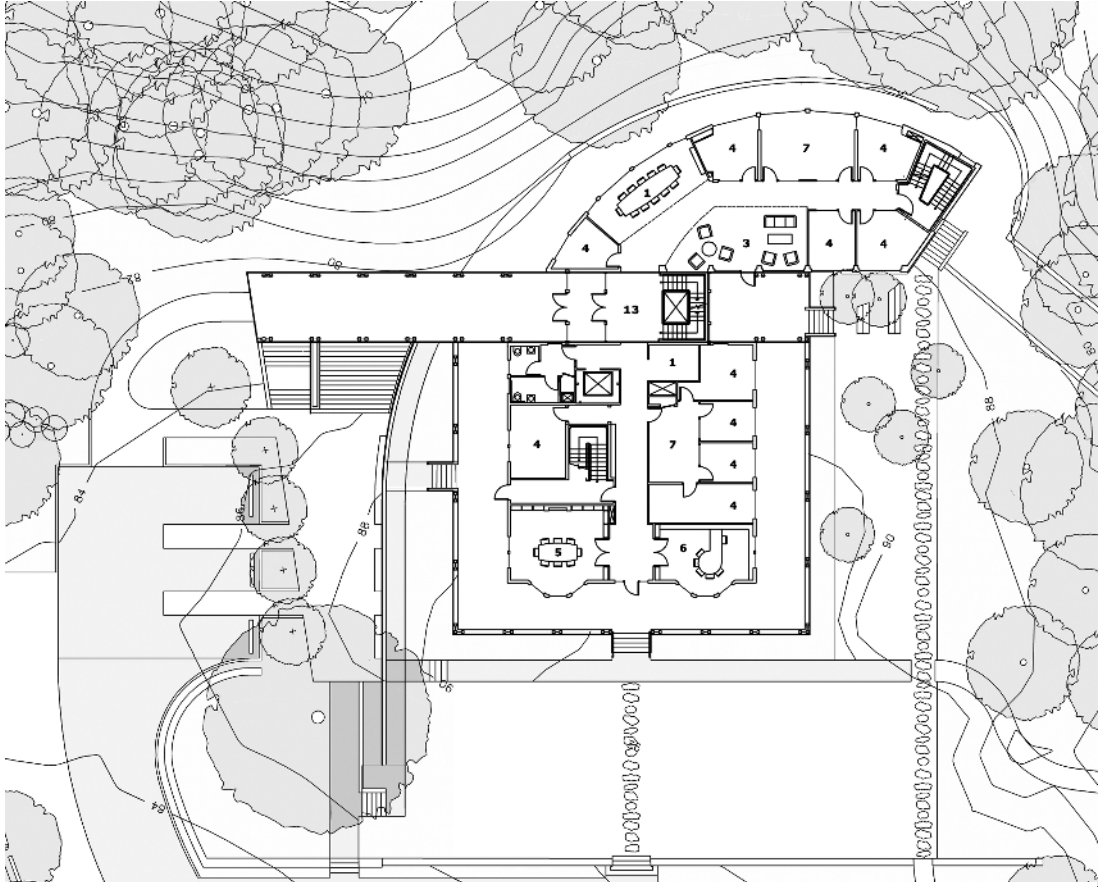


Fig. 1.24 The site/floor plan of WHRC is representative of the evolution of a project as it moves into and through the design development phase. (© William McDonough + Partners; used with permission.)



(a)



(b)

Fig. 1.25 Construction phase photos of WHRC; (a) showing the structure for the new addition and the existing house being remodeled; (b) showing the merger of new and remodeled parts of the building as the envelope enclosure is finalized. (© William McDonough + Partners; used with permission.)



Fig. 1.26 Exterior photo of the completed and occupied WHRC. (Photo © Alison Kwok; all rights reserved.)

- A Ruck wastewater system, 95% on-site retention of stormwater, and collection of rainwater for site irrigation
- A ground source heat pump system for heating and cooling (coupled with a valence delivery system in office spaces)
- A rooftop, net-metered, photovoltaic array

Post-Occupancy Validation Methods. The client has installed an extensive energy monitoring and reporting system. Data collected by this system are available to the public via the World Wide Web (see below) and are also being used internally to optimize systems operations. Soils scientists from the Center are studying the effectiveness of the innovative septic system. In addition, the client has a very open and reflective attitude toward evaluation of the building and its systems. With a relatively small number of occupants, informal exchanges among Research Center users appear to be proving an effective means of POE.



Fig. 1.27 Bird's-eye view of the occupied WHRC building and site. Photovoltaic panels are a prominent feature on the roof. (© Cris Benton, kite aerial photographer and Professor, University of California—Berkeley; used with permission.)

Performance Data. As this is a case study of design process as much as of a building, much of the following performance information relates to process outcomes.

- The building design received an AIA/COTE Top Ten Green Projects Award (2004).
- Measured data from the first year of occupancy show an energy consumption of about 20,000 Btu/ft² (227,200 kJ/m²) per year; this is roughly 25% of the consumption of a typical office building and a 75% reduction from the energy density of the Research Center's previous facility.
- A grant from the Massachusetts Renewable Energy Trust allowed installation of a photovoltaic array consisting of 88 panels (each at 25 ft² [2.3 m²]) that is expected to provide 37,000 kWh annually (about 40% of the building's power needs).

- All of the interior finish woodwork is a Forest Stewardship Council (FSC) certified sustainably harvested product; exterior wood finishes are also FSC certified, including cedar shingles and siding and Brazilian *ipé* wood for the extensive porch, deck, and entrance stairway.
- Paints and coatings meet low volatile organic compound (VOC) criteria; no carpet is used in the building.

FOR FURTHER INFORMATION

Summary and real-time energy performance data for the Woods Hole Research Center building can be accessed at: <http://www.whrc.org/building/education/performance.htm>

A description of the building and design process can be found at <http://www.aiatopten.org/hpb/overview.cfm?ProjectID=257>

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