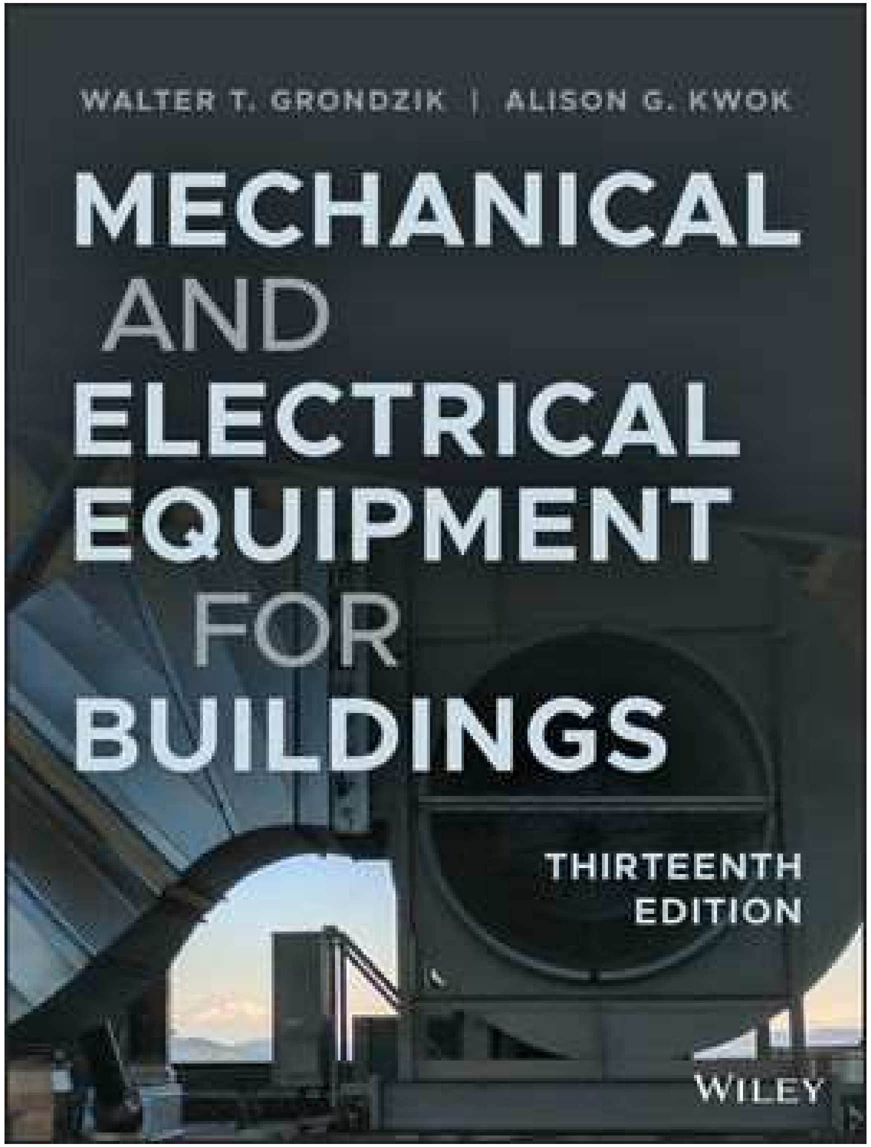
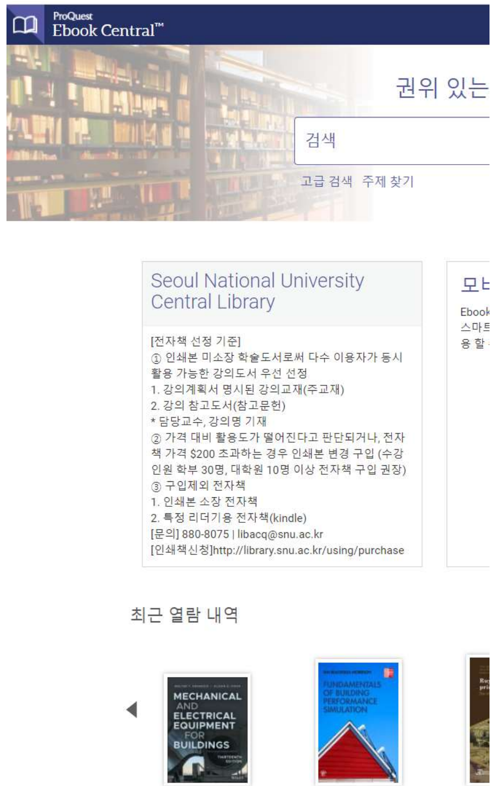
Ch.1 Design process

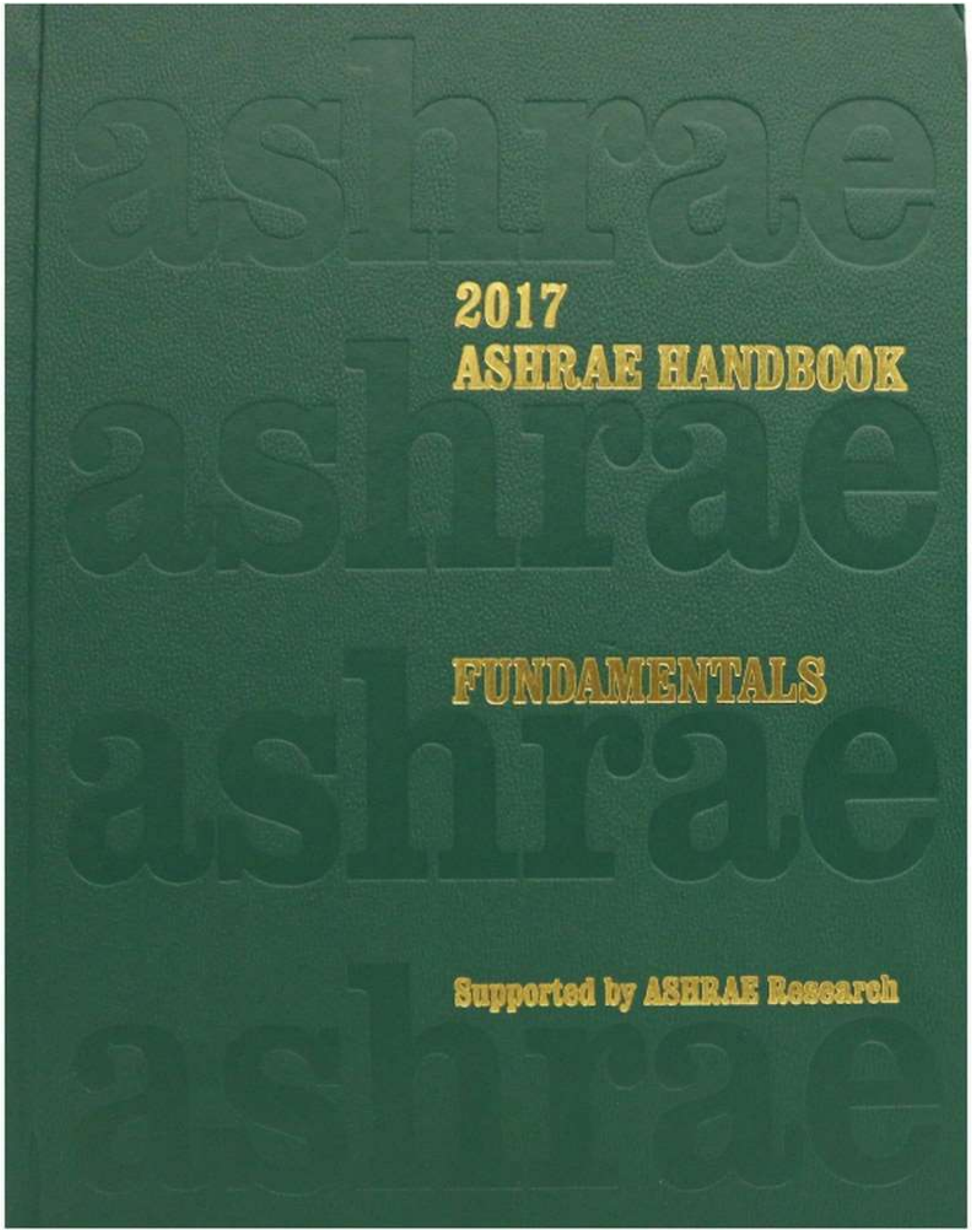
Often the design of mechanical and electrical equipment for buildings is not considered until many important design decisions have already been made. In too many cases, such equipment is considered to have a corrective function, permitting a building envelope and siting to “work” in a climate that was essentially ignored.

Textbook: MEEB 13th Ed.



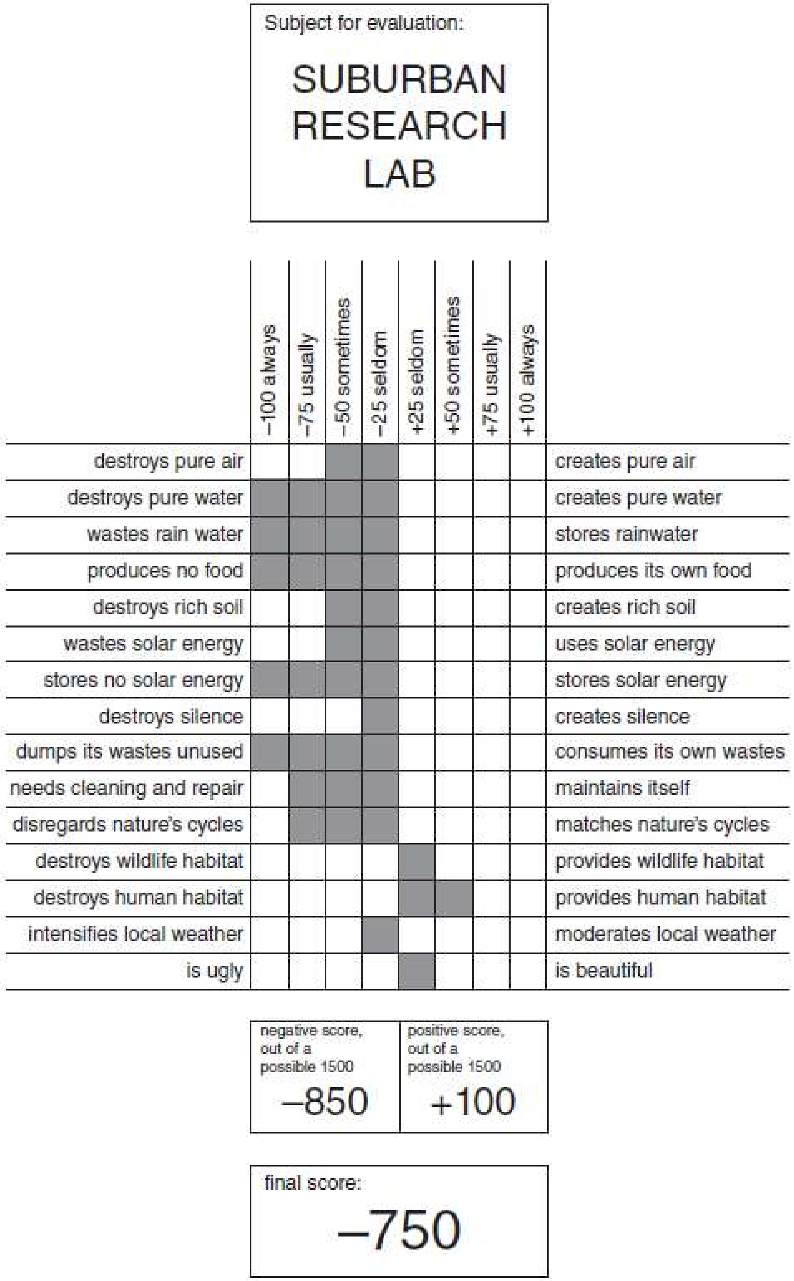


Reference: ASHRAE Handbook F. 2017



Wakeup call

- In 1971, a visionary architect Malcolm Wells published his radical idea: "The absolutely constant incontestably stable architectural value scale" → Wells argued that buildings should be benchmarked against the environmentally regenerative capabilities.
- 21st century: MEP, simulation techniques and information exchange (BIM) have radically improved.
- However, the design process has changed little since the early 1970s.
- What must change in the next decades are the values and philosophy in the design process.



© Malcolm Wells 1969

Design process is

- very complex involved with different building stakeholders
- # of decision makings: more than thousands
- Decisions made on MEP will determine:
  - owner and occupant's comfort
  - operating costs: FM (Facility Management)
  - maintenance needs
  - productivity
- Design phase:
  - Conceptual design: Figs. 1.3-1.6 (an outline of a general solution & fundamental decisions made in this phase)
  - Schematic design: Figs. 1.7-1.8 (the conceptual solution further developed and refined)
  - Design development: Fig. 1.9 (a design solution finalized, construction drawings and specifications prepared)
- Construction phase: Figs. 1.9-1.10
- Occupancy/operation phase

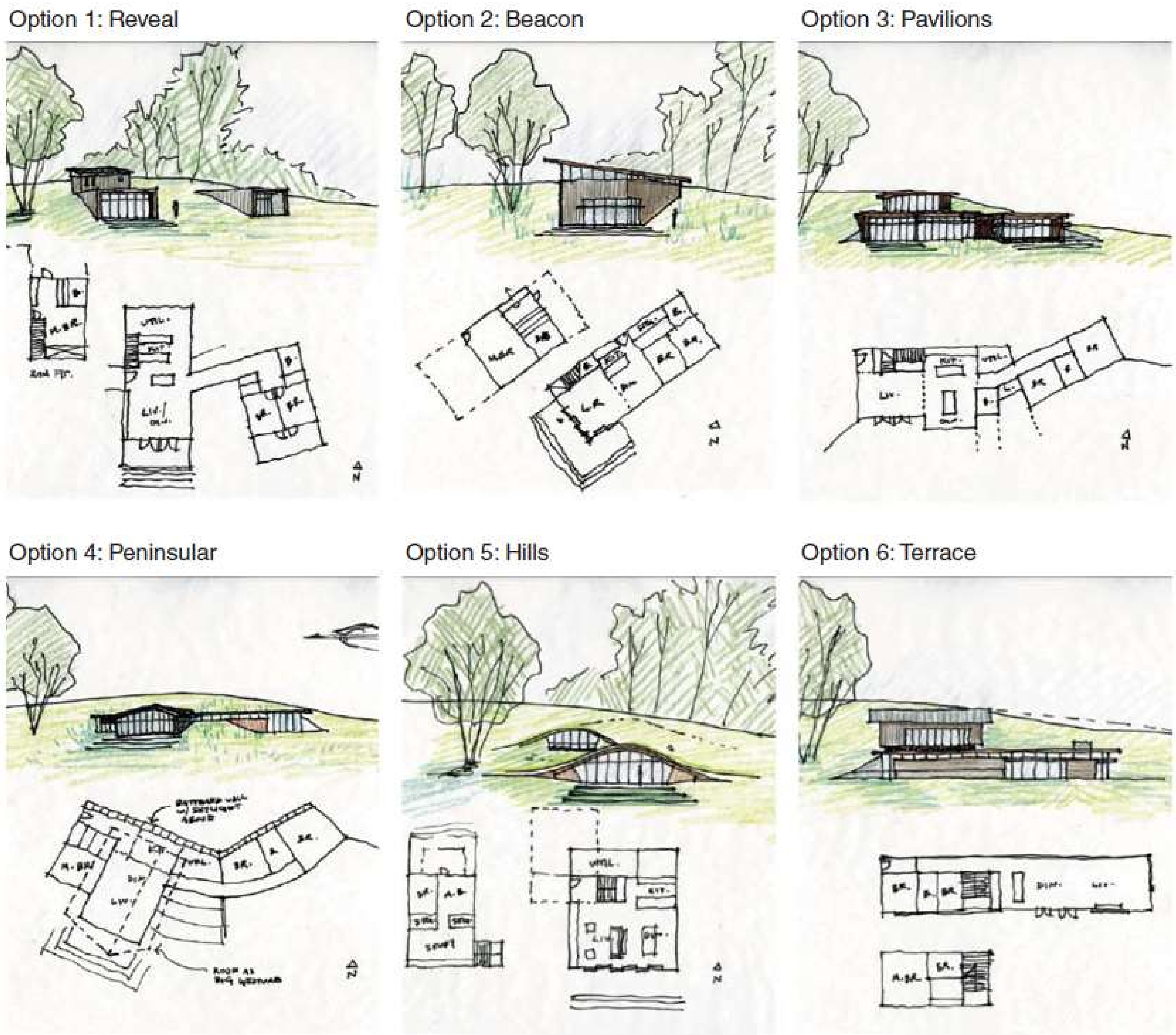


Fig. 1.4 *Design iterations began using hand sketches with attention to earth berming and daylighting zoning. (© Sterner Design, LLC; used with permission.)*

Conceptual design (Figs. 1.3*a* and 1.3*b* and 1.4) outlines a solution to the owner's program that meets the budget and captures the owner's imagination so that design can continue.

(*a*)

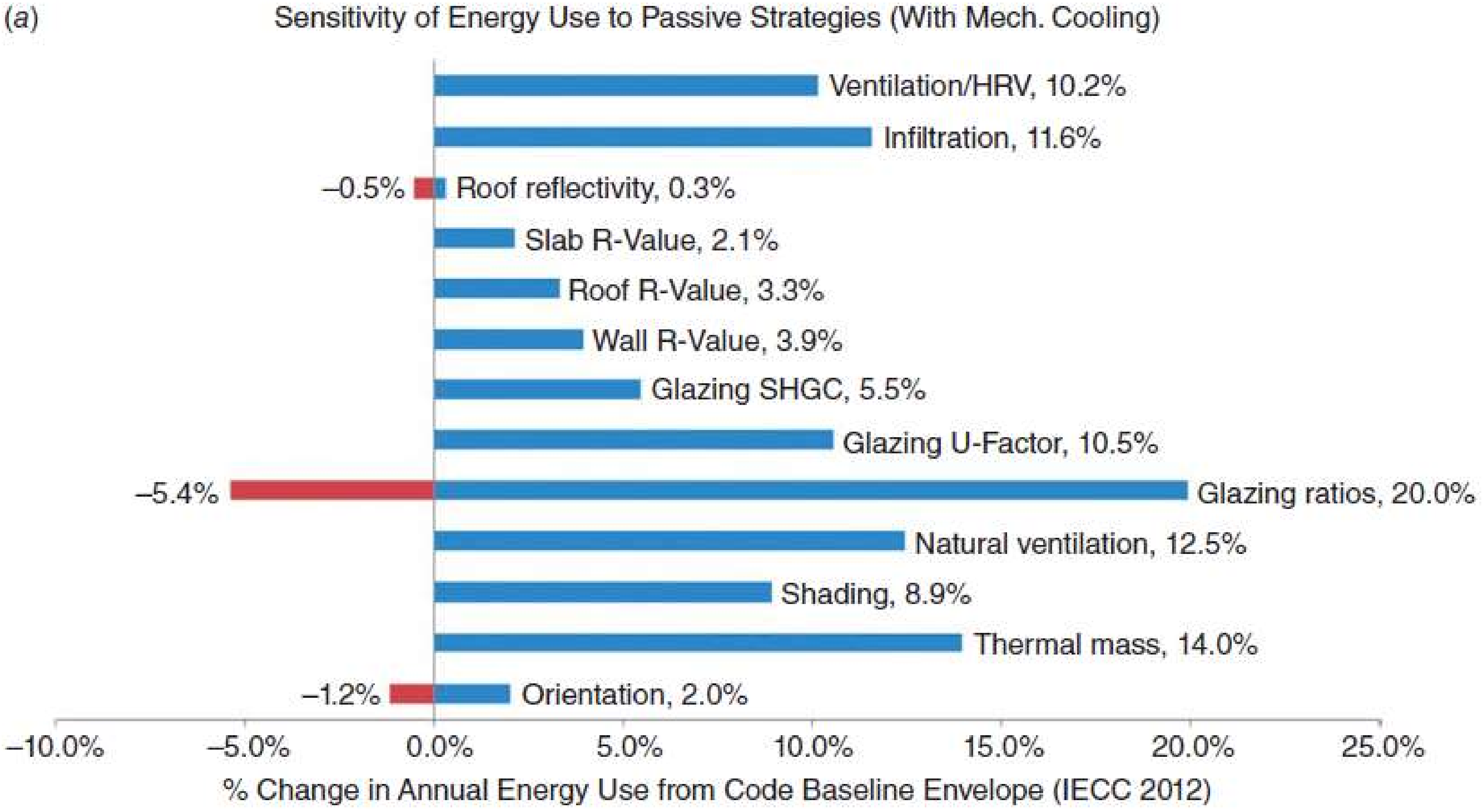


Fig. 1.3 *Several analyses compared potential passive strategies to a code-compliant baseline envelope (a) using mechanical cooling for percentage change in annual energy use; and (b) without mechanical cooling for percentage change in annual hours where the air temperature is above 82.4°F (28°C). (© Sterner Design, LLC; used with permission.)*

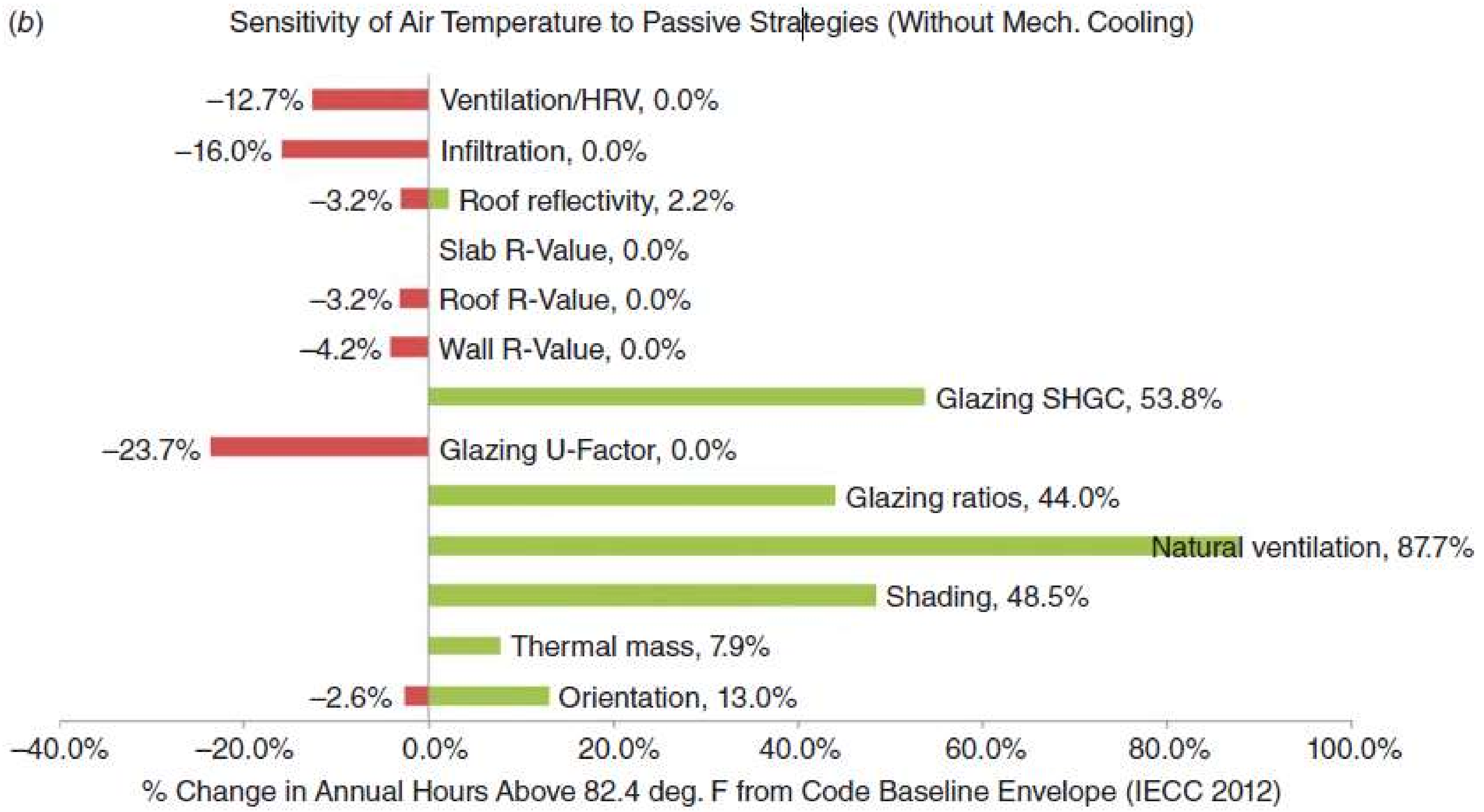


Fig. 1.3 (continued)

Fundamental decisions about the proposed project should be made during conceptual design (Figs. 1.5 and 1.6)

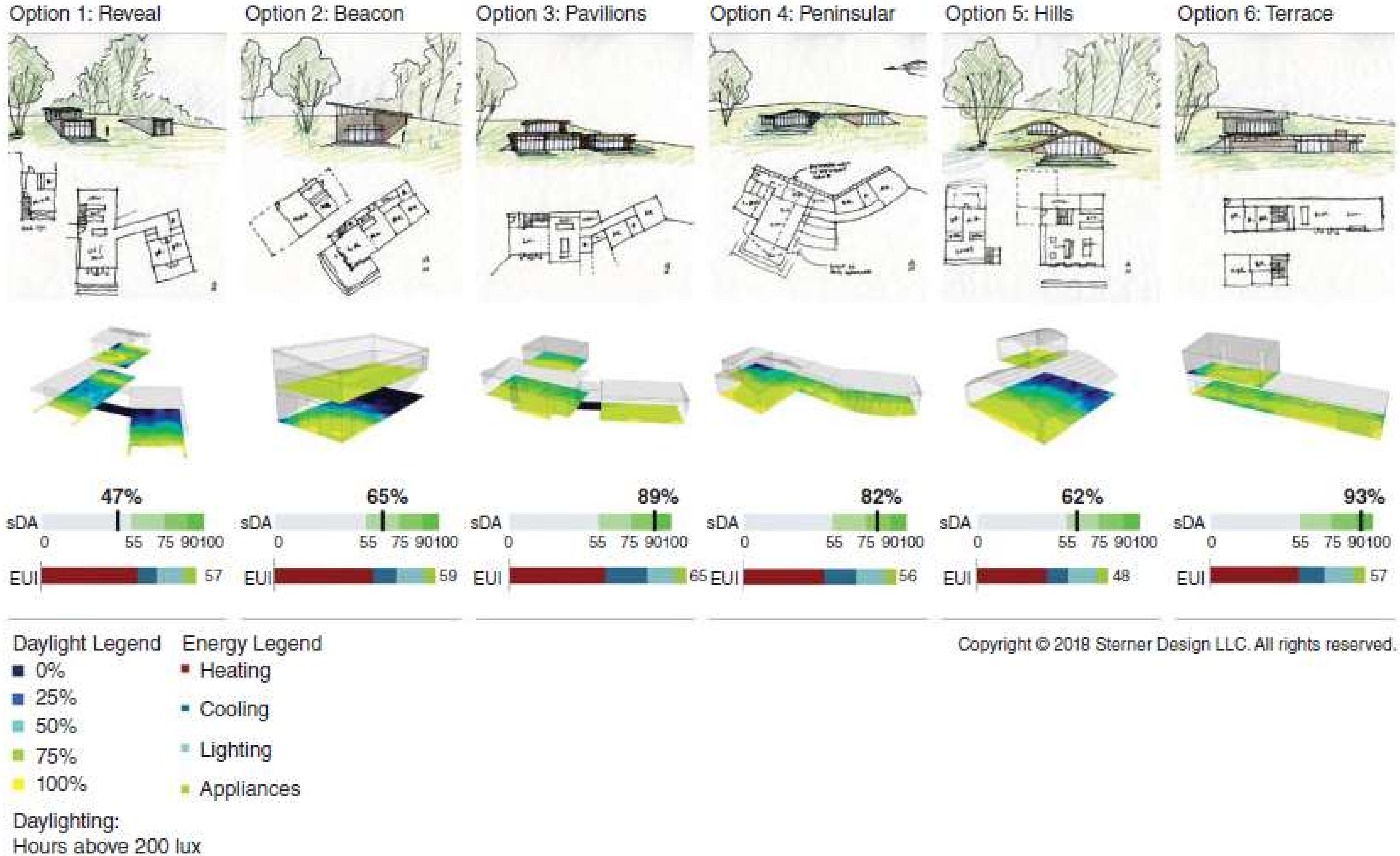


Fig. 1.5 *The design concept was further refined by comparing the different design iterations for daylight and energy performance using Sefaira analysis. Early analysis rarely dictates the selection of a concept, but can nevertheless inform design moving forward. This conceptual study showed a strong correlation between earth berming and low energy use. (© Sterner Design, LLC; used with permission.)*

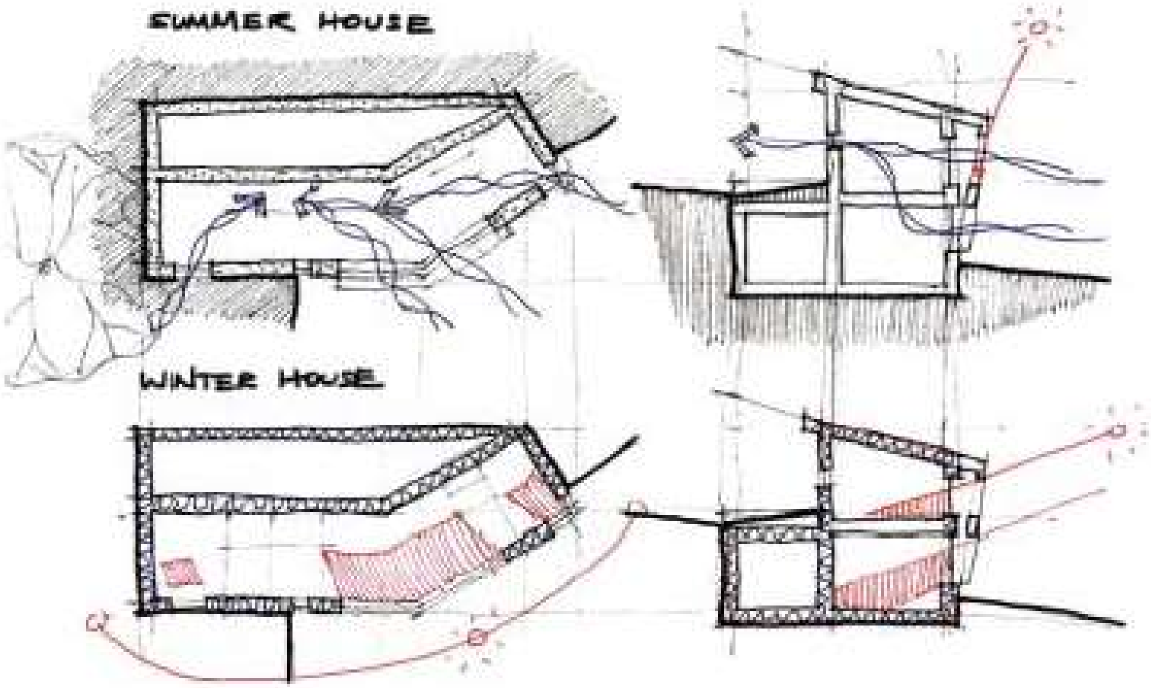


Fig. 1.6 *Conceptual sketches for shading and natural ventilation strategies at the Iowa Nest suggest in fairly strong terms the "first, best moves" for design direction, yet details are left to be developed in later design phases. There is a clear focus on shading, ventilation, earth berming, insulation, and passive solar design even at this stage—a focus that was carried throughout the project. (© Sterner Design, LLC; used with permission.)*

During schematic design (Figs. 1.7 and 1.8), the conceptual solution is further developed and refined. It is worth noting that the design team ended up not going with a ground source heat pump shown in the "waterfall" diagram (Fig. 1.8). The team was able to use a cost-effective system because of good envelope and passive design. The heating loads were too small for a ground source heat pump to be practical.

Fig. 1.7 *Schematic design renderings for the Iowa Nest. As design thinking and analysis evolve, so does the specificity of a proposed design. Site development has progressed, and the building elements begin to take shape. (© Sterner Design, LLC; used with permission.)*

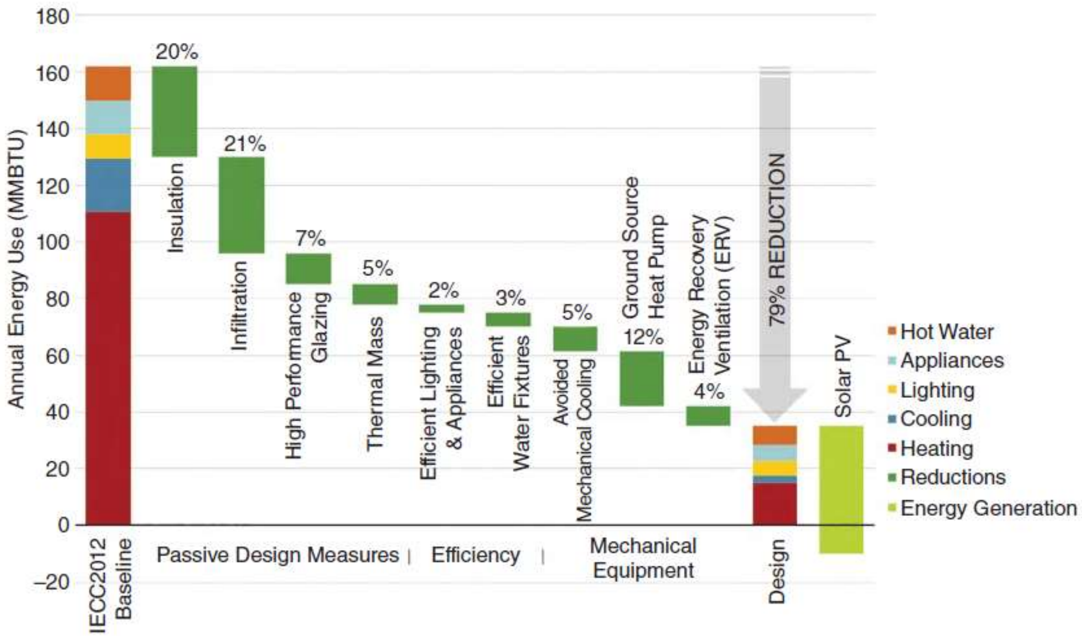


Fig. 1.8 *Further analysis examined potential passive strategies (insulation, reducing infiltration, use of high-performance glass, thermal mass), efficiency strategies (electric lighting, appliances, water fixtures), high-performance mechanical equipment (no air-conditioning, ground source heat pump, and ERV) which drove the estimated annual energy use to almost 80% less than a baseline building. (© Sterner Design, LLC; used with permission.)*

During design development and construction documentation (Fig. 1.9), all decisions regarding a design solution are finalized, and construction drawings and specifications detailing those innumerable decisions are prepared.

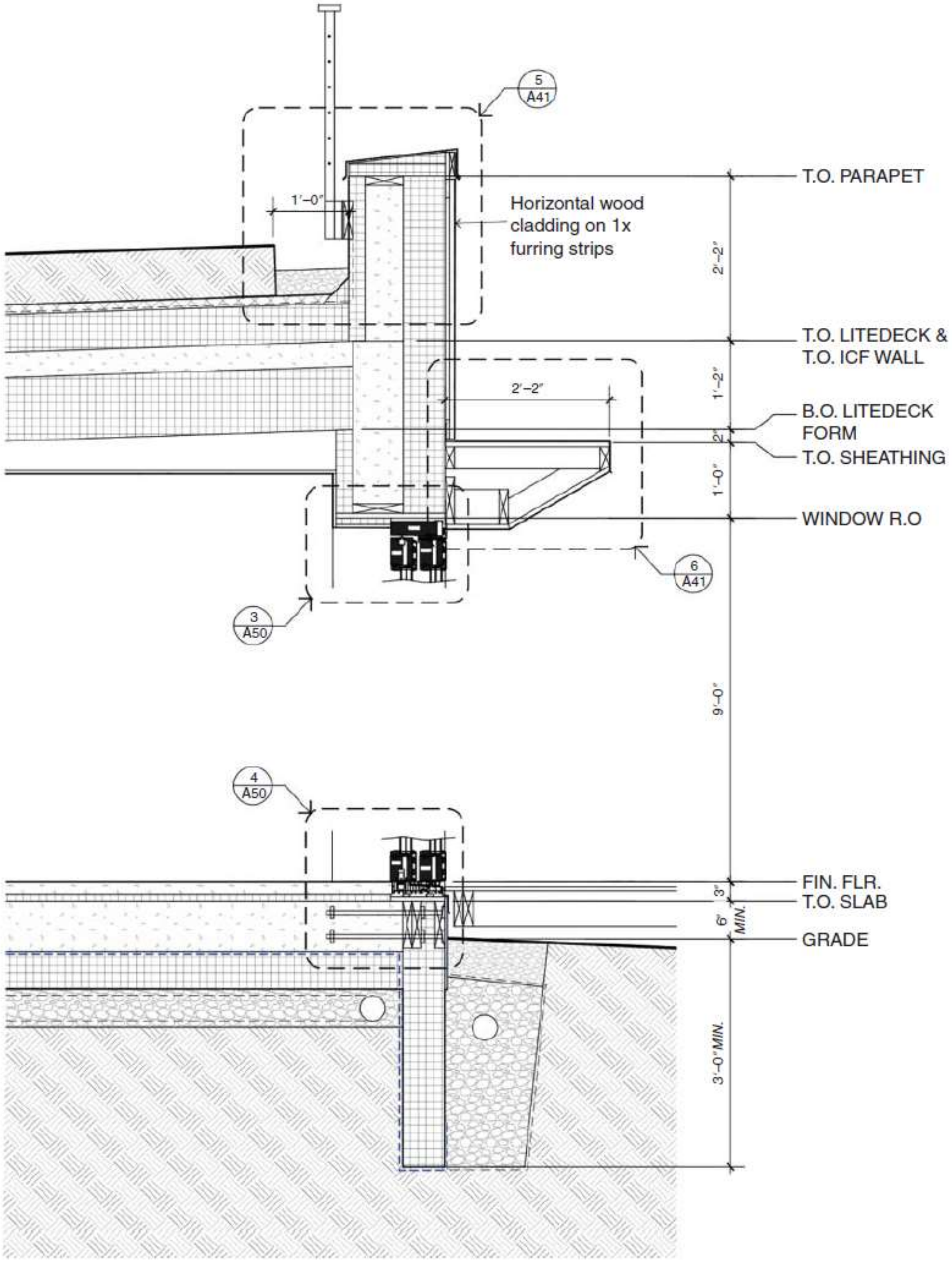


Fig. 1.9 During design development, construction details converting an idea into a building evolve. This drawing illustrates the development of working details for the enclosure used in the Iowa Nest, resulting in an insulated enclosure: R-28 slab, R-45 walls, and an R-70 roof. (© Sterner Design, LLC; used with permission.)

The construction phase (Figs. 1.9 and 1.10) is primarily in the hands of the contractor (and the owner and friends) although design decisions have determined what will be built.

(*a*) (*b*)

Fig. 1.10 *(a) Construction phase photo of the west wall of the Iowa Nest. Design intent becomes reality during this phase, showing the shading of a deciduous tree on the west window on a summer day and (b) the shading of the high-performance, triple-pane sliding doors on the south-facing façade. (Photo © Carl Sterner; used with permission.)*

Occupancy phase

- The building owners/occupants are the key players during the occupancy phase.
- Their experiences with the building (utility bills, comfort, and beauty) 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 learned—both good and bad) to be used by the design team on future projects is essential to good design practice.
- The designer and owner should actively track temperature and relative humidity and will track energy use and production as well, to understand whether the building is performing as intended.
- IEA Annex 66, 79

Design intent

- is simply a statement that outlines the expected high-level outcomes of the design process
  - Comfort level: The building will provide outstanding comfort level
  - IT: The building will use the latest in information technology.
  - IEQ (Indoor Environmental Quality): The building will be green, with a focus on IEQ.
  - Use of passive systems: The building will use primarily passive systems.
  - Flexibility: The building will provide a high degree of flexibility for its occupants.
  - Constructability, operability, accessibility, amenity, serviceability, etc.

Design criteria

- A measure of success or failure in meeting design intent
- Should be established as early in the design process as possible
- Must be objective, normative, unbiased
- Examples
  - Thermal comfort: PPD (Predicted Percentage Dissatisfied) <=10% or meet ASHRAE standard 55.1-2010
  - VCP >=70% for electrical lighting
  - The power density of lighting system will not be greater than $7W/m^2$.
  - LEED: above a silver rating (GSA mandatory regulation)
  - And the list goes on…..

Design tools and implementation methods

- Design tools and implementation methods are the means through which design intent is achieved.
- Don't put the design tools and implementation methods in design intent since there are numerous viable design solutions.

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 systems
Lighting level (illuminance)	Acceptable illuminance levels	Compliance with recommendations in the *IESNA Lighting Handbook*	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 system and equipment strategies
Energy efficiency	Outstanding energy efficiency	Meet the requirements of the ASHRAE 50% *Advanced Energy Design Guide* for the building type	Handbooks, simulation software, manufacturer's data, experience	Envelope strategies and/or system and equipment strategies
Green design	Obtain green building certification	Meet the requirements for the Living Building Certification	International Living Future Institute materials, experience	Any combination of approved strategies to obtain sufficient petals

Validation and evaluation: (1) conventional approaches

- (Quantifiable aspects) Technical building performance assessment
  - Aspects: energy, lighting, thermal comfort, visual comfort, maintenance
  - Hand calculations, simulations, physical models, opinion surveys, nomographs
- (Not quantifiable aspects) Qualitative building performance assessment
  - productivity, satisfaction, way finding, visual image
  - Structured feedback by POE

Validation and evaluation: (2) commissioning

- Emerging approach to QA (Quality Assurance)
- An independent commissioning authority (an individual or, more commonly, a team) verifies that design decisions and related building assemblies, equipment, and systems can meet the owner's project requirements (design intent and criteria).
- Verification of equipment and systems (mechanical, electrical, envelope, security, fire protection, information systems)
- A new concept: "continuous commissioning", "monitoring-based commissioning"

Validation and evaluation: (3) case studies

- 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 broad range of situations.
- U.S.: Vital signs
  - To disseminate the case study and methodology
  - Unfortunately, it appears to be gone!!
  - https://web.ornl.gov/sci/buildings/conf-archive/2001%20B8%20papers/149_Kwok.pdf
  - https://darkwing.uoregon.edu/~akwok/VSCS/
- U.K.: PROBE (Post Occupancy Review of Building Project)

New websites

- https://buildingdata.energy.gov/home
- https://www.energy.gov/eere/buildings/building-technologies-office

Difficulties in validation and evaluation

- A significant difference between AE and ME: mass production, repetitive product test
- Design team hypothesis: "We believe that this solution will work for the given situation."
- The performance gap between reality and prediction (caused by uncertainty)
- Unfortunately, it is not true.
  - Example: Sam Nunn building

Sam Nunn Atlanta Federal Center: measured vs. predicted

Atlanta Federal Center (total floor area = 145,000 m^2)

Architectural design: Kohn Pederson Fox Associates

MEP design: Newcomb & Boyd

Energy consumer	Average	
Heating	8,553,494	7.6%
Fans	9,090,290	8.0%
Lighting	54,949,602	**48.6%**
Pumps	4,579,134	4.0%
Cooling	30,225,076	**26.7%**
Humidifying	4,006,742	3.5%
Domestic hot water	1,691,157	1.5%
Total	**113,095,495**	**100.0%**

Annual energy saving calculation

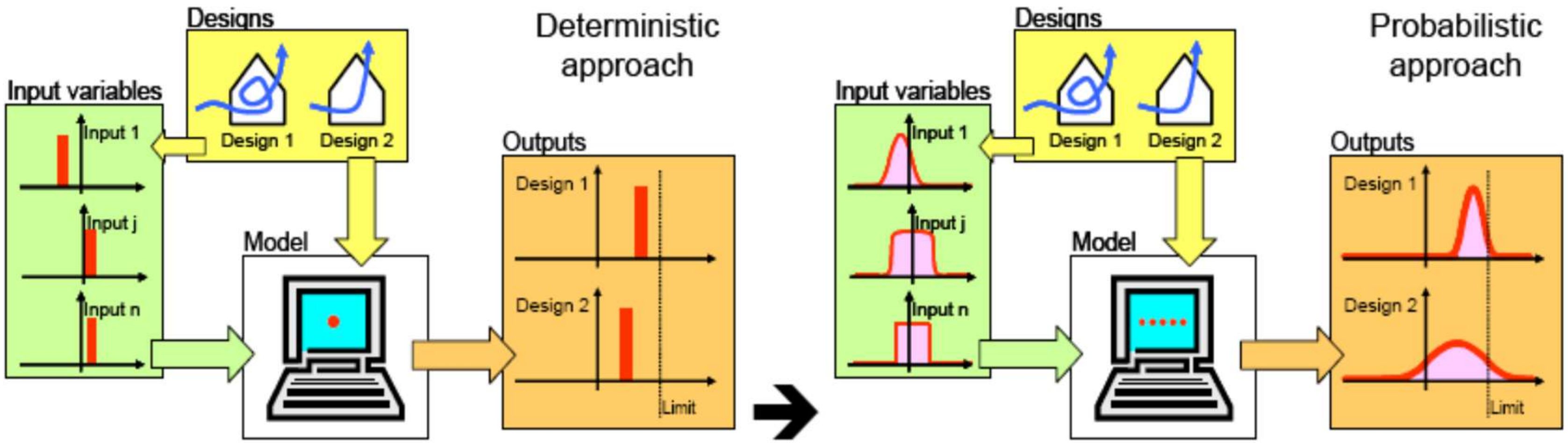
	From	To	**Savings in MBTU/year**	**$/year**
Orientation	SE-NW	South-North	1,300	16,877
Windows ratio	40%	30%	3,583	46,507
Lighting control	Central on/off	Daylight switch	10,407	135,082
Total			**15,290**	**196,913**

* Energy bill in 2003: 1.45 million $

- accurate prediction (8.6%)
- instructive information for better energy-efficient buildings
- annual energy saving opportunities

With an input of 3-4 hours (!) per building the PI's assess the building's technical performance.

Quantification of Uncertainty: Uncertainty Analysis



stochastic

- deterministic vs. stochastic
- rational decision making
- forward uncertainty quantification & inverse uncertainty quantification (Bayesian calibration)

Figure from Wouters, P., N. Heijmans, and X. Loncour. 2004. Outline for a general framework for the assessment of innovative ventilation systems. RESHYVENT final report.

Performance gap: simulated vs. measured

- Weather data
- Thermal properties
  - Conductivity, thickness, Solar Heat Gain Coefficient (SHGC)
  - Chiller COP (coefficient Of Performance), boiler efficiency
  - Degradation over time
- Scenarios
  - Occupant behavior (IEA Annex 66): set-point temperature
  - Lighting: on/off
  - Equipment: PC

Influences on the design process: (a) codes and standards

- Codes
  - Government-mandated (enforced) documents
  - Defines the minimum that society deems acceptable
  - Written in prescriptive language in most cases
- Standards
  - Presents a set of minimum requirements developed by a recognized authority (ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers)
  - Developed under a consensus process with substantial external review and comments
  - Not mandated but often used incorporated into codes
- Guidelines, handbooks: less formal
- General practice: least formalized

STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Appendix I for approval dates by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

TABLE 1.2 Codes, Standards, and Other Design Guidance Documents

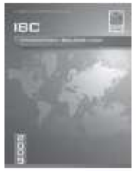
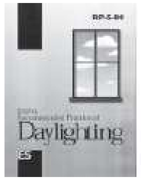
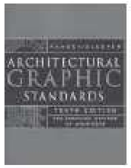
Document Type		Characteristics	Examples
Code		Government-mandated and government-enforced (typically via the building and occupancy permit process); may be a legislatively adopted standard	*Florida Building Code*; *California Title 24*; *Chicago Building Code*; *International Building Code* (when adopted 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, *Energy Standard for Buildings Except Low-Rise Residential Buildings*; ASTM E413–87, *Classification for Rating Sound Insulation*; ASME A17.1, *Safety Code for Elevators and Escalators*
Guideline		Usually a consensus document developed by a professional organization, but within a looser structure and with less stringent public review	ASHRAE Guideline 0, *The Commissioning Process*; *IESNA Advanced Lighting Guidelines*: NEMA LSD 12, *Best Practices for Metal Halide Lighting Systems*
Handbook		Development can vary widely—involving formal committees and peer review or single/multiple authors with no formal external review	*IESNA Lighting Handbook*; *ASHRAE Handbook—Fundamentals*; *NFPA Fire Protection Handbook*
Design guide		Development by experienced practitioners and educators; may offer schematic design process guidance, address architectural implications, links to other resources	Design procedures; general sizing procedures; green design strategies; case studies
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.

Prescriptive vs. performance-based

- Prescriptive: mandates that something be done in a certain way.
  - minimum R-values for wall insulation, U-values of building envelopes, insulation thickness, a minimum number of hurricane clips per length of roof, etc.
  - The majority of codes in the United States are fundamentally prescriptive in nature.
  - A prescriptive code defines means and methods.
- Performance-based: states an objective (outcomes) that must be met
  - Amount of energy, percentage of visual discomfort during an entire year
  - a performance code defines outcomes
- Advantages and disadvantages