1997
TEXAS SUSTAINABLE BUILDING
PROFESSIONAL TRAINING SEMINARS

The Nuts & Bolts of Greening Texas Public Buildings

PREPARED BY:
CENTER FOR MAXIMUM POTENTIAL BUILDING SYSTEMS

TABLE OF CONTENTS

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An accompanying 16-minute videotape (*Sustainable Building in Texas: A Strategy Whose Time Has Come*), produced for SECO by the Center for Maximum Potential Building Systems, highlights historic and contemporary examples of public buildings in Texas which embody sustainable building practices. Contact CMPBS for information on obtaining a copy of this videotape.

The Center for Maximum Potential Building Systems, established in 1975 and based in Austin, Texas, is a non-profit education, research, and demonstration organization that engages in a range of sustainable planning, design, and development activities. For more information on the Center's services, activities and educational materials, contact us at 8604 F.M. 969, Austin, TX 78724, 512/928-4786.

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I. OBJECTIVES

The 1997 Texas Sustainable Building Professional Seminar Series, coordinated by the Center for Maximum Potential Building Systems (CMPBS) in cooperation with the State Energy Conservation Office (SECO), has invited leading practitioners in the field of sustainable design to conduct day long sessions of detailed instruction and interactive exercises on how to make Texas' public buildings more ecologically responsive. Sessions range from improving indoor air quality and selecting environmentally responsible building materials to innovative water management strategies and landscape design.

These seminars are an opportunity for architects, project managers, contractors, and facility managers to learn specific skills related to sustainable design practices and resource-efficient technologies for use in public building projects throughout Texas. This manual includes an introduction to the seminar series as well as outlines for the individual sessions.

The overall objective of the seminar series is to offer practical information that will provide its participants with the tools necessary to ensure that Texas' public buildings manifest exemplary stewardship of human and environmental resources. It is the hope of all of us involved with these seminars that you will give serious consideration to implementing these time-tested principles and practices to secure a brighter future for the Lone Star State and all its citizens.

II. OVERVIEW

The Texas State Capitol, completed in 1888, is easily the most recognizable public building in Texas. It embodies an enduring commitment to Texans, past, present and future: to pursue, preserve and protect our common ideals and well-being. Its original design incorporated natural light, natural ventilation and regionally available materials, out of necessity. But it was not the first building to be *sustainably* designed.

Throughout history, people have traditionally built in ways that specifically responded to their environment. In Texas, generations of families living on the land have learned to build with respect for the hot Texas sun, the preciousness of water, and a reliance on self and site made necessary by vast frontier distances. They learned to balance their demands with the capacity of the land. They also learned that when issues were large, or dangers great, what worked was working together. Texas has a particular opportunity for leadership in sustainable design because of these traditions.

Benefits

Sustainability, defined as meeting today's needs while preserving the capacity to meet our own and others' needs in the future, is simply an imperative for public buildings. The use of public funds requires a long term investment outlook with careful attention to the consequences. Sustainable design offers many benefits, including:

■ **Lower operating costs.**

Over the life of the building, operating costs from energy consumption and building maintenance are considerably decreased when sustainable practices are in place.

■ **Increase in employee health and productivity.**

Effective ventilation, natural and proper lighting levels, indoor air quality and good acoustics have been shown, in a variety of studies, to contribute to workers' comfort and productivity, reducing health complaints and lowering absenteeism. Sustainable design can, and should, be seen as an investment in the State's employee productivity, even as state-owned and leased facilities' square footage allocations per employee have been decreased. The State annually spends over five times more on employees' salaries and benefits than on building construction.*

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*During the 1995 fiscal year, the State of Texas employed 156,088 full-time equivalent employees in agencies and 105,551 in higher education institutions. (*Report No. 97-702, Office of State Auditor, November 1996*) Salaries for state employees during fiscal year 1995 were $6 billion plus an additional $3 billion for benefits and other employee related expenses. (*Fiscal Notes, Texas Comptroller's Office, September 1996*) During the 1995 fiscal year the General Services Commission (GSC) provided office space for nearly 73,000 full time equivalent employees in 16.7 million square feet throughout Texas at a cost of approximately $180 million. (*Facilities Master Plan, General Services Commission, July 1996*)

■ **Decrease in liability for health risks.**
Insurance outlays for health related problems caused by sick buildings can be reduced when appropriate indoor air quality measures are taken.

■ **Building values retained.**
Buildings designed with respect to region and climate can remain useful longer, therefore maintaining the buildings' value, returning more for the public investment.

■ **Environmental costs avoided.**
Reduced energy consumption or choice of renewable energy resources such as wind and solar translates into reduced pollution from energy production. Water management, selection of non-toxic, low-energy materials and recycling prevent many of the "downstream" corrections required by conventional design and construction.

■ **Enhance local economic development.** Specifying materials that are sourced and/or manufactured in the region of use results in significant job generation for the local economy.

Role of public buildings

State agencies and public institutions are in an important and unique position to set the agenda for the future form of public buildings. Civic responsibility extends far beyond the dedication and commitment of the state's employees. The buildings within which they conduct their work, frequently visited by the general public and private business, serve as models for all. They should exemplify the best value in building, the best practice in public policy.

The implementation of sustainable planning, design and operation should be a fundamental component of every public building project in the State. The State Energy Conservation Office's (SECO) recent initiative, *Sustainability in Public Facilities*, provides technical support and incentives to maximize the efficient and economical use of resources, including renewable energy technologies, in state facilities.

Legislative Directives

Resource conservation, economic soundness, as well as enhanced human health and productivity, can be achieved by implementing sustainable design principles. Reflecting these benefits, a number of mandates are already in place.

■ **Conservation of Energy and Water and Renewable Energy.** *Government Code, Title 10, Chapter 2166, Subchapter I* requires state construction to evaluate use of renewable energy systems and to evaluate energy alternatives for all energy consuming equipment and systems; and to employ xeriscape™ methods in the landscape around all state buildings. *Chapter 447* of the Government Code requires a state standard for energy efficient design in public buildings and prohibits agencies from contracting for construction unless plans are certified to comply with the standard.

■ **Procuring Recycled Materials.** *Health and Safety Code, Sections 361.421 ff*, requires a preference to be shown for the use of recycled and recyclable products.

■ **Recycling in Public Buildings.** State of Texas Health & Safety Code, Ch. 361.425 *Government Entity Recycling*, requires state agencies, courts and judicial agencies; university systems and institutions of higher education; counties; municipalities; school districts; and special districts to establish a program for the separation and collection of all recyclable materials generated by the entity's operations, including, at a minimum, aluminum, steel containers, aseptic packaging and polycoated paperboard cartons, high-grade office paper, and corrugated cardboard, and to provide procedures for collecting and storing recyclable materials, containers for recyclable materials, and procedures for making contractual or other arrangements with buyers of recycled materials. School districts and municipalities with a taxable district of fewer than 5,000 people can be exempted from this requirement if the Texas Natural Resource Conservation Commission (TNRCC) determines that compliance would result in a hardship.

■ **Telecommuting.** *House Resolution 797*, 73rd Texas Legislature, urges state agencies to investigate and implement telecommuting as a means to reduce the cost of government in addition to reducing office and parking requirements. Telecommuting increases the ability to meet trip reduction goals and guidelines. Information about starting a telecommuting program in your agency is available from the State Energy Conservation Office, which developed the pilot program. (See Appendix)

Resources

The bibliography at the back of this manual provides some excellent references for further reading. Some immediate practical guidance is also available from these frequently cited sources and programs:

■ *General Services Commission (GSC) Architecture and Engineering Guidelines* (1993 edition) This document provides policy and procedural guidance for projects undertaken by the commission and incorporates a general outline of good design practices relative to sustainability.

■ *Texas Department of Mental Health and Mental Retardation (MHMR)* and the *Texas Department of Criminal Justice (TDCJ)* have also issued guidelines similar to the GSC's.

■ *Center for Maximum Potential Building Systems (CMPBS)*. A non-profit sustainable planning and design firm established in 1975, CMPBS initiated the City of Austin Green Builder Program and works with the State of Texas on a range of sustainability and public buildings initiatives, including design assistance, material specification and training and educational resources.

■ *City of Austin Green Builder Program's* mandate is to lower energy consumption within the city's boundaries, where the Capitol and headquarters of many state agencies are located. This program provides sustainable design and engineering assistance; cash incentives for building owners interested in modelling for energy efficiency and using energy efficient measures; and a cash bonus for design teams that incorporate sustainable design practices.

■ *Texas Energy Conservation Standard for New State Office Buildings* provides a minimum standard for new construction and major renovations, with which all state projects are required to comply. This standard has also been adopted by the City of Austin.

■ In addition to the state and local guidelines and codes, there are national programs such as EPA *Green Lights* and the Conference of American Building Officials (CABO) *Model Energy Code* that have been adopted by local municipalities. The electric cooperative from which you purchase power for facilities around the state may subscribe to a nationally chartered energy program such as *Good Cents*, which can help to reduce both energy demand and cost.

Please contact SECO for information regarding these and other programs.

III. SUSTAINABILITY CONCEPTS

The speakers in this seminar series will each present some inspiring quotes and definitions for sustainability. Each is a leader in terms of both personal commitment and technical accomplishment. And yet, you will find some common threads throughout.

Systems View

The most basic element in sustainable design is the perspective that each thing designed can be thought of as a system, and considered as part of some larger system. It will have interrelationships and consequences in that larger system and its component subsystems. When we speak of naturally occurring systems, we refer to this systems view as *ecology*, and we look in particular at the carrying capacity of the system. We try to understand the needs for all components of the ecological community, identify opportunities to integrate these components, and strive to achieve a balance that can be sustained over time.

Integrated Design Approach

The first consequence of considering building components as subsystems is to begin looking for optimum efficiency of the building as a whole (and its relation to its environment), rather than just trying to compile separate pieces. This requires an approach that keeps track of effects of each component on the others. In fact, the process itself may need to be re-designed.

Too often, conventional design practice has left us with HVAC systems, for instance, which have more motors of larger size than would be required if ducts (or pipes) had been properly sized and efficiently routed; if lighting had been controlled to the levels needed; if the glazing had been properly selected and shaded; or if the building had been differently oriented. This lack of coordination often results in building systems which use resources inefficiently and require more maintenance. The fact that building subsystems are frequently designed by a sequence of specialist consultants poses many problems in coordination. The stock response is for each consultant to add a size factor for unknown coordination, interference problems and opportunity losses. Sometimes the oversizing for a specific component, through this "consultant compounding," may be two or even three times the actual load requirement.

The solution is an **integrated design approach**. Teamwork and continuous communication will allow your design consultants, users and operators to develop a shared understanding of the overall building and mutually develop a design to emphasize efficiencies in the interconnections/interrelations, as well as in the whole building's performance. It is worth noting that this requires an up-front and continuous commitment from you as the owner's representative or design team leader, and a significant investment of time by all participants in the programming, schematic design and design development phases. This often requires a rethinking of the time demands upon each consultant, especially those only familiar with the conventional, sequential relation of architects and engineers.

Life Cycle Analysis

Another significant aspect of sustainable design is an emphasis on the life cycle of systems. At the building scale, we can think of costs and consequences associated with each stage of a building's life: design, construction, occupancy and operation, repair and replacement of major systems, and reuse or demolition. Public building owners in particular should at least analyze the costs of construction (first costs); operations and maintenance (including utility costs); and major system replacement costs (design life) over a long life based on projected ownership, or in bond-funded projects, at least the financial term.

When it comes to selecting specific materials for the building, the life cycle concept is applied to each material. At this scale, consider the energy and material resources required and the waste created from "cradle to grave" or "cradle to cradle"; i.e., from collection and handling of the raw material; transporting and transforming it through manufacturing steps into a specific shape or product distributed to the building site; installing, using and maintaining it; and reusing, recycling or disposing of it. Although such evaluations were daunting 20 years ago, reliable information is increasingly available from sources such as the AIA *Environmental Resource Guide, Environmental Building News,* on-line data-bases and building material manufacturers.

Life cycle considerations naturally result in an emphasis on durability; reducing, reusing and recycling; low operating costs versus first cost; and minimum replacement or disposal costs. These assessments also underline the importance of commissioning building systems that are balanced to each other, so that designed performance levels are achieved.

Site & Regional Sensitivity

Many building codes and standards assume a location in New England or in Washington, D.C. As you undoubtedly know: "that dog won't hunt" here in Texas. This does not refer to basic safety codes, but to mechanical and energy standards developed in other parts of the country. Luckily, the University of Texas at Austin's Center for Energy Studies has adapted the national energy standard (ASHRAE 90.1) for Texas' conditions. But this is not enough. Your design team cannot deliver best value by formula. You must examine and discuss the specifics of your site; its relation to the sun; its water, vegetation and material resources; regional resources and economy; and the materials and character of indigenous design. You may be surprised at how interesting and productive this investigation can be.

Health & Productivity

The central point of good design is to support and enhance human productivity. Sustainable design suggests that a critical measure of success be the health and productivity of the building's occupants. This focuses the attention of the design team on systematic prevention of predictable health and comfort problems (both within and outside the building — based on current science, not necessarily current standard practice), and an energetic search for systems that deliver conditions that people find enjoyable, encouraging and conducive to their work.

IV. OBSTACLES AND OPPORTUNITIES

The benefits of sustainable building are increasingly obvious. Why, then, are there so few examples? First the bad news. As building professionals, perhaps you can recognize some of these common obstacles.

HABIT

The biggest obstacle to overcome is the normal human resistance to change. We all have our habits. Even as organizations. Conventional practices, procedures and contracts all have associated assumptions and behavioral patterns that are hard to change, for professional practitioners as well as agency staff. Changing takes attention and effort. It takes a very deep desire to do better. It takes will.

FIRST COST BIAS

The statutes and rules that govern procurement of professional services and construction of public works are frequently construed as limiting sustainable design practices. In particular, the requirements for competitive bidding (award to lowest responsive bid), and for a professional fee cap based on a percent of construction cost for many state-funded projects, seem to discourage the extent of teamwork and factual preparation required for sustainable design. These apparent limitations will not be overcome without open discussion of your expectations with the design team and active cooperation between the owner, design consultants and contractors.

SELECTION PROCEDURES

Most agencies' selection procedures for professional design consultants have not been revised since legislative requirements were added for evaluation of alternatives for all major energy-consuming systems and design of water-efficient landscapes. Yet, over the past two or three years, a significant shift has occurred in professional and academic standards for sustainable design. Check to see if your own procedures allow or encourage selection of professionals with experience in facilitating an integrated design approach, providing the research and analyses required to make fact-based decisions, and show a commitment to ecological issues in their work.

CONVENTIONAL FEE SPLIT

The integrated design approach, whereby all architectural and engineering consultants, building users, and maintenance personnel are included in the process from the outset, is considered critical for implementing sustainable design. (See page 6.) However, this approach is discouraged by the typical fee arrangements which roughly allocate design fees to engineering disciplines based on subsystem cost as a percentage of conventional construction costs. Engineers frequently have minimal or no involvement in establishing program objectives or basic design schema, perform interference checking as opposed to active system coordination, and are frequently asked to assume major design decisions for all other disciplines. Often, they are asked to "just make it work." Sustainable design requires time to be allocated to teamwork and to specific analyses. If this is not discussed during fee negotiations with the prime design professional, there is little prospect this relationship will be satisfactorily structured in any subcontracts.

Opportunities for Sustainability

The good news, on the other hand, is that *you* can make a difference. There are steps you can take now to further ensure the productivity and health of those who use our facilities while also bolstering the Texas economy.

- Keep these program materials and use them for reference.
- Include sustainability considerations from the earliest discussion of a project, especially during the project analysis or project approval phase of the project. Although sustainability considerations frequently do not result in higher project budget requirements, in some cases they may. In other cases, you may need to get approval or agreement to spend a higher than typical amount for a particular type building system, or for design services or even for in-house administration. Be sure to credit savings resulting from investments in sustainable elements, such as downsizing HVAC equipment as a result of more efficient glazing and lighting systems.
- Set resource efficiency goals and objectives for each project within the formal project program, and monitor them throughout the design process.
- Insist on an integrated design approach, and make your expectations known during the fee negotiations, if not in the invitation to interview. Ensure that the requirements for team involvement and for energy and material analyses are clearly understood.
- Develop a plan and a budget for commissioning. Monitor all systems to ensure that they are performing at least as efficiently as designed.
- Consider performance-based fees. Design fees based on a percentage of first costs for the building provide no incentive for an integrated design approach or operational efficiency. Performance-based fees reward the design team for dollars saved during a building's operation instead of dollars spent during the building's construction. There

must be a reliable model of "base case" operating and maintenance costs against which to calculate savings.

■ Site the building to minimize run-off and maximize the opportunities for daylighting, natural ventilation, water harvesting and passive solar heating and cooling strategies.

■ Wherever possible, specify materials quarried, timbered, or manufactured in Texas, with a preference for materials with recycled content. Such materials include natural stone, brick and concrete masonry units, steel, paint and insulation.

■ Develop a plan for construction and demolition waste which considers materials segregation, reuse and recycling.

VI. CALENDAR OF PRESENTERS, PROFILES AND OUTLINES

This section provides an organizational framework for storing and building on the seminar materials. It begins with the introduction by University of Texas at Austin President Robert Berdahl, outlining the extraordinary significance of these ideas and the work of the Keynote Speaker, William McDonough. Also provided is an abbreviated sketch of each presenter and the outlines of each seminar.

Keynote Address: *"A Declaration of Interdependence: Humanity, Nature and Technology"*
William A. McDonough, AIA
Wednesday, January 29, 1997

Mr. McDonough is the founding principal of William McDonough + Partners in Charlottesville, Virginia where he is the Dean and Edward E. Elson Professor of Architecture at the University of Virginia School of Architecture. Acclaimed as a leader in the field of ecologically intelligent architecture, Mr. McDonough's design work is modelled on the efficiency and elegance of natural systems. Through this environmentally responsible approach, he has executed projects for corporate, commercial, and institutional clients. Due to the success of his built work, Mr. McDonough is also sought as an advisor and speaker. He is the author of *The Hannover Principles/Design for Sustainability*, the guidelines for the World's Fair in the year 2000. He has also worked with Chattanooga, Tennessee on a *"Zero Emissions"* concept; Atlanta, Georgia on the *"Solar City"* concept; Pittsburgh, Pennsylvania on a year long colloquium about crafting an *"Environmental City"*; as well as a Campus Master Plan for St. John's School in Houston, Texas.

This keynote address was coordinated by the Center for Maximum Potential Building Systems and sponsored by the Texas State Energy Conservation Office with funding from the United States Department of Energy Oil Overcharge Fund, and by both the Office of the President and School of Architecture at the University of Texas at Austin.

Introductory Remarks
President Robert Berdahl

Welcome. I'm Bob Berdahl, President of the University of Texas at Austin. We're very pleased that so many of you turned out this morning, for what I think is going to be the first of a very important series of programs. I'd like to recognize first of all the sponsors of this lecture who have combined their resources to bring Bill McDonough here. The Center for Maximum Potential Building Systems, the Texas State Energy Conservation Office, and the UT School of Architecture. I'd also like to welcome those of you who are attending the series, the Texas Sustainable Building Professional Training Seminars—I guess the subtitle of the series is The Nuts and Bolts of Greening Texas Public Buildings. I welcome you to the campus and hope you enjoy your time here.

Last fall, the University of Texas played the University of Virginia in a football game, and about the only exciting moment for those of us from Texas who attended—if you recall our team was beaten like a drum—was a luncheon that was arranged for us at which we had the great good fortune of hearing a presentation by Bill McDonough, the Dean of the College of Architecture at the University of Virginia. It was one of those moments that rarely happen, but in which one begins to see the world in a whole different fashion. I think that for me at least, and for many of us who heard Bill, it was an eye opening experience, and I think you'll have that in store for you here today.

I'm convinced that as a country and as a culture, we need some kind of fundamental paradigm shift in the way in which we think about resources, the relationship of people to resources, how we as an economy and as a culture deal with the resources that we have. We know that the spirit of capitalism is an enormously productive and forceful spirit for providing people with a high standard of living. We also know that it is an extraordinarily wasteful system and that we build throw-away products and we build throw-away systems, and throw-away buildings, and that if our children are to have an inheritance that is worthy of us, we will have to begin thinking differently about our relationship to nature—our relationship to our resources....

As Dean of the School of Architecture, Bill McDonough not only has inherited the mantle of Thomas Jefferson, who designed the University of Virginia and was its founder, but he lives in one of the houses on the campus that was designed by Mr. Jefferson. No wonder he is so productive—Inspiration is close at hand. Lewis Mumford wrote, "Architecture like government is about as good as a community deserves. The shell which we create for ourselves marks our spiritual development as plainly as that of a snail denotes its species." I suspect that after hearing from our speaker today you will reach the conclusion that I did after my visit to Virginia last fall, that the work of this man is helping us build a community that is more deserving of better architecture and that he's designing architecture that is more deserving of the community it serves.

SESSION 1: CLIMATIC DESIGN AND DAYLIGHTING

Monday, February 10, 1997

This session will address implementing climatic design features, including passive solar, energy efficient lighting and daylighting, to achieve building performance that maintains a high level of comfort as well as energy efficiency while lowering operating costs. General principles will be presented in the morning and the class will form teams to work on an actual design scenario in the afternoon.

Nancy Clanton, *PE, President, Clanton Engineering, Boulder, CO*
Ms. Clanton has been project principal on more than 400 lighting and electrical projects, including the new Robert E. Johnson State Office Building in Austin, and was group leader of the lighting team for the "Greening of White House." She has served on the board of the Illuminating Engineering Society (ILES) of North America and currently chairs its Outdoor Environmental Lighting Committee.

Harry Gordon, FAIA, *Principal in Charge, Burt Hill Kosar Rittelmann (BHKR), Washington, DC*
BHKR is one of the nation's largest architectural firms with extensive knowledge and experience in sustainable design. In addition to his work with BHKR, Mr. Gordon has been past chair of the AIA Committee on the Environment (COTE) where he developed the professional format for the *Environmental Resource Guide.* He is Conference Chair for the 1997 American Solar Energy Society's (ASES) Annual Meeting in Washington, DC.

SESSION 1: CLIMATIC DESIGN AND DAYLIGHTING OUTLINE

Instructors: Nancy Clanton, PE and Harry Gordon, FAIA

I. SUSTAINABLE DESIGN PROCESS
- A Conventional
- B. Integrated
  - 1. Energy
  - 2. Environment

II. CLIMATE RESPONSIVE DESIGN
- A. Texas climates
- B. Guidelines
- C. Passive solar atrium design

III. CASE STUDIES
- A. Greening of the White House
- B. Greening of the Grand Canyon
- C. US Embassy in Berlin

IV. ARCHITECTURE AND LIGHTING
- A. Purpose of lighting
- B. Lighting surfaces versus volumes
- C. Conventional approach
  - 1. Providing "even" lighting
  - 2. Reflected ceiling plan design
  - 3. Calculations based on footcandles
- D. Psychological effects of lighting
  - 1. Acceptable brightness ratios
  - 2. Static versus dynamic lighting
  - 3. Connection with outdoors
- E. Bad lighting
  - 1. Uneven
  - 2. Glare
  - 3. No relationship to daylight
- F. Good lighting
  - 1. Vertical surfaces
  - 2. Direct/indirect balance

V. LIGHTING DESIGN
- A. Appropriate lighting
  - 1. Minimal illuminance
  - 2. Comfortable distribution
- B. Layered approach
  - 1. Ambient
  - 2. Accent
  - 3. Task

VI. EQUIPMENT
- A. Advances
  - 1. Superior photometrics
  - 2. Lower cost
- B. Luminaires
  - 1. Integrate with architecture
  - 2. Indirect versus direct distribution
  - 3. Photometric performance
- C. Lamps
  - 1. Correct selection
    - a. Color temperature
    - b. Color rendering index
  - 2. Energy usage
- D. Ballasts
  - 1. Magnetic
  - 2. Electronic
    - a. Standard
    - b. Dimming
- E. Control types
  - 1. On/off switching
  - 2. Occupant sensors
  - 3. Automatic dimming
  - 4. Building automation systems

VII. BLENDING THE COMPONENTS TOGETHER
- A. Decrease energy usage
- B. Increase productivity

VIII. WORK SESSION
- A. Design problem outline
- B. Team setup
- C. Process
- D. Presentation guidelines

SESSION 2: EFFICIENT HVAC DESIGN

Thursday, February 27, 1997

This session will present the new performance-based design methodology that can increase building efficiency without increasing first costs. Mechanical systems utilizing low pressures, low velocities and high accuracy instrumentation will be discussed. An integrated team of design and engineering consultants and the owner/occupant can reduce cooling and heating loads through careful consideration of renewable energy sources, building envelope and lighting strategies.

Ron Perkins, *CEO, Supersymmetry USA, Inc., Plantersville, TX*
Mr. Perkins has been involved in the construction and operation of commercial and light industrial facilities for the past two decades. Previous to the formation of Supersymmetry USA, Mr. Perkins was the Facilities Resource Development Manager for Compaq Computer Corporation in Houston. In this position, Mr. Perkins oversaw the design of two million square feet of commercial office and factory space with 30% enhanced efficiency and reduced building costs.

Eng Lock Lee, *Vice-President & Technical Director, Supersymmetry USA, Inc., Plantersville, TX*
Mr. Lee specializes in optimizing the energy efficiency of HVAC systems. Major clients include Motorola, Hewlett-Packard, Intel, and AT&T.

SESSION 2: EFFICIENT HVAC DESIGN OUTLINE

Instructors: Ron Perkins and Eng Lock Lee

I. THE INTEGRATED DESIGN APPROACH
- A. Reducing loads
- B. Sanity checking models with measurements
- C. Modeling and measuring
- D. The myth of coincident peak demand

II. RIGHT SIZING HVAC EQUIPMENT
- A. Setting performance goals
- B. Strategy for system design
- C. Put on your architect hat
- D. When to take "no" for an answer

III. DEFINING THE PLAYING FIELD
- A. How conventional buildings perform
- B. How sustainable buildings perform
- C. Building cost breakdown
- D. Economic impact of design decisions

IV. CHARACTERISTICS OF EFFICIENT MECHANICAL SYSTEMS
- A. Exploiting the cube law
  - 1. Pressures
  - 2. Velocities
  - 3. Lift
  - 4. Geometry
  - 5. Component efficiencies

V. EXPLOITING OPERATING CHARACTERISTICS OF EQUIPMENT
- A. Chiller
- B. Cooling towers
- C. Fans

VI. MATCHING VARIABLE LOADS WITH VARIABLE SYSTEM DEMANDS

VII. COMMON SENSE APPROACH TO FILLING TECHNOLOGICAL GAPS
- A. Chiller selection, sizing and sequencing
- B. High performance cooling towers
- C. Redefining air handler unit geometry
- D. High accuracy sensors and data loggers

VIII. WHY CONTROL SYSTEMS DON'T WORK
- A. Taming the tiger
- B. Common self-inflicted problems
- C. Matching equipment to loads being served
- D. Upgrading sensors
- E. Commissioning control systems

IX. THE GREAT PUMPING DEBATE
- A. Primary only
- B. Distributed secondary pumps
- C. Central primary/secondary pumping

X. HOW THE COMPUTER REVOLUTION IS CHANGING HOW WE DESIGN BUILDINGS
- A. The expanded limits of hardware
- B. Software coming on strong
- C. Demonstration of new data analysis software
- D. Will new facts change the old rules of thumb?(rule of thumbs?)

XI. THE ECONOMICS OF ENERGY EFFICIENCY
- A. Whole system life cycle cost
- B. Counting the system wide credits
- C. Considering renewable energy sources
- D. Evaluating competing solutions
- E. Return on investment and simple payback criteria
- F. A case study of nine similar buildings

XII. IDEA EXCHANGE – OPEN FORUM DISCUSSION OF ISSUES AND SOLUTIONS

SESSION 3: INDOOR AIR QUALITY AND BUILDING COMMISSIONING

Friday, March 14, 1997

This session will provide an overview of the causes of and problems created by indoor air pollution. The fundamental techniques of controlling indoor air quality and resolving common problems will be presented. Since people spend as much as 90% of their time indoors, the importance of indoor air quality (IAQ) is critical to human health and productivity. Building commissioning will also be discussed as it relates to indoor air issues.

Hal Levin, *Hal Levin & Associates, Santa Cruz, CA; and Editor,* Indoor Air Bulletin
Mr. Levin is an internationally recognized expert on indoor air quality. Since coining the term "building ecology" in 1981, he has consulted on a range of projects in both the public and private sectors, from the federal government to local municipalities, retail and commercial buildings to single family residences. Mr. Levin is also a founding member of the Steering Group of the AIA Committee on the Environment.

SESSION 3: INDOOR AIR QUALITY & BUILDING COMMISSIONING OUTLINE

Instructor: Hal Levin

I. FUNDAMENTALS OF INDOOR AIR QUALITY (IAQ)
- A. Determinants
- B. What can be done
  1. Planning during design and construction
  2. Building commissioning
  3. Operation and maintenance
  4. Managing problem situations

II. WHAT CAUSES INDOOR AIR QUALITY PROBLEMS?
- A. Pollution sources
  1. Microbial
  2. Chemical
- B. Problem Buildings
  1. Sick Building Syndrome (SBS)
  2. Building Related Illness (BRI)
- C. Thermal comfort control
- D. Ventilation: cause or solution?
- E. Operation and maintenance

III. INVESTIGATION OF INDOOR AIR QUALITY PROBLEMS
- A. Collecting information
  1. Sick Building Syndrome
  2. Building Related Illness
- B. History of outbreak, onset of symptoms
- C. Walk through inspection
- D. Documentation review
- E. Preliminary assessment
- F. Measurement methods and procedures
- G. Evaluation of results

IV. HEALTHY BUILDINGS AS SOLUTION TO INDOOR AIR QUALITY PROBLEMS
- A. Design concept
- B. Source control
- C. Ventilation
- D. Ability to be cleaned and maintained

V. MATERIALS SELECTION FOR GOOD INDOOR AIR QUALITY
- A. Emissions (off-gassing) of chemicals from materials
- B. Selecting low-emission products
- C. Cleaning, maintenance and replacement issues

VI. VENTILATION, ENERGY, AND IAQ: WHERE'S THE BEEF?
- A. Defining minimum indoor air quality standards
- B. Ventilation requirements based on health, comfort and productivity

VII. COMMISSIONING FOR IAQ, ENERGY CONSERVATION AND ENERGY EFFICIENCY
- A. Commissioning
  1. What is it?
  2. Why is it important?
- B. Major components of commissioning process
- C. Documentation is essential
- D. Identification of responsibility and authority

VIII. ENVIRONMENTALLY RESPONSIBLE BUILDING
- A. Definitions of sustainability
- B. Establishing environmental goals for project
- C. Identifying important concerns
- D. Prioritizing environmental goals
- E. Evaluating alternatives
  1. Models
  2. Resources
- F. Translating goals into action

IX. DESIGN GUIDELINES FOR ENVIRONMENTALLY RESPONSIBLE BUILDING
- A. Key concepts
  1. Energy and resource conservation
  2. Energy and resource efficiency
  3. Pollution prevention
- B. Life Cycle Analysis (LCA)

X. PRACTICAL STEPS TOWARD SUSTAINABLE BUILDING
- A. Conserve resources
- B. Control pollutant sources
- C. Integrate environmental control systems
- D. Think globally, act locally
- E. Minimize use and release of hazardous materials

SESSION 4: SUSTAINABLE BUILDING MATERIALS

Monday, April 7, 1997

This seminar will outline the range of considerations that determine whether a material is, in fact, *sustainable*. This includes life cycle assessment, environmental ratings programs, as well as regional factors. Materials commonly specified in state buildings will be reviewed, and a template for "greening" the materials component of public projects will be presented.

Alex Wilson, *Publisher,* Environmental Building News, *Brattleboro, VT.*
Mr. Wilson has established the monthly journal, *Environmental Building News* (EBN) as one of the most credible and thoroughly researched publications about sustainable building. In addition, Mr. Wilson also serves as a consultant to the AIA *Environmental Resource Guide*, where he is responsible for product reports.

SESSION 4: SUSTAINABLE BUILDING MATERIALS OUTLINE

Instructor: Alex Wilson

I. GREEN PLANNING AND DESIGN
- A. Materials as small part of larger context of green building
- B. Green planning and design priorities

II. WHY SELECT ENVIRONMENTALLY RESPONSIBLE BUILDING MATERIALS?
- A. Awareness of resources
  - 1. Legacy for future generations
- B. Cost savings
  - a. Direct or indirect
  - b. Front end or operational
- C. Improved indoor air quality
- D. Building value
- E. Occupant satisfaction and productivity

III. MATERIAL SELECTION OBJECTIVES
- A. Conventional criteria
  - 1. Cost
  - 2. Performance
  - 3. Durability
  - 4. Aesthetics
  - 5. Familiarity
- B. "Green" criteria
  - 1. Satisfy conventional criteria
  - 2. Overlay not alternate

IV. UNDERSTANDING THE ENVIRONMENTAL IMPACTS OF BUILDING MATERIALS
- A. Discussion of life cycle assessment (LCA)
  - 1. The Use Phase
    - a. Energy use
    - b. Occupant health
    - c. Durability
  - 2. Manufacturing Phase
    - a. Hazardous by-products
    - b. Energy intensity
    - c. Process waste
  - 3. The Raw Materials Phase
    - a. Resource limitations
    - b. Resource extraction
    - c. Transportation
  - 4. Disposal or Reuse
    - a. Recyclability
    - b. Hazardous demolition

V. SPECIFYING GREEN MATERIALS
- A. Discussion of specification process
- B. Resources to assist in green material specification
  - 1. Design services
  - 2. GreenSpec developed by Alameda County, CA
  - 3. Product directories
- C. Developing specs for a project

VI. DISCUSSION OF AREA PROJECTS
- A. Design criteria
- B. Material selection process

SESSION 5: WATER AND LANDSCAPING

Wednesday, April 30, 1997

Despite years of regulating water management, erosion rates have never been higher. Groundwater levels are dropping while flooding increases, stream base flows are diminishing, and a contamination of ground and surface waters is still a serious concern. These problems are compounded by concern about the cost of regulatory compliance and the difficulty of enforcement. An ecological approach to water management treats all water as a resource, including effluent and stormwater. The goal is to achieve the maximum level of restoration possible given the site's conditions, client needs, and available resources. Often this approach can result in a dramatic increase in value to the client, as well as to the larger community. This seminar will develop a framework to devise intelligent strategies that optimize water flows within a building, matching water quality with specific water demands. Site restoration, featuring native landscape species, will also be presented.

Leslie Sauer, *Partner, Andropogon & Associates, Philadelphia, PA*
Ms. Sauer, in addition to her professional practice with Andropogon & Associates, teaches landscape architecture at the University of Pennsylvania. She is recognized for her innovative, extensive work on regionalism, landscape design, and ecological restoration.

Peter Warshall, *Consultant, Tucson, AZ*
Mr. Warshall is an internationally renowned water consultant and present editor of *The Whole Earth Review*. In 1996, he worked on one of the nation's first municipal greywater ordinances for Malibu, CA. Mr. Warshall's unique perspective on water conservation attempts to match water quality with specific water demands.

SESSION 5: WATER & LANDSCAPING OUTLINE

Instructors: Leslie Sauer and Peter Warshall

I. WATER MANAGEMENT
- A. All water as resource (municipal, effluent, stormwater)
- B. Building wastewater
  - 1. Definition
  - 2. Volume calculations
    - a. Occupancy size
    - b. Use type
- C. Wastewater reuse strategies
  - 1. Conservation
  - 2. Treatment modifications
  - 3. Available technology
    - a. Systems
    - b. Equipment
    - c. Filters
- D. Site stormwater
  - 1. Definition
  - 2. Vegetated stormwater infiltration systems
    - a. Habitat restoration
    - b. Pollution reduction

II. CASE STUDIES
- A. Buildings
  - 1. Commercial projects
  - 2. Correctional facilities
- B. Master planned developments
  - 1. Residential/commercial
    - a. The Woodlands, TX
  - 2. Commercial/industrial
- C. Municipalities
  - 1. Malibu, CA
- D. Landscapes
  - 1. Pond retrofits
    - a. Habitat
    - b. Pollution reduction
  - 2. Modifications
    - a. Turf to tall grass
    - b. Turf to greensward

SESSION 6: CONSTRUCTION/OFFICE RECYCLING

Thursday, May 22, 1997

Each year, Texans dispose of more than three-and-a-half million tons of construction debris. This amount of waste represents millions of dollars of disposal costs and tons of wasted resources. This session will discuss how this enormous amount of waste can be reduced, reused, and recycled. Examples and case studies from projects around the country will be presented. Learn to write specifications, organize your job site, and identify the ways to keep materials from being carted to the landfill.

Gail Lindsey, AIA, *President, Design Harmony, Inc., Raleigh, NC*
Design Harmony helped bring to fruition the Triangle J Council of Governments "WasteSpec;" a computer reference which can be inserted into any standard construction specification. Ms. Lindsey is the 1997 Chair of the AIA Committee on the Environment and Chair of the North Carolina Green Building Council.

SESSION 6: CONSTRUCTION/OFFICE RECYCLING OUTLINE

Instructor: Gail Lindsey, AIA

I. CONSTRUCTION AND DEMOLITION RECYCLING
- A. Current Status
- B. Future Visions

II. CONCEPT OF WASTE
- A. Closed loop thinking
- B. Introduction to "WasteSpec"

III. VIDEO PRESENTATION, "OLD BUILDINGS DON'T HAVE TO GO TO WASTE"
- A. Deconstruction of building
- B. Salvage of wood, brick, stone, and fixtures

IV. OVERVIEW OF TEXAS RECYCLING PROGRAMS

V. CASE STUDIES

VI. WORK SESSION
- A. Design problem
- B. Waste reduction
  - 1. Construction and demolition
  - 2. Office
- C. Implementing recycling
  - 1. Construction and demolition
  - 2. Office

V. CASE STUDIES

The case studies are a more in-depth look at the projects presented in this project's accompanying video, *Sustainable Building in Texas: A Strategy Whose Time has Come.* The 16-minute video, designed as an introduction to the seminars, uses an interview format to highlight the traditional and contemporary building practices associated with sustainable design. A number of award winning Texas projects are featured.

PROJECT
Advanced Green Builder Demonstration Project
Austin, TX

Client
Funding by the State Energy Conservation Office, Meadows Foundation, Educational Foundation of America, Lower Colorado River Authority, On-Site Wastewater Treatment Research Council

Architects
Center for Maximum Potential Building Systems/Austin

Square Footage
2,000 square feet

Budget
$200,000

Start/Completion
1993/1997 occupancy

Sustainable Design & Material Features
Flexible building system

Passive solar design

Recycled steel and rebar

AERT door and window frames

Unfired caliche stabilized block

Compressed earth block

Sustainable Energy Features
Photovoltaics (2.7kw)

Solar hot water heater

Water Conservation Features
On site wastewater treatment for black and greywater

Rainwater harvesting system (13,700 gallons storage)

PROJECT
Parque Zaragosa Recreation Center
Austin, TX

Client
City of Austin Architectural Management/Parks and Recreation Department

Architects
Robert Jackson/Emily Little Joint Venture Architects/Austin

Square Footage
17,500 square feet

Budget
$2.5 million

Start/Completion
1995/1996

Sustainable Design & Material Features
Building orientation

Daylighting

Water source heat pump with ground heat sink

Local limestone

Awards
1996 Design Award, Texas Society of Architects

PROJECT
South Texas Blood and Tissue Center
San Antonio, TX

Client
South Texas Blood and Tissue Center

Architects
Overland Partners/San Antonio

Square Footage
79,000 square feet

Budget
$10 million overall

$110/square foot

Start/Completion
1994/1994

Sustainable Design & Material Features
Building orientation with longer north/south elevations

Limestone wall thermal mass walls north/south

Recessed insulated windows with low-e glass coating

Interior operable solar shading

Insulated skylights

Continuous sun screen constructed of off-the-shelf galvanized pipe and perforated metal mesh

Local limestone exterior walls (Texas)

Regional slate flooring (Mexico)

Natural fiber carpet

Water Conservation Features
Xeriscape™ landscape

Rainwater harvesting system (5,000 gallons storage)

Reuse of mechanical blow down water

Awards
1996 Design Award, Texas Society of Architects

1996 Electrical Design Award, General Building Contractors Association

PROJECT
Great Northwest Branch Library
San Antonio, TX

Client
City of San Antonio

Architects
Lake/Flato Architects, San Antonio

Square Footage
12,000 square feet

Budget
$1.7 million overall

$94/square foot construction

Start/Completion
1995/1995

Sustainable Design & Material Features
Passive solar shading on south elevation

Clerestories with overhangs

Daylighting

Local limestone

Zoned HVAC

Energy efficient lighting

Awards
1996 Design Award, AIA/San Antonio

PROJECT
International Center/North American Development Bank
San Antonio, TX

Client
City of San Antonio

Architects
Lake/Flato Architects, San Antonio

Square Footage
100,000 square feet

Budget
$11.7 million overall

$ 8.9 million construction

Start/Completion
1995/1997

Sustainable Design Features
Reuse of former main public library

Balconies for solar shading

PROJECT
Sustainable Design for High Security Facilities

Client
Texas Department of Criminal Justice
Huntsville, TX

Energy Consultant
ENSAR Group/Boulder, CO

Project Description
A prototype correctional facility was analyzed for four Texas sites: Huntsville, Waco, Kenedy, and Amarillo. The report determined that using conventional energy conserving measures, such as appropriate lighting and efficient HVAC, could reduce the annual energy operating costs by 20 to 40 percent.

PROJECT
Texas Capitol Preservation and Extension
Austin, TX

Client
State Preservation Board

Architects
3D/International, Inc., Houston and Ford Powell & Carson, Inc., San Antonio

Square Footage
360,000 square feet - Capitol
620,000 square feet -Extension

Budget
$155 million

Start/Completion
1988/1995

Sustainable Design & Material Features
Daylighting
Natural ventilation
Interior solar shading
Texas granite
Extension's underground location and orientation north of Capitol

Awards
1995 National Trust for Historic Preservation Honor Award
1995 Design Award, Texas Society of Architects
1995 Preservation Award from Heritage Society of Austin

PROJECT
Franklin High School
El Paso, TX

Client
El Paso Independent School District

Architect
Stanley + PSA, Inc., Joint Venture Architects/ El Paso

Square Footage
305,000 square feet

Budget
$25.9 million

Savings
$1 million under budget

Start/Completion
1994/1996

Sustainable Design Features
Efficient HVAC system
"Smart" HVAC controls
Passive solar shading
Natural ventilation
Increased roof insulation
Protected mechanical equipment

Water Conservation Features
Low-flow fixtures
Rainwater harvesting system & greywater/ blackwater system: designed infrastructure (not yet operational)
Drip and low-flow irrigation system

Awards
1996 Caudill Award, Texas Association of School Administrators
Texas Association of School Boards, Texas Society of Architects
1995 Honor Award, AIA/El Paso

VI. APPENDIX

GLOSSARY

building commissioning: the process of testing and refining the designed systems of new and remodeled buildings to assure proper functioning and consistency with design criteria; also includes preparation of operating manuals and training of building maintenance staff.

carrying capacity: the amount of demand (usage) for a particular resource that can be sustained without depletion or degradation of the dependent life forms.

daylighting: the use of natural light to illuminate building interiors.

design temperatures: used with energy modeling calculations, established for winter and summer for specific cities and represent the calculated low and high extremes.

embodied energy: the measurement of energy required to produce a material or product, generally tracking the energy used during the life cycle including source, process, manufacture, use and transportation involved throughout the life cycle.

fly ash: the cementitious ash resulting from combustion of coal in power plants which, if tested and deemed suitable, can be used in varying percentages as a substitute for portland cement in concrete mixes.

footprint: the area of a building on the ground.

indoor air quality (IAQ): ASHRAE Standard 62-1989 defines acceptable IAQ as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

insolation: amount of solar energy reaching a surface per unit of time.

life cycle: the sequential stages of a material or product, often presented as four stages, source, process, use, reuse/recycle/dispose, or as six stages, inserting transportation between source and process, and between process and use.

life cycle analysis: a comprehensive method to evaluate environmental impacts of a material, product or activity over its life cycle.

orientation: placement of building on a site, determined by the building's horizontal axis relative to compass points, i.e. E-W or N-S.

passive solar: a design approach for buildings and equipment that takes advantage of solar energy for space and water heating, space cooling, and daylighting without reliance on external energy sources to operate the mechanical equipment.

photovoltaics (PVs): solid-state photo cells which directly convert sunlight into electricity.

productivity: unit of work performed per unit of labor or capital resource.

rainwater harvesting: the principle of collecting and using precipitation from a catchment surface, commonly a roof.

renewable resources: natural resources such as the sun and wind which replenish their supply at a rate equal to or faster than the rate they are used, such that their supply over time is not diminished by demand.

sustainability: as defined by the Bruntland Commission, meeting the needs of the present without compromising the ability of future generations to meet their own needs.

xeriscape™: a landscape practice which specifies regionally-adapted, drought-tolerant plants and other water-conserving techniques.

TEXAS ORGANIZATIONS

Center for Energy Studies, University of Texas at Austin

J.J. Pickle Research Center

10100 Burnet Road, Building 133, Austin, Texas 78758 (512) 471-7792

Serves as the central focus of energy research for The University of Texas at Austin and initiates, promotes, and sustains both research and educational activities in energy (energy sources, transmission, demand, end use and conservation) and analysis of energy-related issues and economics. Additionally, the Center cooperates with energy research efforts of other research organizations and academic programs, seeking not to compete with but to complement and enhance energy-related research and educational activities at the university.

Center for Maximum Potential Building Systems

8604 F.M. 969, Austin, TX 78724 (512) 928-4786

A non-profit sustainable planning and design firm established in 1975 which initiated the City of Austin Green Builder Program and works with the State of Texas on a range of sustainability and public buildings initiatives, including design assistance, material specification and training and educational resources.

City of Austin Green Builder Program

206 E. 9th Street, suite 17.102, Austin, TX 78701

Program Manager: Doug Seiter (512) 499-3506

Offers sustainable building guidelines for residential, commercial and municipal buildings in the Austin electric utility service area, and provides educational programs and incentive-based marketing tools to promote green building.

Texas A&M University Energy Systems Lab

College Station, TX 77842

Director: Dr. Dan Turner (409) 845-8699

Provides monitoring for the State Energy Conservation Office Loan Star Program and conducts research in energy conservation design and operation of buildings.

Texas Department of Health Indoor Air Quality Branch (IAQB)

1100 West 49th Street, Austin, TX 78756

Director: Quade Stahl, Ph.D. (800) 572-5548 or (512) 834-6600

Web page: http//www.tdh.texas.gov/ech/env/iaq.htm

Provides information on indoor air pollution and, if needed, conducts on-site indoor air quality investigations for private residents, public agencies, public schools, small businesses and city and county health departments. Covers many indoor contaminants including formaldehyde, organic vapors, common pesticides, carbon monoxide, carbon dioxide, mercury, molds and dusts. House Bill 2850, passed by the 1995 Texas Legislature, allows the Texas Department of Health to establish voluntary guidelines for indoor air quality in public schools. The IAQB is developing these guidelines with a voluntary task force representing many groups and individuals involved with schools.

Texas Solar Energy Society

President: Mike Sloan (512) 476-9899; eselig@tevai.com
Informs the public, institutional and governmental bodies and raises the level of public and governmental awareness to further the development of solar energy and related arts, sciences and technologies with concern for the ecologic, social and economic fabric of the state.

Texas State Energy Conservation Office (SECO)

PO Box 13047, Austin, TX 78711-3047 (512) 463-1931
Educational Facilities: Mel Roberts (512) 463-1757/Lee Gros (512) 463-3576
Sustainability and Renewable Energy: Jane Pulaski (512) 463-1796
Telecommuting: Bob Otto (512) 463-1876
The General Services Commission's State Energy Conservation Office administers and delivers a variety of energy efficiency and conservation programs and provides technical resources to institutionalize energy efficiency, financial assistance to complete energy retrofits and educational materials and workshops to promote energy efficiency. Current SECO programs include alternative fuels, housing partnership, LoanSTAR revolving loan program, renewable energy demonstration, school/local government, state agencies and transportation.

West Texas State University Alternative Energy Institute (AEI)

Box 248, Canyon, TX 79016
Dr. Vaughn Nelson, Dean (806) 656-2731
The Alternative Energy Institute has expertise for monitoring and data collection for wind-generated electrical systems.

COMPUTER PROGRAMS

Energy 10: an energy simulation program for low-rise buildings of 10,000 square feet or less (larger buildings can be zoned in units 10,000 square feet or less). The program will model up to 10 different energy-efficient strategies, such as daylighting, light fixtures and passive solar heating, and will rank the strategies by annual energy use or cost and annual heating or cooling energy. Fourteen analytical charts can be generated including monthly loads and daylighting effectiveness and annual utility costs. The application runs on Windows using a PC486 or higher. For information, contact: Passive Solar Industries Council, 1511 K Street NW, Suite 600, Washington DC 20005, (202) 628-7400 x210, psicde@aol.com

Life Cycle Cost Analysis of Buildings and Building Systems (BLCC 4.0): a set of four computer programs that provide economic analysis of proposed investments in buildings and building systems which are intended to reduce long-term operating costs; especially useful for evaluating costs and savings related to energy conservation projects and for selecting project alternatives with the lowest life-cycle cost. For information, contact: National Institute of Standards and Technology (NIST), Computing & Applied Mathematics Laboratory, Office of Applied Economics, Gaithersburg, MD 20899.

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SOLAR ENERGY

Source: National Renewable Energy Laboratory

AVERAGE DIRECT NORMAL INSOLATION			
COLOR KEY	PER DAY (kWh/m²-day)	PER YEAR (MJ/m²)	PER YEAR (quads/100 mi²)
	<3.0	<3,940	<1.0
	3.0 - 3.5	3,940 - 4,600	1.0 - 1.1
	3.5 - 4.0	4,600 - 5,260	1.1 - 1.3
	4.0 - 4.5	5,260 - 5,910	1.3 - 1.5
	4.5 - 5.0	5,910 - 6,570	1.5 - 1.6
	5.0 - 5.5	6,570 - 7,230	1.6 - 1.8
	5.5 - 6.0	7,230 - 7,880	1.8 - 1.9
	6.0 - 6.5	7,880 - 8,540	1.9 - 2.1
	6.5 - 7.0	8,540 - 9,200	2.1 - 2.3
	>7.0	>9,200	>2.3

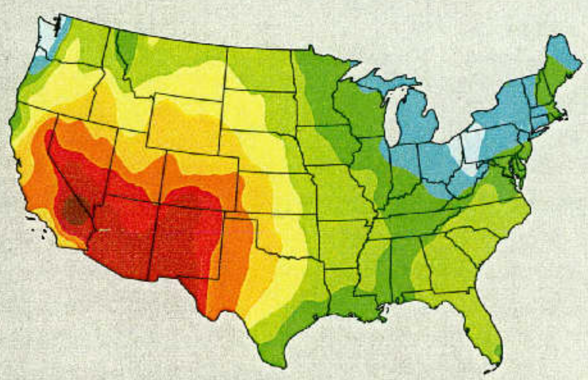
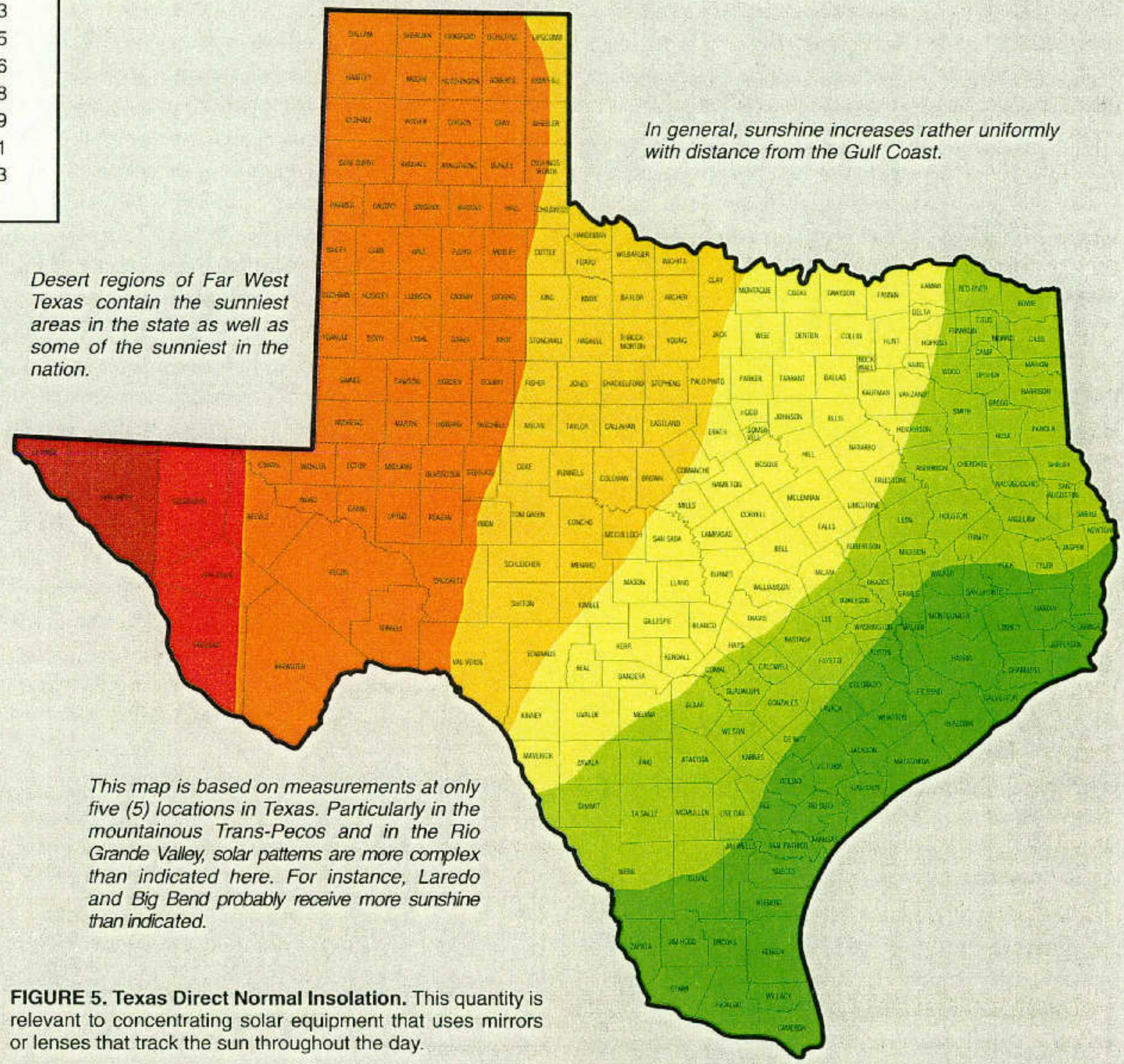


FIGURE 4. U.S. Direct Normal Insolation. (See legend above.)

FIGURE 3. Global Horizontal Insolation for Texas Cities. Throughout Texas, sunshine is adequate to power rooftop systems such as photovoltaic or water heating systems.

In general, sunshine increases rather uniformly with distance from the Gulf Coast.

Desert regions of Far West Texas contain the sunniest areas in the state as well as some of the sunniest in the nation.



This map is based on measurements at only five (5) locations in Texas. Particularly in the mountainous Trans-Pecos and in the Rio Grande Valley, solar patterns are more complex than indicated here. For instance, Laredo and Big Bend probably receive more sunshine than indicated.

FIGURE 5. Texas Direct Normal Insolation. This quantity is relevant to concentrating solar equipment that uses mirrors or lenses that track the sun throughout the day.

WIND ENERGY

Sources: Pacific Northwest Laboratory, Alternative Energy Institute

TEXAS WIND POWER POTENTIAL				
WIND POWER CLASS		WIND CHARACTERISTICS 50 METERS ABOVE GROUND*		
		POWER (W/m^2)	SPEED (mph)	COMMERCIAL VIABILITY
1	1-	0 – 100	0 – 9.8	VERY POOR
	1+	100 – 200	9.8 – 12.5	
2	2-	200 – 250	12.5 – 13.5	POOR
	2+	250 – 300	13.5 – 14.3	
3	3-	300 – 350	14.3 – 15.0	MARGINAL
	3+	350 – 400	15.0 – 15.7	
4	4-	400 – 450	15.7 – 16.3	GOOD
	4+	450 – 500	16.3 – 16.8	
5	5-	500 – 550	16.8 – 17.4	VERY GOOD
	5+	550 – 600	17.4 – 17.9	
6	6-	600 – 700	17.9 – 18.8	EXCELLENT
	6+	700 – 800	18.8 – 19.7	

** Fifty meters (164 feet) is a common tower heighth for large wind turbines.*

The Panhandle contains the state's greatest expanse with high quality winds. Well-exposed locations atop the caprock and hilltops experience particularly attractive wind speeds. As in all locations throughout the state, determination of areas appropriate for development must include consideration of environmental and social factors as well as technical viability.

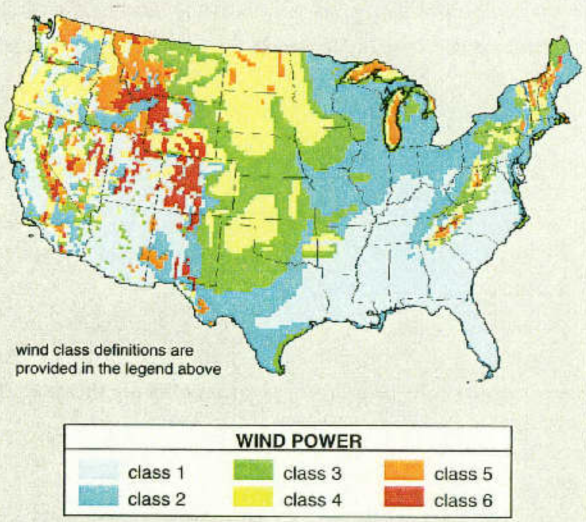
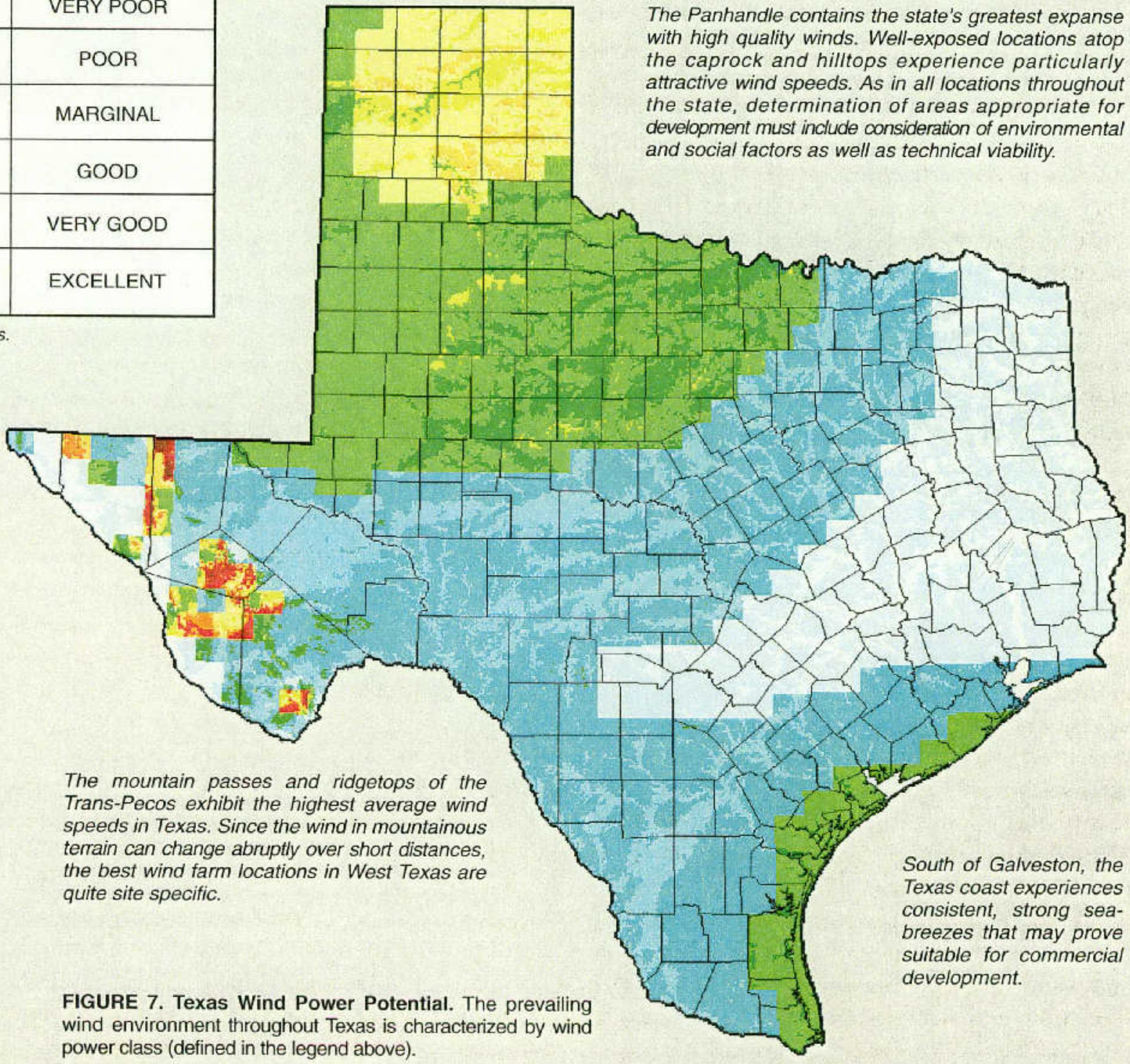


FIG. 6. U.S. Wind Power Potential. While the strongest winds are located along ridgetops in mountainous areas, the Great Plains from Texas to North Dakota contain the preponderance of the nation's wind power potential.



The mountain passes and ridgetops of the Trans-Pecos exhibit the highest average wind speeds in Texas. Since the wind in mountainous terrain can change abruptly over short distances, the best wind farm locations in West Texas are quite site specific.

South of Galveston, the Texas coast experiences consistent, strong sea-breezes that may prove suitable for commercial development.

FIGURE 7. Texas Wind Power Potential. The prevailing wind environment throughout Texas is characterized by wind power class (defined in the legend above).