

THE PRICE OF COMFORT: HOW LANDSCAPE AND ARCHITECTURAL DESIGN CAN REDUCE HUMAN DEPENDENCE ON CLIMATE CONTROL

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INTRODUCTION

In the development of modern sustainable construction there has been a focus on technological solutions. One of the most effective ways to diminish one's carbon footprint is through reducing residential energy consumption. A simple yet overlooked component of residential energy reduction is to better acclimate people to their local environments.

Since the advent of engineered climate control in the mid-20th century, the majority of Americans have “forgotten” how to live with their local climate conditions. This study examines from both quantitative and qualitative perspectives how acclimation via landscape and architecture design interventions can reduce residential energy use. Within a variety of climates in California, it conducts a cost-benefit analysis of reducing enclosed residential square footage to quantify the savings in construction and energy costs. These monies could then be spent on ecologically-appropriate outdoor rooms that fulfill the functional and spatial requirements of the home, requiring little to no extra energy costs. Case studies illustrate a variety of options for the design of the outdoor spaces including: a) multiple spaces around the building for movement with the sun and wind; b) movable controls within a single space such as umbrellas, retractable overhead shade structures, and opening lowered fences for wind; and c) additive devices like fire pits to warm, and water features to cool—all of which would also have aesthetic design qualities.

The study highlights not only energy reduction through moving people to comfortable outdoor “rooms,” but considers the possibility that outdoor spaces can match the spatial and functional needs of indoor rooms. Additionally, this way of thinking about design improves quality of life for the homeowner by increasing the amount time they spend outside. It weaves together a story of successful design solutions in all climates for true sustainable design.

KEYWORDS

climate control, HVAC, residential energy savings, sustainable design, sustainable development, landscape architecture, passive design

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HISTORICAL BACKGROUND: THE RISE OF AIR CONDITIONING

As early as the 1930s, utility companies began to recognize air conditioning's potential to provide a summer load to offset winter heating peaks. By 1957, Commonwealth Edison Co. of Chicago reported that peak energy consumption in August had exceeded the winter high in December (Cooper 1998). However, growth in both per capita usage and total number of conditioned households resulted in neighborhood-wide blackouts as utility companies struggled to meet summertime loads. By the 1970s, air conditioning demand had grown sufficiently significant for President Carter to order all public and commercial buildings to set their thermostats no lower than 78 degrees Fahrenheit during the OPEC energy crisis. Unfortunately, the vast popularity of air conditioning over the prior three decades had resulted in building practices that rejected environmentally-conscious design in favor of artificial climate control. After the advent air conditioning technology, regional modification of architecture for climatic adaptability became increasingly rare. Sophisticated heating, ventilation, and air conditioning techniques had obviated the need for careful site planning or building design to accommodate the local climatic variations and uncomfortable conditions. Residents of poorly-ventilated, heat-retaining structures were unable to tolerate the discomfort of adjusting their air conditioners and this first attempt at reigning in climate control was largely ineffectual. Thirty years later, air conditioning accounts for more than 8% of all the electricity produced in the United States, according to the American Council for an Energy Efficient Economy. This results in approximately 195 million tons of carbon dioxide being released into the atmosphere, at an annual cost of more than \$11 billion to homeowners, with consumption trends indicating little chance of decreasing these amounts in the foreseeable future.

PASSIVE DESIGN TECHNIQUE

Passive design, by contrast, requires no grid-based energy input and can augment both a structure's aesthetics as well as mitigate for climate. The focus of the design is to control wind, solar radiation, and precipitation. Using common trees, shrubs, and groundcovers, it requires a relatively modest financial investment and is one of the few general strategies for some climate control year-round. Using these techniques can reduce up to 30% of a home's energy requirements for heating and cooling (Moffat and Schiler 1981). Moreover, building materials and the use of climate-adapted plantings can integrate a sense of regionalism into the design of the home. The following sections identify four areas of focus for passive design technique.

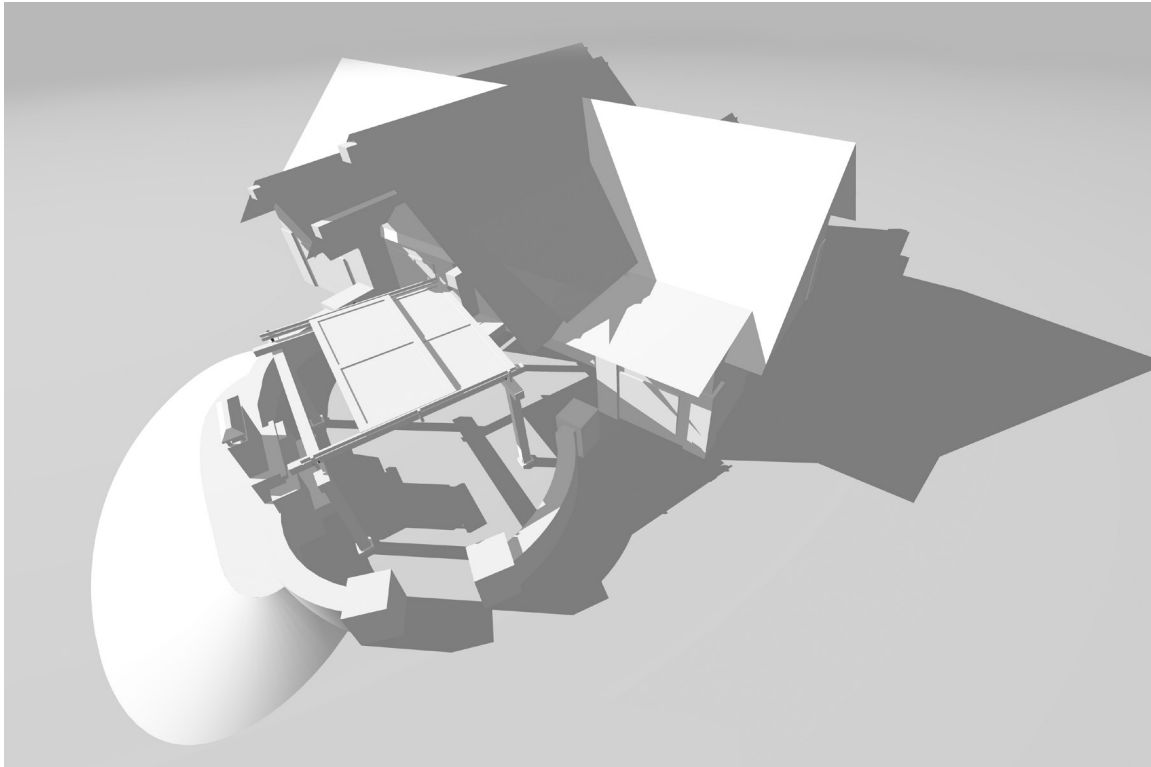
Air Temperature

Earth manipulation provides the most cost-effective method of air manipulation. Berms and swales can be implemented in most landscapes but need to be planned carefully to coordinate with later phases of construction. Plants require slightly more cost input but offer a much wider range of aesthetics from which the designer can choose. Through high moisture retention, plants help to minimize diurnal temperature variation within microclimates. Further control can be exercised over a space's air temperature through the use of deciduous plants, which shade in the summer yet don't interfere with valuable winter sunlight.

Solar Radiation

Trees are a designer's best tool in controlling the amount of sunlight falling upon a space. Vegetation absorbs over 90% of light falling upon it, reduces wind speed to less than 10% of

FIGURE 1. Sketch-Up model of house in Truckee with the shadows reflecting winter morning light.



that in the open, and can increase or reduce daytime temperatures by 15 degrees (Moffat and Schiler 1981). A single deciduous tree can absorb 660,000 BTUs of incoming energy from sunlight, creating a cooling effect equivalent to the use of five 10,000 BTU air conditioning units (Moffat and Schiler 1981). In concert with sunlight mapping tools, 3-D software models like Sketch-Up can be used to test for shadows and for maximized energy absorbance through strategic tree placement (Figure 1).

Air Movement

Wind has both positive and negative qualities for outdoor comfort. Wind can be used to modify microclimate through vegetation placement, as well as built elements like walls, fences, and berms. In warm climates, residents of outdoor spaces depend on shade and breezes for comfort. Accordingly, vegetation should be limbed high to absorb sunlight yet allow ground level breezes to pass through. Landscape designs in cool climates should incorporate tall shrubs around tree trunks in order to create shelter belts to block wind, a design which can reduce winter indoor energy consumption by as much as 33% (Brown and Gillespie 1995). In addition, exterior walls and fences can be used as wind blocks to create protected sun pockets for outdoor rooms.

Humidity

Humidity ties closely into air temperature and can be used to great effect in increasing the comfort level of an outdoor space. In arid climates, existing moisture has to be maximized or else moisture needs to be added by natural process. Water features such as fountains and

shallow pools increase the moisture content of surrounding air to create a temperature moderation effect. Water-intensive plantings such as lawns can also provide similar benefits, but must be used carefully to prevent high water demands.

STUDY METHODOLOGY

The original catalyst for this study was architect Stephen Mouzon's article entitled "Outdoor Room Secrets," which addresses the great potential of outdoor living spaces to both reduce residential carbon footprints and beautify homes. Specifically, this study seeks to evaluate Mouzon's suggestion that "there may be nothing you can do inside your house to reduce utility bills as effectively building great outdoor rooms outside your house . . . it's possible that they might even pay for themselves." To begin this study, a commonly built floor plan was first selected for a hypothetical 1800 square foot tract home. Next, quantitative analyses of the costs and benefits associated with each climate control technique was combined with reducing indoor square footage, providing a financial foundation for the qualitative case study solutions to our query. Construction savings from reducing indoor square footage by 200 square feet provided the budget for outdoor room construction costs, while estimated energy cost savings were used to evaluate pay-back periods. The 200 square feet reduction was carefully taken from a variety of rooms within the floor plan so that the home's spatial function remained largely intact.

Geographic location was expected to cause large variances in both construction costs and climate control related energy costs. Construction costs were expected to vary as a result of availability of materials as well as labor rate (a product of local cost of living and degree of difficulty associated with manual labor and obtaining materials in a given climate). Climate control costs were also expected to display large seasonal differences from region to region. Despite most energy providers offering increased baseline energy allowances to customers in extreme climates, the adjusted rates were not expected to completely mitigate regional cost differences. To account for these expected variances, the study was conducted across five cities in California, each representing a unique climate: Santa Cruz (wet coastal); Long Beach (dry coastal); Bakersfield (open desert); Palm Desert (sheltered desert); and Truckee (alpine forest). The tract home floor plan functioned as the fixed variable between the five hypothetical project sites. Moreover, the study also examined energy loads in terms of CO₂ footprint. When electrical generation method was held constant, CO₂ footprint provided an absolute measure of energy use unaffected by baseline rate adjustment.

A Cost-Benefit Analysis of Passive Design

To obtain the value of construction cost savings, and therefore the budget for the outdoor rooms, general contractors with building experience in single-family residential homes were contacted in each city to estimate the construction cost/ft² for the hypothetical home. In addition to the floor plan, contractors were provided with the following construction specifications in order to ensure uniform quality of construction:

- Foundation was slab on grade (except Truckee which required a basement)
- R-19 framing, 2" × 6" studs
- R-38 roof, attic with composite roof
- Double pane Low-E windows

The data yielded by their responses is shown in Figure 2.

FIGURE 2.

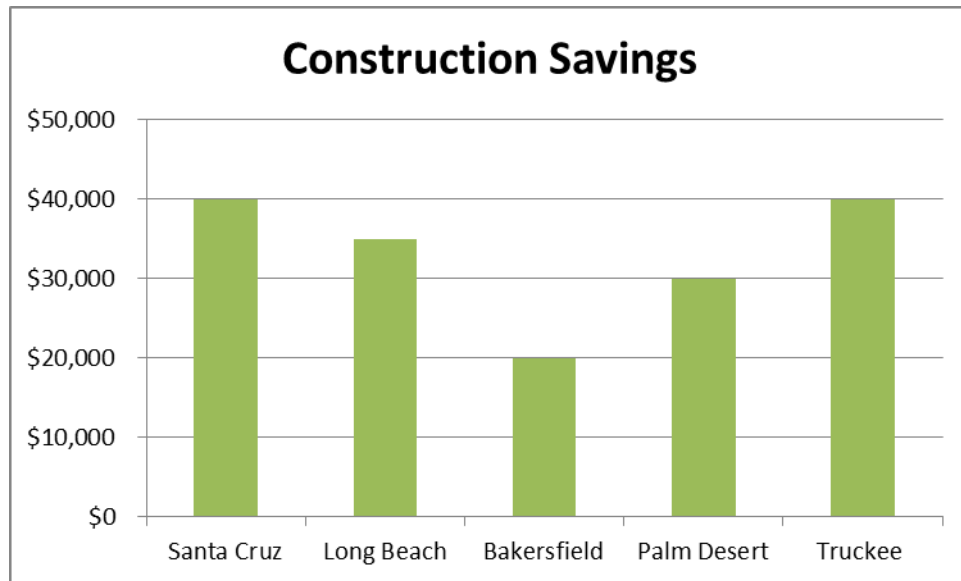


Figure 2 illustrates the range of cost savings between our five project sites. The values shown represent the savings of a 200 square foot reduction in construction for each region, and therefore the budget for the outdoor space design. High cost in Truckee results from the difficulty both of procuring materials and the labor rate for work conducted at high altitude in extreme weather conditions. Santa Cruz's price is also tied to labor rate, which is high due to the local cost of living.

Next, energy costs associated with heating and cooling the homes in the five different regions were generated. This was done using a modeling program called Home Energy Efficient Design (HEED), developed at UCLA's Department of Architecture and Urban Design. HEED allows users to input detailed home specifications in order to generate accurate, appliance-specific energy costs. In addition, HEED contains climate data and utility rates which allow the program to account for spatial variation of heating and cooling costs at the zip code scale. The previously mentioned construction specifications were used in generating electrical costs, as were the following zip codes:

- 95005—Ben Lomond neighborhood, Santa Cruz
- 90803—Belmont Heights neighborhood, Long Beach
- 93308—Central Bakersfield
- 92211—Central Palm Desert
- 96161—Truckee City

Each zip code was selected for its exemplification of climate type, as well as population density. After HEED had generated annual heating and cooling costs for the original 1800 ft² house, the results were converted to cost/ft² so that an estimate of energy savings from subtracting an average 200 ft² could be provided. HEED also generated CO₂ site production estimates, which were then converted to savings via the same process. Both estimates were generated using average energy consumption rates for a split heating and cooling system with a heat pump that met the minimum requirements of California Title 24 (SEER rating 13.0, HSPF rating 7.7) The results are shown on the next page.

Figures 3 and 4 illustrate the annual energy and carbon savings of removing 200 square feet of interior space from the 1800 square foot home, as calculated by HEED. It is important to note that Truckee owes its high carbon footprint reduction to a higher overall carbon footprint of the home due to the climate-necessitated use of a furnace rather than heat pump.

FIGURE 3.

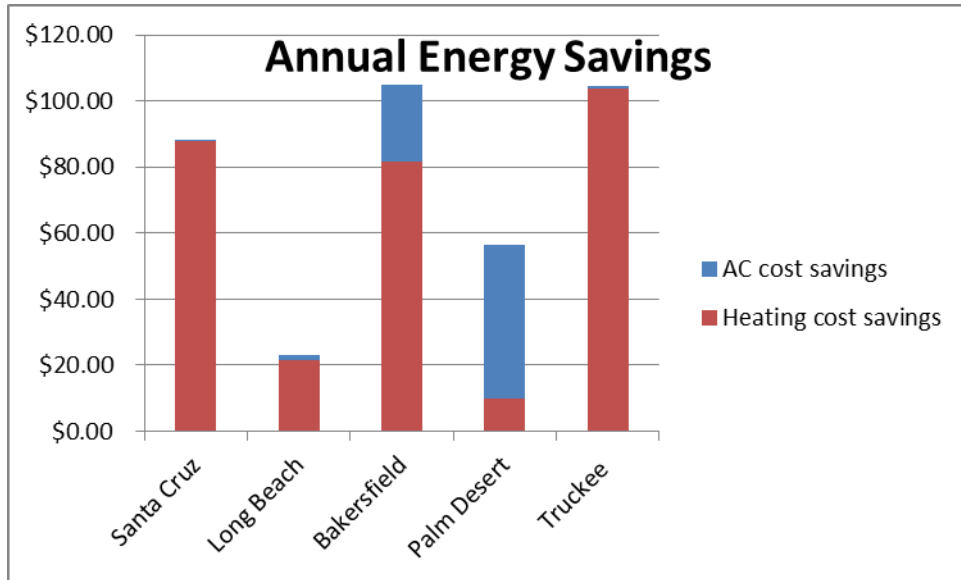
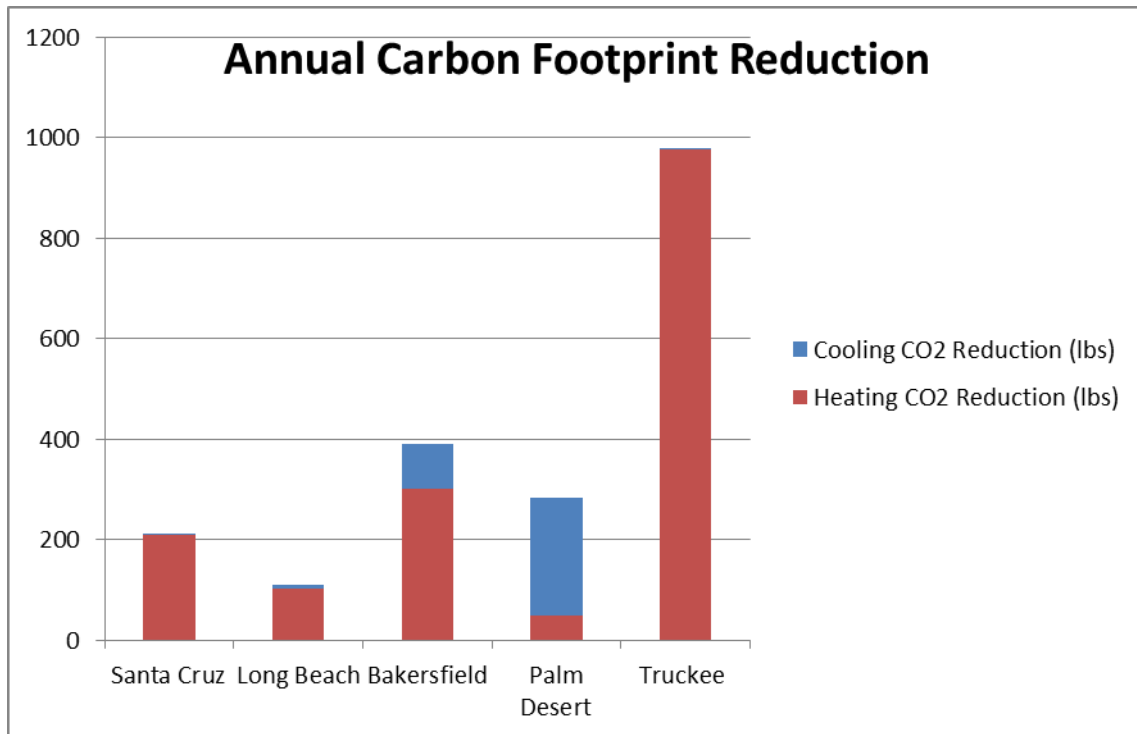


FIGURE 4.



Creation of Passive Design Models

Once project budgets were determined from construction cost savings, landscape solutions utilizing passive design were developed to modify microclimates for the five study sites. All five sites had the same size property of 75 feet × 40 feet, typical for many subdivisions, to maintain another consistent variable. Designers incorporated climate studies, shading models, and prevailing wind analyses to create solutions that were both aesthetically pleasing and would provide residents with comfortable, year-round outdoor rooms. While a single prototypical residence was chosen for design at each of the five cities, house placement varied in order to maximize climate modification. Designs illustrated two modified houses placed on adjacent properties where the layout of the house was rotated to provide additional shade, sun, or wind protection. The landscape design often bridged both properties and planting along property lines allowed things like trees to serve dual purpose for adjacent properties. Note all site plans shown are oriented with north up.

CASE STUDIES

Santa Cruz region

The city of Ben Lomond, slightly inland from the city of Santa Cruz, was chosen because of its high level of rainfall. Despite precipitation rates of over 49 inches per year, Ben Lomond's temperate climate meant that if rainfall was moderated by landscape interventions such as covered spaces, the outdoor design could be utilized year round. Moreover, designs could incorporate water features to make use of the large annual influx of stormwater.

The landscape design looked first to stormwater management (Figure 5). A series of detention ponds were used to collect and store stormwater, with a shared space between two homes that would accommodate volume from both sites. A larger collection area on one site became a pond that added to the overall aesthetic of the design.

To modify wind, deciduous trees were planted to screen the northeast prevailing winds during the winter. Activity areas with seating and dining were located on the south side of the property to maximize warmth. Flexible climate control was added via a collapsible overhead on the pergola and a movable fire pit to provide heat on cold days or nights.

Long Beach

Long Beach, specifically the Belmont Heights neighborhood, is located along the coast in south Los Angeles County. It is a temperate climate with average year-round temperatures between 56–76 degrees Fahrenheit. However, while Ben Lomond was selected for its heavy rainfall, Long Beach is known for strong sun and a low precipitation rate of 15 inches of annual rainfall.

Wind modification elements consisted of evergreen trees used as breaks to diffuse prevailing winter winds (Figure 6). Placed along property lines, they served a dual role of allowing for morning light for one house and afternoon shade for the adjacent house. Large deciduous trees were located on the south side of the properties in the more active spaces to provide afternoon shade in the summer, while still allowing dappled light in the winter. Owing to the sun-dominated climate, south-facing patios required overhead structures for year-round protection. Deciduous vines on the pergola created summer shade that also served to cool the home's interior. To provide sunny places in the winter, some patios were left uncovered so people could move between the spaces for maximum comfort.

FIGURE 5. Passive design techniques applied in Ben Lomond. Design by Sean Clark.

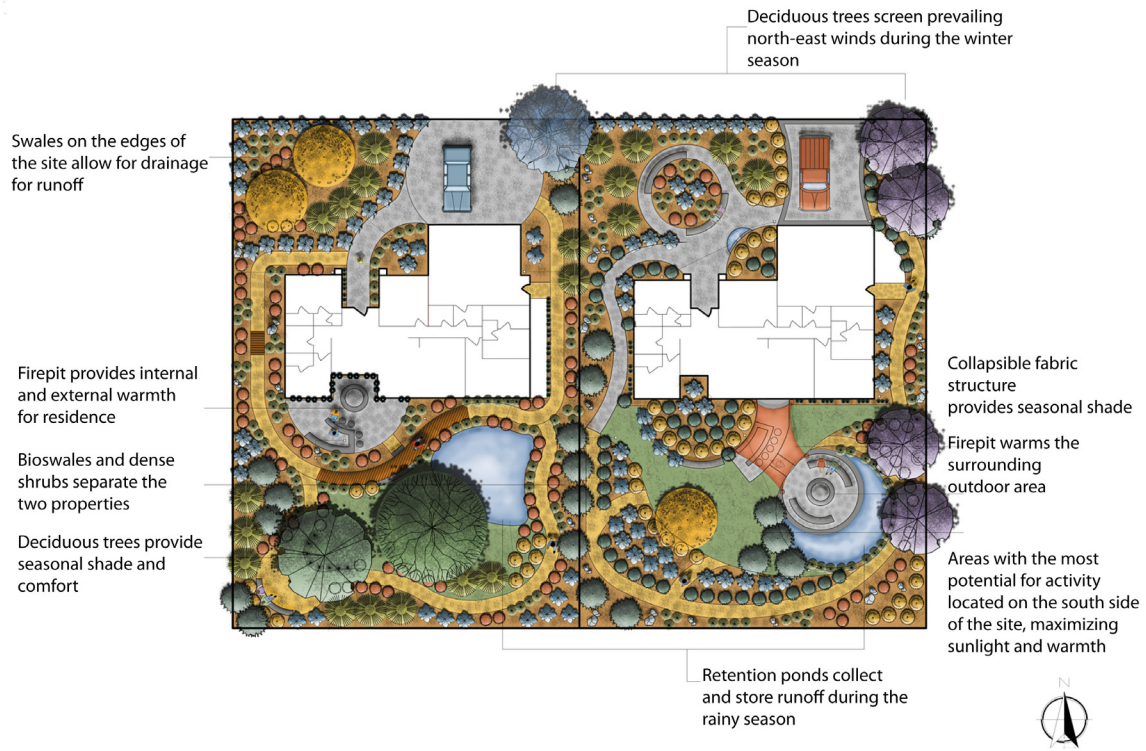
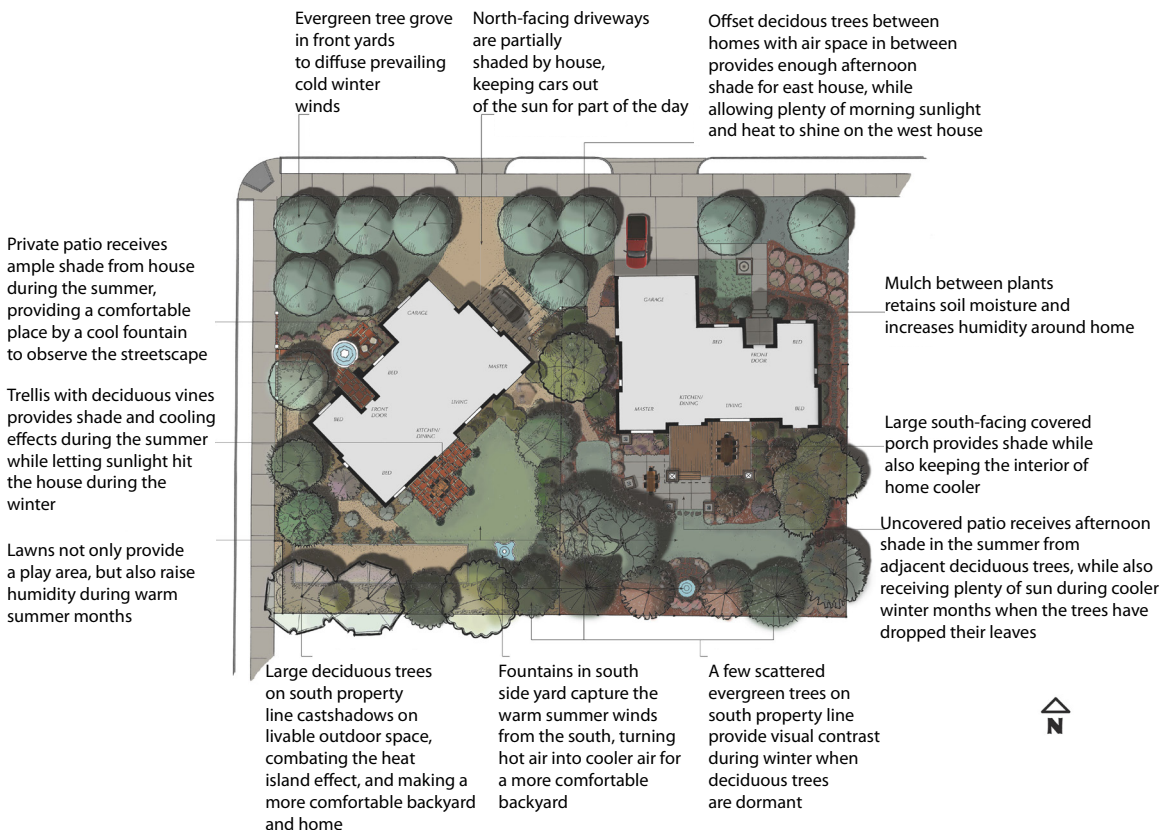


FIGURE 6. Passive design techniques applied in Belmont Heights. Design by Daniel Beck.



Backyard lawns provided for active use, and through their climate-requiring need for irrigation, humidity levels rose in the summer months to further cool the outdoor spaces. Mulch cover over planting beds helped retain soil moisture for the plants.

Palm Desert

Palm Desert is very hot and dry, with average high temperatures of 72–107 degrees Fahrenheit, average lows of 44–80 degrees, and a very low annual rainfall of 3.5 inches. Wind patterns come from a range of directions with seasonal variation that required a design response to manage these changing conditions.

A heavy use of trees was the easiest solution to cooling. A study of the indigenous Cahuilla tribe revealed settlement in native honey mesquite groves that provided not only shade, but wind protection. Additional native trees such as Palo Verde were grouped for maximum cooling of the homes on the south- and west-facing sides.

Drawing on Moorish cooling techniques, one home's water feature was oriented such that northwest winds would blow across the water to cool the patios and interior spaces. Fencing was louvered so that wind could be directed, or blocked when necessary. Fire pits added additional warmth for cool evenings to encourage outdoor use during the winter. Covered and uncovered spaces allowed flexible use—day and night, winter and summer—with the variation of temperatures.

Bakersfield

Bakersfield's similarities to Palm Desert include its high heat and low rainfall of 6.5 inches, concentrated over winter and spring. The city typically has over 108 days of 90 degree Fahrenheit weather and 36 additional days of over 100 degrees Fahrenheit. With Bakersfield's extended record high temperatures, managing for heat was the primary focus in the design.

FIGURE 7. Passive design techniques applied in Palm Desert. Design by Stephen Nunez.



FIGURE 8. Passive design techniques applied in Bakersfield. Design by Trevor Cassidy.



Sun exposure was managed through carefully locating trees as well as designing overhead shade structures. Wind cooling was created by locating trees on the western edge of the property to funnel air flow to the active areas. Aromatic trees, such as lemons, provided the additional value of bringing fragrance into the home through wind.

The heat island effect—a change in the thermal properties of surface materials and a lack of evapotranspiration in paved areas—is prevalent in hot cities such as Bakersfield. Materials such as concrete and asphalt have significantly higher thermal and radiative properties than vegetated areas. For this reason, both the front and back yards of the properties included lawns. While often criticized for water use requirements, lawns can provide an open, semi-private space, as well as cooling humidity to the air. Vegetation was added to the driveway to reduce hardscape, with added plants that could handle vehicular traffic. Hardscape materials like decomposed granite, rather than concrete, also reduced the heat near the house.

Lastly, water features were used both as an aesthetic design element as well as a cooling one. Umbrellas provided flexibility as they could be moved to modify shade.

Truckee

Chosen as the coldest site, Truckee's annual average temperatures range widely from 15–83 degrees Fahrenheit. It has an annual precipitation rate of over 202 inches, mostly in the form of snow. The snowfall season extends from October until May, requiring design solutions that worked in conjunction with snow nearly year-round.

A living fence, or line of vegetation, was developed between the two properties to block snowdrifts and wind. South-facing active areas were designed with flexible overheads, such as a movable roof cover on the pergola. This cover provides solid shade during the summer but can be removed in the winter to avoid being crushed by the snowload.

FIGURE 9. Passive design techniques applied in Truckee. Design by Richard Kane.



Evergreen trees were placed on the north sides of the property to maximize wind protection, while deciduous trees were located on the south-facing side for dappled winter light and summer shade. South-facing active areas capitalized on warmth with any additional outdoor areas placed in sun pockets found between the trees and building shadows. While many might not consider sitting outside in the winter, the warm patios and outdoor fireplaces were designed to encourage outdoor use during this time of year.

CONCLUSION

In *The Original Green: Unlocking the Mystery of True Sustainability*, Steve Mouzon writes that architecture is responsible for 41% of all energy use in the United States, which constitutes the largest share of American energy consumption. Mouzon argues that energy conservation will provide the most viable, sustainable solution to this problem. Yet if landscape architecture offers such an effective means of conserving energy, why hasn't it received more widespread public recognition? According to Anne Simon Moffat and Marc Schiler:

“Landscape design is a passive, energy-saving technique and relies on quality design in simple materials, not on complex technological fabrications. It saves energy by reducing demand for energy at the point of use.”

This is in contrast to the more recently popular active system of design which has resolved energy overuse through encouragement of “the development of systems that increase production” (Moffat and Schiler 1981). An active solution is often favored over the more passive system approach because its effects are more immediately recognizable. Yet, over thousands

of years of human history prior to the advent of air conditioning, passive design techniques proved an effective means of climate control with little environmental impact.

Particular to the geographical region, and at a smaller scale specific to the microclimate, passive design takes its clues from local ecology and cultural traditions to create outdoor spaces that both improve quality of life and inform regional expression. Air conditioning's efficacy in cooling all types of indoor spaces in all climates has reduced regional architectural expression in many communities. To be more aware of historical solutions, the study of indigenous practices of landscape and architectural design begins to offer paradigms of how to live most comfortably with local climate.

Exchanging construction of a small amount of indoor space, 200 square feet in this example, can yield substantial funding to cover the upfront cost of outdoor rooms. The design solutions, furthermore, will continue to provide energy reduction over the lifespan of the home through siting of both the structure and landscape elements. Though the annual energy savings from the 200 square foot reduction alone would not result in a short payback period for the outdoor room construction costs, continued energy savings using the passive design techniques would result in additional energy cost reductions not accounted for in our figures. Additionally, a functional, fully-developed landscape for a new home would have an immediate, substantial increase in its property value and likely a much shorter payback period. Furthermore, the economic feasibility of these design solutions might be improved by another factor: the behavior of the homeowners.

Mouzon's suggestion that outdoor rooms might pay for themselves was based largely on the idea that homeowners would move outside more often because of these design solutions, acclimate to their local environments, and become less dependent on their air conditioning running indoors. Beautiful and comfortable outdoor spaces throughout the year should certainly draw the homeowner outdoors, but a literature review reveals little study undertaken on residential human acclimation behavior, and none on consequential energy use. Case studies of development of passive design projects in comparison to similar developments with more traditional design methods would yield useful results regarding the range of energy savings, and may be the next step in pursuit of an answer to Mouzon's question. In practice, perhaps this design method should also include education that demonstrates how further energy savings could be realized from the homeowner's acclimation to their local climate via time spent in these outdoor rooms. For developers, this energy savings might also be a way to negotiate projects within a community and planning board as a true sustainable design solution.

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ACKNOWLEDGEMENTS

The authors would like to thank Murray Milne (UCLA Department of Architecture and Urban Design), Michael Downey (Cypress Construction Services, Inc.), Paula Jo Wilson (De Witte Construction, Inc.), Russ Sherman (Wallace & Smith Contractors), Christian Edwards (Timberline Construction), Steve Booth (Monroe Construction), Jeff Barrow (Image Builders and Developers, Inc.), Ali Nehme (Title 24 Pro), Steve Downey (Stocker and Allaire), Stephen Mouzon (Author of *The Original Green*), and California Polytechnic State University, San Luis Obispo, landscape architecture students who contributed their designs to this paper: Daniel Beck, Trevor Cassidy, Sean Clark, Richard Kane, and Stephen Nunez.