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Retrofitting existing commercial buildings in the desert southwest to be energy efficient

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RETROFITTING EXISTING COMMERCIAL BUILDINGS IN THE
DESERT SOUTHWEST TO BE ENERGY EFFICIENT

by

Andrea Lee Wilkins

Bachelor of Interdisciplinary Studies
Arizona State University
2003

A thesis submitted in partial fulfillment
of the requirements for the

**Master of Architecture Degree
School of Architecture
College of Fine Arts**

**Graduate College
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THE GRADUATE COLLEGE

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Andrea Lee Wilkins

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ABSTRACT

Retrofitting Existing Commercial Buildings in the Desert Southwest to be energy efficient

by

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Dr. Lee-Anne Milburn, Committee Chair
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This research proposes recommendations specific to the desert southwest for retrofitting existing commercial buildings. A dry, arid region such as Las Vegas, Nevada must contend with different ecological concerns than other parts of the United States. The city of Las Vegas sits in a valley in the Mojave Desert of the Southwestern United States and has a population of over 2.5 million inhabitants. The Las Vegas summers are rather hot and frequently exceed 100 degrees F, while the winters are usually mild, about 60-70 degrees F with cool nights. The state of Nevada receives an average of four inches of rainfall per year. Higher temperatures during summer months increase energy demand for cooling in buildings and simultaneously add stress to the electricity grid during peak periods of demand, which results in greater emissions of air pollutants and greenhouse gases. Most existing commercial buildings located in Las Vegas were not designed for energy efficiency, but retrofitting represents one of the easiest, most immediate and cost effective ways to reduce carbon emissions.

A case-study evaluation was employed to identify energy efficient design strategies that can effectively be implemented to retrofit existing commercial

buildings in the southwest. Buildings in Tempe (AZ), Seattle (WA), San Jose (CA), and Pittsburgh (PA) were evaluated for their energy-saving and climate responsive strategies, their design (re)development processes, and construction technologies. Successful retrofitting in the Desert Southwest begins with the consideration of using the earth's basic elements, such as the sun, water and air to efficiently heat and cool the building. However, the research indicated that not all existing commercial buildings are properly oriented to take full advantage of the earth's natural elements. In this case, efficient mechanical systems were introduced to supplement the design.

In the near future it will be important to ensure that building codes are published with efficiency increases, and that all states adopt the new codes. Many of these policies should also incorporate measures and stipulations that are especially suited to encourage higher efficiency through retrofits and renovations in existing commercial buildings. The most important lesson learned through this research when trying to retrofit an existing commercial building is to continually monitor energy usage and communicate openly with employees. Workers spend over eight hours a day in their place of employment, more than they spend sleeping or spending time with their families. By using monitoring software, energy usage can be collected, analyzed, and mended if necessary, saving businesses money and creating a healthier work environment which bolsters productivity.

TABLE OF CONTENTS

ABSTRACT	iii
LIST OF FIGURES	vii
ACKNOWLEDGEMENTS.....	viii
CHAPTER 1 INTRODUCTION	1
Purpose of the Study.....	6
The United State’s Push for Energy Conservation	8
The American Southwest Energy Use	13
CHAPTER 2 BUILDING SOLUTIONS FOR CLIMATE CHANGE IN NEVADA	15
HVAC Systems	16
Active Renewable Energies	17
Passive System Design	18
Energy Efficient Strategies for Commercial Building Retrofits.....	20
CHAPTER 3 CASE STUDY RATIONALE	31
CHAPTER 4 CASE STUDY: ARIZONA STATE UNIVERSITY BIODESIGN INSTITUTE – TEMPE, ARIZONA	33
Project Overview	33
Background	35
Building Description	36
Energy Efficiency Strategies	37
Use of HVAC Systems	42
Lessons Learned.....	43
CHAPTER 5 CASE STUDY: THE TERRY THOMAS OFFICE BUILDING – SEATTLE, WASHINGTON.....	45
Project Overview	45
Background	46
Building Description	47
Energy Efficiency Strategies	49
Use of Passive Design	54
Lessons Learned.....	56
CHAPTER 6 CASE STUDY: ADOBE TOWERS – SAN JOSE, CALIFORNIA.....	57
Project Overview	57
Background	58
Building Description	59

Energy Efficiency Strategies	60
Use of HVAC Systems	61
Lessons Learned.....	62
CHAPTER 7 CASE STUDY: THE CCI CENTER – PITTSBURGH, PENNSYLVANIA.....	63
Project Overview	63
Background	64
Building Description	65
Energy Efficiency Strategies	65
Lessons Learned.....	68
CHAPTER 8 RECOMMENDATIONS/LESSONS LEARNED.....	70
CHAPTER 9 CONCLUSION.....	83
Further Research	86
REFERENCES.....	87
VITA	102

LIST OF FIGURES

Figure 1.0	Energy consumption of existing commercial building.....	5
Figure 2.0	Rectangular form on east-west axis is optimal for passive Design.....	19
Figure 3.0	Passive solar heating blocks summer sun, while welcoming winter sun.....	20
Figure 4.0	Clerestory window on higher portion of wall with operable window on lower portion.....	21
Figure 5.0	Interior light shelf.....	22
Figure 6.0	2.5H Rule-of-Thumb.....	23
Figure 7.0	Use of cross-ventilation, and stack ventilation	25
Figure 8.0	Natural ventilation through open floor plan of 45 feet in width.....	26
Figure 9.0	Cool Roof	27
Figure 10.0	Double-skin façade	28
Figure 11.0	Arizona State University Biodesign Institute Building B.....	34
Figure 12.0	Master-plan for ASU's Biodesign Institute.....	35
Figure 13.0	Interior Atrium.....	36
Figure 14.0	East Elevation	38
Figure 15.0	West façade	38
Figure 16.0	Labs primarily lit by natural day light from atrium, supplemented with artificial light.....	39
Figure 17.0	Wooden louvers as double-skin façade	40
Figure 18.0	Building section of ASU's Biodesign Institute.....	41
Figure 19.0	Atrium.....	41
Figure 20.0	Rooftop photovoltaic array	42
Figure 21.0	Terry Thomas Office Building.....	46
Figure 22.0	Ground Floor Plan showing relationship of front entry and courtyard	48
Figure 23.0	Glass Sunshades.....	50
Figure 24.0	Interior space	50
Figure 25.0	Courtyard with operable windows	51
Figure 26.0	Section showing operable windows and upper louvers to help regulate carbon dioxide.....	51
Figure 27.0	Courtyard Stack Effect	52
Figure 28.0	Glass sunshades and operable blinds	53
Figure 29.0	Adobe Towers.....	58
Figure 30.0	CCI Center	64
Figure 31.0	Skylight	66
Figure 32.0	Rooftop gardens and light covered pavers.....	66
Figure 33.0	PV panels.....	68
Figure 34.0	Depth of building should not exceed 40 feet	73
Figure 35.0	Interior light shelf.....	76
Figure 36.0	Shading Devices	78
Figure 37.0	Use of wing walls	78

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CHAPTER 1

INTRODUCTION

Climate change is the most important environmental issue the world is combating today: it has the potential to dramatically impact the lives of future generations (UNEP, 2009). Global temperatures are increasing by an average of 0.29°F per decade causing seasons to occur earlier over land and later over the oceans, and sea levels to rise due to melting snow and ice (NOAA, 2008). Warming of the planet can negatively increase the impact of natural storms, causing catastrophic damage to cities along the Atlantic and Gulf Coasts (New Energy Future Reports, 2009). The Intergovernmental Panel on Climate Change (IPCC) concluded human activity was the main driver behind global warming (2007). These human activities can include the use of fossil fuels for transportation, manufacturing, heating and cooling of buildings, and generation of electricity (The Copenhagen Diagnosis, 2009). A report by the National Research Council (2009) estimated that \$120 billion was spent in the United States in 2005 for health damages from air pollution associated with vehicle transportation and energy generation. The United States consumes far more energy than any other country, about 23 percent of the world's overall energy, while only producing 16 percent (EIA, 2009). The building sector currently consumes 40 percent of the United State's energy and produces 40 percent of its carbon emissions (DOE, Buildings Technologies Program, 2009). Electricity used in commercial buildings is the largest consumer, accounting for 79 percent of all building energy use, thus making it the fastest growing fuel with a projected increase of 44 percent by 2030

(DOE, Buildings Energy Data Book, 2009). Implementing upgrades to outdated standard building systems in existing commercial buildings, such as integrating energy efficient design strategies and equipment, can save up to 8 percent of forecasted energy consumption and carbon emissions for the building sector in just one year and lower overall operating costs (Brown, et al., 2005, Smart Market Report, 2009).

A report from the McKinsey Global Institute (2008) calculates that a \$21.6 billion investment in simple, cost-effective building efficiency for existing structures would save enough energy to eliminate the need for 22.3 conventional coal-fired power plants. Currently, fossil fuels such as oil, coal, and natural gas count for 85 percent of the United States energy supply (New Energy Future Reports, 2009). It is projected that between 2010 and 2030, Americans will spend \$23 trillion on coal, oil and natural gas, if we continue our present habits (New Energy Future Reports, 2009). There is an opportunity to slash energy use in half while saving money and resources within ten years and begin to make considerable progress toward achieving energy independence and reduced global warming emissions by retrofitting buildings to be more energy efficient (New Energy Future Reports, 2009).

Over the last decade, more stringent energy guidelines and voluntary green building programs within the United States have helped reduce energy consumption and carbon emissions in new construction (Energy Star, 2009; USGBC, 2009; ICC, 2009). However, with over 70 billion square feet of commercial building space already constructed in the United States, large

energy-saving opportunities may be harvested from existing commercial buildings (DOE, Buildings Technologies Program, 2009; Smart Market Report, 2009). In conjunction, almost three-quarters of our nation's existing buildings were constructed before 1979 (when energy codes did not exist) and have never had any energy related renovations, including HVAC or lighting upgrades, or have had windows replaced or insulation improvements, all of which have proven to be energy efficient techniques (DOE, 2009). Improvements to these existing buildings would have a profound effect on our national resource consumption (Palmer and Burtraw, 2004).

The demand for saving our planet and reducing greenhouse gas emissions is nothing sudden and would not entail a return to a pre-industrial age but does call for an implementation of more energy responsible actions of the entire world population (DOE, National Laboratory Directors, 1997). In the late 18th century, human development was evident by unassuming rates of growth in population, per capita income, and energy use (Owen, 2005). As the Industrial Revolution progressed, societies began to modernize and shift from traditional forms of energy, such as wood and crop residues, to commercial forms of energy, like fuels and electricity (Dias, Mattos & Balestieri, 2004). The industrialized world saw a growth rate of 57 percent at the escalation of the Industrial Revolution, increasing the human population by six billion people in the last 250 years (McLamb, 2008). "Population, global warming and consumption patterns are inextricably linked in their collective global environmental impact,"

reports the Global Population and Environment Program at the non-profit Sierra Club (2008).

Similar projections today suggest the United States population will grow by another 50 percent over the first half of this century (to approximately 430 million by 2050), leading to a possible triple rate of energy consumption (Passel & Cohn, 2008). Population increases result in more buildings, cars, energy use and emissions that contribute to global warming. The warm climate plays a major role in population increases to the Southwest United States and is an enticing feature for attracting corporations, retirees, and tourists (Climate Variability and Change in the Southwest Final Report, 1997).

One of the most popular destinations and fastest growing cities in the American Southwest is the “entertainment capital of the world,” Las Vegas, Nevada. The city of Las Vegas sits in a valley in the Mojave Desert of the Southwestern United States and has a population of over 2.5 million inhabitants (City of Las Vegas, Demographics, 2009). Demographers predict Las Vegas will reach 3.5 million residents by 2012 (Leahy, 2007). The Las Vegas summers are rather hot and frequently exceed 100 degrees F, while the winters are usually mild, about 60-70 degrees F with cool nights. The state of Nevada receives an average of four inches of rainfall per year (Mojave Desert, 2010). Over the last century, the state of Nevada has experienced increased precipitation and average temperatures, which are expected to increase an additional 3-4°F in the spring and fall and 5-6°F in the summer and winter by the year 2100 (Climate Change and the Economy, 2008). By the end of the century, the Southwestern

United States is estimated to experience heat waves lasting two weeks longer, as the number of hot days is projected to incrementally rise (USGCRP, 2000).

Higher temperatures during summer months increase energy demand for cooling in buildings and simultaneously add stress to the electricity grid during peak periods of demand, which results in greater emissions of air pollutants and greenhouse gases (EPA, Heat Island Effect, 2009). Likewise, energy production is anticipated to become more carbon intensive, increasing the emissions of greenhouse gases (Brown, et al., 2005). As a result, an increase in energy consumption is expected to expand by 1.7 percent in commercial buildings. If we continue to generate and use energy like we currently do, buildings will account for 43 percent of total U.S. energy consumption by 2030 (New Energy Future Reports, Building a Better Future, 2009).

The diagram below represents those factors that influence the overall energy consumption of commercial buildings:

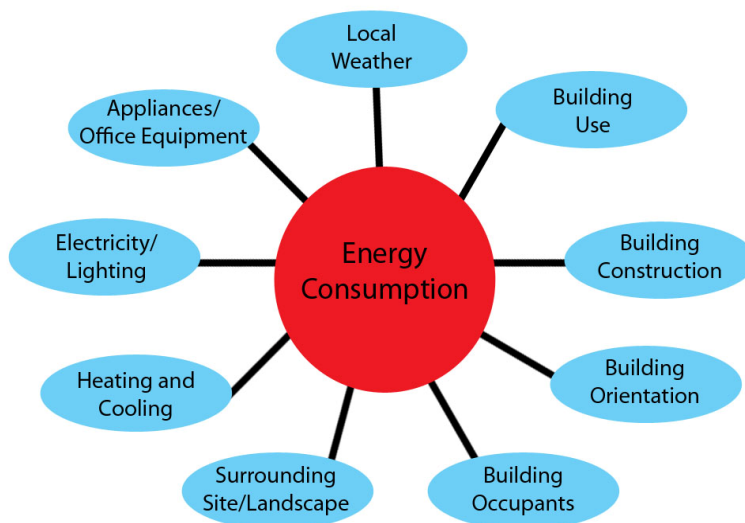


Figure 1.0: Energy consumption of existing commercial building

The energy consumption of existing commercial buildings can be reduced by the use of renewable resources. Renewables play a significant role in the survival of the United States, especially the southwestern portion where population and energy demands are increasing. The American Southwest, especially Nevada, has plenty of natural resources which provide the potential for solar, wind and geothermal energy production. However, it would take 3.8 million large wind turbines, 90,000 solar plants and hundreds of thousands of geothermal plants, and rooftop photovoltaic installations worldwide, costing trillions and trillions of dollars to provide 100 percent of the world's energy with renewable energies (Greenblatt, 2009). Yet, with approximately 75 percent of our buildings scheduled to be new or renovated by the year 2040, we have an opportunity to save energy by executing efficiency measures while working towards renewable energy production (GSMI, 2009).

Purpose of the Study

A dry, arid region such as Las Vegas, Nevada must contend with different ecological concerns than other parts of the United States. Most existing commercial buildings located in Las Vegas were not designed for energy efficiency, but retrofitting represents one of the easiest, most immediate and cost effective ways to reduce carbon emissions (Clinton Climate Initiative, 2009). This research proposes recommendations specific to the desert southwest for retrofitting existing commercial buildings.

A case-study evaluation was employed to identify energy efficient design strategies that can effectively be implemented to retrofit existing commercial buildings in the southwest. Buildings in Tempe (AZ), Seattle (WA), San Jose (CA), and Pittsburgh (PA) were evaluated for their energy-saving and climate responsive strategies, their design (re)development processes, and construction technologies. In addition, a literature review was conducted to identify the effective strategies currently being suggested as a means of energy efficiency in building construction. These strategies emphasize the use of passive building systems in a retrofit setting that optimize renewable resources and require less dependence on traditional building systems that utilize fossil fuels.

Special consideration for this research was given to a hot, arid climate like Las Vegas, Nevada to help identify a series of process and product recommendations which can lead to regionally-specific design and improved energy efficiency in retrofitted commercial buildings. Simple design solutions to existing commercial buildings that respond to location and climate provide an immense opportunity to reduce heat loads and provide an economic savings potential between 10 and 20 percent (Belzer, 2009). Successful retrofitting in the Desert Southwest should begin with the consideration of using the earth's basic elements, such as the sun, water and air to efficiently heat and cool the building. However, the research may indicate that not all existing commercial buildings are properly oriented to take full advantage of the earth's natural elements. In this case, efficient mechanical systems shall be introduced to supplement the design (Green Building Characteristics, 2009).

Research Goals

Two research goals are intended with the outcome of this project:

- To provide energy-saving and climate responsive strategies and recommendations for successful commercial building retrofits, particular to the Desert Southwest.
- To demonstrate existing commercial building retrofits in a hot, arid climate can incorporate passive system design for energy efficiency, while being supplemented by efficient, active building systems if necessary.

The United State's Push for Energy Conservation

Improving energy efficiency is a solid strategy, saving money for consumers and businesses, reducing the need for traditional power plants and energy imports, and reducing emissions, when less fossil fuels are being used in existing buildings. The United States is now incorporating a range of regulatory measures intended to reduce its greenhouse gas emissions and support energy sovereignty (EPA, Climate Change, 2009). The Energy Policy Act of 2005 provides tax credits for energy efficiency and use of renewable energy in buildings, homes and products. These tax credits have been extended to 2013 through the Emergency Economic Stabilization Act of 2008 (Smart Market Report, 2009). Also, education and research in energy efficiency and renewable energy has been funded by the Energy Independence Act of 2007, which has

aided in establishing targets for the U.S. Department of Energy's (DOE) Building Technologies Program (DOE, Building Technologies Program, 2009).

In 2009, Congress passed the American Recovery and Reinvestment Act, providing more than \$25 billion for weatherization, and energy efficiency upgrades for commercial and government buildings (New Future Energy Reports, 2009). President Obama announced an ambitious but achievable goal of increasing existing building efficiency by 25 percent, by 2020 (DOE, 2009). In addition, the Climate Change Bill aims at a 17 percent reduction in carbon emissions from 2005 levels in 2020 and 83 percent in 2050 (Goldenberg, 2009). Legislation also adopted a Renewable Electricity Standard in early 2009 that will require utilities to generate 16 percent of their electricity from renewable resources by 2020 (Doggett, 2009).

Several government voluntary programs have been established to support green building efforts. The Energy Star Program, supported by the U.S. Environmental Protection Agency (EPA) and the DOE, concentrates on lessening energy consumption in buildings through efficient appliances, products and equipment (Energy Star, 2009). Energy Star rated appliances are at least 15 percent more efficient than standard appliances, and the label allows consumers to purchase energy efficient products (Energy Star, 2009).

LEED (Leadership in Energy & Environmental Design) is a popular green building rating system developed in 1999 by the United States Green Building Council (USGBC) that provides certification for green building, awarding points for meeting specific performance criteria. LEED certified buildings are rated at

one of four competitive levels: certified, silver, gold, and platinum (USGBC,2009). Energy efficiency is covered by the “Energy and Atmosphere” credits, which requires commissioning and energy efficiency above required code. Energy efficiency is only one part of LEED certification, which also looks at a building’s effect on water use, transportation, and inhabitants’ health, among other criteria (USGBC, 2009).

LEED is becoming a comprehensive standard for green building and a tax incentive in some state and local governments. Oregon’s Department of Energy offers a Business Energy Tax Credit to help offset the cost of commissioning and applying for LEED certified commercial buildings. The rebate is based on the square footage of the building being renovated or built (Oregon Department of Energy-Conservation Division, 2009). Another state, Connecticut, has legislated that new commercial buildings projected to cost more than \$5 million must achieve a silver rating from LEED starting in 2009, and all major renovations over \$2 million must do the same starting in 2010 (Novak, 2009).

Several states have adopted the LEED standard, but in addition established their own emission reduction and energy saving targets. Wisconsin is one state leading the transition away from fossil fuels toward a clean energy future. In 2008, the state of Wisconsin generated the equivalent of more than 5 percent of its annual electricity consumption from renewable resources. At this rate of growth, the state should achieve its target of 25 percent of electricity produced from renewable energy sources well ahead of the 2025 deadline (Clean Energy Wisconsin, 2008). At the same time, more than 400 homes and commercial

buildings in Wisconsin have been equipped with solar photovoltaic panels, and installations are increasing at a rate of 80 percent per year (Wisconsin Energy Statistics, 2008).

The state of Nevada has set a target of generating 15 percent of the state's electricity from renewable resources by 2013 (DSIRE, 2009). Nevada has also made the commitment to becoming the Solar Capital of the nation, requiring utilities to achieve 6 percent of their energy necessities through solar energy beginning in 2016 (Pew Center on Global Climate Change, Renewable Portfolio Standard, 2009). Nevada is simultaneously involved in the Western Governor's Association (WGA) and the Western Climate Initiative (WCI), both organizations concerned with energy efficiency and climate change. The state of Nevada is also incorporating more stringent building codes for new construction and existing building retrofitting (Nevada Climate Change Advisory Committee Final Report, 2008).

Strengthening the local building codes to incorporate more stringent green building requirements is the best way to have an encouraging effect on building efficiency in new construction and retrofits (Kaplan, 2008). In general, building energy codes are adopted at the state or local level and based on national model codes: the International Energy Conservation Code (IECC) for residential buildings, and the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standard 90.1 for commercial buildings. These model codes and standards are updated every few years and local and state governments have the option of adopting them once the updated version is

published (OTA, Building Energy Efficiency, 1992). Almost every state has standard energy codes for new residential and commercial buildings, but very few have any related codes or requirements for existing buildings. Building code enforcers tend to prioritize health and safety codes over energy codes and consequently provide little or no training in energy code enforcement among building officials, builders and designers (Kaplan, 2008). If all states offered proper training courses to all members involved and adopted building energy codes that are 30% more efficient by 2015 and 50% more efficient by 2025, and enforced them with 90 percent compliance, in 2030, we would be using less than 10 percent of our current annual energy use (Architecture 2030, 2008).

The local actions of California prove that aggressive public policies can enforce the desire to realize energy-efficient building. California has the nation's most stringent building energy codes, and enforces rigorous programs for promoting energy efficiency (California Energy Commission, 2008). Since 1990, California has reduced greenhouse gas emissions per person more than 10 percent (Baker, 2009). The California Public Utility Commission has set a goal of net zero energy codes for all new commercial buildings by 2030 (Kaplan, 2008). Other goals set out for 2010 include a Commercial Energy Efficiency Program that will benefit existing commercial buildings in energy planning, audits and financial rebates and incentives for efficient retrofits, saving over 3 million tons of greenhouse gas emissions over the next two years (California Energy Commission, 2008).

The American Southwest Energy Use

Las Vegas has a climate that is hot, arid and windy and includes a pleasing landscape dotted by cacti and other desert plants, surrounded by beautiful mountain vistas.

The push for energy efficiency and alternative methods of energy production is necessary and pertinent to the survival of the human population on this planet. The United States has the ability today to produce renewable energy, and to help Americans use energy more efficiently, not only by designing new efficient buildings, but by retrofitting their existing homes and businesses (New Future Energy Reports, 2009). However, proper design strategies implemented successfully in new construction or retrofits is highly dependent on specific building location and regional climate (Givoni, 1994). For example, an existing commercial building located in a cold, humid climate such as Juneau, Alaska would definitely have dissimilar energy consumption patterns than a commercial building located in a hot, arid climate such as Las Vegas, Nevada (Olgay, 1963; Brown & DeKay, 2000).

Commercial building developers have identified real financial benefits such as lower operating costs for energy, water and waste, increased rental rates, higher tenant retention rates due to increased comfort and productivity, lower liability and risk leading to lower insurance rates, and higher building value upon sale that can be derived from creating a more sustainable building (Kat, 2003). Implementing national efficiency standards, more stringent building codes and incentives for energy efficiency investments by 2030, energy demand will be two-

thirds what it is now, making the transition to renewable energies much more feasible. The natural resources located in the southwestern region of the United States can be immediately employed in the use of passive systems to provide building energy more efficiently over traditional building mechanical systems.

CHAPTER 2

BUILDING SOLUTIONS FOR CLIMATE CHANGE IN NEVADA

Many businesses are small and unwilling to take risks by using unfamiliar practices and new technologies. A lack of awareness about the potential for energy savings in retrofitting existing buildings seems to be to blame. Many businesses do not know that large amounts of energy can be saved by undertaking a thorough analysis of how energy is used in their existing facilities. The most important step in beginning a retrofit process is to identify broken, disabled or malfunctioning equipment/systems (U.C. Santa Cruz, Campus Sustainability, 2005). Intelligent building software is now commercially available that can monitor the energy usage in buildings and help determine where wasted energy is occurring. Wasted energy in the majority of existing commercial buildings can be blamed on poor insulation, leaky windows, inefficient lighting, heating or cooling systems, and poor construction techniques (New Energy Future Reports, Building a Better Future, 2009). Monitoring the usage of lighting systems and heating and cooling equipment can determine which efficiency measures are most appropriate. The results can range from simple light bulb changes, to more substantial and expensive solutions, such as efficient mechanical systems or double skin façades. Several strategies are outlined below that demonstrate an attempt towards an energy efficient future in existing commercial buildings.

HVAC Systems

Commercial buildings use more than half of their overall energy for heating, ventilation, and air conditioning (HVAC) systems (EIA, Energy Kids, 2008). Reducing heating and cooling loads is the first step to a highly energy efficient building which allows existing systems to operate less and new systems to be designed smaller, thereby lowering operating costs (ACE3, 2009). Load reduction strategies include adding insulation, adding efficient windows, reducing solar gain through shading and proper daylighting, and controlling natural ventilation (Energy Star, Reducing Supplemental Loads, 2007). Equipment upgrades must also be considered as an overall system design rather than as individual HVAC components to achieve optimal energy efficiency performance. Minimum energy efficiency standards set forth by the National Appliance Energy Conservation Act (NAECA), the Energy Policy Act (EPAct), and the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) must also be complied with when upgrading existing equipment (EPA, HVAC Systems, 2009).

Although improved heating and cooling requirements have resulted in a decrease in energy consumption in a typical office building, there is a limit to the savings produced by improved technology alone. Passive design techniques that utilize regenerative energy sources must be considered and put into practice as well. (Petterson, 2007).

Active Renewable Energies

Every part of the United States receives enough sunlight to produce enough power to offset building energy use (EIA, Energy Kids, 2008). Solar photovoltaic panels convert sunlight directly into electricity and are the most commonly used renewable electricity source associated with zero energy buildings (DOE, Energy Efficiency and Renewable Energy-Solar, 2009). Typically, photovoltaic panels work best when facing due south and tilted at a specific angle, usually equal to the latitude of the location in which the building resides (Beyond Oil Solar, 2009). In Las Vegas, Nevada the ideal tilt for photovoltaic panels is 36 degrees, although research has shown that panels oriented towards the east or west at the same angle can still produce almost as much power (Kaplan, 2008).

Wind turbines are another option of producing energy that can be cheaper than solar panels. However, wind turbines cannot be connected directly to a building and are not as easy to install in urban or high-density suburban areas due to their size (EIA, Energy Kids, 2008). Smaller models have been known to make a low humming noise which has been linked to moderate health concerns such as headaches and increased levels of anxiety (Harry, 2007; Frey & Hadden, 2007). Still, many parts of the United States have huge wind resources, so wind power can be a better option for larger buildings especially when combined with measures to first make the building highly energy efficient (American Wind Energy Association, 2009).

Nevada has definite potential for the use of solar and wind technologies, as well as other renewable energy sources such as geothermal. Geothermal energy

pulls heat from deep in the earth's crust for electricity production (Union of Concerned Scientists, 2009). Geothermal energy is a rapidly renewable resource, but transmission becomes an issue; it cannot be shipped. The power must be transmitted directly from a geothermal power plant where the resource exists, creating a long journey for the power in most cases that results in tremendous transmission loss (Fleischmann, 2006). Although the Department of Energy estimates that the upfront costs of a geothermal retrofit installation is three times the cost of traditional systems, it can be recouped in two to ten years (DOE, Geothermal Heat Pumps, 2009).

Passive System Design

There are passive uses of renewable energy that do not involve the use of mechanical and electrical devices, such as using the sun's light to replace artificial sources of light or using building windows, walls, and floors to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat to cool in the summer (DOE, Energy Savers, 2009). Passive cooling is a strategy for cooling buildings without mechanical systems, mostly by employing natural ventilation. Humans have used passive renewable energy for thousands of years, before electricity was readily available and fuel was so cheap and convenient (Cook, 1971).

Ideally, designing a building that relies completely on passive systems would be the most beneficial solution not only for the planet, but for a building owner who is looking for lowering operating and maintenance costs. However,

retrofitting an existing commercial building to be solely passive may not be possible, as many factors need to be considered to determine if a passive design is the ultimate resolution. The most important factor when analyzing a building for a thriving passive design is building orientation. A narrow, rectangular building form in the east-west direction (Figure 2.0) is most desirable when implementing passive design strategies.

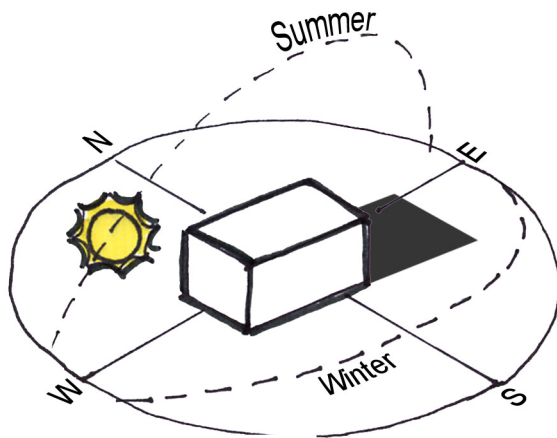


Figure 2.0: Rectangular form on east-west axis is optimal for passive design.

An elongated floor plan on the east-west axis allows the majority of glazing to face either north or south, which provides an advantage to maximize winter solar gains (Passive Solar Design, 2009). Passive solar heating buildings are those where the heat from the sun is blocked in the summer and maximized in the winter, lowering heating and cooling costs (Figure 3.0) (DOE, Building Technologies Program, 2009).

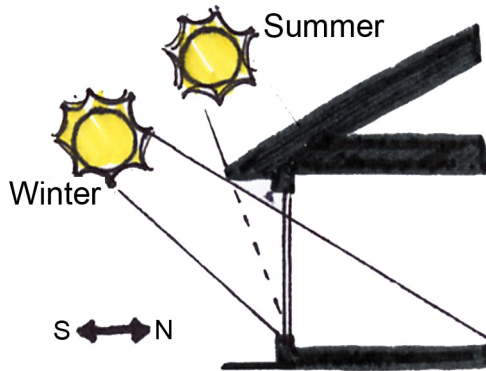


Figure 3.0: Passive solar heating blocks summer sun, while welcoming winter sun.

Unfortunately, building orientation in an existing commercial building is not always on an east-west axis, but this does not mean the building is not capable of being energy efficient. There are several other strategies, both passive and active, that can be implemented to help reduce energy consumption. This research focuses on combining energy efficient equipment and active systems with passive design as a sustainable and economical solution for most retrofit projects. Research has shown that office buildings using a combination of passive solar design and energy-efficient technologies can reduce energy costs by 30 to 50 percent (DOE, Building Technologies Program, 2009).

Energy Efficient Strategies for Commercial Building Retrofits

Daylighting

Passive solar goes hand in hand with daylighting, using light from the sun to replace electric lighting, reducing electricity costs. Research has shown that

daylighting can have a profound impact on well-being, productivity and overall happiness (Flex Your Power, 2009). Daylighting systems are designed to maximize daylight while minimizing glare by providing diffused daylight into a space.

Good daylight design relies on proper window placement so that the light distribution is deeper into a space (Kozlowski, 2006; DOE, Energy Savers, 2009). Glass placed high on a window wall, such as clerestory windows, accounts for better daylight contribution. Another common strategy, shown in Figure 4.0, involves making an operable lower window for individual control of the user, while the higher level window or clerestory is utilized purely for daylight (Kozlowski, 2006).

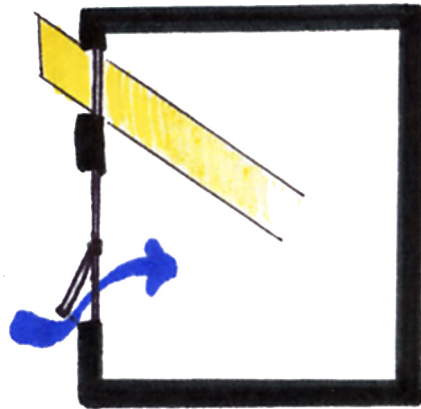


Figure 4.0: Clerestory window on higher portion of wall with operable window on lower portion

If windows in an existing building are full height, running from floor to ceiling, then installing horizontal light shelves at 7 to 8 feet above the floor for a conventional floor height will produce similar results in distribution of daylight and

further reduce glare (Petterson, 2007; DOE, Energy Savers, 2009). An interior light shelf between the upper and lower window (Figure 5.0) would help to reflect daylight deeper into the space by bouncing light off the shelves (Barber, 2007).

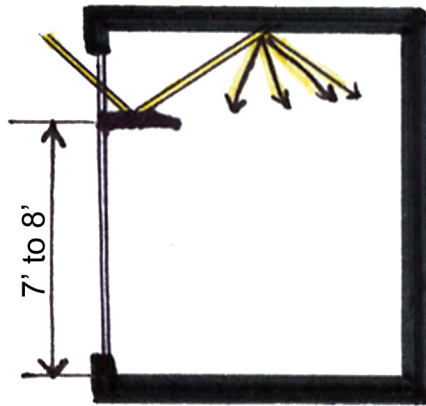


Figure 5.0: Interior light shelf

Light-colored, reflective surfaces on walls and ceilings help penetrate the natural daylight further into the building more evenly making the space feel lighter (Daryanani, 1984; Hakkarainen, 2005). Research recommends a range of 50 to 70 percent reflectance for these surfaces (Hampton, 1989).

If site conditions do not dictate a proper east-west orientation that is optimal for passive design, daylighting can still be successful. Using simple rules-of-thumb, such as limiting the room depth to be no greater than 2.5 times the window head height can produce sufficient daylighting (Stein, 2006). Following the 2.5 method should limit perimeter spaces to be 20 to 25 feet deep for buildings with conventional ceiling heights (Figure 6.0) (Mansy, 2003, Stein 2006).

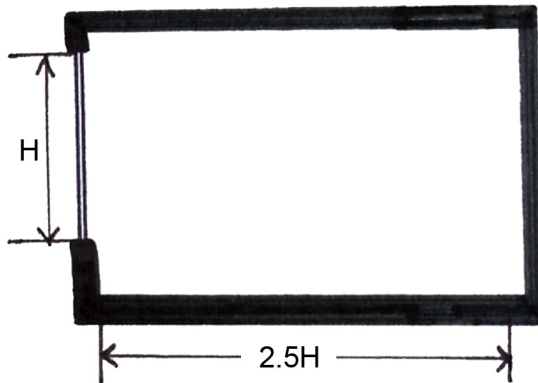


Figure 6.0: 2.5H Rule-of-Thumb

Even the most efficiently daylit spaces cannot save energy or money if lights are not turned off when not needed. It is important to use appropriate daylighting controls and/or occupancy sensors for dimming or turning off lights in locations where artificial lights are not necessary (DOE, 2009; Hakkarainen, 2005; Dunn, Britt & Makela, 2008).

Glazing

The type of glazing chosen should provide good visible light transmission for proper daylighting, but low solar heat transmission (Place et al., 1984). Single-pane windows conduct heat to the outside and should be replaced with dual-pane windows with a $\frac{1}{2}$ inch to $\frac{3}{4}$ inch air space between the sheets of glass (California Energy Commission, 2008). Double or triple glazing with low-emissivity (Low-e) coatings is the best option for energy efficiency (DOE, Energy Savers, 2009). Low-e windows typically cost about 10–15 percent more than regular windows, but reduce energy loss by 30–50 percent (Efficient Windows

Collaborative, 2009). A low-e coating is a microscopically thin layer of metal or metal oxide deposited on window glass that reflects warmth into the building in the winter and prevents unwanted heat from entering the building in the summer (DOE, Energy Savers, 2009). A more economical solution for retrofits would be to apply low-e coated films to existing windows. These low-e films last 10–15 years without peeling, save energy, and increase interior comfort without adding the expense of full window replacements (DOE, Energy Savers, 2009).

Natural Ventilation

Natural ventilation happens when the use of wind velocity flows through a building, effective in cross-ventilation or wind through a building or utilizing a stack effect with inlets and outlets (Figure 7.0) (Brown et al, 2005). Prevailing winds in Las Vegas, Nevada are from the South and Southwest, complimenting the increased glazing on the south side needed for passive heating, making it possible to achieve helpful solar gain and ventilation (Western Region Climate Center, 2009).

Operable windows are a must and should be shaded with proper window treatments on the East, South and West façades. Overhangs, awnings, or other shading devices have a profound effect on shading in the summer and preventing heat gain, but should be designed to still allow sun penetration during the colder months to allow for passive heating (DOE, Energy Savers, 2009).

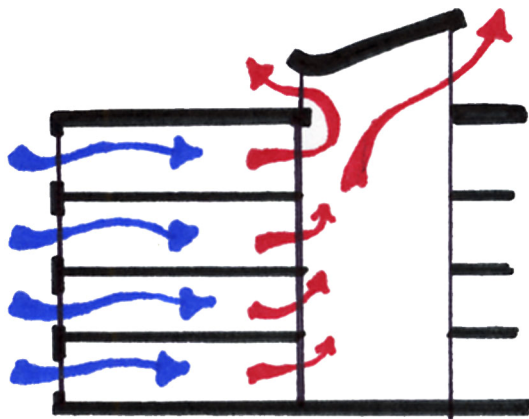
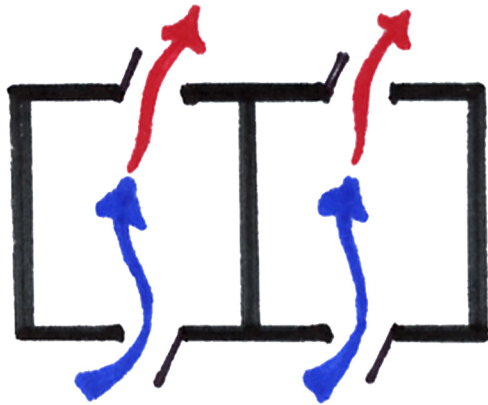


Figure 7.0: Use of cross-ventilation (top), and stack ventilation (bottom)

Naturally ventilated buildings should be no wider than 45 feet to distribute fresh air proportionally through the space (Walker, 2010). An open floor plan is also desirable to help the natural ventilation easily navigate through the building (Figure 8.0).

If incorporated correctly, natural ventilation in lieu of air conditioning can save 10 to 30 percent of total energy consumption (Walker, 2010).

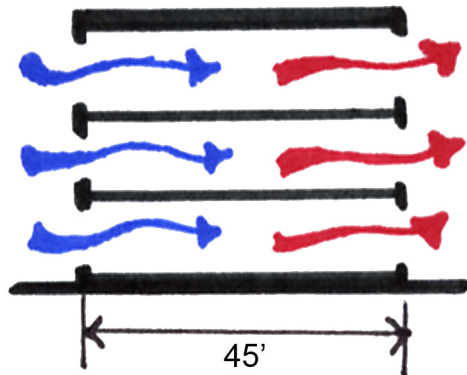


Figure 8.0: Natural ventilation through open floor plan of 45 feet in width.

Courtyards and Atriums

Just as building orientation might not be achievable in all cases, so is the use of courtyards and atriums. However, if possible in a retrofit and controlled effectively, courtyards and atriums can contribute to the overall energy efficiency of a commercial building. Both are central spaces in buildings that provide direct links to the outdoor environment, natural ventilation and daylight (Chappell, 2009). Courtyards are open and do not have a roof, but are enclosed with three to four surrounding walls. Atriums are enclosed spaces within a building that usually contain a glass or semi-transparent roof structure to help funnel natural daylight.

The courtyard is a viable option for a low-rise building (less than 10 floors), while the atrium is more conducive to buildings with more stories (Aldawoud & Clark, 2007). Recent research indicated that in a hot-dry climate similar to Las

Vegas, a courtyard having low-e glass walls used 39 percent less total energy (Aldawoud & Clark, 2007).

Roof

Exterior materials in existing commercial buildings are key providers of both solar gain on the building and of the air conditioning load, especially in hot climates. Typical building envelope upgrades for commercial buildings include increasing roof/ceiling and exterior wall insulation levels. Commercial building roofs receive the most direct heat gain from solar radiation, and in hot climates such as those in the Southwest, buildings provide an opportunity for the use of white roofs or cool roofs to reduce the cooling loads (California Energy Commission, 2009; Balcomb, 1992). Cool roofs are reflective, emissive roofing materials that stay 50 to 60 degrees F cooler than a normal roof (Figure 9.0) (Barringer, 2009).

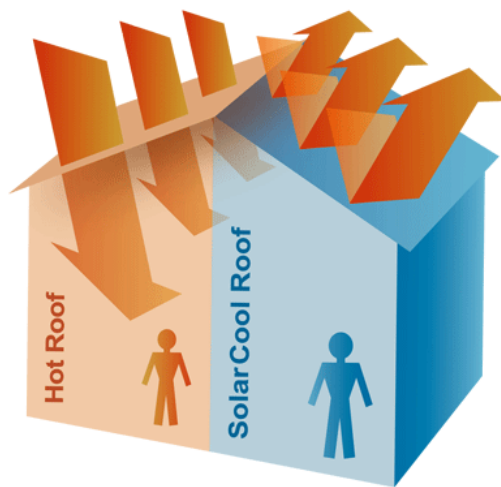


Figure 9.0: Cool Roof

Building Envelope

Double skin façades can be considered and have been known to reduce outside noise in dense urban areas to buildings with operable windows, while providing opportunities as a thermal chimney (Lee et al, 2002). A double skin façade is a second façade installed over an existing façade. The space between the second skin and the original façade is a buffer zone that serves to insulate the building (Uuttu, 2001). The buffer zone is heated by solar radiation that is utilized in the winter time, but is vented to avoid overheating in the summer (Figure 10.0) (Claessens and DeHerte).

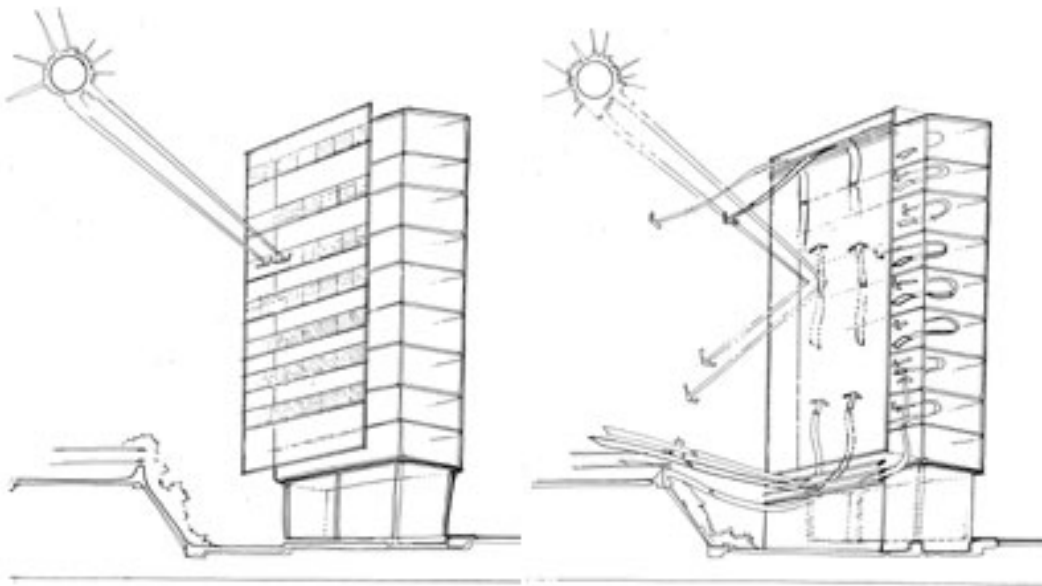


Figure 10.0: Double-skin façade

Insulation plays an important role in the energy performance of a building. Insulation is cost effective in lowering winter heat loss and summer cooling loads (DOE, Energy Savers, 2009). However, incorporating additional wall insulation in

existing buildings can be difficult and expensive but roof or attic insulation should be highly considered because it is easier and typically low cost (DOE, Building Technologies Program, 2009).

Recycled Materials

Recycling and reusing materials in commercial building retrofits can reduce greenhouse gas emissions and offset energy used to extract new raw materials. Recycling materials can also save building owners money while providing additional safety to their building inhabitants. Recycled building products have less embodied energy than new conventional building materials and help keep additional materials from landfills (Mumma, 1995).

Water Conservation and Landscape

Water and energy are so closely connected that it would not be fair to talk about energy efficiency and not mention water conservation. Almost 70 percent of water use in commercial buildings is consumed by boilers and cooling systems (deMonsabert and Liner, 1996). To conserve water, commercial building retrofits should consider using discharged water from a cooling system for landscape irrigation or converting their once-through cooling system to a closed loop or all-air system (deMonsabert and Liner, 1996).

Water conservation efforts can also be achieved by fixing leaks, installing low-flow fixtures, waterless urinals, treating surface runoff, and drought resistant landscaping (Whole Building Design Guide, 2009). Landscape can also minimize energy use in commercial buildings by allowing the building to be in partial to full sun but out of the wind in winter, to full shade in the hot summer months. This

can be achieved by planting deciduous trees, such as Palo Verdes, on the south, west and east sides of the building (Brown and Gillespie, 1995). Vines on walls and small shrubs can also help to reduce summer heat by providing shade and acting as a wind break (Moffat and Schiler, 1994).

Commercial Building Retrofits

Sustainable commercial buildings should have certain building elements that work cohesively with nature yet the changes should not seem obtrusive to the original building, but should compliment the design of the existing structure (Petterson, 2007). Achieving aesthetic and sustainable goals for existing commercial buildings can be accomplished through retrofits similar to the strategies just mentioned. In this research, four case studies were evaluated to determine the best and most effective approaches for a successful commercial building retrofit. Research has proven that successful commercial building retrofits supply existing businesses with substantial reductions in energy use, water use, waste disposal, and maintenance, providing more healthy buildings and cost advantages (Shiers, 2000). Green workplaces offer visual, thermal and acoustical comfort that have been shown to improve productivity and reduce absenteeism of employees (Revival of Passive Design, 2010; EPA, HVAC Systems, 2009).

CHAPTER 3

CASE STUDY RATIONALE

Relevant case studies were difficult to identify when trying to classify successful retrofits for commercial buildings. Therefore, out of the four case studies chosen for this research, two of the case studies were of new construction. Although new construction, these two projects were chosen for two very distinct reasons: one for location and the other for their use of passive design. The Biodesign Institute on the Arizona State University's campus had to deal with similar outdoor conditions as Las Vegas, Nevada. The hot, arid climate is also a design factor in Tempe, Arizona and creates unique obstacles that need special consideration. The design team for the Thomas Terry Office Building in Seattle, Washington also had unique weather factors to compete with, yet was successful in constructing a completely passive design with no mechanical air system. These two case studies provide inspiration and incentive for commercial building retrofits in the Las Vegas valley and are triumphant examples of design strategies particular to the southwest climate and passive design.

The remaining two case studies are indicative of energy efficiency measures in a specific retrofit situation. The Adobe Towers was chosen because of its heavy influence on consistent energy monitoring and valiant efforts to upgrade traditional HVAC systems. The CCI Center in Pittsburgh is chosen because of its similarity to the architectural style, structural type and relative size of many local buildings that will necessitate a retrofit in Las Vegas.

All case studies, either new construction or a retrofit, have one thing in common: they all have received Gold or Platinum LEED ratings, indicating that energy efficient measures were included in the design. The Adobe Towers was the first project to ever receive a Platinum LEED certification in the Existing Buildings category, while ASU's Biodesign Institute was the first building in the state of Arizona to receive a Platinum LEED certification for new construction. Respectively, the Terry Thomas has also received a Platinum LEED certification for new construction and the CCI Center has received a Gold LEED certification under the Existing Buildings category. Receiving LEED certification in all of these instances, sometimes the first in its category, sets a precedent for all future commercial building construction and retrofits.

The four case studies represent diverse energy efficient strategies that when evaluated can be combined to truly create the best possible options for an existing commercial building retrofit. Each case study is ordered in its own chapter with the following headings:

- Project Overview

- Background

- Building Description

- Energy Efficiency Strategies

- Use of HVAC Systems (or Passive Design)

- Lessons Learned

Information for each case study was collected from multiple sources included in the reference section.

CHAPTER 4

CASE STUDY: ARIZONA STATE UNIVERSITY BIODESIGN INSTITUTE –

TEMPE, ARIZONA

Project Overview

Architect: Lord, Aeck & Sargent; Gould Evans

Owner: Arizona State University

Engineers: Newcomb & Boyd (MEP); Paragon Structural Design (Structural);
Evans & Kuhn Associates (Civil)

Landscape Designer: Ten Eyck Landscape Architects

General Contractor: Sundt Construction and DPR Construction

Commissioning Agent: Bryan Brauer, PE, and Working Buildings

Cost: \$104 million

Date completed: Building A: December 2004, Building B: November 2005

Gross Square Footage: 347,000 S.F. (Buildings A & B)

Program: Laboratory space, lab support spaces, open office space, private offices, conference rooms, atrium, public entry lobby, auditorium, and café

Energy Highlights: Adequate daylight provided by interior atrium, variable-volume exhaust, efficient ventilation for laboratories with the use of remote sensors, north-south orientation with interior dual louver system, exterior double-skin shading system, reflective roof with photovoltaic array, desert landscaping used as exterior shading.



Figure 11.0: Arizona State University Biodesign Institute Building B

The Arizona State University (ASU) Biodesign Institute's building B (Figure 11.0) was the first facility in Arizona to earn platinum level LEED certification for new construction in 2005. The Biodesign's building A received a gold LEED certification just one year earlier. The Institute was named Lab of the Year in 2006 by R&D Magazine. The Biodesign Institute has also attracted more than \$300 million in external funding since inception, including competitive grant awards and support from philanthropic sources for its research and industry contributions (biodesign.asu.edu).

Background

The Biodesign Institute is located on the eastern edge of ASU's Tempe, Arizona campus and currently comprises two four-story buildings (A and B). Buildings A and B are two buildings constructed from a master plan that will eventually house four interconnected buildings (A,B, C and D), totaling over 800,000 square feet (Figure 12.0). The Biodesign Institute project happens to be Arizona's largest investment in bioscience infrastructure to date. George Poste, director of the Biodesign Institute says, "Our research attempts to imitate nature's design. So in constructing our facilities, we strove for minimal impact on the natural environment that inspires us" (Architecture week, Page E1.2, 19 Sept 2007).



Figure12.0: Master plan for ASU's Biodesign Institute

Building Description

Once complete, the 13-acre site will form an L-shaped plan that will all share a common entry. The facility's visitor entrance is at the north end of building B. The buildings are reinforced concrete frame structure utilizing a 22' x 28' column bay and cast-in-place flat slab construction. The Biodesign Institute's building materials connect it to the other buildings on the Arizona State University campus with the use of brick as well as transparent materials. An open, four-story atrium, which allows adequate daylight links people visually, vertically, and horizontally, as well as connects building A to building B on a north-south axis. This design encourages faculty and students to cross public spaces, which provides opportunities for social interaction and collaboration in the hallways and stairwells (Figure 13.0). The Institute's architects used the concept of "science brings illumination, discovery and connection to our future" (biodesign.asu.edu). Special research and coordination for state-of-the-art technologies was conducted to ensure optimal building performance and the integration of green design features.



Figure 13.0: Interior Atrium

Energy Efficiency Strategies

Daylighting

- The eastern elevations of buildings A and B, as show in Figure 14.0, contain a large area of glass that continues around the buildings' corners. A dual internal louver system, devised by Gould Evans, is automatically controlled by photocells and sun-tracking software.
- The dual louver system maximizes daylight distribution by reflecting diffused light in the upper portion onto the ceiling, yet minimizes direct sunlight from entering the interior rooms, while the bottom section allows individual control and provides a visual connection between interior and exterior.
- Palo Verde trees in the building's courtyard will also provide extra shade, but allow for adequate daylight for occupants on the East side.
- An exterior shading system on the south and west glazing serves as a decorative element, as well as a deterrent of solar gain, while providing abundant daylight to the interior spaces (Figure 15.0).
- Occupancy sensors control electric lights, reducing electricity and associated energy demands by 29 percent.
- The sky-lit atrium runs north-south through the length of buildings A and B, allowing natural light to penetrate adjacent laboratories and office areas on all four levels (Figure 16.0).



Figure 14.0: East Elevation



Figure 15.0: West façade



Figure 16.0: Labs primarily lit by natural day light from atrium, supplemented with artificial light

Building Envelope

- The western elevation is primarily masonry to block out the desert sun in the late afternoon and evening hours. The little glazing that is on the west façade utilizes an exterior shading system similar to the south façade.
- Moveable wooden louvers protect the interior spaces on the north and east sides from the desert sun, while acting as a double-skin façade (Figure 17.0).
- Reflective surfaces on the building's roof reduce the absorption of heat from the desert sun and therefore, create lower energy consumption.



Figure 17.0: wooden louvers as double-skin façade

Recycled Materials

- The project exceeded LEED criteria for use of recycled materials (about 15 percent) that included aluminum ceiling panels, recycled-content carpet and rubber stairwell flooring, all part of a construction waste management plan that reduced the landfill construction waste by more than 60 percent.
- Fly ash was used to offset the energy demands of a typical concrete structure.

Atrium

- The atrium's height is the same of both buildings A and B with glazed interior walls that line offices to the east and laboratories to the west. The

clear and open spaces allow colleagues to glimpse each other's work
(Figures 18.0 and 19.0).

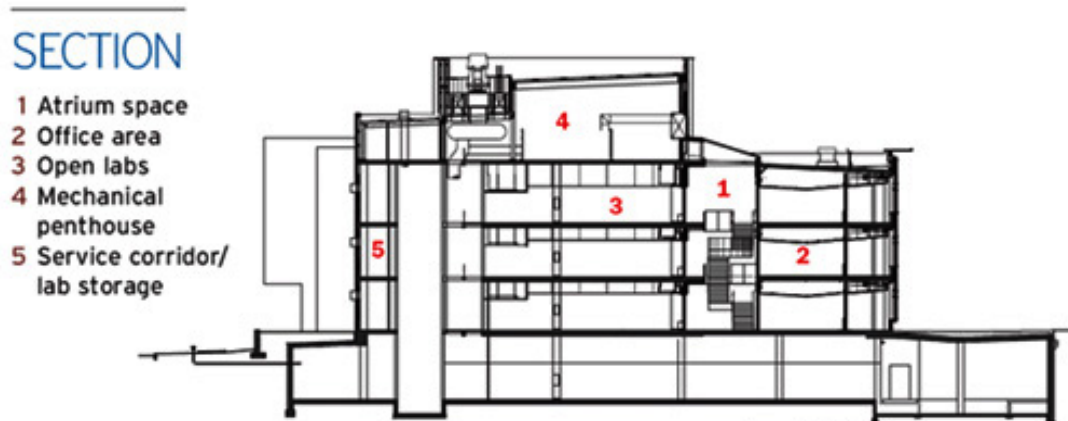


Figure 18.0: Building Section



Figure 19: Atrium

Water Conservation

- Low-flow fixtures and waterless urinals use up to 40% less water than conventional fixtures throughout the project contributing to their energy savings.

Renewable Energies

- Both buildings also support a 150-kilowatt rooftop photovoltaic array, which generates 10 percent of the Institute's electricity (Figure 20.0).
- Bicycle storage and access to shower and changing facilities within the buildings facilitate alternative transportation use.



Figure 20.0: Rooftop photovoltaic array

Use of HVAC System

Institutional buildings with research labs in the United States use eight times more energy per square foot than any other building type. To compensate for

this, the building's mechanical systems feature a variable volume exhaust system and high efficiency monitors in lieu of conventional, constant volume exhaust systems, to meet laboratory ventilation requirements in the hot, desert climate. The mechanical system draws chilled water and steam from a campus central plant, while the condensate water from the air conditioning system is harvested in a 5,000 gallon cistern and recycled for the landscaping.

A reflective roof membrane, painted white, also helps mitigate urban heat-island effect, while reducing the overall cooling loads of the buildings.

Lessons Learned

This particular project contains pertinent information for commercial building retrofits although the buildings are of new construction. The north-south orientation of these buildings is unique in that it provides adequate daylighting while eliminating direct solar gain through the use of its innovative dual internal louver system. The dual internal louver system also allows user participation for individual daylighting and maintains a visual connection from the interior to the exterior. Another energy saving strategy was the intentional limitation of the buildings to four levels to encourage occupant use of stairs, rather than elevators.

The innovative mechanical system contributes to efficiency in energy use, while helping to mitigate the use of potable water, by recycling the air conditioning condensation for landscape purposes. The desert landscape or the use of native plant species can also be employed as an energy efficient

technique, just as the Palo Verde trees were used for shading on the east side of the building in this project. The Palo Verde trees help to block the sun's radiation to keep cooling loads low, yet still allow adequate daylighting into the space.

The incorporation of the Photovoltaic (PV) array is usually a more expensive option when trying to increase energy efficiency. Successful retrofits of existing commercial buildings in the Desert Southwest could very well benefit from the use of solar technologies much like the Biodesign incorporated for energy generation. This PV installation is what catapulted building B to a LEED Platinum rating, bringing building B's total energy offset to 58.39 percent over the base case; prior to the PV installation, that reduction totaled 52.4 percent.

CHAPTER 5

CASE STUDY: TERRY THOMAS OFFICE BUILDING – SEATTLE,

WASHINGTON

Project Overview

Architect: Weber Thompson

Owner: Thomas and Terry

Engineers: Stantec Consulting (MEP); DCI Engineers (Civil, Structural)

Interior Designer: Heidi Fahy

General Contractor: Rafn Company

Sustainable Building Coordinator: Peter Dobrovlny of Seattle City Light

Commissioning Agent: Keithly Barber Associates

Cost: \$11.2 million

Date completed: April 2008

Gross Square Footage: 64,000 S.F.

Program: Office, retail, courtyard, underground parking

Energy Highlights: Passive design without the use of mechanical air systems, outdoor courtyard creates a stack effect exhausting hot air from the building, shallow floor plates for natural daylighting and cross ventilation, automated exterior blinds, exposed structural elements painted white to help reflect daylight and reduce material waste, and solar powered low-flow water fixtures.



Figure 21.0: Terry Thomas Office Building

Due to its innovative design, the Terry Thomas project (Figure 21.0) has won many prestigious awards since its conception including: Washington State's Sustainable Development of the Year in 2008, and many American Institute of Architects (AIA) awards such as AIA 2009 Northwest and Pacific Region Design Honor Award. The project was also among COTE's top ten green projects of 2009, and received a LEED Platinum certification.

Background

An architectural firm, a marketing firm, and a real estate firm occupy the office space in Seattle's first office building to be built without air conditioning in nearly 50 years. The building is located at 225 Terry Avenue, on the corner of Terry and Thomas in the middle of Seattle's emerging South Lake Union neighborhood.

Ninety-three percent of the material from the 1920s light industrial building that previously sat on the site was recycled or reused in the new building's construction. The original building was a two-story brick building that could not have been rehabilitated to meet current codes or the sustainability goals of the project.

Healthy inhabitants were a goal of The Terry Thomas design team who created a design concept tailored to its specific site by using energy, water and other natural resources more efficiently. Before starting work on its new office, the building's main occupant and project architect surveyed their 84 employees and asked what they wanted most. The answers did not involve fancy finishes or luxuries; it simply was natural ventilation and maximum daylighting throughout their office. The team took several measures to address ecological impacts common to urban commercial buildings and decided that a completely passive building could achieve their goal and become a learning tool and model for other commercial projects. The design succeeded in reducing ambient temperatures and taking advantage of prevailing winds for a successful passive cooling system in lieu of mechanical air-conditioning.

Building Description

The Terry Thomas is a four level office building occupied by 170 people, 40 hours per week. In form, Terry Thomas is just a box designed on a 1:2 proportional ratio so that it can be broken down into one-foot, two-foot, four-foot, and eight-foot modules for ease of construction, reduction of material waste, and

optimum flexibility of interior layout. The ground level features 3,032 square feet of retail and restaurant space, and a central courtyard. The corner entrance into the courtyard, as seen in Figure 22.0, letters “B” an “H”, designates the building entry. The circulation paths in the building are along the glass on the outside of the building and on the courtyard. Parking for cars and bicycles is available on two levels of an underground garage totaling 24,596 square feet.

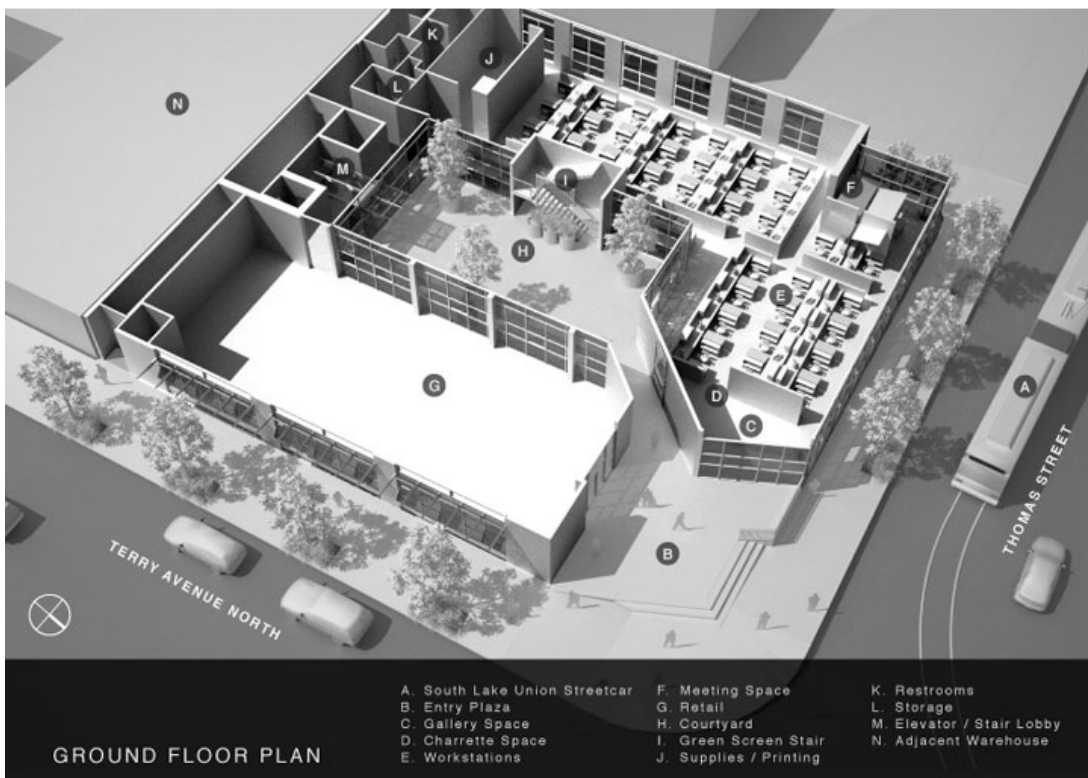


Figure 22.0: Ground Floor Plan showing relationship of front entry (B) and courtyard (H)

Energy Efficiency Strategies

Daylighting

- The narrow floor plates at just 35 feet in depth, surround the courtyard and allow natural light to penetrate the interior of the offices from both the exterior of the building and the core open-air courtyard.
- The shallow floor plates also provide even light distribution that help reduce loads from artificial lighting.
- The east and west façades feature custom-designed glass sunshades (Figure 23.0) that reduce solar heat gain but allow natural light to penetrate to the interior.
- The castellated steel beam structure was left exposed and painted white, allowing natural daylight to bounce further into the space and air to circulate throughout the building (Figure 24.0).
- Workstations have a maximum height of 42" to allow all employees to have direct outside views, while indirect light provided by natural daylight minimizes glare and provides soft, even lighting (Figure 24.0).
- All lighting is on dimmers and turns off when there is enough daylight, helping to reduce electricity needs. However, task lights provide user control at each workstation if an employee feels they are in need of individual supplemental lighting.



Figure 23.0: Glass sunshades

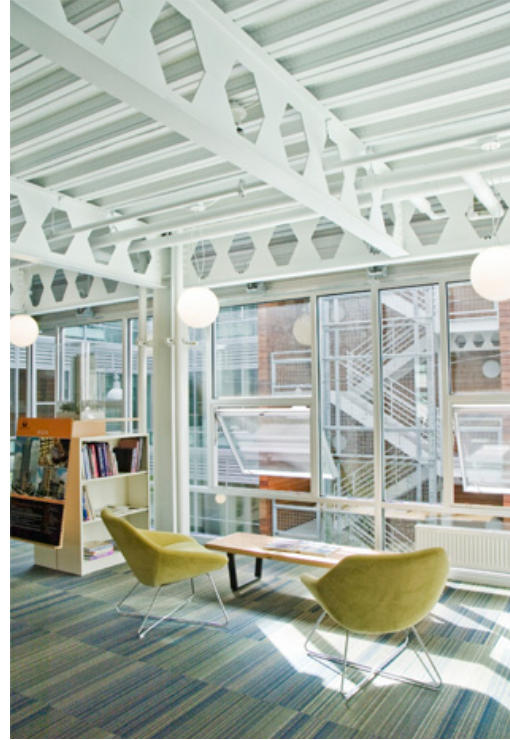


Figure 24.0: Interior space

Natural Ventilation

- Operable windows along all the façades provide cross ventilation and allow occupants control over airflow into the space, eliminating the need for any HVAC systems.
- Automated exterior blinds are controlled by a rooftop sensor to reduce solar heat gain and glare in the south-facing courtyard (Figure 25.0).
- Carbon dioxide sensors will automatically open louvers in the building's exterior walls when the air needs to be freshened (Figure 26.0).



Figure 25.0: Courtyard with operable windows

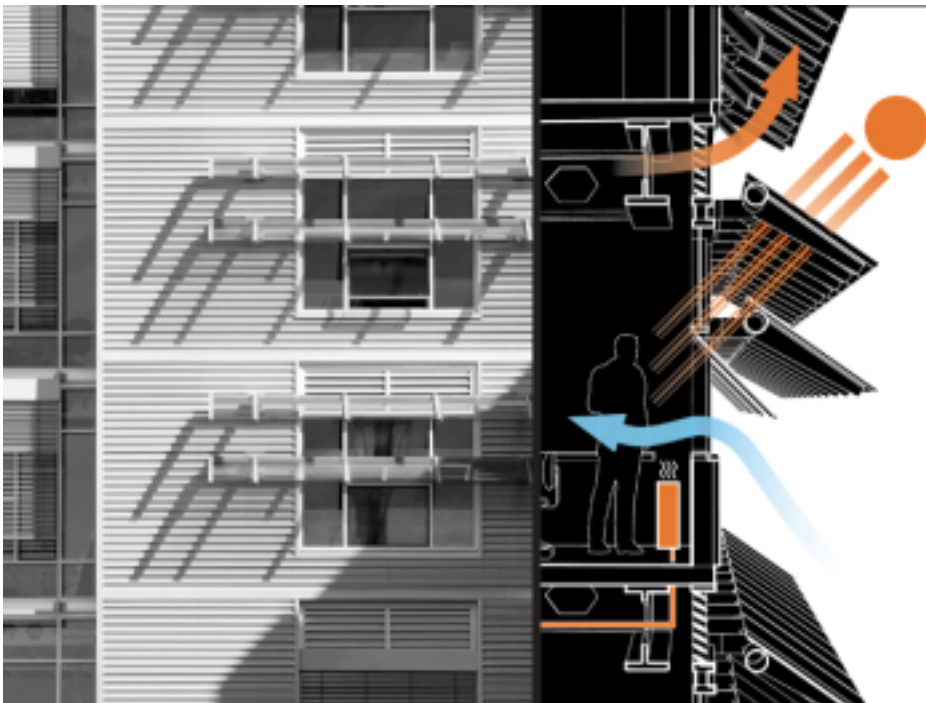


Figure 26.0: Section showing operable windows and upper louvers to help regulate carbon dioxide

Courtyard

- The Courtyard not only allows natural daylight to penetrate the interior of the building, but also works together with vents, controls and window openings to create a stack effect, drawing warm air out of the building and releasing it up through the courtyard helping to keep a tolerable indoor temperature (Figure 27.0).

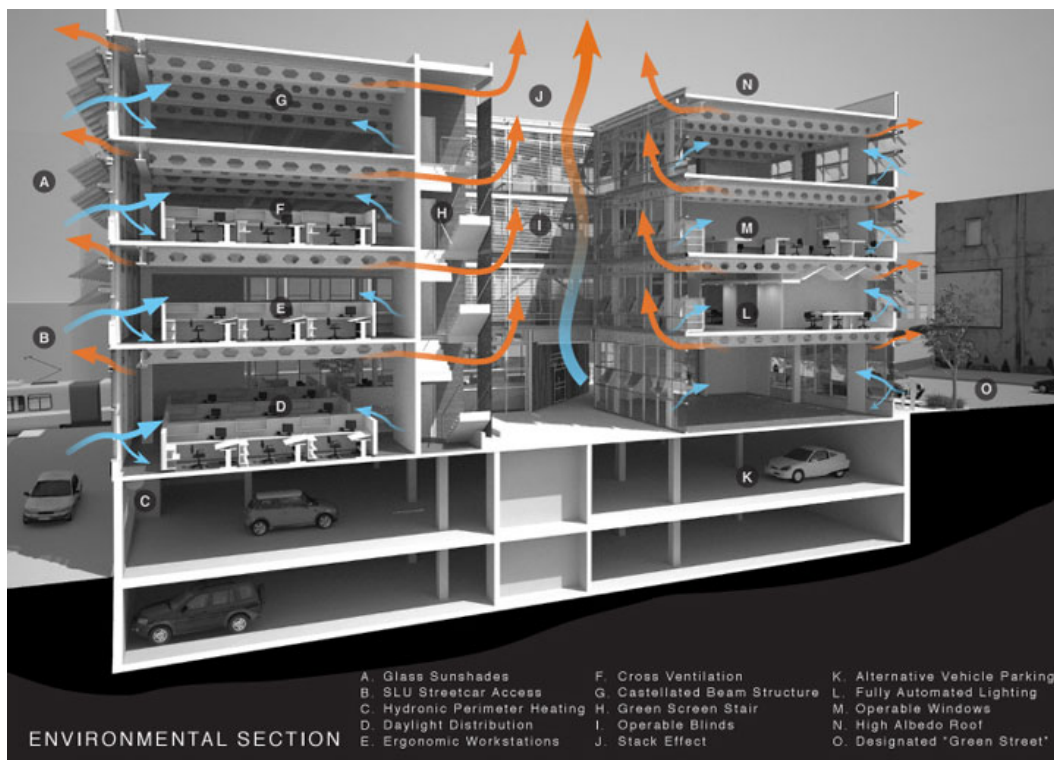


Figure 27.0: Courtyard Stack Effect (J)

Building Envelope

- The designers increased thermal insulation throughout the building to help regulate and maintain indoor temperatures.

- The glass sunshades and operable blinds (Figure 28.0) on all façades block about 90 percent of the sun's heat, while 40 percent of the sunlight is distributed inside.
- Hydraulic radiators are provided and placed along exterior walls as part of their effort for energy reduction.



Figure 28.0: Glass sunshades (left) and operable blinds (right)

Recycled Materials

- Structural materials contain a large percentage of recycled content and are used as finished surfaces, reducing costs and energy savings with a reduction of materials.

- Exterior cladding is made of rapidly renewable materials and recycling and composting facilities are conveniently located throughout the building helping to reduce energy waste.

Water Conservation

- Even with Seattle's heavy rain, The Terry Thomas building was designed to conserve water as much as possible. All restrooms have dual-flush toilets and waterless urinals promoting energy efficiency by eliminating the use of potable water.
- Shower facilities to encourage bicycle use in lieu of gasoline run vehicles are equipped with low flow showerheads.
- Kitchens in the office spaces have solar-powered low flow faucets and water saving dishwashers.

Renewable Energies

- Solar Thermal power is used to provide hot water to low-flow restroom fixtures and kitchens in the office spaces.
- Weber Thompson hopes to add solar panels to the roof in the future to help offset some of the electricity costs.

Use of Passive Design

The team was successful in eliminating an HVAC system and the associated ductwork which in turn decreased both first costs as well as further maintenance needs, which allows the building to have a lifespan of more than 100 years. The benefits of fresh air, natural light and control over personal work environments

were staff priorities early on in the design process and the team decided that the inconvenience of a few warm afternoons a year is something they can live with. Energy modeling during the design process indicated there were roughly 20 hours throughout the year where the temperature would reach higher than 85 degrees on the interior of the building. Building occupants are encouraged to dress for the elements on these days and are welcome to shift their work hours to accommodate.

The building was designed to reduce dependence on purchased energy and its operational costs reflect this: the tenants pay 30 to 40 percent less, or about 7 dollars less per square foot (due to its lack of purchased energy) as opposed to the average 10-12 dollars per square foot that is typical for a conventional office building. All equipment is Energy Star rated including appliances, computers, printers and copy machines. To ensure the operational costs stay at their minimum, ongoing monitoring of building systems performance is a high priority. Staff also provides regular feedback in order to calibrate the building systems, in particular the lighting control systems, automated vents, exterior blinds, and radiator temperature. Finally, only one elevator was integrated into the building. Use of the stairs by employees is encouraged to promote not only physical fitness but also to help eliminate the overall operational energy costs.

As both the designers and inhabitants of Terry Thomas, the Weber Thompson employees now enjoy the benefits of strong natural connections while simultaneously increasing their productivity potential. The design team and the

building occupants have created an experimental and educational tool for promoting passive design in commercial buildings.

Lessons Learned

The principles of daylighting, natural ventilation, and passive heating and cooling design without air conditioning have proven to be effective in the day-to-day operations of the Terry Thomas Office Building. Passive cooling integrated into this project encourages airflow throughout the Terry Thomas building, reducing ambient temperatures by preventing heat from being trapped. Passive night cooling with thermal mass reduces peak cooling loads during the day. Thermally insulating the building and incorporating operable windows in this project are crucial elements that ensure comfortable temperatures for all occupants inside. The central courtyard is an important design feature that should be considered if possible for addition into the design of other commercial building retrofits, particular to the southwest to allow natural daylight to enter the building from multiple sides. Interior surfaces that are white or light-colored are beneficial to help minimize the need for additional artificial light. However, an open floor plan, such as in the Terry Thomas Building, is optimal to allow exterior daylighting to effectively penetrate all interior spaces.

The use of Energy Star computer equipment and appliances are also important to implement when trying to be energy efficient as they lessen the impact on cooling loads and overall electricity usage, especially in hot climates as the American Southwest.

CHAPTER 6

CASE STUDY: ADOBE TOWERS – SAN JOSE, CALIFORNIA

Project Overview

Architect: Cushman & Wakefield, HOK

Owner: Adobe Systems

Design Team: Randy Knox, director of real estate (Adobe); Michael Bangs, global director of facilities (Adobe); Tex Tyner, facilities manager (Adobe); Bruce Chizen, Adobe's CEO

Cost: \$1.4 million

Date completed: 1996, 1998, and 2003

Gross Square Footage: West Tower: 391,000 S.F.; East Tower: 391,000 S.F.; Almaden Tower: 273,000 S.F.

Program: Office, underground parking

Energy Highlights: Motion sensor controls, integration of intelligent building system, lighting modifications for duration and frequency, windspire turbines, HVAC upgrades and retrofits.

The Adobe Towers (Figure 29.0) was the first project to ever receive a platinum certification for the LEED Existing Buildings category in June 2006. The project has also received several awards by the state of California including: the Preservation Design Award in recognition of Outstanding Achievement in the Field of Historic Preservation and Rehabilitation; First Place Award for Landscape Maintenance from the California Landscaping Contractors

Association; and Best Overall in Comprehensive Energy Management in the State of California. Numerous other awards have been received from the Building Owners and Managers Association (BOMA), as well as Adobe being chosen as the Green Business of the Year in 2005 by the U.S. Environmental Protection Agency.



Figure 29.0: Adobe Towers

Background

Company-wide efforts to improve energy conservation became a major focus during the California energy crisis in 2001. The state government called upon large electricity users like Adobe to reduce energy consumption by 10 percent. Beginning with that challenge and committing to go even further, Adobe took

corporate environmental performance to an entirely new level. The successful implementation of over 64 energy and energy-related projects has resulted in an annual savings of \$1 million from reduced building operating costs.

Adobe Towers, comprising three high-rise office buildings and totaling almost one million square feet of space and parking facilities was built between 1996 and 2003. The towers serve as Adobe corporate headquarters, which has effectively reduced electricity use by 35 percent, natural gas by 41 percent, domestic water use by 22 percent, and irrigation water use by 76 percent. According to an audit performed by engineering firm Sebesta Blomberg, Adobe has reduced total pollution from all sources by 26 percent.

Building Description

Adobe's headquarters consist of three high-rise office towers located in downtown San Jose, California resting atop 938,473 square feet of parking garage. The three buildings, known as Almaden Tower, East Tower, and West Tower, are 17, 16, and 18 stories high, respectively, and 7, 12, and 14 years old. Combined, the three building towers total 989,358 square feet and house approximately 2,300 employees.

Energy Efficiency Strategies

Lighting

- Turning off unnecessary lights and switching lamps to compact fluorescent lamps (CFL's) cost Adobe \$11,088 to install, but saves the company \$105,059 per year in energy costs.
- Each desk was equipped with a motion-activated power strip that shuts down the computer monitor and task lighting if the desk is unoccupied or no movement has occurred in five to seven minutes.
- Parking garage lighting has been retrofitted with programmed lighting controls to shut off from midnight to 6 AM, reducing operating hours from 168 to only 80 per week. Additional emergency and night lighting has been installed in dark areas and has produced a savings of almost \$35,000 in energy costs each year.

Water Conservation

- Adobe uses two satellite-based evapo-transpiration (eT) controllers to regulate irrigation. The eT controllers communicate with local weather stations through wireless technology and adjust water flow according to local weather, even postponing irrigation if rain is in the forecast.
- Outdoor fountains have also been reduced to run only 60 hours a week instead of 119 hours, saving Adobe \$4,418 each year in electrical costs.
- Adobe was also the first company in Santa Clara County to install waterless urinals.

- Automated flush valves, faucets, and soap and paper-towel dispensers conserve water and minimize waste.

Renewable Energies

- Adobe installed 20 new windspire vertical axis wind turbines in January of 2010. The turbines have been estimated to generate 2500KWh of renewable energy, providing enough energy to power approximately five American homes.

Use of HVAC Systems

- Installation of an adaptable frequency drive (AFD) on the primary chiller in Adobe's West Tower resulted in savings totaling approximately \$39,000.
- The modification of cooling tower staging and sequencing in two buildings resulted in a 50 percent decrease in energy consumption from the cooling towers.
- Exhaust fans in the parking garage were running twenty-four hours a day. After analysis, it was determined that the fans could run for just 3 hours during the morning commute and 3 hours during the evening commute to keep air quality above minimum standards. Reducing operating times on garage supply fans cost Adobe a total of just \$100, yet this modification resulted in savings of approximately \$67,000 per year.
- Motion sensor controls were installed in all conference rooms so that the HVAC systems would only be "on" in these zones when it is actually needed.

Lessons Learned

The most important lesson to learn from the Adobe Tower retrofit project is to use evaluation and monitoring to determine where energy is going, where the issues are and what the trends indicate. One of the Adobe Towers highlights was the development of a Web-based building monitoring and control system. The Intelligent Building Interface System (IBIS) allows Adobe staff to monitor and operate many different building controls with a single program. Adobe measures the performance of Cushman & Wakefield's facilities management using a set of eleven key performance indicators (KPIs) that were jointly developed. For example, the KPI's require that all three office towers qualify for the ENERGY STAR label each year. The staff has used the system to identify and correct problems, resulting in annual savings of \$98,000. Adobe has saved more than \$1.2 million a year in energy and maintenance costs due to their energy and water conservation efforts.

CHAPTER 7

CASE STUDY: CCI CENTER – PITTSBURGH, PENNSYLVANIA

Project Overview

Architect: Tai + Lee Architects

Owner: Conservation Consultants, Inc.

Environmental Consultants: Green Building Alliance, and Pennsylvania Resources Council

General Contractor: Clearview Project Services Company

Commissioning Agent: Bert Davis & Associates and Tudi Mechanical Systems, Inc.

Cost: \$1.2 million

Date completed: 1998

Gross Square Footage: 12,000 S.F.

Program: Office, education center

Energy Highlights: Insulated Panels with straw filling, PV panel array doubling as shading device, and recycled or salvaged materials from demolition were used in retrofit.

The CCI Center (Figure 30.0) has been recognized by several design awards including: the Northeast Green Building Awards in 2001 (3rd Place); City of Pittsburgh Preservation Award; AIA/COTE Top Ten Green Projects in 1999; and, the Governor's Award for Environmental Excellence. The project has also received gold level certification in the LEED Existing Buildings category.



Figure 30.0: CCI Center

Background

Two existing buildings from 1910 were renovated and one was demolished to make way for an addition in the historic South Side neighborhood of Pittsburgh. The adaptive reuse of the building used exterior design consistent with the neighborhood. The CCI Center houses Conservation Consultants, Inc. (CCI), the Green Building Alliance, the Pennsylvania Resources Council, and Healthy Home Resources. The renovated building saves \$12,000 in energy costs annually. The reduced energy consumption in turn reduces greenhouse gas emissions by 6 million pounds annually.

Building Description

The building is three levels totaling 12,000 square feet with a building footprint of 4,150 square feet. The building is nearby local transportation, bike racks are available for employees and visitors, and a parking plan benefits carpools and alternative-fuel and hybrid vehicles.

The use of salvaged materials in the CCI Center was so extensive that a nonprofit organization, Construction Junction, was formed as a result of the project. Wood trim and flooring, glass, doors, cabinetry, and the original tin ceiling were all salvaged while recycled steel studs and insulated panels filled with straw were used in the new addition.

Energy Efficiency Strategies

Daylighting

- Windows were strategically placed so that every workspace has access to natural daylighting to reduce artificial lighting, which decreases electricity consumption.
- Skylights were installed to help distribute natural daylight without glare to all public spaces (Figure 31.0).

Roofing

- The roof is covered with light-colored pavers that allow water and ventilation to pass under them for cooling while lowering the internal cooling load.

- Rooftop gardens planted with native vegetation account for 60 percent of open space and provide shaded break areas for employees. (Figure 32.0).



Figure 31.0: Skylight



Figure 32.0: Rooftop gardens and light covered pavers

Building Envelope

- A high performance thermal envelope was created with insulated panels filled with straw.

Recycled Materials

- Excess natural linoleum was ground up for mulch and used in landscaping and the rooftop gardens.
- Wood scraps from demolition were donated to a local artists' community. In the entire renovation only enough wood for a small exterior overhang was purchased.

Water Conservation

- The project has no irrigation system, and no potable water is used outside the building for irrigation or other purposes, reducing overall energy consumption.
- Installation of a gravel parking lot as opposed to black top allows water to soak into the ground instead of entering the sewers.

Renewable Energies

- Along with salvaged materials, a 5-kilowatt photovoltaic (PV) panel doubles as a shading device on the southern façade of the building, producing electricity and, in the cooling season, blocking unwanted heat gain (Figure 33.0).
- The PV array generates 12 percent of the CCI Center's energy on site.



Figure 33.0: PV panels

Lessons Learned

In existing building retrofits, salvaging materials not only helps cut costs for new projects, but also keeps material from heading to a landfill. The project's recycling program annually diverts 960 pounds of glass and plastic, 1,200 pounds of cardboard, and 3,600 pounds of paper from the landfill.

The CCI Center project is a terrific example of reuse of various materials such as wood, glass, cabinetry and flooring.

Insulation is key in energy efficiency and can be implemented in the Desert Southwest climate. Insulation can be installed using a sustainable alternative similar to the CCI's use of straw in insulated panels to help manage cooling loads. Shading building walls is also beneficial for reduced cooling loads while rooftop gardens instigate employee interaction by creating exterior meeting spaces. The furnace and air conditioner have been upgraded and use Energy

Star rated equipment that is 96 percent efficient. The CCI Center is using approximately 60 percent of the energy of a typical office building in the Pittsburgh region.

CHAPTER 8

RECOMMENDATIONS/LESSONS LEARNED

The four case studies evaluated in this research have proven to be effective in energy efficiency for their respective locations. Through an investigation of literature and the case study evaluation, recommendations can now be made to best support the efforts of a commercial building retrofit in a hot, arid climate such as Las Vegas, Nevada. There were ten overall main ideas that need to be executed when conducting a commercial building retrofit; they are summarized below:

1. Energy monitoring using an Intelligent Building Interface System will aid in identifying areas that need retrofitting to create an energy efficient building. The system also allows continuous monitoring of equipment and systems once the energy efficient retrofit is complete.
2. Upgrading or replacing incompetent mechanical systems with new, more efficient equipment can complement passive design strategies and reduce overall energy use.
3. Thermal insulation in walls, floors and ceilings can help keep constant temperatures within a space by keeping solar radiation from heating up the interior in the summer and not allowing heat to escape from within the building in the winter.
4. To optimize natural ventilation, the building should not be more than 40 feet in depth and needs operable windows. This 40 foot dimension also

permits the building to utilize effective daylight, allowing 20 feet of daylight distribution from each side of the building.

5. Vertical louvers or operable shading devices should be implemented on the east and west facing windows and can effectively be developed as a double-skin façade.
6. Light shelves, overhangs or fixed shading devices should be installed on the south windows. Double-skin façades can also be utilized on the south side of a building. The north side of the building need little to no window treatments in Las Vegas.
7. Recycled materials should be considered when carrying out a commercial retrofit. Existing building materials should be salvaged and reused if possible, while new building materials should be made of recycled content.
8. Water efficiency measures should be put into practice such as waterless urinals, low-flow fixtures, gray water harvesting for irrigation, as well as, drought resistant landscaping.
9. Renewable energy devices such as photovoltaic panels should be used to generate on-site energy. The PV panels should also be installed over a cool roof with reflective, emissive roofing materials to help reduce cooling loads.
10. Daylighting controls or occupancy sensors should be installed to dim or turn off lights when artificial lights are not necessary.

These ten criteria have been outlined even further in this section, providing more detail and specific recommendations for retrofitting commercial buildings in the Desert Southwest to be energy efficient. The strategies include:

Building Orientation

- Literature has shown that a rectangular building form on the east-west axis is ideal for utilizing passive solar heating and cooling strategies. However, different building shapes and orientations can be designed to perform efficiently by combining effective glazing, solar exposure, and shading into the building form, as seen in the ASU Biodesign Institute's north-south orientation.
- Effective shading and efficient glazing should be taken into consideration in all orientations; vertical shading or operable shading devices on the east and west facing windows and overhangs and fixed shading devices on the south façade.

Courtyards and Atriums

- If possible, courtyards can benefit any retrofit in the hot, arid climate. The ideal depth for the surrounding building is 40 feet. This will allow natural ventilation to flow entirely through the space and allow adequate daylighting. Atriums can also be used to allow daylighting with stack ventilation (Figure 34.0).
- Open courtyards, as suggested in the literature, should be considered for buildings that are at least 10 stories or less; atriums are best for buildings with more than 10 stories.

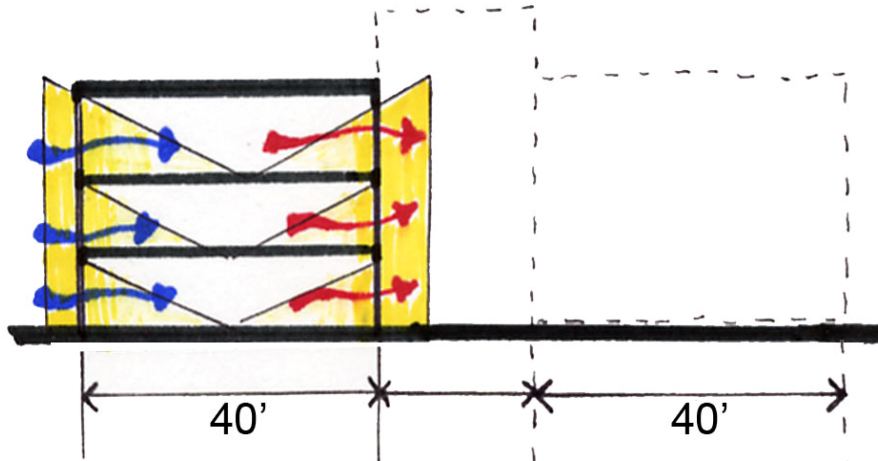


Figure 34.0: Depth of building should not exceed 40 feet

HVAC Systems

- Adobe Towers is a prime example of how a thorough energy analysis or energy audit can benefit decisions about upgrading HVAC systems and equipment. It is important to know where the energy is being used, wasted, or lost and which equipment simply needs upgrading or completely replaced.
- Intelligent Building Software is now commercially available and is a significant tool for any commercial building retrofit. The Adobe Towers were able to save millions of dollars in energy savings by implementing this type of technology.
- Condensate water from air conditioning systems should be harvested and recycled for gray water use, such as landscaping or toilet flushing, just like in the ASU Biodesign Institute.

- Motion sensor controls put in the Adobe Towers are another energy saving tip, allowing the HVAC to “turn on” only when the room or space is being occupied.
- Parking garages, especially here in Las Vegas, can sometimes waste energy. Considerations to frequency and duration of its exhaust fans can generate significant energy savings. Adobe Towers provides a good example of this energy efficient strategy.

Active Renewable Energies

- Photovoltaic Panels should be incorporated into any retrofit in Las Vegas, Nevada. All the case studies in this research either have or plan to implement PV panels into their project as a means of creating their own energy on-site. PV panels can have a dual purpose, such as at the CCI Center, where they were also used as shading devices on the south façade. This is a wonderful solution for the Desert Southwest to help mitigate solar heat gain.
- Wind turbines should be considered here in the Desert Southwest, especially in Las Vegas, as we do receive high winds. The vertical windspires used at Adobe Towers are relatively new products and will need further assessing to determine their validity. However, if the research in the coming years demonstrates a positive contribution, it is possible this technology can be utilized in commercial building retrofits in Las Vegas.

- The advancements constantly being made in Geothermal energy is something to keep an eye on. If this technology becomes more efficient and easily obtainable, it definitely is worth incorporating into a commercial building retrofit to help control indoor environments and contribute to energy savings.
- Alternative transportation options should be encouraged and supported as part of a commercial building retrofit. Several case studies in this research provide incentives for employees who utilize public transportation, carpool, or ride their bicycle.
- Businesses should consider special parking for carpoolers, rebates on bus passes, and should provide shower facilities or similar for employees who commute daily on their bicycles.

Daylighting

- Building depth should not exceed 20 feet from one side for best daylight distribution, thus if daylighting is optimized from opposite sides of a building, this allows 40 feet in total building depth. The 40 foot building depth is also consistent and does not exceed the requirement for natural ventilation.
- If in doubt, the 2.5H Rule-of-thumb can be used to determine effective daylight distribution for varying window heights.
- Good daylight design relies on proper window placement so that the light distribution is deeper into a space. Clerestory windows with an operable lower window for individual control of the user should be

incorporated to maximize daylight, but not to interfere with natural ventilation.

- If windows run from floor to ceiling in a conventional 9 to 10 foot space, installing interior light shelves at 7'-6" above the floor will produce effective daylighting results (Figure 35.0). The literature noted 7 to 8 feet above the floor; a compromise at 7'-6" has been made to allow at least an 18 inch vertical window above the light shelf for adequate daylight.

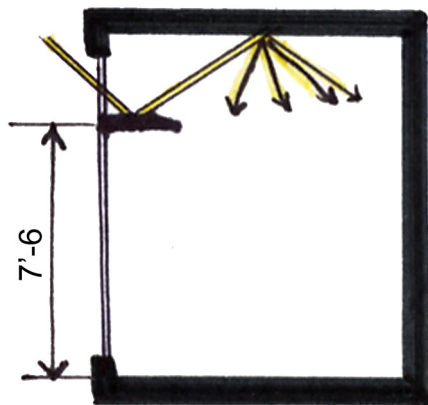


Figure 35.0: Interior light shelf

- Light-colored or white reflective surfaces (50 to 70 percent reflectance), similar to the Terry Thomas Office Building, on walls and ceilings help penetrate the natural daylight further into the building more evenly reducing glare.

- Exposed structural elements can be painted white and used to bounce daylight further into the space and air to circulate throughout the building, while reducing the need for additional building materials.
- Skylights are a viable option in distributing daylight effectively without added heat gains. Skylights can only be implemented on the top floor of a building but can eliminate the need for artificial light, eliminating electricity costs.
- Always be sure lights are turned off when not needed. It is important to use appropriate daylighting controls and/or occupancy sensors for dimming or turning off lights in locations where artificial lights are not constantly necessary.

Glazing

- Dual or triple-pane windows with a $\frac{1}{2}$ inch to $\frac{3}{4}$ inch air space between the sheets of glass and a low-emissivity (Low-e) coating is the best option for energy efficiency in the Desert Southwest.
- Low-e coated films can also be applied to existing windows. These low-e films last 10–15 years without peeling, save energy, and increase interior comfort without adding the expense of full window replacements.
- Overhangs, awnings, or other shading devices should be designed to still allow sun penetration during the colder months to allow for passive heating (Figure 36.0).

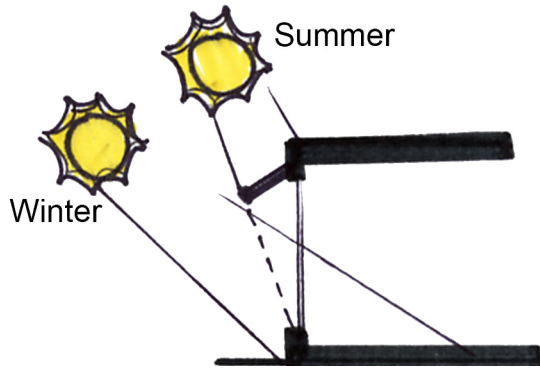


Figure 36.0: Shading Devices, awnings should block sun in summer, but allow sun penetration in winter.

Natural Ventilation

- For best results of natural ventilation, building windows should be positioned to take full advantage of the Las Vegas prevailing winds (out of the South and Southwest). However, wing walls can be also be implemented on the exterior of the building to help direct wind in the desired location (Figure 37.0).

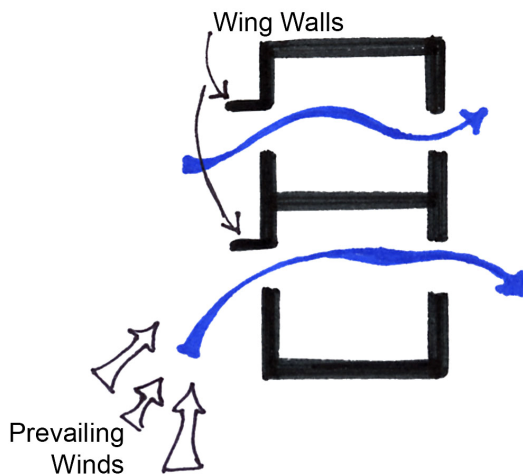


Figure 37.0: Use of wing walls.

- Operable windows are a must and should be shaded with proper window treatments on the East, South and West façades to prevent overheating.
- Naturally ventilated buildings as shown in Figures 34.0, should not exceed 40 feet in depth.
- An open floor plan is also desirable to help the natural ventilation easily navigate through the building. Push back workstations from the windows to reduce glare on computers and allow naturally ventilated air to move more freely.

Roof

- Cool roofs with reflective, emissive roofing materials should be applied to any commercial building retrofit to help reduce cooling loads.
- Cool roofs with light-colored pavers, similar to what the CCI Center installed on its roof, allows water and ventilation to pass under them for cooling while lowering the internal cooling load.
- Insulation should be installed in the ceilings or attic spaces to help reduce cooling loads in the summer and to keep constant, warmer temperatures in the winter. Many sustainable types of installation should be explored, such as straw bale, to find which is most economical and most efficient for the individual project.
- PV panels or Solar Thermal panels coupled with a white, reflective surface can also provide benefits. Bi-facial PV systems are one

product to look into, as these panels are capable of collecting sun radiation from two faces.

Building Envelope

- Double skin façades can be considered and have been known to reduce outside noise while providing opportunities as a thermal chimney. Double skin façades can be used on portions of a façade, such as the ASU Biodesign Institute or along an entire face of a particular elevation. The space between the second skin and the original façade is a buffer zone, heated by solar radiation that is utilized in the winter time, but is vented to avoid overheating in the summer.
- Thermal insulation is very important in regulating heating and cooling loads and should be added to ceilings, walls, and floors. Adding insulation can be very expensive and in some cases very difficult, so adding insulation to walls should only be considered if doing an extensive retrofit. However, it is fairly easy and inexpensive to add insulation in the floors and ceiling. Again, several types of insulation should be considered to determine which sustainable option is best for the individual project.
- Despite what experts think, east and west facing glazing can be effective in energy efficiency if treated properly. Windows should be low-e glazing and shaded properly with movable louvers, such as ASU's Biodesign Institute incorporates, or similar that acts as a double

façade and eliminates early morning and evening sun, but still provides adequate daylight.

- Other window treatments for the east, west and south façades include operable blinds and sunshades, similar to the Terry Thomas Office Building, that still allow daylight, while blocking the sun's heat.
- The building envelope materials should use low embodied energy materials or recycled materials.

Recycled Materials

- Recycling and reusing materials in commercial building retrofits can reduce greenhouse gas emissions and offset energy used to extract new raw materials. The CCI Center was a good example of recycling materials, as some of their existing materials were ground up and used as mulch for landscaping.
- New materials being selected for commercial building retrofits should also be made from recycled content, meaning they have less embodied energy than others.
- A construction waste management plan during the retrofit process should also be implemented to help keep materials out of landfills.

Water Conservation

- Fix all leaks that were determined during the upfront energy analysis.
- Install low-flow fixtures for all sinks, toilets, showers, etc. as all case studies have shown.

- Shower facilities should be considered when retrofitting commercial office buildings, especially if encouraging employees to commute with a bicycle.
- Incorporate dual-flush toilets and waterless urinals.
- Plant drought resistant landscaping and harvest gray water for irrigation.
- Utilize the sun to heat water in commercial building applications by installing solar hot water systems, similar to the Terry Thomas Office Building, which can reduce the need for traditional fossil fuels by about two-thirds (Solar Water Heating Systems, 2009).

Getting back to simple design is the ideal concept behind sustainable design. Architects were designing for centuries, using passive design techniques before mechanical systems were introduced. Remembering these passive strategies and employing them in commercial building retrofits in the Desert Southwest is not only cost effective but also beneficial to the planet. If passive design cannot be achieved alone, its strategies should be supplemented with highly efficient mechanical systems.

CHAPTER 9

CONCLUSION

Sustainable commercial buildings should have certain building elements that work cohesively with nature, yet the changes should not seem obtrusive to the original building, but should complement the design of the existing structure (Pettersen, 2007). Achieving aesthetic and sustainable goals for existing commercial buildings can be accomplished through retrofits similar to the strategies mentioned in this research. The next step in this research would be to categorize the energy efficient strategies above into groups associate with cost. A thorough cost analysis would determine the initial investment of a particular retrofit strategy and subsequent rate of return, thus providing cost estimates for various levels of retrofitting.

Another step would be to investigate and inventory the existing commercial building stock in the Las Vegas area. This investigation will determine existing building characteristics, conditions and other parameters that could help the inhabitants of these existing buildings to choose the best possible retrofit solutions. Existing buildings vary in size, shape, and material, and therefore, can contain many constraints when it comes to retrofitting for energy efficiency. These constraints can include, but are not limited to: varying floor to ceiling heights, window sizes and shapes, depth of tenant space (distance of usable space from perimeter wall), type of construction, column locations, egress patterns and exit location, and building envelope to floor area ratio. Each of these constraints will dictate which strategies would be most appropriate when

retrofitting for energy efficiency. Discovering and documenting these constraints can also inform new building design and construction to best equip new buildings with beneficial parameters to ensure a more seamless retrofit process during its lifetime.

In the near future it will be important to ensure that building codes are published with efficiency increases, and that all states adopt the new codes. Many of these policies should also incorporate measures and stipulations that are especially suited to encourage higher efficiency through retrofits and renovations in existing commercial buildings. The building codes and guidelines should also take regional climate into consideration. Las Vegas, Nevada has different ecological concerns being located in the Southwest portion of the United States than other parts of the country. The city of Las Vegas has already started the process of creating green building programs and building code guidelines for existing buildings. Several existing federal buildings in the Las Vegas valley will receive an energy retrofit within the next two years with efforts from President Obama's Recovery Act. Once complete, these buildings will set examples that inform public policy changes, initiate incentives, and force the private sector to comply with energy efficient standards.

The most important lesson learned through this research when trying to retrofit existing commercial buildings is to continually monitor energy usage and communicate openly with employees. Workers spend over eight hours a day in their place of employment, more than they spend sleeping or spending time with their families (Bureau of Labor Statistics, 2009). By using monitoring software,

energy usage can be collected, analyzed, and mended if necessary, saving businesses money and creating a healthier work environment which bolsters productivity.

Incorporating all of these factors together, retrofitted commercial buildings will begin to see higher occupancy rates, higher rents and sales premiums, lower utility bills, healthier buildings and employees, and booming businesses due to increased productivity. Commercial building retrofits are economically and environmentally friendly solutions that can range from small “quick fixes,” to more involved and expensive options. The bottom line is that any step taken for an existing commercial building to become more energy efficient is a step in the right direction.

Further Research

This particular research was highly concerned with design strategies for retrofitting existing commercial buildings in a hot, arid climate. However, through the process, several questions and topics of further research were created.

These include:

- What are the hidden costs when retrofitting existing buildings?
- What are the costs associated with the recommended design strategies for retrofitting existing commercial buildings? What is the return on investment (ROI)?
- What incentives are provided for retrofitting an existing commercial building in the City of Las Vegas, Nevada?
- How does the LEED rating system support retrofitting an existing building in the Desert Southwest?
- How will model/local building codes change to support retrofitting and renovations?
- How will model/local building codes change to support completely passive buildings?
- Will corporations/businesses need to change policies and practices to support an energy efficient building?
- What is the total energy consumption for water use (heating and cooling, landscaping, domestic, etc.) in buildings?

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