AN ANALYSIS OF THE BENEFITS OF PHOTOVOLTAIC-COATED GLAZING ON OWNING AND OPERATING COSTS OF HIGH RISE COMMERCIAL BUILDINGS

A Dissertation

by

Keith Everette Sylvester

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 1999

Major Subject: Architecture

AN ANALYSIS OF THE BENEFITS OF PHOTOVOLTAIC-COATED GLAZING ON OWNING AND OPERATING COSTS OF HIGH RISE COMMERCIAL BUILDINGS

A Dissertation

by

KEITH EVERETTE SYLVESTER

Submitted to Texas A&M University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Approved as to style and content by:

Jeff Haberl
(Co-Chair of Committee)

Larry Degelman
(Co-Chair of Committee)

Louis Tassinary
(Member)

Mike Aucoin
(Member)

Julius Gribou
(Head of Department)

December 1999

Major Subject: Architecture

ABSTRACT

AN ANALYSIS OF THE BENEFITS OF PHOTOVOLTAIC-COATED GLAZING ON OWNING AND OPERATING COSTS OF HIGH RISE COMMERCIAL BUILDINGS. (DECEMBER 1999)

Keith Everette Sylvester

B. Arch., University of Louisiana at Lafayette;

M. Arch., University of Houston

Co-Chairs of Advisory Committee: Dr. Jeff Haberl
Professor Larry Degelman

Energy efficient glazing is necessary to reduce heat gains or losses that contribute to the high-energy use of buildings. However, high-rise commercial buildings that use energy efficient glazing are still consumptive. To reduce their energy use further, recent studies have integrated photovoltaic glazed window systems into the building shell. With limited light transmittance due to their required production of electricity, photovoltaic (PV) glazed windows can be developed with thermal properties similar to Low-E coatings. Consequently, these window systems can reduce operating costs of buildings without reducing the human satisfaction of the built environment. To understand the relationship between PV windows, energy use and human satisfaction, this study investigates the effects of PV glazed windows on energy use of large commercial buildings and includes an assessment of the overall human satisfaction of the workers within PV glazed office spaces.

This study targets high-rise commercial buildings and their occupants in urban centers of the four census regions - West, Northeast, South, and Midwest. A prototypical building was used to develop the base case simulations for the DOE-2 energy simulation program and the PV F-Chart energy analysis program. By substituting the appropriate variables in the base case simulation for each site, the building was simulated to evaluate the impact of the PV glazing on the building's heat loss/gaining as well as the amount of electricity that could be expected from the PV. To test for human satisfaction, a survey was performed to assess the overall preference of the subjects to the office spaces using the PV glazed windows. An analysis of the variance was also conducted to test for significantly different treatment means.

Overall, the findings of this study show that PV windows significantly decrease the energy used by high-rise commercial buildings. Payback periods 11 to 20 years could be expected for buildings using energy efficient PV glazing in the Houston, Los Angeles, Detroit, and New York, when compared to single-pane clear and Low-E glazing.

When assessing the effects of clear glazing and PV glazing on human satisfaction, the data revealed that lower levels light transmissions and visibility do affect the satisfaction of workers. Although, these effects are seen as significant, they are not perceived to be negative or undesirable.

DEDICATION

As I end the beginning of my newfound understanding of the complexities and interactions of life, I dedicate this composition to my father – a man who found simplicity in his life's journey. Now, I find myself reverent of the times when I viewed life with a young heart, only trying to recapture, trying to replicate those moments for my son. Whether misunderstood and simply naïve, from this new point of view I can re-evaluate my life and begin my search for the same simplicity.

ACKNOWLEDGEMENTS

I would like to acknowledge my family and relatives for their support and encouragement and especially thank my mother and father for continued guidance.

During my study here at Texas A&M University, I have been afforded many opportunities due to the assistance and patience of many people and organizations. First I would like to thank my committee co-chairs, especially Dr. Jeff Haberl. You were never too busy to help me with my work. Also, I would like to thank Professor Larry Degelam, my other committee co-chair, Dr. Louis Tassinary and Dr. Micheal Aucoin for their guidance and participation on my committee. I would also be remiss if I did not mention Dr. Roger Ulrich and Dr. Michael Longnecker for their time and assistance while serving as substitutes during my dissertation defense. In addition, I would like to thank Linda Fritcher of the Department of Architecture and Dr. DanTurner, Dr. David Claridge, Peter Klima and Victor Kootin-Sanwu of the Energy Systems Laboratory.

Various people in industry gave me needed guidance and support as I defined my research efforts. Of these companies, I would like to especially thank Jeff Gerber of Goodwin, Alexander, and Linville Architects in Houston, Texas, Gregory Kiss of Kiss, Cathart, and Anders Architects, P.C. in New York, New York, Roger Taylor of the National Renewable Energy Laboratories, Jeff Maser with the Department of Defense, Washington, DC, and Mike MacDonald of the Energy Information Agency.

Furthermore, I would like to thank my colleagues at the University of Houston for their encouragement, especially Professor Tom Colbert, Professor Bruce Webb, and Professor John Perry.

In concluding, partial support for this project was provided by the American Architectural Foundation through the American Institute of Architects national chapter in Washington D.C.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

1 INTRODUCTION

1.1 The Need for Energy Conservation

Despite the reduction in the per capita energy use and the steady increase in the GNP[1] in America, the consequences of future energy shortages and the increases in energy costs (Kraushaar and Ristinen, 1998) can be seen in the recent blackouts in America's northeastern and pacific northwestern states[2]. In Texas, the energy consumption was predicted to surpass their production of energy in 1993 (Sloan, 1995). On a national level, once this trend affects all states, who will supplement the energy needs of America and who will control the energy distribution and costs?

To answer these questions, we must give immediate attention to preparing for possible increased energy shortages, while maintaining a stable economic and social structure for future generations. This section discusses government policies that support the research and application of PV systems, deregulation of the utility industry, BIPV systems in buildings, the energy use of commercial buildings and the social acceptance of BIPV systems.

1.2 Government Policy and Support

Because of governmental concerns to improve energy conservation, research and development of Building Integrated Photovoltaic (BIPV) systems have been congressionally mandated in the United States (Ashley, 1992). Additionally, major

---

This dissertation follows the style and format of ASHRAE Transactions.

[1] Gross National Product is the value of total goods and services produced in a nation not inclusive of the government sector.

[2] In 1999, extreme summer weather conditions caused blackouts in Chicago, Illinois.

government demonstration programs using BIPV systems have been initiated in Austria, Germany, Switzerland and the Netherlands (Schoen & Blum, 1994).

With efforts to significantly increase the use of clean and renewable resources, President Clinton announced the Million Solar Roofs Initiative for the United States in 1994. Working with businesses and communities, the U.S. Department of Energy is coordinating the installation of solar panels on one million new roofs by the year 2010. The President's program targets: 1) electric utilities and energy service organizations, 2) PV manufacturers and PV infrastructure organizations, 3) community, city and corporate personnel, 4) community development organizations, 5) residential and commercial real-estate developers, 6) architects and energy consultants and 7) local and regional financial institutions (UPG, 1997).

Likewise, the Department of Energy promotes partnerships between the public and private sectors to lead to sustainable utility PV markets (UPG, 1997). The Technology Experience to Accelerate Markets in Utility Photovoltaics (TEAM-UP) program funds ventures that develop sustainable markets and opportunities for PV applications. It also funds programs that take advantage of business opportunities with PV technologies and supports the expansion of utility PV markets through collective market actions or pre-commercial installations. With continued support from the government and increased public awareness, the use of PV systems is expected to increase and expand into new applications.

1.3 Deregulation of the Utility Industry

The Public Utility Regulatory Policies Act (PURPA) of 1978 and the Energy Policy Act (EPACT) of 1992 increased competition in the electric generation industry. PURPA requires utility companies with a need for more electricity to receive bids from alternative suppliers. EPACT deregulates the sale of electricity to promote competition among power sellers and to create lower electric rates (King, 1996) and extends the scope of non-utility producers by creating a new class of suppliers that are permitted to sell power in wholesale markets. EPACT also requires the owners of transmission facilities to provide independent suppliers with open access to the electric grid to transmit power to wholesale utility customers. With a shift from large, central power plants to smaller generating facilities, a restructured electricity industry is now poised to offer significant opportunities to increase the deployment of renewable energy using integrated PV systems (Brown et al., 1999).

1.4 Building Integrated Photovoltaics (BIPV)

When considering BIPV systems, it is now possible for an owner to use BIPV systems to provide some or all of the building's energy. As a power supplier, the owner can sell the electric energy produced by the PV system to the tenants of his or her building. Conventional or other renewable sources of electricity could then be used to provide the electricity not provided by the BIPV system. Conversely, this concept may not apply to all building management structures. Therefore, more research is required to develop feasible financial solutions for building owners and management groups. Projected to provide up to 70% of a building's electric demand when designed for their optimal energy production, research and application of BIPV systems have been aimed at integrating PV elements directly into buildings (Ashley, 1992).

To offset our predicted energy shortage, we can provide electric energy at the point of demand using BIPV systems. Converting sunlight into electricity, these systems integrate with the energy use and structure of buildings as weathering skin, sun shading, and roof and window systems. Because they provide a viable alternative and renewable method for generating electric energy, BIPV systems can improve and secure our economic growth by reducing our dependence on non-renewable energy.

While roof mounted modules have been tested and used intensively, as seen in the solar roof programs around the world, efforts to integrate PV systems into facades have been hampered by several unsolved problems in the module design and the cost of wiring and framing (Bendel et al., 1994). Nonetheless, several demonstration projects are investigating PV systems as cladding and glazing for facades (Strong, 1994). In the United States, Advanced Photovoltaic Systems (APS) company integrated PV skylights and semi transparent curtain walls into their new manufacturing facility in Fairfield, California. In Germany, the Bavarian Environment Ministry uses amorphous silicon modules in the non-window areas of the facades. In Japan, Sanyo has installed a prototype PV façade in a building for the Tsukasa Electric Industry Company.

1.5 Energy Use of Commercial Building

Among commercial buildings, one of the most significant energy users has been the tall building. Typically sealed enclosures without operable windows, tall buildings are oriented to match the prevailing street layout, and therefore, may not have an optimal solar orientation. To maintain a comfortable environment for the building's occupants, in southern climates, tall buildings depend on mechanical cooling and heating to compensate for heat gain from the sun or heat and humidity gains in ventilation air.

To offset the existing drain on non-renewable energy, commercial buildings will eventually have to increase their use of renewable energies and energy conserving technologies. Although current applications are few, PV systems are potentially one of the most useful renewable energy technologies. According to Kiss et al., (1995), PV systems using glass substrates, as compared to flexible PV modules using stainless steel substrates, are the most available PV products that can be immediately integrated into current building systems.

1.6 Societal Impacts

Despite the known benefits of PV systems, architects, builders and developers are still reluctant to use PV systems as integral building elements (Goethe, 1994). Their reluctance is due to a lack of understanding about the economic and aesthetic aspects of BIPV systems. To address the economic and aesthetic concerns of the public and the building community, economic and environmental benefits of PV building products must be defined. In addition, we must determine the aesthetic factors that influence the acceptance of BIPV systems (Kiss and Kinkead, 1996).

Finally, if society continues to demand architects to design in climates where ambient conditions are inhospitable, reducing energy consumption becomes paramount due to the continuous need for mechanical cooling and heating. Furthermore, if architects continue to seek new forms of architecture that are independent of the climate and orientation, renewable energy conservation methods must be utilized to provide as much renewable energy that is financially viable to operate such buildings. Thus, to improve the building's sustainability, an economic and psychological analysis of PV glazing in commercial buildings will lead to a better understanding of their potential to save energy and social acceptance.

In the following section, this dissertation reviews issues surrounding the application of PV glazing and the affect of PV systems on owing and operation costs of commercial buildings. In addition, this dissertation discusses the state of the art energy simulation software, as well as methods for predicting the thermal and electrical performance of BIPV systems. The effects of windows on people and the measurement tools that are used to determine human satisfaction are also presented.

2 LITERATURE REVIEW

This literature review has been divided into the following subsections regarding the previous work concerning: a) owning and operating costs, b) the energy use of commercial building, c) the simulation of PV facades in buildings, d) psychological effects of PV-coated glazing on occupants of commercial buildings and e) measurement issues.

2.1 Owning and Operating Costs of Photovoltaics

Emerging as newly commercialized building products, PV glazing systems are extremely attractive for use in facades because they provide a guaranteed electrical energy production (Bendel, et al., 1994). The following paragraphs discuss: 1) manufacturing processes, 2) manufacturing and installation costs, 3) construction constraints and 4) federal and state investment tax credits for PV glazing.

2.1.1 Manufacturing Processes

With the development of new manufacturing technologies, three types of PV glazing have been developed. First, Flachglas Solartechnik of Germany is currently developing a thin film curtain wall application that allows visibility through a continuous PV coating applied to a glass substrate (as cited in Strong, 1995). Second, Sanyo of Japan is working on a double pane silicone-on-glass (Si-on-glass) module also for curtain wall applications (also cited in Strong, 1995). Sanyo's PV inner element is semi-transparent silicon on glass a panel with uniformly spaced, laser cut microscopic holes in the inner pane of a two pane system. The laser cut holes allow varying light transmission through the PV coating, while at the same time allowing the exterior glazing to remain intact and weather tight. Third, the Swiss Federal Institute of Technology (EPFL) is testing a system that has a slight spacing between the cells to allow a gentle pattern of direct sunlight to pass through a clear glass substrate (cited in Strong, 1995). Consequently, this type of modules does not serve as primary daylight window systems in current applications. For this dissertation, silicon on glass with uniformly cut microscopic holes was investigated as the PV glazing and was a suitable prototype to determine the window properties[3].

2.1.2 Manufacturing and Installation Costs

Unfortunately, the use of BIPV materials increases the purchase, design, installation and maintenance costs of a building's envelope as compared to traditional building materials (Kiss, 1993). However, these costs must be weighed against the energy cost savings over the life of the building in order to obtain a proper assessment of the viability of PV buildings. The cost of curtain walls on existing buildings depends upon several factors including glazing cost. In this study, cost for various glazing systems (Kiss et al.,1995) were used as a basis for developing building owning costs.

2.1.3 Construction Constraints

When using PV systems in buildings, major issues that must be addressed are power conditioning and the fault recognition (Bendel et al., 1994). Power conditioning units, also know as inverters, convert DC energy produced by PV arrays into 120V AC energy for use with standard appliances and equipment. Additionally, micro inverters have been developed that link one-kilowatt of PV

---

[3] Window properties refer to the calculation of u-value, solar heat gain factor and light transmission through a given window.

generated electricity to the building. Micro-inverters are attached directly to the PV module and are predicted to reduce the installation costs by one dollar per watt, roughly one-eight of the system costs. (Cochran, 1997).

Overall, there are two basic types of integrated PV systems - stand-alone and grid interconnected. In stand-alone systems, all the electrical needs of the building are provided by the PV system using battery storage devices. Grid interconnected systems are stand-alone systems connected to the existed utility grid. In this case, when the energy demand of the building exceeds the electricity production of the PV system, electricity from the utility grid is used. When considering system reliability and material cost, parallel PV systems with grouped modules serially connected to independent inverters[4] should be considered. This is not only beneficial in fault recognition when a module fails, but also to the electrical constraints of serial or parallel connections[5].

In this study, the PV system is not required to match the load requirements of the building, but only to reduce the energy needs of the building. This dissertation, therefore, uses a grid interconnected PV system. However, no power conditioning methods are included in this study because of insufficient cost data regarding newly developed module integrated systems. In addition, batteries for electricity storage were not required.

---

[4] Inverters are required to convert DC power to AC power for use within the building. Although traditional photovoltaic systems use remotely located inverters, module integrated inverters can be used to minimize costs and provide usable energy closer to the point of demand (Bendel et al., 1994).

[5] If a system were designed completely in series, the failure of one module would cause the failure of the entire system. If the system were designed completely in parallel, costs and fault recognition requirements are increased. Thus, using groups of serial connected modules that are linked to other groups in parallel is recommended (Bendel et al., 1995).

2.1.4 Federal and State Investment Tax Credits

Federal Investment Tax credits for solar property, also known as a Business Energy Tax credits, have been established as a part of the Energy Policy Act of 1992. This act allows an investment tax credit of 10% to commercial entities on the portion of the investment in solar property that is not subsidized by other financial institutions. Although the tax credit cannot exceed the total tax owed in any one year, credit not allowable in one year may be taken in other tax years.

In addition to the investment tax credit, an accelerated depreciation schedule can be used by any commercial entity that invests in a qualified solar property[6] (U.S. Code Citation: 26 UCS Sec. 169). The actual deduction schedule is a Modified Accelerated Cost Recovery System (MACRS) five year depreciation schedule that uses a 200% declining balance method. In addition to these Federal tax incentives, individual states also offer varying economic incentives when using renewable energy sources. However, in this study only federal tax incentives are used and are discussed further in the section 3.5.

2.2 Commercial Building Energy Consumption

This section discusses the energy use of commercial buildings. It has been divided into two subsections that describe commercial building characteristics and the thermal performance of glazed windows.

[6] For the purpose of depreciation, solar energy property is defined as equipment that uses solar energy to generate electricity and includes storage devices, power conditioning equipment, transfer equipment and related parts and equipment required to transmit or generate electricity (SEIA, 1998). The solar property must be completely installed and operational in the year that the depreciation was first used, constructed, reconstructed, or erected by the taxpayer, originally used by the taxpayer, and in conformance with any performance or quality standards prescribed by regulation. If a taxpayer takes the tax credit, 95% of the original investment should be used. However, if the taxpayer does not take the tax credit, the full one hundred percent of the original investment should be used as the basis of the depreciation.

2.2.1 *Commercial Building Characteristics*

In 1989 commercial buildings in the United States consumed 5.8 quadrillion Btu of energy using four major sources - electricity, natural gas, fuel oil, and district heat. Of the four energy sources, electricity accounted for 48%; natural gas 36%; district heat, 10%; and fuel oil 6%. Of all commercial buildings, 96% used electricity as an energy source; 27% were heated by electricity and 73% were air-conditioned (EIA, 1992). In addition, the energy consumption of the surveyed buildings differed due to variations in climate, construction patterns and energy source preferences. When focusing on electricity consumption in the four census regions, commercial buildings in the South census region consumed the largest amounts of electricity - 35% of the total net consumption of electricity in commercial buildings. By comparison, the Northeast consumed 21%; the Midwest consumed 22%; and the West, 22%. Overall, the energy use in large commercial buildings shows that outside air conditions have a smaller impact on heating and cooling systems than do activities within the buildings such as equipment used, lighting levels, number of people, and hours of operation (EIA, 1994). Additionally, due to the varying sizes of commercial buildings, energy consumption patterns are made clear by examining their gross energy intensities[7] (EIA, 1992).

2.2.2 *Thermal Performance of Window Glazing*

To offset the high-energy consumption in commercial buildings, Low-E coatings have been proven effective in reducing energy use. In cold climate regions,

---

[7] Gross Energy Intensity for a specific energy source is the ratio of the consumption of that energy source to the total floor-space in the building. Using a measure of the gross energy intensity, the energy patterns of buildings can be compared across divisions as well as across energy sources (EIA, 1992).

these coatings block or reradiate the infrared heat back into the space to reduce heat loss. In hot climate regions, by reversing the location of the solar control coating, infrared heat is reflected to the outside to reduce heat gain (Johnson, 1991). In a study of various types of solar control glazings (double tint, bronze, double Low-E ($e_2 = 0.04$), heat mirror and double Low-E electrochromatic glazing), buildings using Low-E electrochromatic used the least energy while buildings using the heat mirror consumed the most energy (Lee et al., 1996). When comparing their energy use patterns and the glazing costs, Lee showed that Low-E glazing was the most effective material. Consequently, this dissertation used PV and Low-E coated glazing for all comparisons and selected the appropriate window design for the climatic conditions of the sites. To provide a reference for all comparisons, a typical single-pane clear glass unit was used to develop the base-case simulations for each census region. More detail is provided in Section 3.3.

2.3 Simulation of Photovoltaic Integrated Facades in Buildings

Although relatively little work has been published about the vertical facades using PV glazing, research in the general area of BIPV systems is considerable. To simulate these systems, a combined thermal and electrical modeling approach is required. Additionally, ventilating these systems can improve electrical production and thermal performance by lowing the cell temperature and reclaiming heat from the air space between the glass layers (Posnasky, et al., 1994, Clarke, et al.1997, and Gutschler, 1997). Once trapped, this energy can be reclaimed using forced or natural ventilation. According to Posnasky et al. (1994), a hybrid PV system[8] can have a combined electrical and thermal efficiency of 40% to 55%. In agreement, Clark et al. (1997) simulated the electricity and thermal output of the PV façade and showed a seasonal performance of 33.2%, 44.1% and 56.9% efficiency for winter, spring, and summer respectively.

While hybrid systems are beneficial in cold regions due to the location of the solar coating on the inner glass pane, these systems are not beneficial in hot and humid climate, where windows are designed to reflect the solar radiation back to the outside. This condition reduces the heat gain between the glass layers.

In cases of vertical applications, the task of matching existing loads is not as important as determining the available area on the building facade to apply PV materials. This is because the building's electricity demand far exceeds the potential electricity production by the PV glazing. Nonetheless, we can determine the available PV area and electricity production using a procedure known as the 'photovoltaic resource assessment' (Pearsall & Hill, 1994). In the case of high-rise commercial buildings, the goal of a vertical PV installation is to use all of the available vertical surface area, not affected by shadowing, to produce electricity.

According to research at the Solarex Corporation, the output of PV modules varies linearly downward to about 10% of the normal full-sun intensity during cloudy weather. In the case of horizontal flat plate collectors, only 50% – 70% of

[8] A hybrid PV power plant is a system that produces electricity and recovers heat trapped within the air space of double glazing using forced and natural convection.

their rated output can be attained under bright overcast skies. A dark overcast sky is said to correspond to only 5% – 10% of the full intensity of the sun and, therefore, would fall below the threshold of power production for PV systems. Conversely, according to Solarex, vertical modules are predicted to produce 50% of their rated output during clear sunny days and 5% - 10% during weather with bright overcast skies.

A resource calculation of urban centers in the UK was performed to develop an understanding of the solar insolation falling on the walls and roofs of buildings in eight UK city-centers. When compared to traditional electricity production methods in the UK (Pearsall & Hill, 1994), the study revealed that commercial, industrial, and domestic buildings using PV systems could provide a significant amount of cost effective electricity in areas with good to poor solar energy availability. Overall, the assessment accessed the amount of potential PV electricity as effected by shading, but did not consider technical and economic barriers to PV cladding implementation.

This dissertation research used the assessment methods developed by Pearson and Hill (1994) as a basis for determining the potential electricity produced by the PV glazing. To determine the effects of shading new methods were developed. Although it is recommended to use PV glazing on vertical surfaces not affected by shadowing, the shadows of adjacent building vary due to the path of the sun and seasonal affects caused by the tilt of the axis of the earth. Consequently, this study used PV glazing on the entire building and accounted for shadowing by deducting a monthly average shading percentage from the overall production of the PV system. Section 3.4 discusses this method further. Effects of ventilation were not considered, but are perceived to be most beneficial for cold regions due to the location of the PV film.

With improvements in silicon solar cell manufacturing technology, silicon cells with efficiencies up to 25% efficiency are feasible (Green et al., 1998). However, semi-transparent laser cut modules are an amorphous silicon with efficiencies ranging from 8% to 10%, which reduces to about 3% to 6% after a few months of exposure to sunlight (Martel and Presnell, 1999). In this study, high-efficiency silicon modules were selected for the spandrel glass that makes up 33% of the building's façade, while amorphous silicon cells were selected for the vision glass that makes up 66% of the building's facade. Accounting for efficiency losses in the amorphous silicon, an average PV efficiency of 12% was determined using 6% efficiency for the vision glass and 18% efficiency for the spandrel glass.

2.4 Effects of PV Glazing on People

In the design and use of PV glazed windows in commercial buildings, there are many questions asked by the building community. Although many of their concerns are quantitative, qualitative issues continually arise. The National Renewable Energy Laboratory (NREL) has stated that the greatest environmental concern surrounding BIPV systems is how they aesthetically affect people (DOE, 1993). The following section discusses this condition and searches for a causal relationship between window transmittance and human satisfaction. For clarity, it has been divided into the following subsections: a) people and windows, b) electromagnetic fields (EMF) and people, and c) assessment measures.

2.4.1 People and Windows

As indicated by the prior research (Biner & Butler, 1989), people desire windows in their indoor spaces. In the studies by Cuttle (1983), Collins (1975), Keighly (1973), Markus (1967), Wells (1965) and Wotton (1983), (as cited in Biner & Butler, 1989), it was demonstrated that people prefer the visual presence of daylight or sunshine to artificial light in offices. The studies showed that there was a positive relationship between the size of the window and people's preference to them. That is, larger windows that allowed more daylight and sunshine into spaces are generally preferred over smaller ones that do not.

However, other researchers have found that subjective responses to window preference are more influenced by the past standards in building construction than the personal preferences of people (Biner and Butler, 1989). Biner and Butler also found that window preferences and factors vary more widely than previous research indicates. Hence, the effect of reduced light transmission and visibility of PV glazed windows on human preference is uncertain. Nonetheless, based on Cuttle's study (as cited in Biner & Butler, 1989), this research assumes that there is a positive linear relationship between transparency (visibility) of the PV window and preferences of people. Accordingly, this study attempts to validate that PV are acceptable to human subjects when compared to clear glass.

2.4.2 EMF and Health Issues

Electromagnetic fields are composed of electric and magnetic fields and are produced by all electrical equipment, including PV systems. 60 Hz electric and magnetic fields are used most in our homes, offices, and factories (Morgan et al., 1989). Using physics and electrical engineering formulas, field strengths can be calculated in simple situations like that of transmission lines. However, the calculation of field strengths in complex settings becomes very difficult. The complex shapes of objects affect the current and voltage patterns in electricity. More important to their existence, electric fields that are in phase and moving in the same direction can combine to create stronger fields. On the other hand, electric fields that are exactly out of phase and moving in opposite directions can cancel each other.

In general, two kinds of effects have been observed: 1) stimulation of the skin by interaction with surfaces of cells and 2) a slight tingling sensation by people standing in electric fields. Specifically, in studies involving people, laboratory experiments show increases in the heart rate and reaction time of people exposed to strong magnetic fields (Morgan et al., 1989). In studies of people sleeping with electric blankets (as cited in Morgan et al., 1989), changes in the level of melatonin were reported. However, Morgan's study did not indicate an increase or decrease in the level of this hormone. This condition is of particular importance because in the absence of melatonin in animals, tumors feed on linoleic acid – the primary fat in corn oil (Science News, 1999). Still there is no conclusive evidence to support the idea that electromagnetic frequencies cause cancer (EPA, 1990).

More importantly, some researchers argue that there is enough evidence to conclude that exposure to high levels of EMF do cause cancer. Consequently, a few states have passed standards for the acceptable strength of electric fields from high voltage transmission (Morgan et al., 1989). Other countries like Britain, Japan, Poland, and the Soviet Union have also established standards and guidelines for exposures to electric fields. Additionally, the International Radiation Protection Association has issued exposure guidelines for the power frequency of electric and magnetic fields.[9] In this study, because consumption of electricity is reduced when using PV systems, the strength of the electric and magnetic fields generated by the building are expected to decrease. However, in this study, the strength of electromagnetic field was not studied. Future work is required to measure the electric and magnetic fields produced by the PV systems and to verify that they are not a health risk.

2.4.3 Assessment Measures

Past studies, aimed at providing a description of affective quality attributes to environments, indicate that three dimensions – arousal, pleasure, and dominance – are required to assess the affective attributes that an individual assigns to a place.

Measurement of these three dimensions was suggested by the semantic differential[10] evidence of Osgood (as cited in Russell and Pratt, 1980). In addition,

---

[9] The International Radiation Protection Association reviews scientific evidence and proposes safety standards for the international community.

[10] Semantic differential scaling is a popular and versatile method of measuring the connotative meaning of concepts, including attitude change, anthe appraisal of individuals, groups, situations and objects, abstract concepts, and self concept. It is a combination of association and scaling procedures (Piotrowski, 1985).

other multidimensional scaling studies of the influencing parameters indicated that, besides dominance, there are a number of secondary dimensions beyond arousal and pleasure that are cognitive in nature (as cited in Russell and Pratt, 1980). When denoting the emotional state, it is the view of Russell and Pratt (1980), that only two orthogonal and bipolar dimensions – pleasure and arousal – are required. On these grounds, Russell and Pratt developed the affect grid[11] to assess pleasure and arousal simultaneously.

Assessment of reliability of the Affect Grid was obtained through a comparative analysis of scales within four experiments: a) group ratings of emotion-related words, b) group ratings of facial expressions of emotion, c) individual ratings of facial expressions and d) mood (Russell and Pratt, 1980). Scales compared in their study were: a) direct circular scaling, b) multi-dimensional scaling, c) uni-dimensional scaling, d) semantic differential scales of pleasure and arousal (Hehrabian and Russell, 1974), and e) Positive and Negative Affect Schedule (PANAS)[12] (Watson et al., 1988). Because the Affect Grid shows strong evidence of convergent validity with other measures of pleasure and arousal, it was used in this study to assess the emotional effects of PV glazing on office workers within a typical office space.

---

[11] The affect grid is a single-item scale designed to assess two dimensions of affect – pleasure and arousal - by recording judgments about a single instance (Russell et al., 1989). Pleasure and arousal are considered independent dimensions, where pleasure is the bipolar opposite of displeasure and arousal is the bipolar opposite of sleepiness.

[12] The Positive and Negative Affect Schedule (PANAS) are two, ten item mood scales developed to satisfy the need for reliable and valid Positive and Negative Affect Scales (Watson et al., 1988) that are brief and easy to administer.

2.5 Measurement

The best and most accurate way to study the built environment is to build and instrument a prototype that best suits the design inquiry. When this is not possible, researchers resort to numeric and visual computer simulation. Therefore, this section discusses numerical computer simulation methods for determining energy use, the electricity production of the PV glazing, owning and operating costs, and the window properties. In addition, visual computing methods for presenting the real environment are discussed. Furthermore, the application of human assessment measures required for testing human satisfaction is discussed. For clarity, this section has been divided into the following subsections: a) economic analysis, b) energy simulation and c) human assessment.

2.5.1 Economic Analysis

According to Duffie and Beckman (1991) there are several methods that can be used to evaluate the cost effectiveness of solar energy systems. They are least cost solar energy, life cycle cost, annualized life cycle cost, and payback time. Least cost solar energy is used when solar energy is the only energy resource. Life cycle cost, also referred to as owning and operating costs, is the sum of all costs associated with the energy delivery system over its lifetime or a selected period, in today's dollars. Annualized life cycle cost is the average yearly outflow of money, which can include annualized life cycle costs. Payback time is the time that is needed to return one's investment due to savings in fuel.

With no universal agreement on which economic analysis method should be selected, most studies use simple payback to reveal the short-term economic performance between systems. Therefore, this study used a simple payback analysis to evaluate three window systems – single pane clear, Low-E, and PV. However, when using this method, energy cost escalations and other future costs are ignored and therefore a simple payback may produce misleading results (Watson, 1993).

2.5.2 Energy Simulation

Energy simulation programs are widely used to predict the energy consumption and the thermal performance of buildings. Because of continued government support, most of the fundamental developments in energy calculation procedures have occurred in the public domain (Ayres and Stamper, 1995). Thus, the major developments in public domain simulation software have occurred at Lawrence Berkley Laboratories (LBL), the University of Illinois and the University of Wisconsin.

At Lawrence Berkley Laboratories (LBL) engineers have developed and validated computer programs to assist in the design of energy-efficient and cost-effective buildings. Their work includes the development and maintenance of the current-generation energy-analysis programs, such as: 1) the DOE-2 program (LBL, 1993), which calculates the hourly energy use and energy cost of commercial and residential buildings, 2) the Simulation Problem Analysis and Research Kernel (SPARK) (LBL, 1995), which is an equation-based, object-oriented simulation environment for constructing and running models of complex systems, 3) the

Window 4.1 program (Window 4.1, 1997), which determines the heat transfer through windows as using glazing characteristics, gas-fills, frame properties, and 4) the radiance program, which performs detailed analyses of lighting and daylighting systems (Ward, 1994).

Originally developed by the U.S. Army Construction Engineering Research Laboratory (USACERL), the Building Loads Analysis and System Thermodynamics (BLAST) program is maintained by the BLAST Support Office at the University of Illinois at Urbana-Champaign. The BLAST system is a comprehensive set of computer programs for predicting the energy consumption, cost and the performance of the systems within the building (Hittle, 1979). More recently, a current version of the BLAST program, known as IBLAST, was developed to integrate the building, system and plant simulation. Combining DOE-2 with the IBLAST program, the Department of Energy is developing new software known as EnergyPlus which uses a heat balance approach (Strand et al., 1999). In this study, the DOE-2 program was used to conduct the thermal simulations of the prototype building.

In the Solar Energy Laboratory at the University of Wisconsin, a modular energy-simulation software, known as TRNSYS, has been developed. TRNSYS simulates the transient performance of any thermal energy system and relies on a modular approach to solve large systems described by FORTRAN subroutines, versus the fixed schematic approach of DOE-2 or Blast. Each FORTRAN subroutine contains a model for a system component or sub-component (Beckman et al., 1999). In addition, the Solar Energy Laboratory is also noted for the development of the F-Chart and the PV F-Chart program (F-Chart Software, 1997), which are the authoritative solar system analysis and design programs. In this study, PV F-Chart was used to determine the electricity production of PV systems.

2.5.3 Properties of Window Glazing

In 1989, a U-value determination method was adopted by all glass manufactures in the United States. This method was based on the U.S. Department of Energy's "WINDOW 3.1" computer program for predicting U-values based on the center of the insulating glass unit. While measurement of the optical properties of advanced glazing have been established (Rosenfeld, 1998), the National Renewable Energy Laboratory (NREL) has developed a measurement guide for PV performance testing (Myers, 1997). Using spectral radiometric instrumentation[13], broadband optical radiation, otherwise referred to as the broadband wavelength within the total spectrum, is separated into spectral components to understand the spectral dependence of the PV device.

Nonetheless, the measured data for optical properties of advance glazing are necessary inputs to computer simulation programs used to determine the energy performance of glazed systems and their effects on the building's energy use. These data also determine quantitative measurements to assess of the quality of the transmitted light and its spatial distribution. Such quantitative assessments are

[13] Spectral radiometric instrumentation consist of an 1) optical receiver that defines the field of view and captures the radiation, 2) a dispersion element for separating the light by wavelength, 3) a scanning control to set the radiometer to different wavelengths, 4) a detector for collecting and determining the amplitude of the signal, 5) and a signal processor unit to control the system (Myers, 1997).

necessary for the successful introduction of advanced glazing concepts by architects, designers and the contractors (Rosenfeld, 1998).

In this study, the optical properties of the PV glazed system were determined using experimental data gathered from a test apparatus and are discussed further in the Methodology section. These data were then used in the Window 4.1 program, an enhanced version of Window 3.1, to further define properties of the PV glazing and to create output data necessary to conduct the DOE-2 energy simulation. Due to the complexity of measuring all the optical properties for the PV windows, this part of the study was limited to the solar transmittance of the glazing. The impact of the layered electrical semi-conductor on the thermal performance of the window was not considered, but should be studied further.

2.5.4 Human Assessment

When presenting simulated environments to a group of subjects, a valid appraisal relies on how we display the environment (Danford & Williams, 1975). Presentation methods include: a) the real environment, b) scale models, c) slides, d) photographs and e) video recordings. Due to time, cost, efficiency and the ease of the analysis, studies of human responses to environmental stimuli by Danford and Williams used simulations such as scale models rather than the actual environment. It was found that the reproduction of important environmental properties and the selection of a reliable means for simulating those properties elicited responses that have some degree of agreement with responses elicited by the actual environment (Bechtel et al.). Therefore, in this study, to convey an impression of an office environment with and without the PV glazing, videotape of computer simulated office environments was used[14].

State of the art software that visually simulate virtual environments include: Radiance (Ward, 1994), Lightscape (Lightscape Technologies, Inc., 1997) and RadioRay software (Autodesk, 1998). These sofware use radiosity algorithms to define numerically accurate renderings. When using such programs, the environment is modeled as three-dimensional geometric descriptions that are associated with building materials, properties of reflectance, color[15], specularity (shininess) and opacity.

Conversely, an enormous time for the setup and simulation of short animated segments[16] is required when using radiosity software. Designed to allow simple animated movement of objects, radiosity systems do not determine the irradiance levels for specific sites, nor do they determine the reduction in solar irradiance due to the time of day. Therefore, complex lighting calculations make it inefficient to use radiosity algorithms to simulate changing lighting variables. Because this study used an animated video to elicited responses from subjects[17], radiosity algorithms are not

---

[14] In this study, an animated video using sequential targa files was developed and used to simulate the office space. The video contained segments representing daytime hours for one day. See the methodology section on human assessment for more detail.

[15]Color, within simulation software, is defined using color mixtures for two sets containing three variables – Hue, Saturation and Lightness, and Red, Blue and Green components. For radiosity algorithms, the color of the light that the bulb emits is associated with a distribution curve of the light.

[16] When discussing animation, real time refers to the time it takes to perform real world events. In the case of video production, it is the time required for video to display real world events. In the latter case, one second of video contains 30 image frames. Thus, in theory, to represent one second of real time requires 30 image frames on tape in an NTSC format.

[17] In the human assessment, the video presented a time lapse representation of one day for the summer solstice for each site. The Methodology section provides further details.

used. Instead, to simulate the office space, a modified lighting approach was developed and is discussed further in the following paragraph.

In this study, 3D Studio Max (Autodesk, Inc., 1996), a popular visual simulation software, was chosen because it allows the expedient and animated control of variables such as solar irradiance and the solar position of the sun. To obtain numerically accurate images with reference to lighting, the solar irradiance was calculated using PV F-Chart software and modified for input into the 3D Studio Max software. The Methodology section provides more detail.

2.6 Summary of the Literature Review

This literature review has discussed: a) owning and operating costs of PV systems, b) commercial building energy use, c) simulation of BIPV systems, d) psychological effects of PV windows, and e) measurements. A summary of each section follows.

2.6.1 Owning and Operating Costs of Photovoltaic Systems

To determine building-owning costs of PV-coated glazings, tables developed by Kiss et al. (1995) were used to conduct a simple payback analysis which included current federal tax-incentives for solar property.

2.6.2 Commercial Building Energy Use

This study targeted high-rise commercial buildings using PV glazing consisting of silicon on glass with uniformly cut microscopic holes. For all comparisons, PV glazed windows were compared to a single-pane clear-glass and

Low-E glazing[18]. It is important to note that, in this study, the PV glazing is not required to match the electric load of the building, but only to supplement the energy demand of the building. Hence, this study assumes that the system is a grid interconnected PV system that does not use batteries to store electricity.

2.6.3 PV Electric Production

In addition, this study used PV glazing on the entire building and accounted for shadowing by deducting a monthly hourly average shading percentage from the overall production of the PV system (Pearson and Hill, 1994). Although effects of ventilation were not considered, the literature indicates that ventilation would be most beneficial for cold regions due to the location of the PV film. Overall, the efficiency of the spandrel and vision glass was averaged to determine the electric production of the PV. A 12% average PV efficiency was used for the spandrel and vision glass.

2.6.4 Psychological Effects of Photovoltaic Windows

Based on Cuttle's study (as cited in Biner & Butler, 1989), this research assumes that there is a positive linear relationship between transparency (visibility) of the PV window and human preference. Accordingly, the study attempts to validate that PV windows have no significant effect on human satisfaction at levels of visibility that are common to energy efficient glazing. The effect of electromagnetic fields produce by PV systems was not be studied. Nonetheless, to

[18] Two window type were developed for Low-E and the PV glazing for application in hot and cold climates. In hot climates, the coating was placed on the back of the first pane within a double glazed system. In cold climates, the coating was placed on the front of the second pane in the double glazed layer. In both cases, the front of the first paned faces the outside environment and the back of the second pane faces to the inside of the space.

assess human satisfaction, the Affect Grid was used in this study to determine the emotional effect of PV glazing on office workers within a typical office space.

2.6.5 Measurements

The measurement apparatus for this study included thermal energy, electric, thermal, and visual simulation software. To conduct the energy analysis the study used the DOE-2 energy simulation software. PV F-Chart was used to determine the electricity contribution of the PV system, which was modified by shading values calculated by the DOE-2 program. Because the PV system provides electricity and shades the building, this study conducted a field experiment to validate the transmittance of the PV glazing. These data were then used within the Window 4.1 program that simulated the thermal performance of the PV window.

To simulate the office environment; visual simulation software was used to create a time lapse video used to solicit human responses. Specifically, 3D Studio Max was used to create virtual geometric descriptions and their associated building materials. To obtain accurate solar irradiance levels, PV F-Chart was used to determine average hourly solar irradiance profiles for the summer solstice in each location.

2.7 Significance of Work

A better understanding of the potential to save energy and social acceptance of PV windows will provide valuable information to aid in the development of sustainable buildings and cities. Large commercial buildings using PV windows could provide continuous renewable energy that would help to achieve municipal goals by assisting in the economic development of cities. Such buildings would also maintain and protect our quality of life by reducing environmental problems associated with inefficient energy use. Overall, buildings using BIPV systems contribute to our national security by reducing our vulnerability to fossil fuel shortages and price increases that are predicted for the near future.

Although various aspects of PV facades have been studied, there is no comprehensive model to evaluate the effectiveness of PV glazing in buildings. Thus, this research uses a comprehensive approach to validate existing data and to model the energy analysis. Overall, the model includes the development of PV glazing properties, a resource assessment that determines the electricity production of the PV system, including the shading effect, an energy simulation and a single payback analysis. Details of each component are provided in the methodology section.

3 METHODOLOGY

3.1 Introduction

This study targets high-rise buildings within densely populated urban centers in the United States. Within each census region (Northeast, Midwest, South, West) a typical city was selected. To insure that the selected sites had the appropriate characteristics of a downtown district within large urban centers, each selected city had a population greater than one million people, based on 1992 US Census Data. Furthermore, in census regions where more than one city met the selection criterion, the city with the largest population was chosen. The selected cities are as follows:

Census Region:	City:
South	Houston
West	Los Angeles
Northeast	New York
Midwest	Detroit

Figure 3-1. Selected Sites for Each Census Region

The sites selected contained a human population greater than one million. In census regions where more than one city met selection criteria, the one with the largest population was selected.

Using a typical high-rise building and city block, this study used a forty-story building surrounded by buildings one-half its height. Because of their density and grid layout, general characteristics of the city block, as observed from maps, are small-building footprints, multi-lane roadways with off-street parking and setbacks for pedestrian sidewalks. To determine the dimensions of the typical city block mentioned above, downtown Houston was used as a basis for all four cities. After review of the appropriate maps and building sites,[19] this study used a building footprint of one hundred by one hundred feet square, six-lane roadways with off street parking and a twenty feet setback for pedestrian sidewalks (Figure 3-2 and Figure 3-3).

To determine the building's height, a survey of high-rise structures within each downtown business district was conducted. In general, various data were available regarding historical and prominent buildings within each downtown area. However, very little comprehensive data existed for Houston, regarding the building's sizes. For Detroit, no statistical data was available for review regarding its high-rise buildings. Nonetheless, using the compiled data, representing mainly Los Angeles and New York, the average height of high-rise buildings was determined to be 42 stories (See Appendix). Thus, a 40-story building was used in this study. After a survey of the photographs[20] of the selected cities, the surrounding buildings in this study were set at one half the height of the 40-story high-rise building discussed earlier.

In general, the building is a steel frame structure with four-inch concrete floors and roof, a fifteen feet floor-to-floor height, and ten feet ceilings. The curtain wall is 100% glass, with typical floors containing five vertical feet of spandrel[21] glass and ten feet of windows. The interior of the building has suspended acoustical tile ceilings, typical partitions for the interior spaces, and recessed fluorescent lights.

---

[19] To determine the dimensions of the site, the roadways and the off-street parking, this study used the site of the Harris County Criminal Justice Center design by the architectural firm of Pierce, Goodwin, Alexander, and Linville of Houston.

Occupancy of the building was determined using 100 square feet per person for perimeter spaces and 200 square feet per person for core areas.

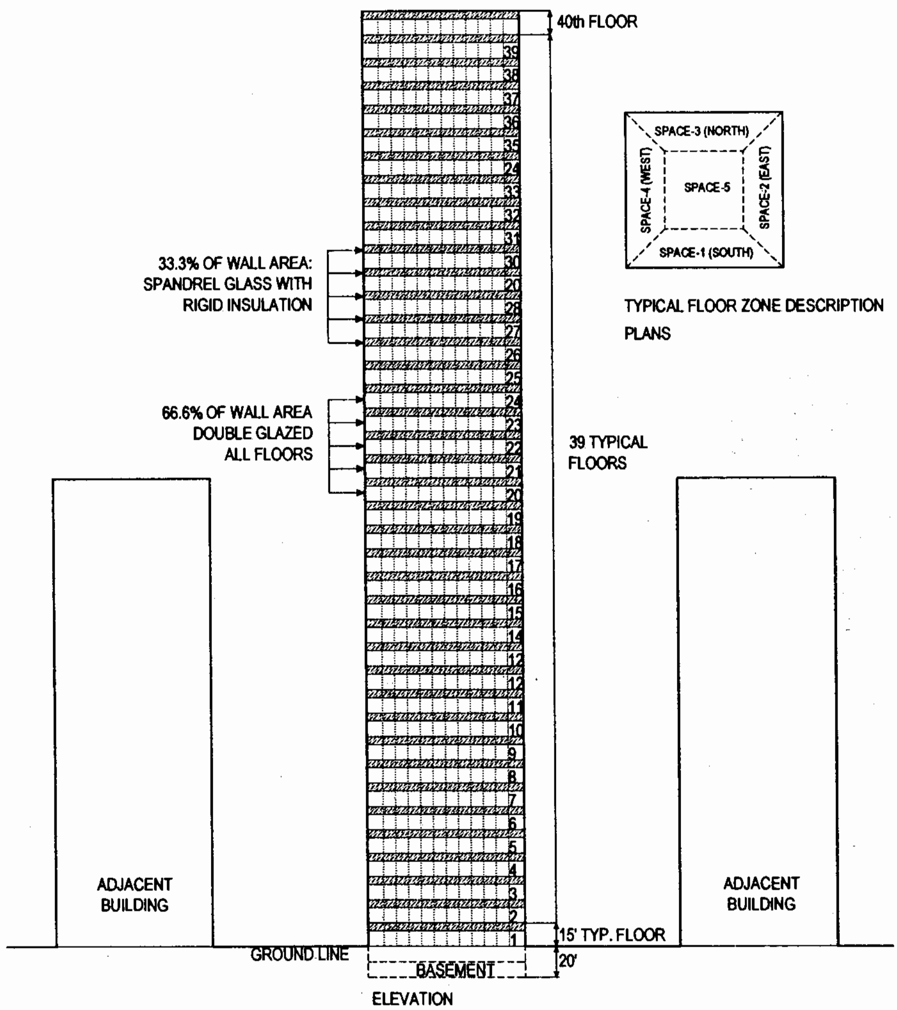


Figure 3-2. Typical High Rise Building in Downtown City Block

The figure shows a 40-story high-rise building within a typical city block and the surrounding buildings that are 20 stories high. The distance between each building is 100 feet and accounts for off-street parking. The building contains 33% spandrel glass and 66% vision glass with a floor-to-floor height of 15 feet. Each floor has five zones with the basement being a single independent zone.

[20] Photographs of downtown buildings and the city skyline were used to determine the relationship between the high-rise structure and their adjacent buildings. Due to copyright issues, these photos have not been included. However, their web-sites are listed in the appendix.

[21] Spandrel glass covers the areas between floors where no view or light transmission is required. See Figure 3-2.

Based on the cities selected, the prototype building, and the site configuration, the next sections discuss methods used to conduct: 1) the human assessment, 2) window experiment and simulation 3) the resource assessment, 4) the energy simulation, and 5) the economic analyses.

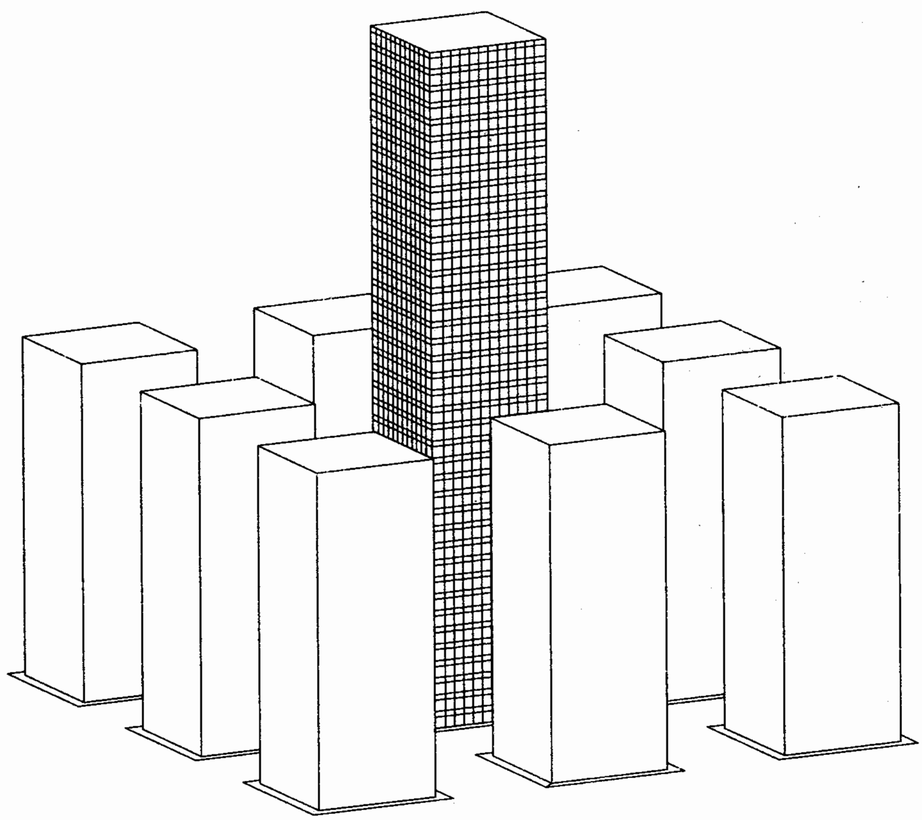


Figure 3-3. Three Dimensional Model of Prototype Building

The figure shows the spatial relationship of the prototype building and its surrounding buildings. Based on visual analysis of photographs of the selected sites, all buildings are 100' x 100' in length and width. The surrounding buildings are 20 stories tall. The middle building is 40 stories tall.

3.2 Human Assessment

To understand interior psychological effects of the visible light transmittance of windows on office workers, this study used a controlled experiment to test 188 subjects at Texas A&M University. This section describes the experimental procedures that were used when testing the subjects and the response format used to solicit the subject's feelings. The average age of the subjects was approximately 20 years. In addition, the modification of the measurement instrument and its interpretation are also discussed. Due to issues that arise when using computers to simulate the real environment, the mode of analysis – computer simulation of the real environment – is discussed in relation to material and light properties.

3.2.1 Experimental Procedures

Following standard instructions, the subjects viewed videotape of randomly ordered digital image sequences (Figure 3-1). The videotape was shown twice, and the students were only allowed to respond during the second viewing. For five seconds, the video displayed a preparatory segment and notification that the sequence was about to begin. Following, a digital image sequence appeared as a time-lapse representation of one day from sunrise to sunset. For the initial screening, the segment lasted for 15 seconds and for the final screening the segment lasted for 10 seconds. Last, text stating, "Please record your response" was held on a blank screen for 10 seconds. In total, sixteen sequences were shown.

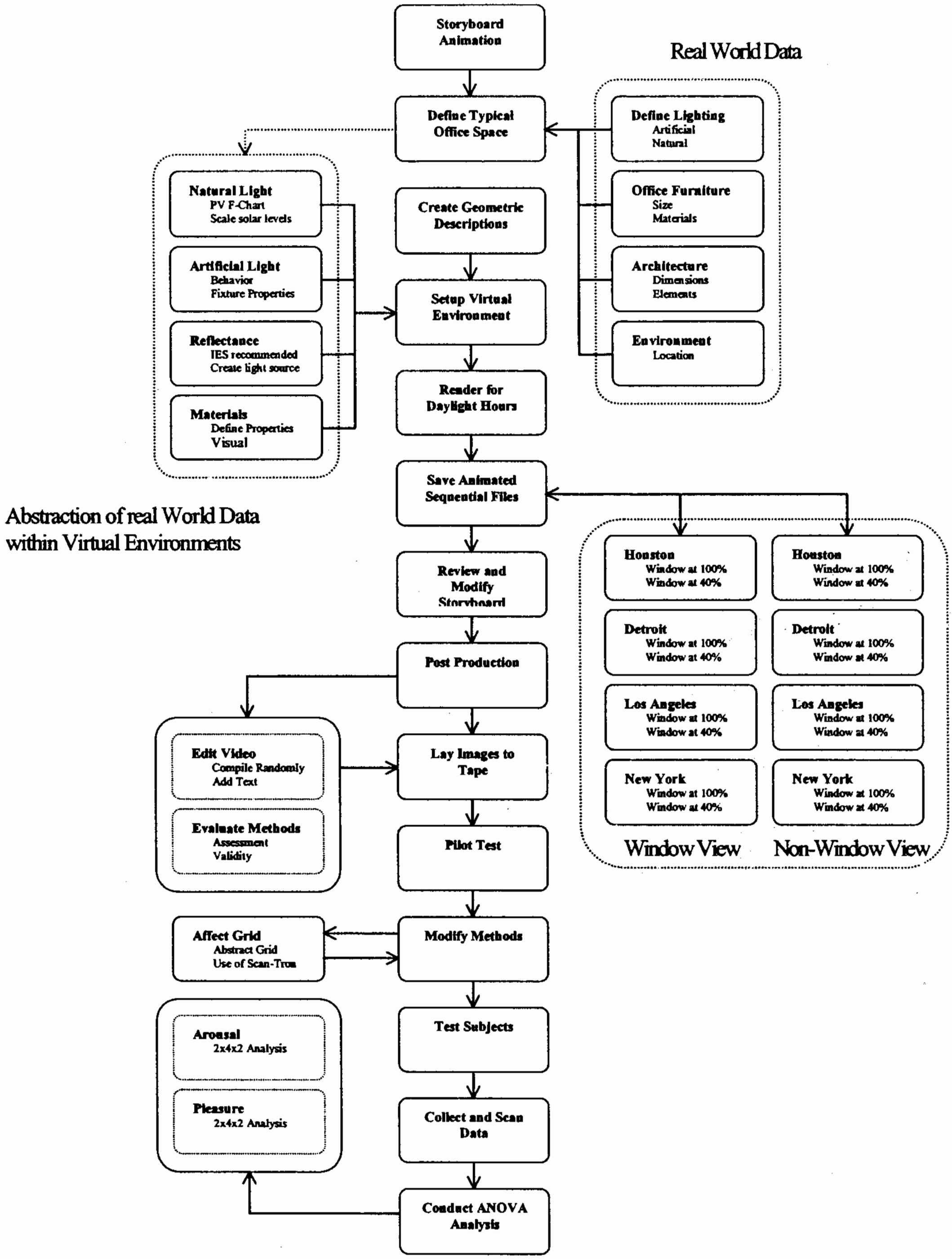


Figure 3-4. Human Assessment Method

The diagram above shows the data processing method required to conduct the human assessment. In general, major issues addressed in this study were: a) the definition of the real environment, b) determining how lighting variables are represented and controlled within the virtual environment of the computer and c) the modification of the Affect Grid to accommodate a ten item scale scanning sheet.

Table 3-1. Animated Sequences

Window View	*Non Window View*
Location/View/Glazing	Location/View/Glazing
H-W-C	H-NW-C
H-W-F	H-NW-F
D-W-C	D-NW-C
D-W-F	D-NW-F
L-W-C	L-NW-C
L-W-F	L-NW-F
N-W-C	N-NW-C
N-W-F	N-NW-F

The figure shows the variables used to assign and block the data. For the location, "H" represents Houston, "D" represents Detroit, "L" represents Los Angeles and "N" represents New York. For the View, "W" represents a window view and "NW" represents a non-window view. In the case of GLAZING, "C" represents clear at 100% and "F" represents 40% transmittance.

A_1

	B_1	B_2	B_3	B_4	
C_1	y_{111}	y_{121}	y_{131}	y_{141}	$y_{1.1}$
C_2	y_{112}	y_{122}	y_{132}	y_{142}	$y_{1.2}$
					$y_{1..}$

A_2

	B_1	B_2	B_3	B_4	
C_1	y_{211}	y_{221}	y_{231}	y_{241}	$y_{2.1}$
C_2	y_{212}	y_{222}	y_{232}	y_{242}	$y_{2.2}$
					$y_{2..}$

$y_{...}$

Figure 3-5. Humans Assessment Model

The figure shows the statistical model used to conduct the ANOVA analysis. In the figure, "A" represents the view (Window or Non-Window), "B" represents the solar characteristics of the site (Houston, Detroit, Los Angeles, and New York), and "C" represents the window treatment (100% and 40% transmittance).

Using the Affect Grid to measure arousal and pleasure as independent variables, the subjects anonymously responded to window stimuli by marking the appropriate squares that expressed his or her feelings. The mean for each window treatment response was computed. These data were then averaged across subjects for all trials: 2 x 4 x 2 (transmittance/visibility x solar condition for each census region x transmittance levels –100% and 40%) (Figure 3-5). An analysis of variance

(SAS Institute, Inc., 1993) was then used to test for significantly different treatment means.

3.2.2 Response Format

As shown in Figure 3-6, the "Affect Grid" is a square grid abstraction of the "circular ordering of eight descriptors" (Russell & Pratt, 1980). The center of the square represents a neutral, average, everyday feeling. It is neither positive nor negative. In this study, the subjects used the grid to value arousal and pleasure as independent variables, one along each axis. The pleasure-displeasure score is taken as the number of the square checked, with squares numbered along the horizontal dimension, counting 1 to 9, starting at the left. The arousal – sleepiness score is taken as the number of the square checked, with squares numbered along the vertical dimension, counting 1 to 9, starting at the bottom.

3.2.3 Abstraction of the Affect Grid

Because of the large study population, a general-purpose answer sheet was used to solicit responses and automate the evaluation process. The answer sheet used in this study was a general purpose NCS answer sheet and was scanned by the Measurement and Research Service at Texas A&M University. However, to use the answer sheets, the Affect Grid was abstracted to fit the answer sheet format[22].

To abstract the Affect Grid onto the answer sheet, the first nine answers and first nine questions defined the grid. Within the grid, only one answer would be marked. Similar to the Affect Grid that uses a scale of nine on both axes, the answer

[22] The answer sheet contains 120 questions, each having ten answer bubbles. It allows the recording of the subjects' name, sex, level of education, birth date, identification number and other special codes.

sheet grid also used two axes defined by the response letter and the item number. The letter of the response represented the arousal effect and the item number represented the pleasure effect.

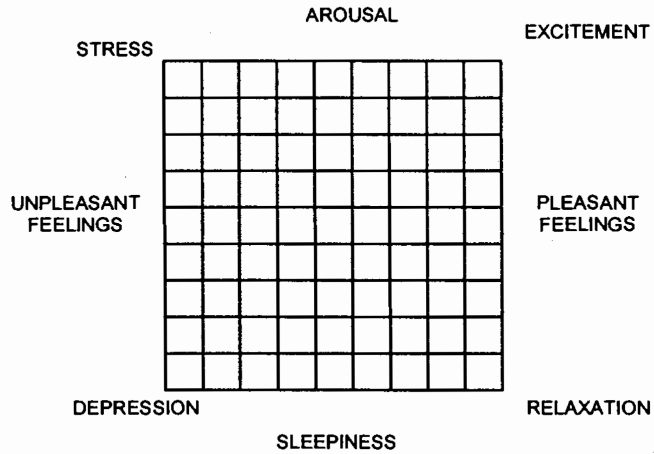


Figure 3-6. Affect Grid

The figure has been recreated using figures created by Russell and Pratt (1989). According to Russell and Pratt (1989), the horizontal dimension represents pleasure where the right half of the grid represents pleasant feelings (the farther to the right the more pleasant) and the left half represents unpleasant feelings (the farther to the left, the more unpleasant). Pratt states that the vertical dimension of the map represents the degree of arousal, which relates to how wide-awake, alert or activated a person feels, independent of whether the feeling is positive or negative. Russell and Pratt also state that the top half is for feelings that are above average in arousal and the bottom half is for feelings that are below average. This represents sleep.

3.2.4 Scaling of the Results

Twelve grids in increments of ten were defined on each sheet. Because the study required sixteen responses, each subject used two sheets in the study. To identify the sheet sequence, the first sheet was labeled "A" and the second sheet was labeled "B". To insure proper sequencing when scanning, the sheet label was used in place of the name of the person. Specifically, grids 1 – 12 corresponded to sheet "A" and grids 13 – 16 corresponded to sheet "B".

To scale the results, letters "A" through "I" represented values 1 through 9 for the pleasure effect, while items 1 through 9 represented values 9 through 1 for the arousal effect. As shown in the chart below, response "A" is equal to a value of 1, response "B" is equal to a value of 2, response "C" is equal to a value of 3 and so on. In the case of arousal, questions 1 through 9 corresponded to values 9 to 1, where question 9 is equal to a value of 1, question 8 is equal to a value of 2, question 7 is equal to a value of 3, and so on (Figure 3-7).

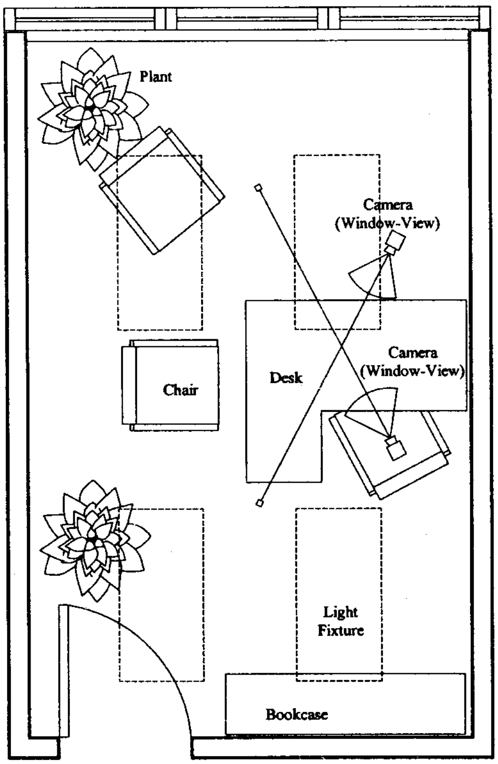
Arousal		**Pleasure**	
Question Number	Scaled Value	Recorded Value	Scaled Value
1	9	A	1
2	8	B	2
3	7	C	3
4	6	D	4
5	5	E	5
6	4	F	6
7	3	G	7
8	2	H	8
9	1	I	9

Figure 3-7 Scaled Results for the Answer Sheet

The table represents the scaling of the letter responses that are related to the pleasure effect and the item numbers that are related to the arousal effect. In all cases, only one bubble is marked within each grid boundary. The study required sixteen grids to be defined by each subject.

3.2.5 The Simulated Environment

The simulated office space has dimensions of 10 feet by 15 feet. The floor plan, shown in Figure 3-8, contains: a) two plants, one near the door and one near the window, b) three chairs, one for the occupant and two for visitors, c) a desk, d) the location of the light fixture, e) the camera positions for window and non-window view and f) a bookcase.



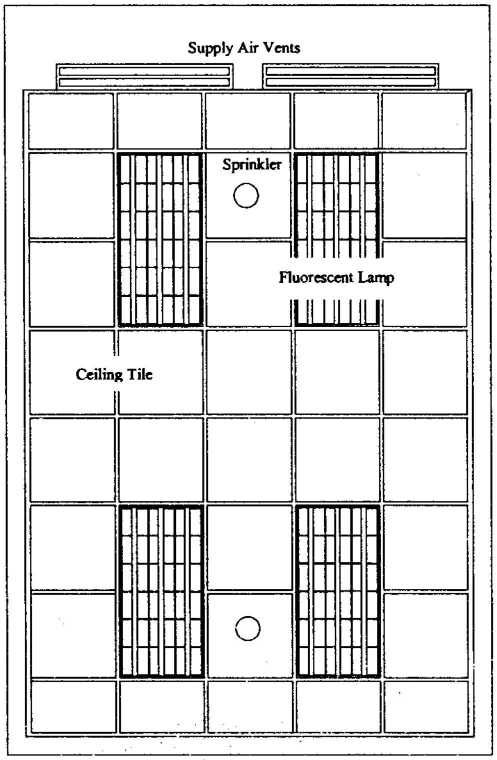


Figure 3-8. Floor Plan and Reflected Ceiling Plan of a Typical Office Space

The floor plan on the right contains two plant, one near door and one near window, three chairs, a desk, light fixture locations, the camera positions and a bookcase. On the right is the reflected ceiling plan showing a) the fluorescent fixtures which contain three 32 watt lamps each, the sprinkler system, the 2' x 2' ceiling tile layout and the supply air vent. The return air vents have a ¼ inch gap on the peripheral of the light fixture. Major materials are the carpeted floor, painted metal door, egg shell painted walls with gray base molding, textured ceiling tile with grill and the glass material of the window.

In Figure 3-8, the reflected ceiling plan shows: a) the fluorescent light fixtures containing three 32 watt lamps each, b) the sprinkler system, c) the 2 foot by 2 foot ceiling tile layout, and d) the supply air vents. The return air vents are designed into the light fixture as a ¼ inch peripheral gap. Major materials are the carpeted floor, the painted metal door, the eggshell painted walls with gray base molding, the textured ceiling tile with a grill and the glass material of the window.

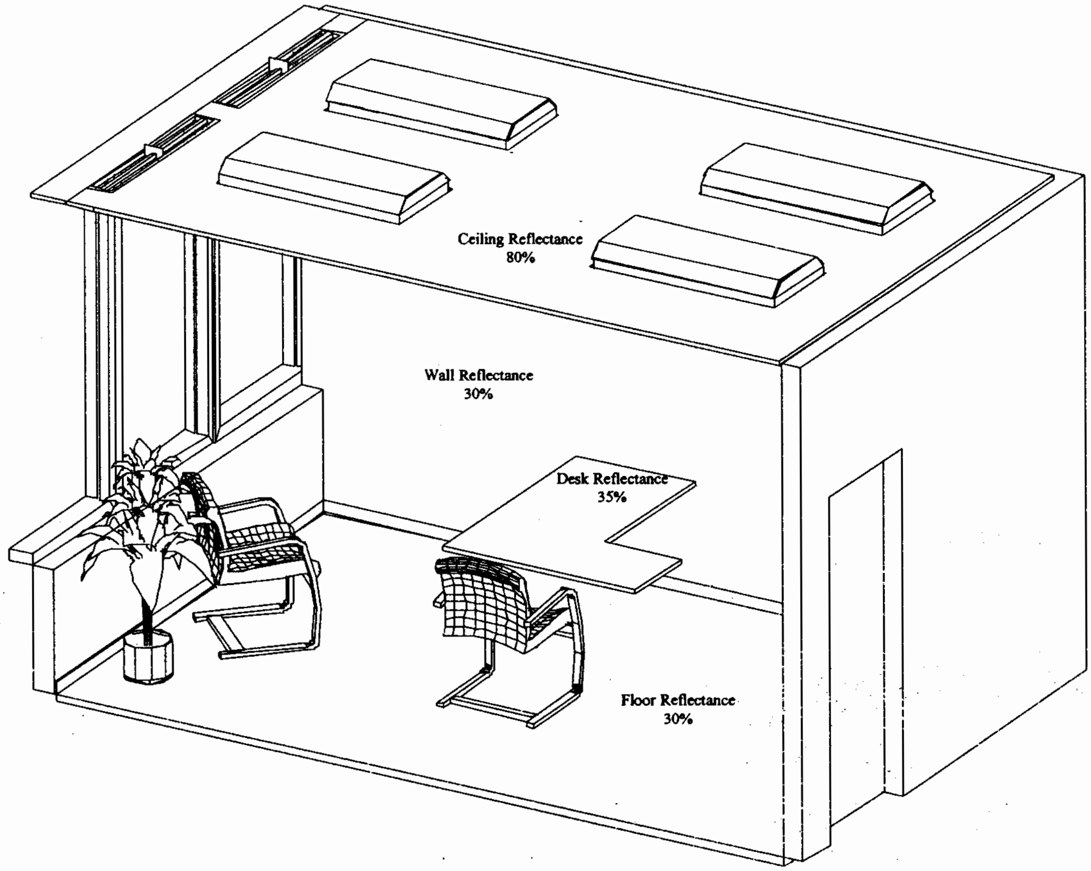


Figure 3-9. Sectional View of Typical Office Space

In the figure, the major surfaces (the floor, the walls, the roof and the desktop) have been labeled to show their recommended reflectance (IES, 1981). In addition, the figure is a hidden line representation of the computer model used in office simulation.

3.2.6 Mode of Simulation

As mentioned in the literature review, 3D Studio Max (Autodesk 1996) was used to simulate the office environment that was then recorded to videotape. Due to their complexity and importance to the validity of the simulation, the material properties and the lighting calibration are discussed in the next few paragraphs.

In the real world, the reflectance of a material is determined by its surface properties. However, visual simulation software used, as well as all other software, divides reflectance of a material into two independent components - shininess and reflection. Therefore, in this study the reflectance of surfaces maintained their relative values acquired from the IES Handbook (1981); and shininess factors were subjectively adjusted to obtain visual correctness. As illustrated in Figure 3-9, the recommended average reflectance of the painted walls and floor is 30%; the desktop is 30%; and the ceiling is 80%.

In the case of lighting, the light fixtures were recessed and contained three T8 thirty-two watt fluorescent lamps, which translated into 96 watts (6720 lumens) per fixture. However, because the lights are always on during the simulation, effects of the artificial lights were mainly checked for visual correctness. To account for the change in time[23], the selected day (June 21) was a fixed variable for all selected sites. Time is the period of daylight hours that varied according to the selected sites. As a time lapse video[24], the simulation[25] represented a period from sunrise to sunset. The hourly solar energy levels stricking the windows were determined using time series plots generated with PV F-Chart software (F-Chart Software 1997) and the path of the sun was determined using the internal programming of the software. Specifically, solar energy levels were scaled in relation to the computers intensity levels for lights sources that range from zero (lowest) to 255 (highest). In addition, the reflected light of the sun by the interior spaces was calculated by offsetting the

---

[23] The simulation spanned from sunrise to sunset, and was shown to the subjects as a time lapse of one day.

[24] Time lapse refers to an increase in video play speed of real world events due to the limitations of the recording media to record real world events in actual time. In terms of time, real time is the actual time its takes to perform a task; in terms of video, it is thirty visual frames recorded per second when using NTSC video formats and 20 visual frames per second when using PAL video formats. In the case of this study, the real world event that occurs over one day was shortened to a ten-second-time period for the human assessment. Note that sixteen simulations were displayed in a fifteen-minute period.

[25] Simulation refers to the animated targa sequence created using Autodesk's 3Dstudio Max software.

scaled time series plots[26] using the average surface illustrated in Figure 3-9. See Appendix. However, only one reflection interaction was considered[27] and was accomplished by creating an artificial light source to approximate the reflected light of the sun and the fixture lamps. Additionally, because this study offsets the window transmittance by 60% for the PV glazing, the calculated reflected light in the scaled time series plots was again adjusted to the decrease light entering the space.

[26] In this study, the solar energy levels falling on the windows, generated using PV F-Chart, were scaled for all sites. All sites were grouped and the highest solar energy level was assigned to the highest software lighting level. All light was considered white in color. In addition, as a function of the program, a multiplier of four increased the sun's intensity in relation to the artificial light sources.

[27] The interaction of reflected light refers to the number of times that a surface is allowed to receive and emit a calculated reflected light. It is important to remember that this is an intensive method used by radiosity rendering modules and was modified for the study because of software limitations.

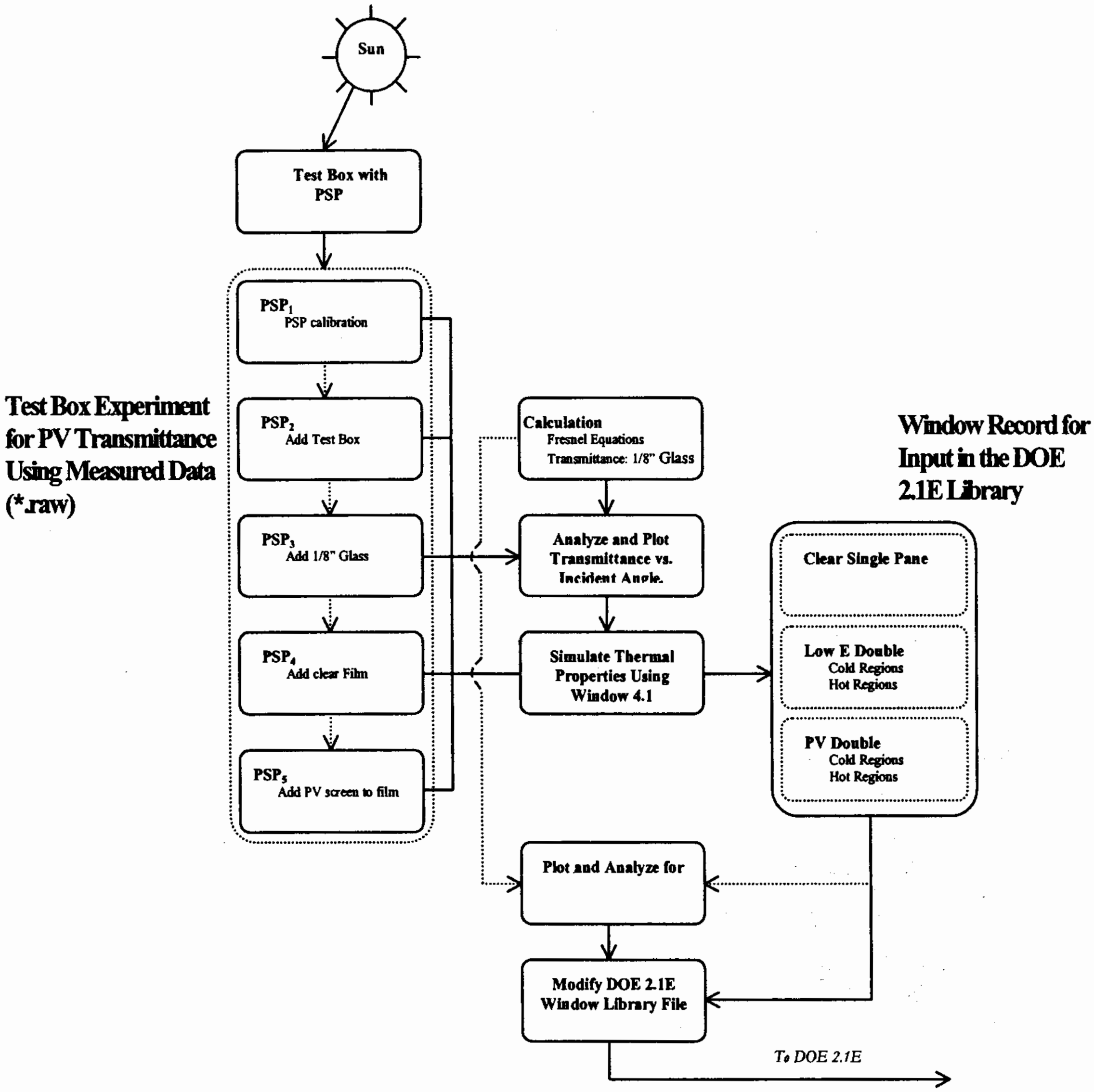


Figure 3-10. Methodology: Window Properties

The diagram above shows the data processing method required to determine the window properties in this study. In general, major issues addressed were a) the measurement of transmittance data of the PV prototype and b) simulating the experimental results within Window 4.1 software.

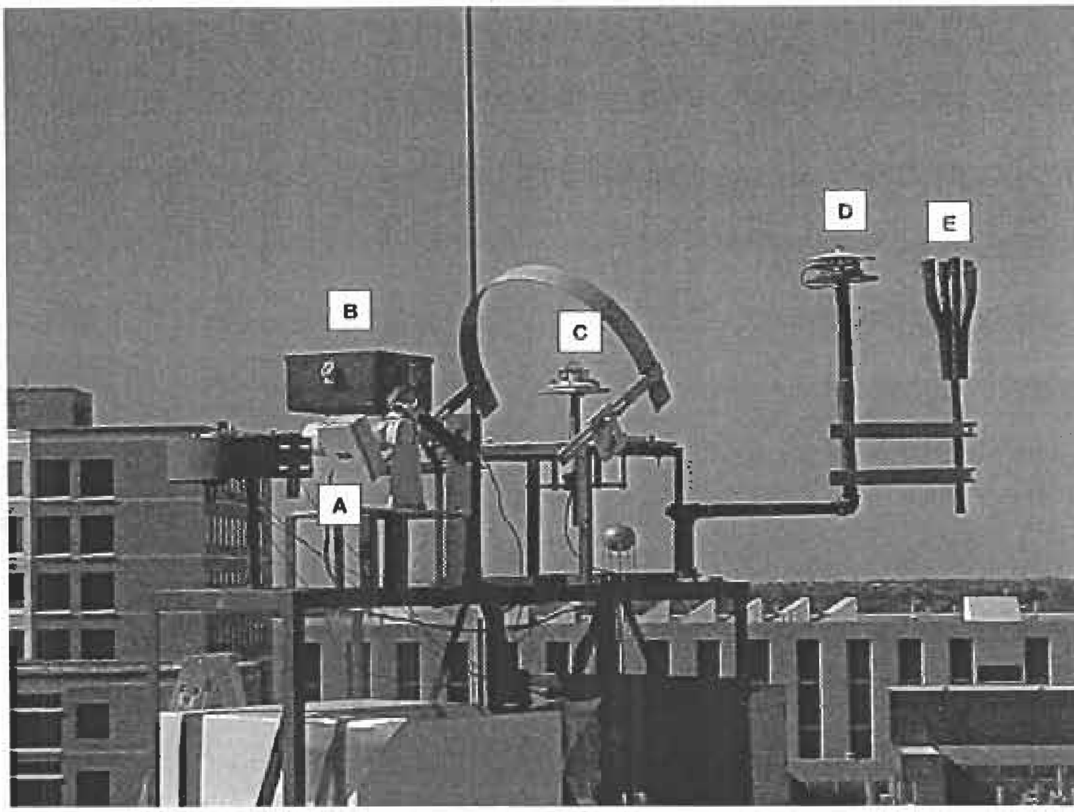


Figure 3-11. Solar Test Bench.

The illustration is an image of the Solar Test Bench located on the roof of building A of the Langford Architecture Center at Texas A&M University. The components include: a) Eppley Normal Incidence Pyrheliometer, b) - transmittance test box containing an Eppley Precision Spectral Pyranometer, c) Eppley Stationary Shadow Band Stand with an Eppley Black & White Pyranometer, d) Eppley Precision Spectral Pyranometer, and e) licor sensor calibrators (Munger, 1997).

3.3 Window Properties

Some Low-E coatings have as little as 8% visible transmittance (ASHRAE, 1997). In comparison to typical Low-E coatings which are designed to allow visible light in and reflect infrared, in this study the PV coating is designed to block all light equally, visible and infrared, and was given no spectral selectivity. Specifically, this study used a circular PV laser-cutting method for all PV assessments and comparisons (Figure 3-10).

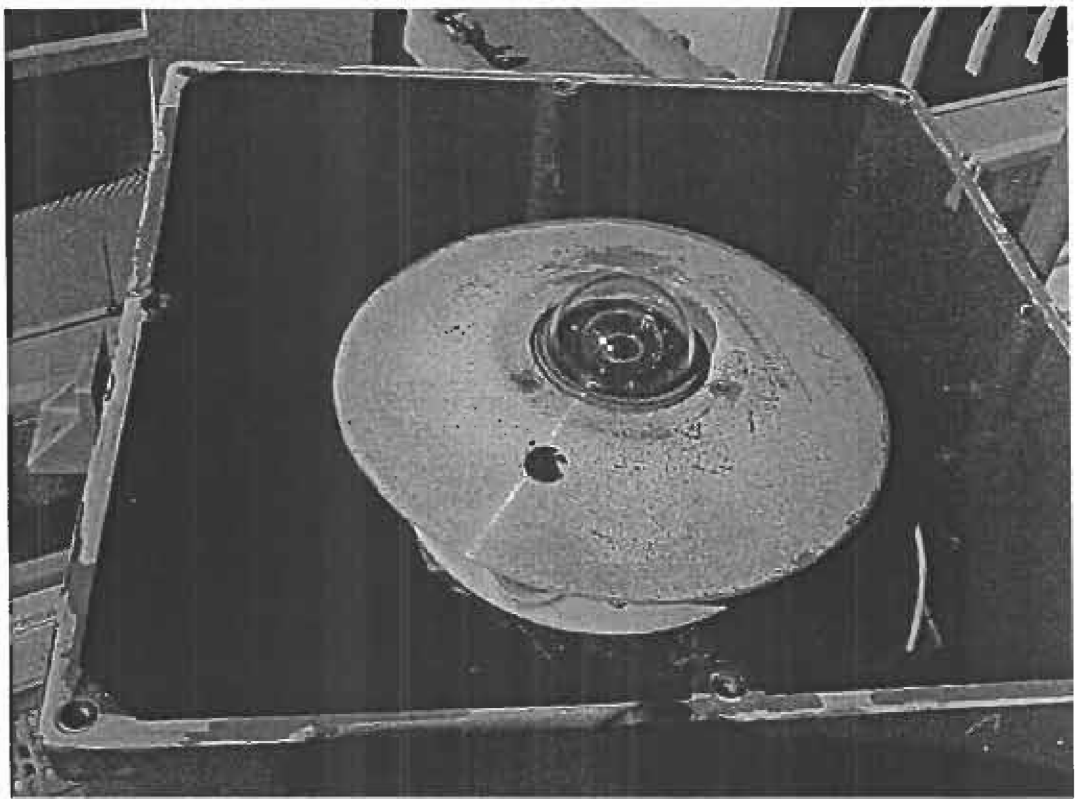


Figure 3-12. Transmittance Test Box.

The illustration is an image of transmittance test box located on the roof of building A of the Langford Architecture Center at Texas A&M University. To obtain maximum light striking the sensor, the Eppley Precision Spectral Pyranometer (PSP) is placed on a glass sheet that lifts the glass dome 1/8 inch from the top of the PV prototype's bottom surface. In addition, the prototype extends beyond the edges of the box when screwed in place to improve light level readings during the early morning and evening hours.

Therefore, this section will discuss the experimental methods used to validate the solar transmittance of the PV glazed window, the experimental testing and simulation of the PV window and the exporting of this data for use by the energy analysis software. However, because Low-E and clear glazed window systems are commonly used, this study does not perform a detailed analysis of these systems and relies instead on previously published data (LBL, 1997).

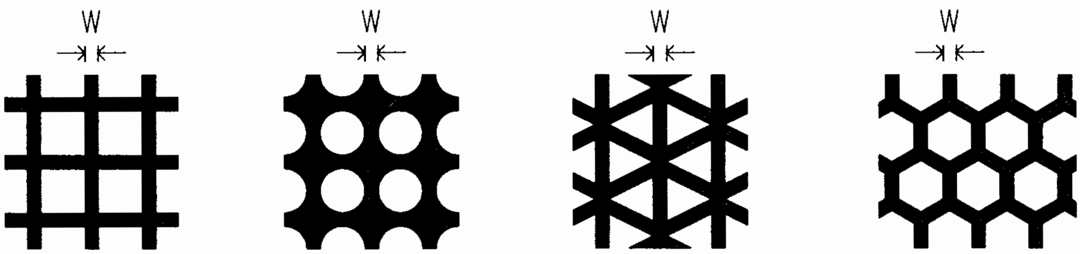


Figure 3-13. PV Laser Cutting Methods.

The diagram shows laser cutting methods for creating transparent PV glazing (Ishikawa, 1994). The relationship between transmittance and the area of each unit hole are provided in the in the proceeding paragraph.

3.3.1 Test Bench Experiment

In the study, the test box experiment used 1/8 inch glass with a covering that approximated the optical properties of the PV window material. To measure the transmittance of the prototype, the solar test bench, maintained by the Energy Systems Laboratory at Texas A&M University, was outfitted with at test box (Figure 3-11, Figure 3-12. The test box measured solar radiation for five conditions using a pyranometer. The data was collected for five stages for the experiment. They were: 1) pyranometer only (calibration), 2) pyronometer with test box, 3) pyranometer with test box and clear 1/8 inch glass, 4) pyranometer with test box, clear 1/8 inch glass and substrate, and 5) pyranometer with test box, clear 1/8 inch glass and substrate with PV film. These are now referred to as PSP^1, PSP^2, PSP^3, PSP^4, and PSP^5 respectively. The data were recorded over an eight-month period and only clear days were selected for analysis.

The desired transmittance for the PV glazing was determined using equations for four cutting methods defined by Iishikawa (1994) (Figure 3-13). Thus, the transmittance, τ, of the PV glazing is determined by a defined relationship between the area of each unit hole, *S,* and the width of photovoltaic area between each hole, *W*, yielding,

$$\tau = \frac{S}{\left(\sqrt{S} + W\right)^2} \tag{3.1}$$

for the square laser cutting method,

$$\tau = \frac{S}{\left(2\sqrt{\frac{S}{\pi}} + W\right)^2} \tag{3.2}$$

for the circular laser cutting method,

$$\tau = \frac{\sqrt{3}S}{9\left(\sqrt{\frac{\sqrt{3}}{9}S} + \frac{W}{2}\right)^2} \tag{3.3}$$

for the triangular laser cutting method, and

$$\tau = \frac{2S}{\sqrt{3}\left(2\sqrt{\frac{\sqrt{3}}{6}S} + W\right)^2} \tag{3.4}$$

for the hexagonal laser cutting method. In this study, the circular laser cutting method was used. Visual anaylis of the prototype PV glazing is shown in Figure 3-14.

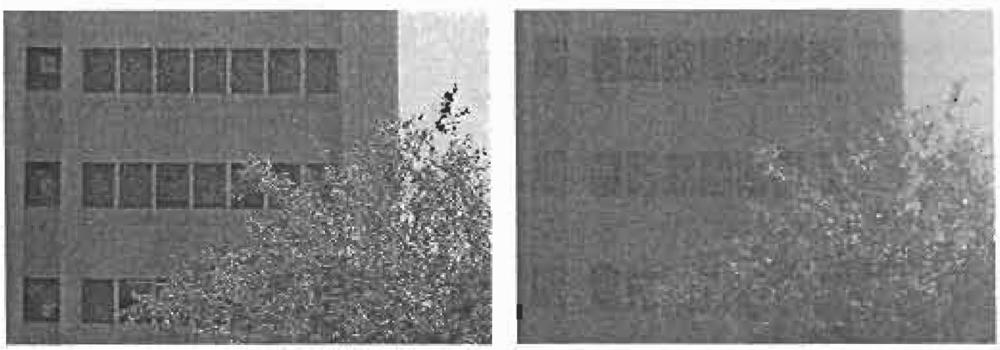


Figure 3-14. Prototype PV Coating.

In the above illustration, the image to the left shows a view through a window with no PV coating while the image to the right shows the same view through a window with the simulated PV coating. The window used in this illustration is a single pane clear ¼ inch glass unit.

3.3.2 Simulated Window Properties

After collecting transmittance data and validating the PV formula for circular laser cut holes, discussed earlier, the results of this experiment were then compared to the results of Fresnel's transmittance equations (Duffie &Beckman, 1991). Additionally, the data were compared against the Window 4.1 software library (LBL, 1997) to determine the window's thermal properties that are required to conduct the energy simulation described later in the dissertation. The next few paragraphs will discuss the formulas used to calculate the transmittance and methods used to simulate the PV window's thermal properties.

In the study, the transmittance of a 1/8-inch clear single pane was determined using equations developed by Fresnel (Duffie and Beckman, 1991). These equations define the reflection of unpolarized radiation that passes from one median with a refractive index of n_1 to another median with a refractive index n_2 (Figure 3-15).

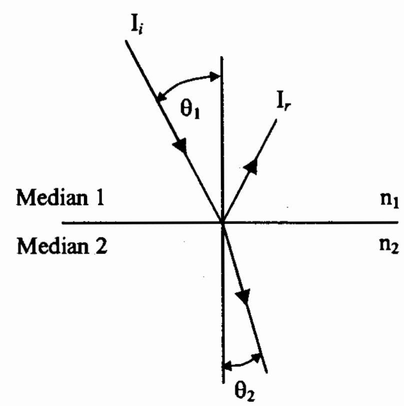


Figure 3-15. Reflection of Radiation.

The illustration shows the angles of incidence and refraction in media with refractive indices n_1 and n_2.

Thus, the angles θ_1 and θ_2 are related to the indices of refraction by Snell's Law,

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} \tag{3.5}$$

where θ_1 is the incident angle and θ_2 is the refraction angle. In this case, the angle of incidence and refractive indices are known. Thus, the perpendicular, $r_\perp$ and the parallel, $r_{\|}$, component of the unpolarized radiation were determined using

$$r_\perp = \frac{\sin^2(\theta_2 - \theta_1)}{\sin^2(\theta_2 + \theta_1)} \tag{3.6}$$

$$r_{\parallel} = \frac{\tan^2(\theta_2 - \theta_1)}{\tan^2(\theta_2 + \theta_1)} \tag{3.7}$$

As stated by Duffie and Beckman (1991), Bouguer's Law assumes that the absorbed radiation is proportional to the local intensity in the medium and the distance the radiation has traveled, thus integrating the actual path length in the medium yields

$$\tau_a = \exp\left(-\frac{KL}{\cos\theta_2}\right) \tag{3.8}$$

Where K is the extinction coefficient and varies from approximately of 4 m^{-1} for white glass to 32 m^{-1} for poor quality glass; L is the thickness of the medium.

Allowing for both the reflection and absorption loses, transmittance of a single cover can be determined using ray-tracing techniques. For the incident unpolarized radiation, the optical properties are found by the average of the two components,

$$\tau = \frac{\tau_a}{2}\left[\frac{1-r_{\perp}}{1+r_{\perp}}\left(\frac{1-r_{\perp}^2}{1-(r_{\perp}\tau_a)^2}\right)+\frac{1-r_{\parallel}}{1+r_{\parallel}}\left(\frac{1-r_{\parallel}^2}{1-(r_{\parallel}\tau_a)^2}\right)\right] \tag{3.9}$$

Further development of the thermal properties of the window was accomplished using Window 4.1 software (LBL, 1997). In this study, three-window types were defined: 1) a ¼ inch clear single pane, a ¼ inch Low-E double-glazed and a ¼ inch PV double-glazed. To account for construction patterns in hot and cold regions, the solar coating for the Low-E and PV glazing was placed on the second and third layers, creating two windows for each type. In the case of the PV window, the PV coating was treated as a complex fenestration[28] within the double glazed system.

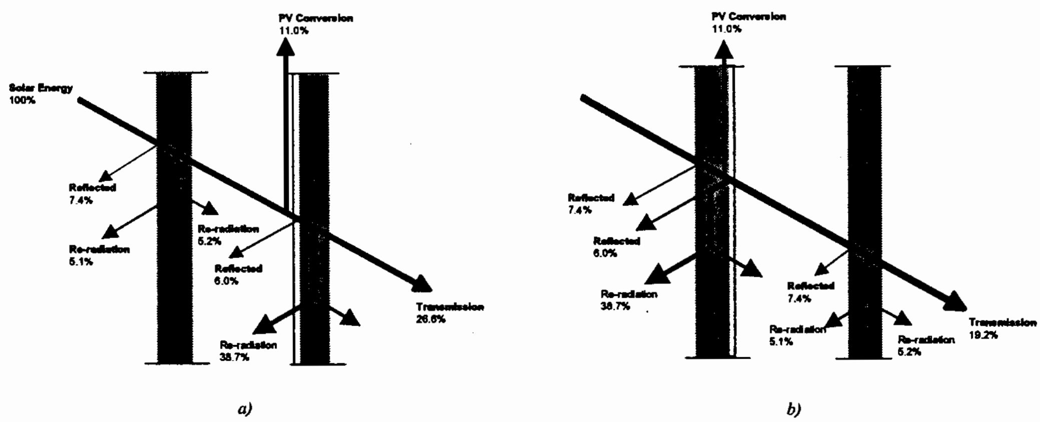


Figure 3-16. Solar Energy Distribution in PV Windows.

The figure shows the solar energy distribution for double-glazed PV Windows in cold and hot climates. The PV Coating has a 40% transmittance and is based on glazing performance of 1/4-inch plate glass (Watson, 1993) and a monocrystalline cells with 15% efficiency at 65 degrees Celsius.

The resistance of the coating was assumed to be zero due to the thickness of the PV material. Thus, only visible and solar transmittances were modified to create the PV module. This will be discussed further in section 3.3.2. The predicted distribution of the solar energy is shown in Figure 3-16.

3.3.3 The Window Library

Fundamental to the DOE-2 energy software, solar transmission coefficients are used to describe the relationship between transmittance of the window and the incidence angle of the sun. In addition to the physical description of the window, the thermal properties such as conductance, spectral properties, emissivity, and the solar

[28] A complex fenestration contains one or more non-spectral optical elements in the glazed area of the window, which affects the window performance based upon its solar heat gain coefficient.

heat gain coefficient are input in the energy software. Using Window 4.1, this study created window library entries for each window type and appended the existing window library file of the energy software. See the Appendix for the window library entries.

3.4 Resource Assessment

To determine the electricity production of the photovoltaic material, the contribution of each façade and the roof was determined independently for each site. The photovoltaic output (kWh) was summed and used to offset the electric energy consumption of the building for each site condition. The following paragraphs discuss the methods used to determine the photovoltaic output, the available building area for photovoltaic application, and the data processing methods.

3.4.1 Building Photovoltaic Area

The area of photovoltaic material for the facades was determined by summing the spandrel area and window area. Due to the semi-transparent nature of the windows, the electricty production of the two-façade elements are calculated separately and then summed. Additionally, the mullions were subtracted from the area of the façade and roof elements to increase the accuracy of the simulated photovoltaic output.

3.4.2 PV F-Chart.

Using PV F-Chart, the type of solar collector and electrical connection was determined. Overall, characteristics of the photovoltaic element were modified for area, location and orientation of the array and were saved as the base file information for all simulations. To vary the site and collector area, which were determined by previous methods, separate input files were developed for each site. The PV F-Chart software produced output for the spandrel, glass, and roof elements for each site. Samples of the input and output files can be found in the appendix.

3.4.3 Shading Adjustment

To account for shaded conditions for each site, DOE 2.1e was used to calculate average monthly shading percent for each façade, which was validated using 3D Studio Max visual simulation software. The DOE 2 values were then used to adjust the photovoltaic output determined previously by the percent of the wall not shaded for a given month. These values were then totaled to acquire annual photovoltaic production for a shaded and unshaded effect as shown in Figure 3-1.

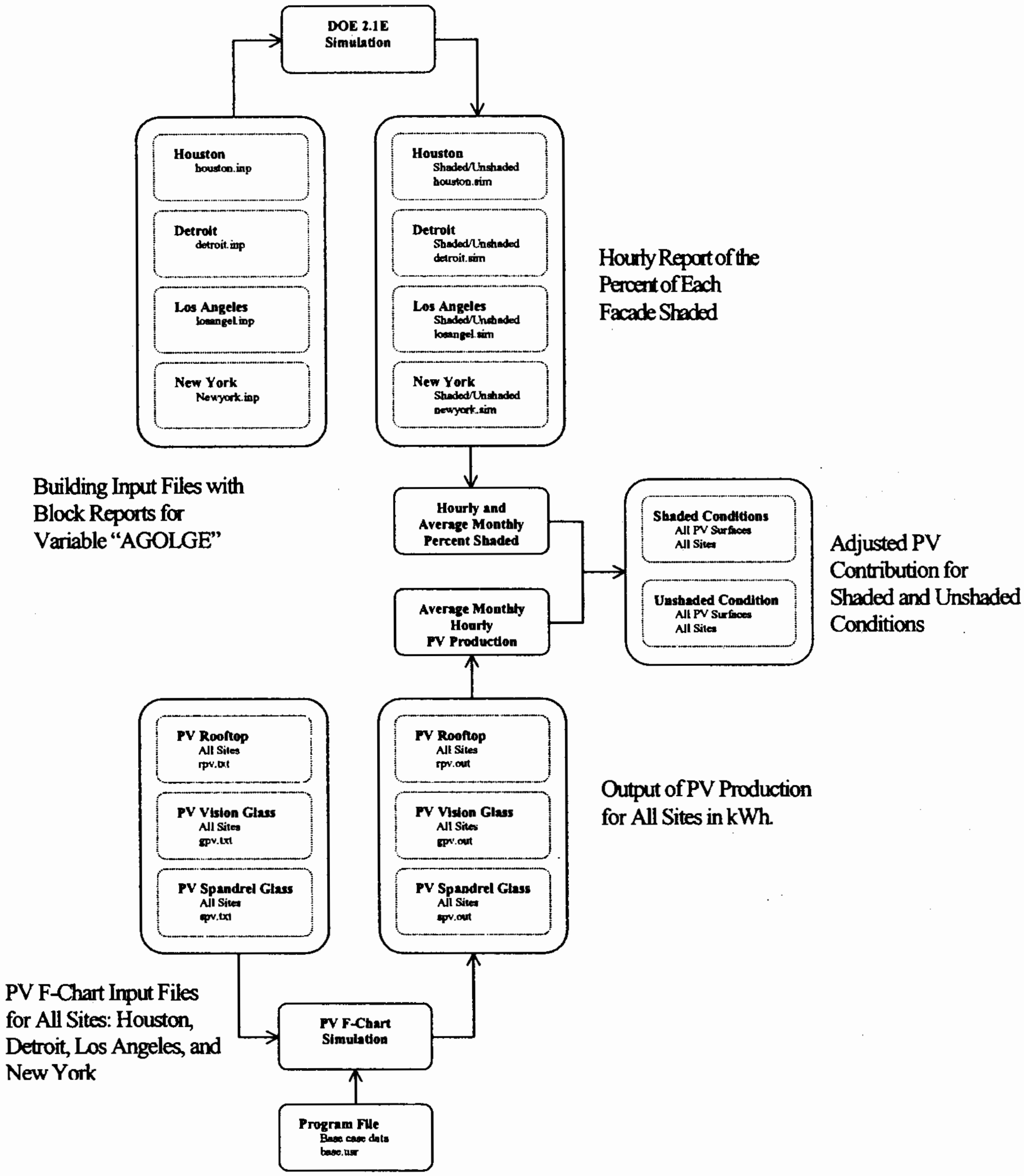


Figure 3-17. Methodology for Resource Assessment

The diagram above shows the data processing method required for the resource assessment in this study. In general, major issues addressed by this method were the development of input files to generate hourly reports from DOE 2.1E and script-input files for PV F-Chart.

3.5 Energy Simulation

As a reference point, the sample2.inp file, distributed with the DOE 2.1e software, was used to develop the input files used in this study. More discussion about the sample input file is in the next section. Before modification, the file was simulated using weather data for Houston, Texas and the output was examined for reliable results. The input file was then modified to increase the building's gross energy intensity to be comparable to those of area cities in Austin, Texas.

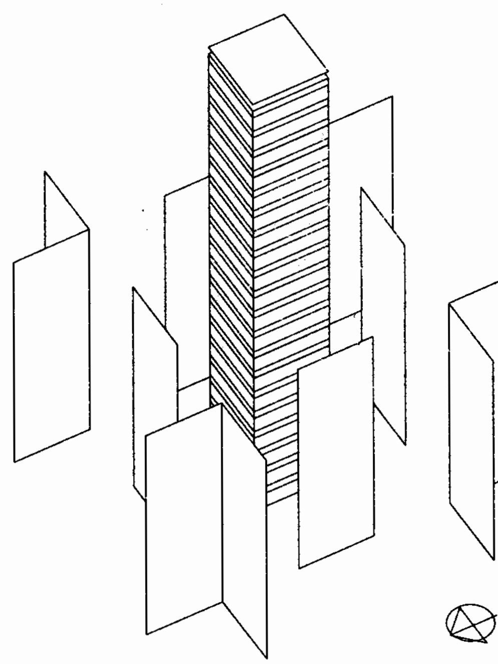


Figure 3-18. Draw BDL Model of Prototype Building.

The figure represents how DOE 2.1E sees the geometry of the building. Due to software constraints which sets limits on the number times a command can be used (LBL, 1993) in an input file, the building input defined the 40 story building using 20 double height floors and ceiling spaces. In addition, the surrounding buildings were defined using only the facades that would affect the shading of the building. In general, corner buildings required the definition of two adjacent facades that were closest to the building while the other buildings, on the North, South, East, and West axis, were only defined with the innermost façade to the center building.

Using the typical city block defined earlier, the input file was again modified using data of the prototype building (Figure 3-18), a national average electric and gas cost, and weather data of the selected sites. Each file used the parametric input command to vary window types and shading conditions. In summary, each file produced outputs for six conditions, which represents shaded and unshaded condition for clear, low-e and photovoltaic glazing.

Last, a window library entry was created for the three window types using Window 4.1 and replaced the existing window library file. Due to the effect of the location of the solar film on the window's performance, two window types were created for the Low E and photovoltaic windows. In total, the file contained five window entries. For the output data, the plant summary (PS-A), building energy performance (BEPS) and energy costs summaries (ES-D) were reported. However, for this analysis, only the BEPS and PS-A reports were plotted and analyzed for all conditions (Figure 3-19). The ES-D reports were tabulated for the economic analysis and will be discussed later.

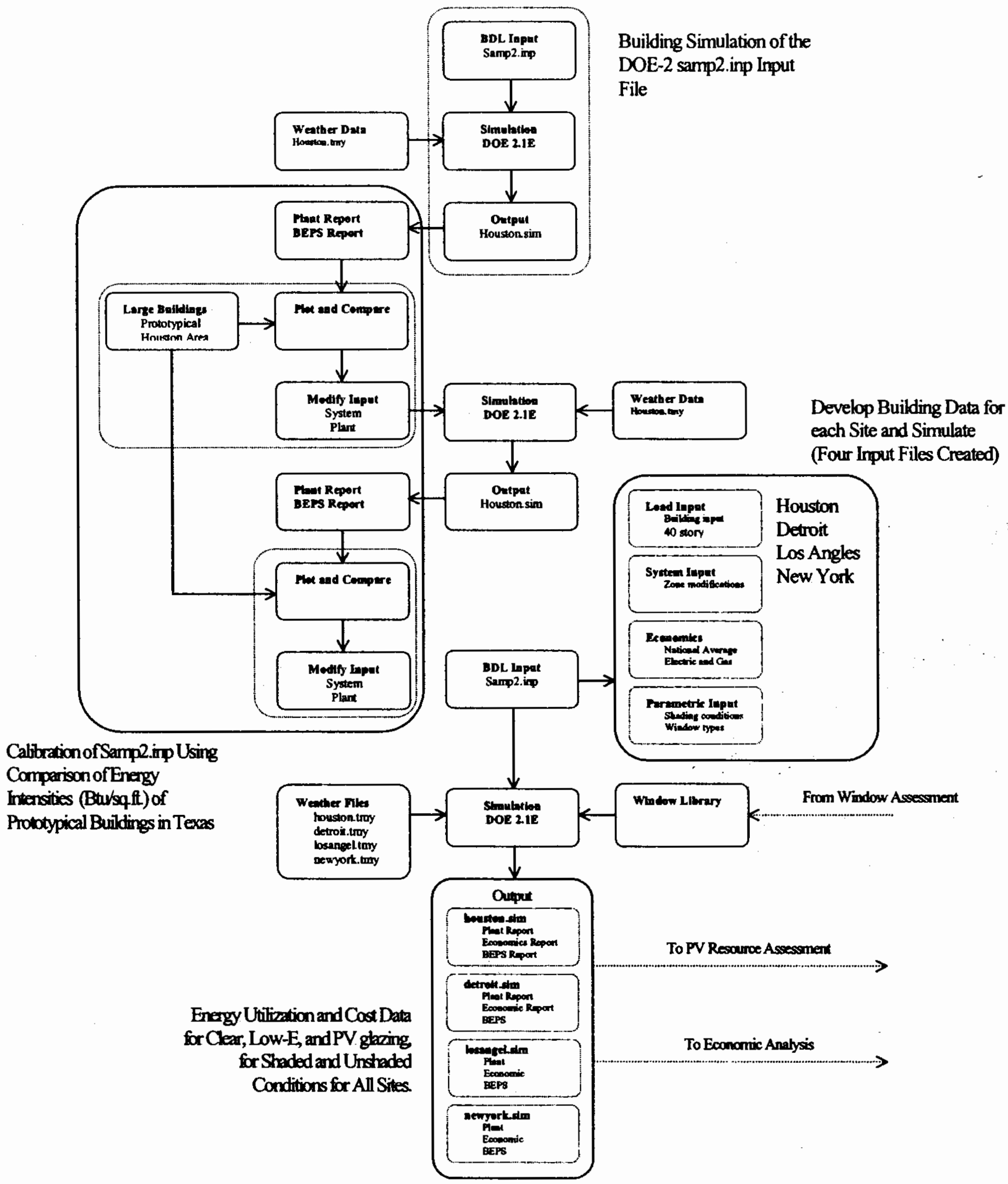


Figure 3-19. Methodology: Energy Analysis.

The figure represents the methods used to conduct the energy analysis in this study. Major components of this part the study are the simulation of the samp2.inp file of DOE-2, the calibration the DOE-2 input file, and the final energy simulation. As shown above, the PV Resource Assessment and the Economic Analysis described ealier used the resulting data.

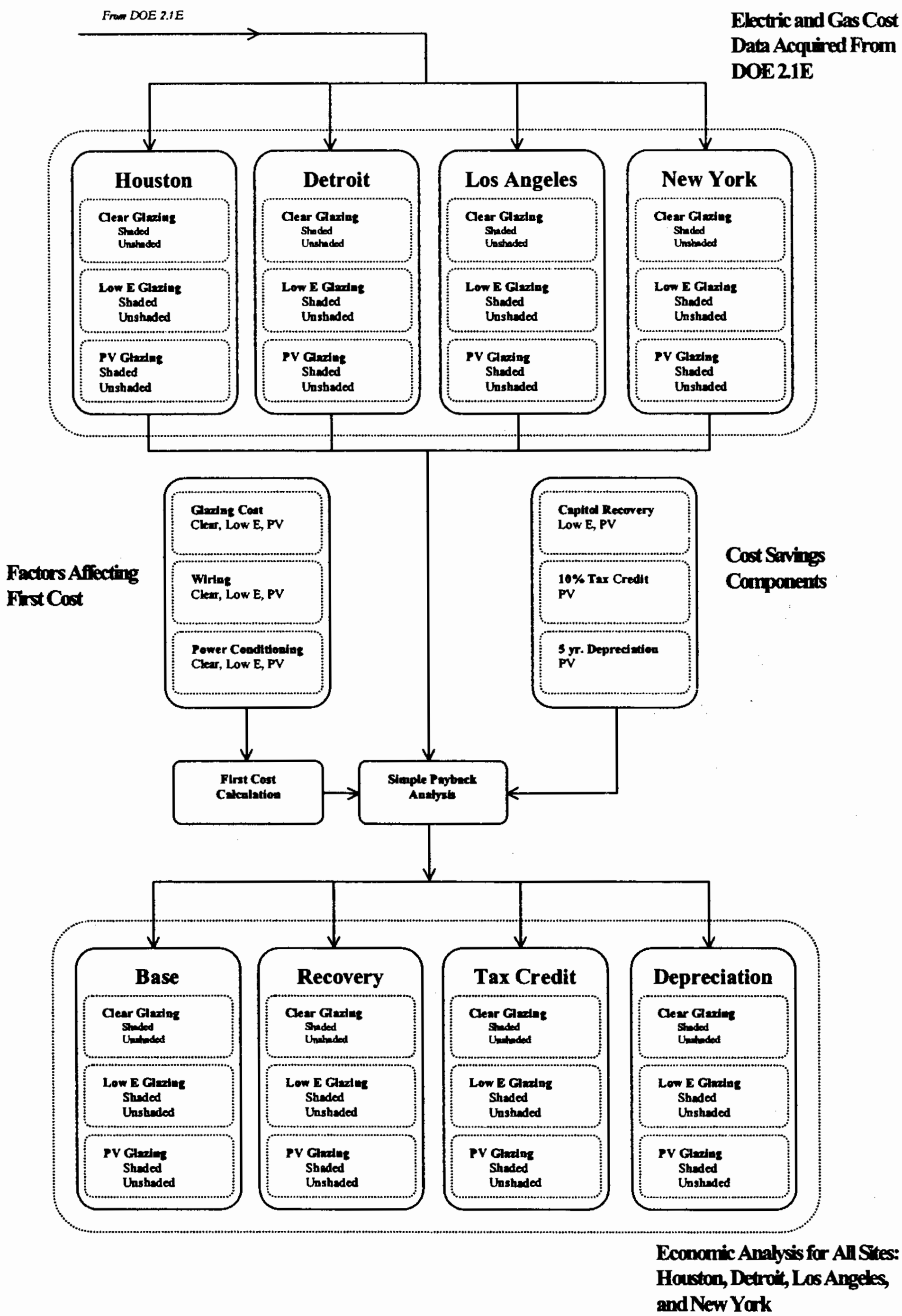


Figure 3-20. Methodology: Economic Analysis

The diagram above shows the data processing method required for the resource assessment in this study. In general, major issues addressed by this method were the development of input files to generate hourly reports from DOE 2.1E and script-input files for PV F-Chart.

3.6 Economics

An economic analysis of the four sites compared the shading effect (effects caused by surrounding buildings) and non-shading effects (effects with no surrounding buildings) and the type of window treatment (single pane clear, Low-E, and photovolataic coatings) using the simple payback method. (Figure 3-20).

Table 3-2. Payback Analysis Scenario

Scenario	*No Capitol Reduction (Clear, Low E, PV)*	*Capitol Reduction (Low E, PV)*	*Capitol Reduction (PV)*	*Capitol Reduction (PV)*
1	Simple payback			
2	Simple payback	chillers		
3	Simple payback	chillers	Investment Tax	
4	Simple payback	chillers	Investment Tax	5-Year Depreciation

Table 3-3. Five-year depreciation schedule

Year	*Deduction*
1	20.00%
2	32.00%
3	19.20%
4	11.52%
5	11.52%
6	5.76%

Using this method, the initial cost of each alternative is the product of the area of window and the cost per square feet. The investment cost of the alternative was then deducted from the base case, which is referred to as investment over the base. Second, the annual costs were determined using energy costs tabulated from the energy costs summary of DOE 2 output and were used to determine the first year annual savings[29]. The payback in years was then calculated by dividing the investment cost by the annual savings (Figure 3-21). Four-payback analyses were as conducted for the four scenarios (Table 3-2). In the case of the photovoltaic glazing, a 5-year depreciation schedule for solar energy property is used in addition to a ten % investment tax credit (Table 3-3).

$$Payback = \frac{SystemCost}{AnnualSavings}$$

$$Annual\ Savings = (Base\ Energy\ Costs) - (Alternative\ Energy\ Costs)$$

Figure 3-21. Simple Payback Analysis

3.7 Summary of Methodology

This study targets commercial buildings with 100% glazing and twenty or more floors. They are simulated on a selected urban site - one within each census region (West, Midwest, South, and Northeast). The selection of the site was limited to those with populations greater than one million people to ensure appropriate characteristics such as the existence of large business districts, downtown development, and significantly large buildings.

An economic analysis of the four sites compared the shading effects caused by surrounding buildings, the non-shading effects which had no surrounding buildings, and the type of window treatment (single pane clear, Low-E, and photovoltaic coatings). The DOE 2.1E program was used to measure the energy consumption of

[29] The first year annual saving is the difference between the base case and the alternative conditions.

commercial buildings. PV F-Chart was used to calculate the electric output of the photovoltaic façade. These data were offset by average hourly monthly shading values calculated by DOE 2.1E and validated using 3D Studio Max software. The window properties of the photovoltaic glazing were simulated using Window 4.1 and validated through experimentation. The economic analysis was performed using simple payback analysis method, which is the investment costs divided by the annual savings.

In the human assessment, the subjects were males and females obtained from a university population with an average age of 20 years. This study was limited to human satisfaction for a window and non-window view in office spaces using PV windows. Measurement of overall satisfaction was accomplished by surveying the individuals after exposure to the simulated environments using a time lapse video for one day. This study used the solar irradiation levels for the summer solstice (June 21) for each census region, as generated by PV F-Chart. A 2 x 4 x 2 factorial analysis of variance analyzed the design[30] and compared the light transmittance of PV glazing and view for the varying solar conditions of each selected site.

[30] Independent variables are window transparency and position. Window transparency is the window treatment at the varying levels of 40% and 100% (clear glass). As a block factor, position will account for the effects of a window view to measure the effect of window transparency and non-window view to measure the effects of visual light transmittance. Dependent variables are human responses to the window treatments and visual light transmittance. Visual light transmittance is dependent upon window transparency. Fixed variables are the office environment, view through the window, window location and size, time of day and sky conditions. This study used solar irradiation levels for the summer solstice (July 21) at solar noon for each selected urban center of each census region. These values will be determined by algorithms that currently exist within visual simulation software.

4 APPLICATION OF THE METHODOLOGY

4.1 Introduction

To review, this study used a typical high-rise building as the subject of this study. In all cases, the data were tabulated or plotted for shaded and unshaded conditions for the four sites selected. The selected sites were Detroit in the Midwest, Houston in the South, Los Angeles in the West, and New York in the Northeast (Figure 4-1). In total, sixteen sets of results were collected for each part of this study.

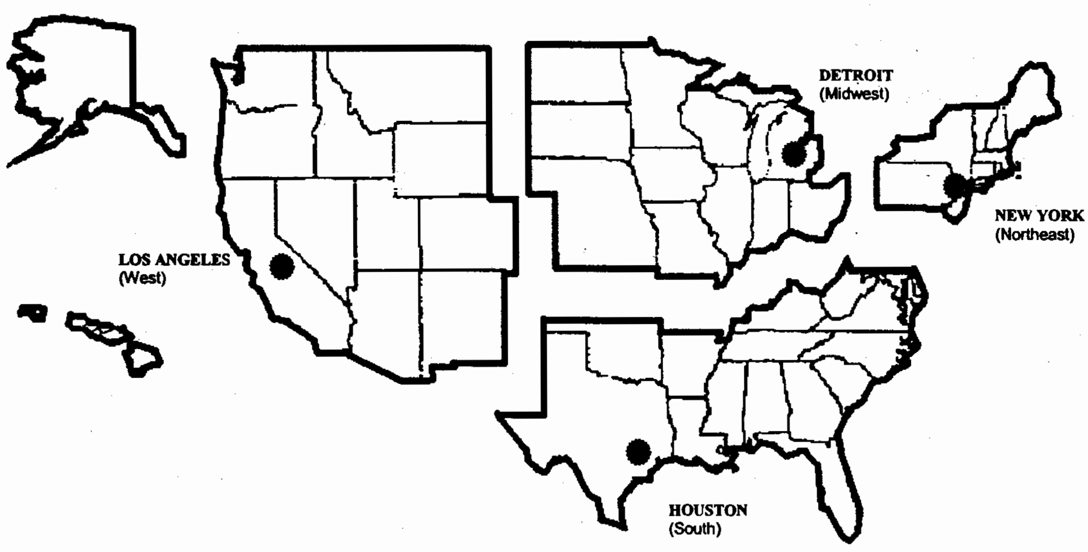


Figure 4-1. Census Regions and Selected Cites

The figure shows the geographic boundaries of the four census regions and selected sites within each region used in this study.

Overall, this section discusses the results of various simulations and experiments presented in the previous section. For clarity, it is divided into the following subsections: 1) human assessment, 2) window properties, 3) resource assessment, 4) simulation and 5) economics.

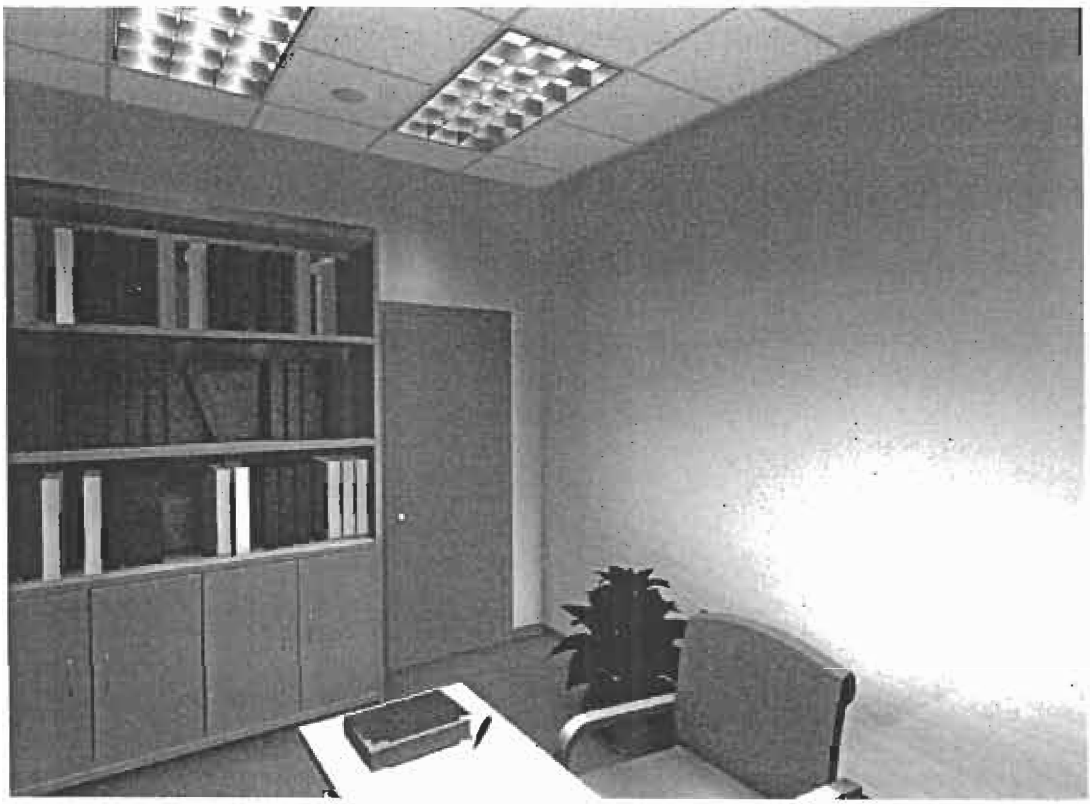


Figure 4-2. Typical Non-Window View

This view represents a non-window view within the typical office space and was taken from a sitting position at the desk.

4.2 Human Assessment

As stated earlier, in this assessment, the subjects were males and females obtained from a university population. 16 test subjects were surveyed in pilot test and 188 test subjects were surveyed in the final experiment. Limited to overall human satisfaction for a window and non-window view in spaces using PV windows, this part of the study used a time-lapse video representing one day to measure the overall satisfaction for a window and non-window view. Specifically, the time lapse video used the solar irradiation levels for the summer solstice (June 21) in each simulation. A 2 x 4 x 2 factorial analysis of variance analyzed the design. Overall satisfaction of the group compared the light transmittance of PV glazing and view for the varying solar conditions. In summary, this section discusses the test apparatus used to present the simulated view, pilot test results and results of the final experiment.

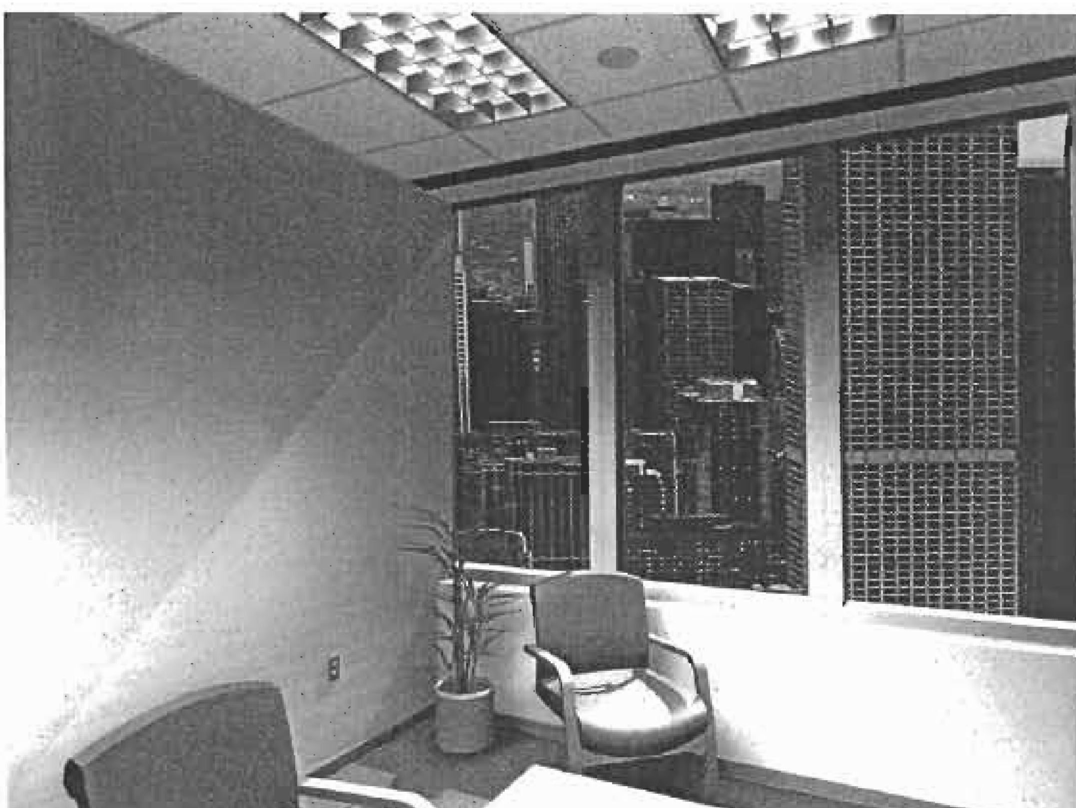


Figure 4-3. Typical Window View

This view represents a window view within the typical office from a sitting position at the desk.

4.2.1 Apparatus

PV F-Chart software was used to determine the average hourly solar energy striking the window. To input these data into the visual simulation software, the highest level of solar insolation was set to the highest light level within the program (255); all other values were scaled according to the relative values. The Appendix provides more data. However, because of the sun's overall intensity in the real world, as compared to artificial light, the exposure of the sun was multiplied by a factor of four in the visual software.

In addition, one interaction level for reflected light was considered using the average reflectance of major horizontal surfaces within the scene (carpet, desk) [31]. In the case of the artificial lights, the recessed fluorescent lamps in the space were always on and were therefore only checked for visual correctness. Once complete, the scene was rendered within the 3D Studio Max software and then recorded to videotape (Figure 4-2, Figure 4-3, Figure 4-4)

[31] Typical office space with windows having 100% and 40% visible light transmissivity was simulated using Kinetix's 3Dstudio Max software. The test apparatus (video) was created using animated targa sequences recorded to tape using SpeedRazor non-linear editing software.

Figure 4-4. Sample from Animated Sequence

The figure represents an animated sequence created for Houston at solar noon on the summer solstice (June 21) from sunrise to sunset. The windows have 100% transmittance. To enhance the simulation, the night lights of the surrouding buildings should be integrated.

4.2.2 Pilot Test Results

As discussed earlier, the pilot tested 16 students who were males and females with an approximate average age of 20 years. In all cases, an analysis of the variance is a repeated measure for within subjects' effects at levels of VIEW, LOCATION, and GLAZING for sixteen treatments as shown in Table 4-1.

Table 4-1. Levels of Repeated Measures

Factors	Y^1	Y^2	Y^3	Y^4	Y^5	Y^6	Y^7	Y^8	Y^9	Y^{10}	Y^{11}	Y^{12}	Y^{13}	Y^{14}	Y^{15}	Y^{16}
Level of View	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Level of Location	1	1	2	2	3	3	4	4	1	1	2	2	3	3	4	4
Level of Glazing	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

The table shows variables y1 through y16 and the matrix of the statistical. VIEW represents the window and non-window view; LOCATION represents the four selected sites; and GLAZING represents the window transmittance.

In this assessment, levels of VIEW represent two blocks of eight conditions for a window and non-window view; levels of LOCATION represent four blocks for the Detroit, Houston, Los Angeles and New York; and levels GLAZING represent the window transmittance, which are 100% and 40%. In addition, the variables y^1 through y^{16} were randomly ordered in this study (Table 4-2).

To test the validity of the simulations, this pilot study surveyed the subjects for general comments about the study, in addition to their window preferences. In all, the responses of the students varied and often times were related to the interior design of the space. Some commented that the space required more activity, sound, desk items and pictures on the wall. Others commented that direct light was preferred over indirect light and that the non-window view was boring or unpleasant because of the absence of direct light. A few responses categorized the changes as insignificant. Overall, the time lapse presentation was well received. See the Appendix for a summary of their comments. In the next few paragraphs, the results of the window assessment are discussed in terms of arousal and pleasure for the pilot study.

Table 4-2. List of Variables

Window View		Non Window View	
Location/View/Glazing	**Y variable**	**Location/View/Glazing**	**Y variable**
H-W-C	Y1	H-NW-C	Y1
H-W-F	Y2	H-NW-F	Y2
D-W-C	Y3	D-NW-C	Y3
D-W-F	Y4	D-NW-F	Y4
L-W-C	Y5	L-NW-C	Y5
L-W-F	Y6	L-NW-F	Y6
N-W-C	Y7	N-NW-C	Y7
N-W-F	Y8	N-NW-F	Y8

The figure shows the variable used in the study to assign and block data. For the location, "H" represents Houston, "D" represents Detroit, "L" represents Los Angeles and "N" represents New York. Next, for the View, "W" represents a window view and "NW" represents a non-window view. In the case of GLAZING, "C" represents clear at 100% and "F" represents 40% transmittance.

As shown in the Table 4-3, a comparison of means for the arousal effect shows a greater mean score of 5.85 for the window view as compared to the score 4.62 for the non-window view. There is also greater mean score of 5.82 for the clear window as compared to the score 4.65 for windows with a 40% transmittance. To interpret these data, a score of 4.5 represents a normal, everyday feeling. A higher score indicates that the subjects were more aroused and a lower score indicates that the subjects were sleepier. These measurements are based on a scale from 1 to 9.

Overall, the subjects were slightly aroused by both views, with the window view having the greater effect.

Table 4-3. Mean Responses for Arousal in Pilot

AROUSAL

	Window View						**Non Window View**				
	Houston	Detroit	Los Angeles	New York	*Mean*		Houston	Detroit	Los Angeles	New York	*Mean*
100	6.00	6.88	6.19	6.69	6.44	100	5.25	5.00	5.94	4.63	5.20
40	4.56	5.25	5.81	5.44	5.27	40	3.88	4.56	3.63	4.06	4.03
					5.85						4.62

Overall Mean: 5.23

In agreement with the mean responses, an analysis of variance[32] shows that the factor VIEW and GLAZING are significantly different. However, this cannot be interpreted as a negative effect because of the relatively small differences in the mean responses. This simply indicates that the students prefer window views and clear windows.

In addition, the F statistic shows no significant difference among the LOCATION means (Table 4-4). Concerning interaction, the ANOVA analysis indicates that no significant level of interaction exists between LOCATION and GLAZING. A comparison between VIEW and GLAZING shows a low level of interaction, while a comparison between VIEW, LOCATION, and GLAZING shows

[32] The analysis of variance (ANOVA) was conducted using SAS statistical software.

the highest level of interaction. That is, VIEW is creating different levels of effect at different levels of transmittance for LOCATION and GLAZING.

Table 4-4. ANOVA for Arousal in Pilot

Source	DF	Anova SS	Mean Square	F Value	Pr > F
View	1	92.820	92.820	8.240	0.064
Location	3	2.648	0.883	0.330	0.804
Glazing	1	21.945	21.945	4.240	0.132
View *Location	3	6.086	2.029	4.860	0.028
View*Glazing	1	5.695	5.695	1.680	0.286
Location*Glazing	3	3.211	1.070	0.560	0.657
View*Location*Glazing	3	16.961	5.654	3.250	0.074

The analysis of variance procedure is a repeated measure that uses a univariate test of hypotheses for within subject effects. There were 16 subjects used in this pilot analysis. In the table, source is the factor. The Degrees of Freedom (DF) is the estimate of variance using the standard deviations in the sample size. The ANOVA Sums of Squares is a measure of the variably of the sample measurements about their means. The Mean Square is the Sums of Squares divided of the Degrees of Freedom. The F value is the test statistic. If the null hypothesis is true, then all means are not significantly different and the F value would be near one. When the hypothesis is false, the F value is larger than 1, due to significant differences among the population means. The last column shows the probability of F value (Pr>F).

The results of the pilot study for the arousal effect show a linear relationship between the window view and non-window view, which are in agreement with Russell and Pratt (1989). Specifically, a plot of the effect of transmission against the view shows no interaction and shows that changes in response for the window treatments are directly proportional (Figure 4-5).

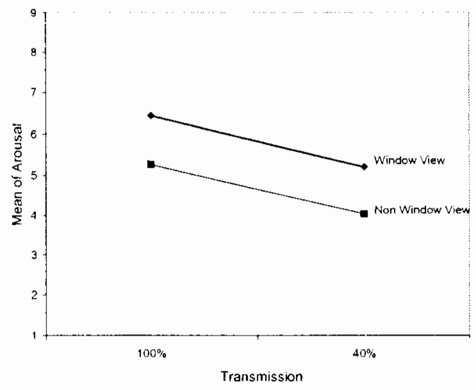


Figure 4-5. Arousal Interaction Plot

The illustration shows an interaction plot for VIEW vs. GLAZING. Human preferences for a window and non-window view are parallel and indicate that a linear relation exists when the transmittance is varied. That is, the higher the window transmittance, the more people prefer them.

In the case of the pleasure effect, a comparison of means shows that there is a greater mean score of 5.94 for the window view as compared to a score of 5.30 for the non-window view (Table 4-5). There is also a greater mean score of 6.16 for the clear window as compared to a score of 5.09 for the window with 40% transmittance. Like that of arousal, the subjects were slightly pleased by the views and the window view had the greater effect than the non-window view. Also, the subjects were slightly more pleased by the spaces using PV glazing.

Table 4-5. Mean Responses for Pleasure in Pilot

PLEASURE

	Window View						**Non Window View**				
	Houston	Detroit	Los Angeles	New York	*Mean*		Houston	Detroit	Los Angeles	New York	*Mean*
100	6.75	6.13	6.50	6.25	6.41	100	5.81	5.69	5.88	6.25	5.91
40	5.44	5.56	5.50	5.38	5.47	40	4.44	5.06	4.81	4.50	4.70
					5.94						5.30

Overall Mean: 5.62

Table 4-6. ANOVA for Pleasure in Pilot

Source	DF	Anova SS	Mean Square	F Value	Pr > F
View	1	4.88	4.88	0.52	0.51
Location	3	2.46	0.82	0.47	0.71
Glazing	1	61.88	61.88	88.01	0.00
View * Location	3	16.27	5.42	2.68	0.09
View * Glazing	1	6.57	6.57	1.14	0.35
Location * Glazing	3	0.15	0.05	0.02	1.00
View * Location * Glazing	3	4.09	1.36	0.73	0.55

The analysis of variance procedure is a repeated measure that uses a univariate test of hypotheses for within subject effects. There were 16 subjects used in this pilot analysis. In the table, source is the factor. The Degrees of Freedom (DF) is the estimate of variance using the standard deviations in the sample size. The ANOVA Sums of Squares is a measure of the variably of the sample measurements about their means. The Mean Square is the Sums of Squares divided of the Degrees of Freedom. The F value is the test statistic. If the null hypothesis is true, then all means are not significantly different and the F value would be near one. When the hypothesis is false, the F value is larger than 1, due to significant differences among the population means. The last column shows the probability of F value (Pr>F).

When plotting the data, the effect of GLAZING indicates that there is some interaction (Figure 4-6). Specifically, the treatment means varied more for windows at 40% transmittance as compared to those at 100% transmittance. As indicated by the analysis of variance, a comparison of VIEW and LOCATION shows no interaction. Likewise, a test for interaction between LOCATION and GLAZING indicates that there are no varying effects of LOCATION at different levels of GLAZING. Also a comparison between VIEW, LOCATION, and GLAZING shows that there a no varying effects for VIEW at various levels of LOCATION and GLAZING. However, in the case of VIEW and GLAZING, the data indicate that VIEW has different effects on response at different levels of GLAZING. Although the analysis of variance indicates that the treatment means for LOCATION and View are not significantly different, those for GLAZING are (Table 4-6).

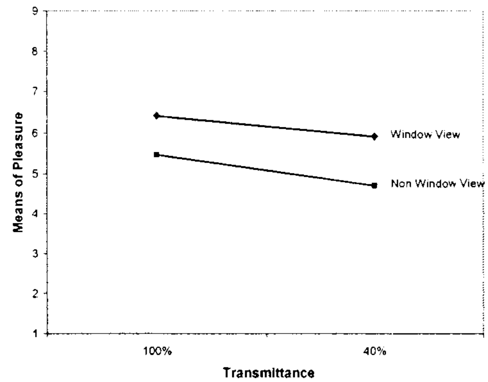


Figure 4-6. Pleasure Interaction Plot for View vs. Transmission

In the figure, a test for interaction is conducted for the View and Glazing effect. The diagram shows that minor effects of View exist at different levels of Glazing.,

4.2.3 Final Experimental Results

Testing 188 students this part of the study modified the Affect Grid to accommodate electronic scanning using the Department of Measurement and Research Services of Texas A&M University. The ANOVA results of this experiment are presented in Table 4-8 and Table 4-10.

In this final experiment, unlike the pilot study, the F statistic indicates a significant difference in the treatment means for all factors – VIEW, LOCATION, and GLAZING. Specifically, LOCATION has the least mean variance, while GLAZING has an extremely high variance, indicating extreme reactions of subjects to the window's transparency. In addition, unlike the pilot results, the test for interaction shows that the effects of VIEW vary slightly at different levels of

LOCATION. In addition, interactions are being detected for a comparison of LOCATION and GLAZING and for a comparison of VIEW, LOCATION, and GLAZING.

Table 4-7. Means Response for Arousal

AROUSAL

	Window View						Non Window View				
	Houston	Detroit	Los Angeles	New York	*Mean*		Houston	Detroit	Los Angeles	New York	*Mean*
100	5.05	6.72	5.78	6.77	6.08	100	6.13	4.98	6.35	5.47	5.73
40	2.58	4.79	5.41	5.00	4.45	40	3.17	4.41	4.10	3.22	3.73
					5.26						4.73

Overall Mean: 5.00

The table contains mean data for the various views, locations, and glazing type.

Table 4-8. ANOVA for Arousal

Source	DF	Anova SS	Mean Square	F Value	Pr > F
View	1	221.01	221.01	64.59	0.0001
Location	3	267.11	89.04	35.46	0.0001
Glazing	1	1127.31	1127.31	309.76	0.0001
View *Location	3	130.90	43.63	14.84	0.0001
View*Glazing	1	4.38	4.38	1.59	0.2110
Location*Glazing	3	133.47	44.49	15.35	0.0001
View*Location*Transmittance	3	177.90	59.30	20.72	0.0001

The analysis of variance procedure is a repeated measure that uses a univariate test of hypotheses for within subject effects. There were 188 subjects used in this pilot analysis. In the table, source is the factor. The Degrees of Freedom (DF) is the estimate of variance using the standard deviations in the sample size. The ANOVA Sums of Squares is a measure of the variably of the sample measurements about their means. The Mean Square is the Sums of Squares divided of the Degrees of Freedom. The F value is the test statistic. If the null hypothesis is true, then all means are not significantly different and the F value would be near one. When the hypothesis is false, the F value is larger than 1, due to significant differences among the population means. The last column shows the probability of F value (Pr>F).

As shown in the Table 4-7, a comparison of means for the arousal effect shows a greater mean score of 5.26 for the window view as compared to the score 4.73 for the non-window view. There is also greater mean score of 5.90 for the clear window as compared to the score 4.09 for windows with a 40% transmittance. Like the pilot test, the subjects were slightly aroused by the window views, but the were slightly tired by the non-window views. In agreement with the mean responses, an analysis of variance[33] shows that the mean scores for GLAZING are significantly different. Furthermore, the ANOVA shows that there is no interaction between VIEW and LOCATION. That is, there are no effects of VIEW being detected at different levels of LOCATION.

Table 4-9. Means Response for Pleasure

PLEASURE

	Window View						**Non Window View**				
	Houston	Detroit	Los Angeles	New York	*Mean*		Houston	Detroit	Los Angeles	New York	*Mean*
100	6.19	6.51	5.64	5.97	6.08	100	5.49	5.63	4.9	5.7	5.43
40	4.6	6.14	6.15	6.09	5.74	40	4.27	5.1	5.18	4.36	4.73
					5.91						5.08

Overall Mean: 5.5

The table contains mean data for the various views, locations, and glazing type.

In the case of the pleasure effect, as shown in the Table 4-9, a comparison of means for the arousal effect shows a greater mean score of 5.91 for the window view as compared to the score 5.08 for the non-window view. There is also greater mean score of 5.76 for clear windows as compared to the score 5.24 for windows with a

[33] The analysis of variance (ANOVA) was conducted using SAS statistical software.

40% transmittance. Like the pilot test, the subjects were slightly please by the window views and non-window views, with the window view having the greater effect. In agreement with the mean responses, an analysis of variance[34] indicates that there is no significant difference in treatment means for factors of LOCATION and GLAZING, while a significant difference has been detected for the factor VIEW (Table 4-10). When testing for interaction, the results show all levels are interacting with each other.

Table 4-10. ANOVA for Pleasure

Source	DF	Anova SS	Mean Square	F Value	Pr > F
View	1	191.36	191.36	56.64	0.0001
Location	3	35.83	11.94	3.07	0.0287
Glazing	1	76.08	76.08	7.39	0.0082
View *Location	3	9.57	3.19	0.91	0.4384
View*Glazing	1	77.05	77.05	26.61	0.0001
Location*Glazing	3	126.23	42.08	10.68	0.0001
View*Location*Transmittance	3	128.48	42.83	15.43	0.0001

The analysis of variance procedure is a repeated measure that uses a univariate test of hypotheses for within subject effects. There were 188 subjects used in this pilot analysis. In the table, source is the factor. The Degrees of Freedom (DF) is the estimate of variance using the standard deviations in the sample size. The ANOVA Sums of Squares is a measure of the variably of the sample measurements about their means. The Mean Square is the Sums of Squares divided of the Degrees of Freedom. The F value is the test statistic. If the null hypothesis is true, then all means are not significantly different and the F value would be near one. When the hypothesis is false, the F value is larger than 1, due to significant differences among the population means. The last column shows the probability of F value (Pr>F).

Overall, the results of the final study show that students prefer clear windows to those with a lower transmittance. Although there are significant differences in the mean responses for the varying window types, the subjects were only slightly

[34] The analysis of variance (ANOVA) was conducted using SAS statistical software.

aroused and pleased as indicated in the overall mean scores. Thus, the windows with a 40% transmittance are not perceived to create negative effects.

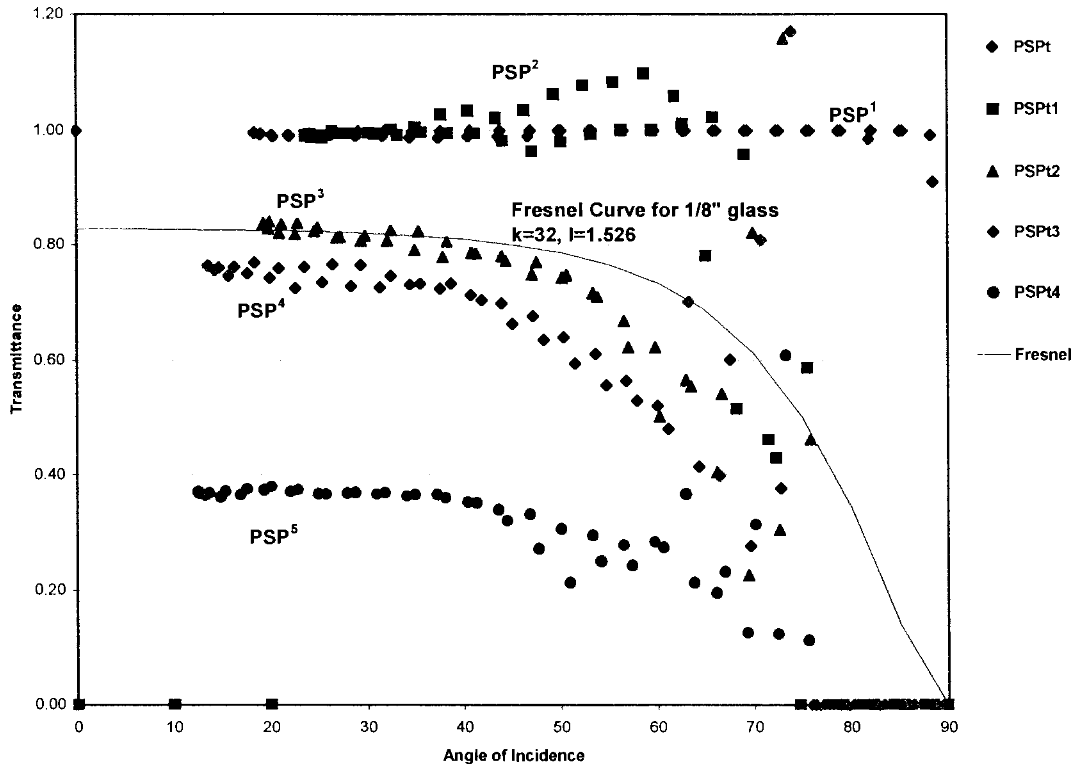


Figure 4-7. Transmittance vs. Incident Angle: Experimental

PSP[1] is the measure with no box.
PSP[2] is the measure with the box added to the test bench.
PSP[3] is the measure with the glass and frame added the box.
PSP[4] is the measure with the transparent film added to the glass
PSP[5] is the measure with the PV added to the transparent film.

4.3 Window Properties

In this study, experimental methods were used to validate the transmittance of the PV glazed window. Computer software was used to simulate the thermal properties of the PV window for use by the energy analysis software. Because Low-

E and clear glazed window systems are commonly used, this part of the study focuses on the development of the PV window properties. Using Ishikawa's formula described earlier in the methodology, a prototype material was developed with a transmittance of 42%. In the prototype, the openings that transmit light through the window have a radius of 0.45 mm and the width between each hole was 0.32 mm. The prototype PV glazing, developed on a computer, was printed on transparent film and placed on the test bench. In the next paragraphs, the results of the window experiments and the thermal simulations of the prototype glazing.

4.3.1 Test Box Experiment

As shown in Figure 4-7, the plot compares the transmittance and the incidence angles of the sun for an entire day. PSP^1 is the measured solar radiation with no test box or glass material. When adding the box in PSP^2, the transmittance is significantly reduced at incident angles below 65 degrees. Consequently, the transmittances of all subsequent experiments using the box were affected. Other Abnormal fluctuations in the readings are attributed to the worn condition of the PSP sensor.

In the curve labeled PSP^3, which uses 1/8" glass, the measurements are plotted against a Fresnel curve for a similar piece of glass. The Fresnel equation for 1/8 inch glass shows a good fit with the experimental data of PSP^3. However, a comparison of the two conditions show that the test box begins to affects the transmittance at angles above 30 degrees with a complete drop-off of the data at angles 75 degrees.

In the case of the PSP[5], when testing the prototype glazing, the data showed a 37% reduction in transmittance. After eliminating the effect of the transparent film[35], the adjusted reduction becomes 44% at a zero degree incidence angle. In summary, the adjusted transmittance of the PV glazing (44%), shows a good agreement with the calculation from Ishikawa's formula for circular holes, which was 42%.

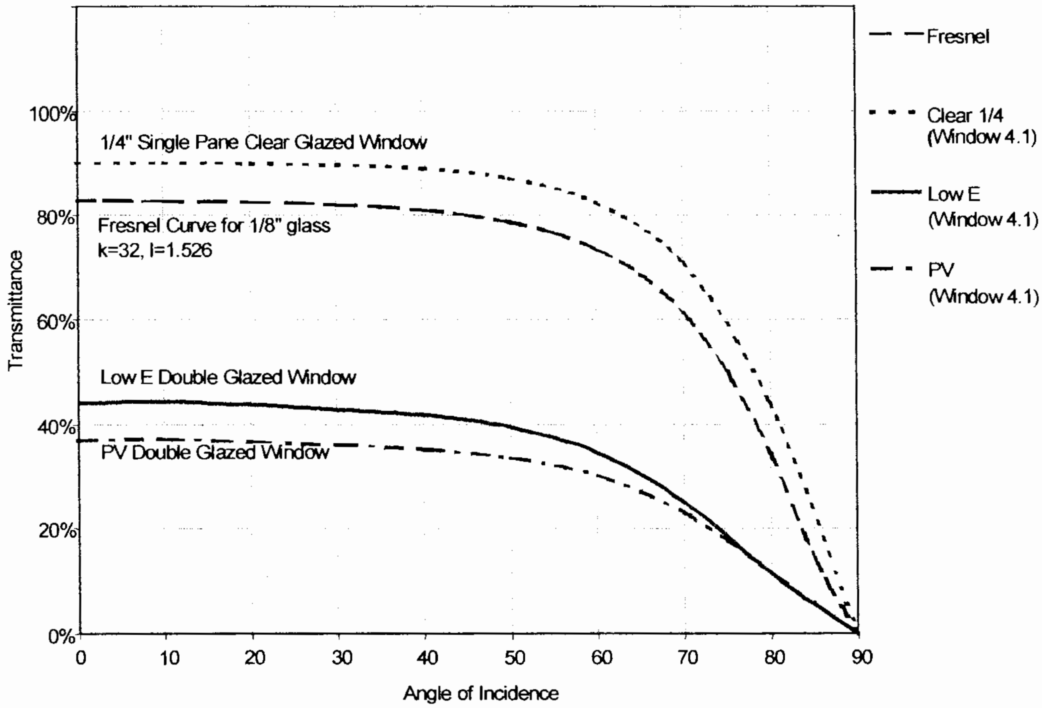


Figure 4-8 Transmittance vs. Angle of Incidence: Simulated

The diagram shows a plot of transmittance against the incident angle of the sun for the five window types created within Window 4.1. As a point of reference, a Fresnel curve for a 1/8 inch pane of glass is also shown.

---

[35] The effect of the transparent film is the difference between PSP3 and PSP4.

4.3.2 Simulation Using Window 4.1 Software

Using the Window 4.1 software, clear single pane glazing, Low-E double glazed and PV double glazed windows were evaluated. For the clear single pane and Low-E glazing, standard window types were chosen from the glazing library of the window software. To simulate the effect of the PV glazing, a double glazed window was constructed using 1/4" clear glazing. Furthermore, a transmittance of 40% was applied to the second layer and third layer for windows that were used in hot and cold climates respectively (Table 4-11). The window properties were then calculated and saved for input into the DOE-2 window library.

In summary, a plot comparing the transmittance and the angle of incidence for the simulated and experimental data is shown in Figure 4-8. Overall, the figure shows the transmittance of the ¼ " single pane clear glass at a zero incident angle to be 95%. The Low-E transmittance is 45% and the PV glazing is 37%.

It is important to restate that the clear and Low-E glazings simulated within the Window 4.1 software were created using predefined values contained in the glazing library of the software.

Table 4-11 Window Glazing Variables

Glazing Type	*Name*	*D(in)*	*Tsol*	*Rsol*		*Tvis*	*Rvis*		*Tir*	*Emissivity*		*Keff*
				1	2		1	2		1	2	
Clear	Clear	0.236	0.775	0.071	0.071	0.881	0.08	0.08	0	0.84	0.84	0.52
Low-E [c]	Clear	0.236	0.775	0.071	0.071	0.881	0.08	0.08	0	0.84	0.84	0.52
	Air	0.5										0.037
	Low-E tint	0.236	0.36	0.093	0.2	0.5	0.035	0.054	0	0.84	0.1	0.52
Low-E [h]	Low-E tint	0.236	0.36	0.093	0.2	0.5	0.035	0.054	0	0.84	0.1	0.52
	Air	0.5										0.019
	Clear	0.236	0.775	0.071	0.071	0.881	0.08	0.08	0	0.84	0.84	0.52
PV [c]	Clear	0.236	0.775	0.071	0.071	0.881	0.08	0.08	0	0.84	0.84	0.52
	Air	0.5										0.028
	PV Layer	0.236	0.4	0.6	0.071	0.4	0.6	0.08	0	0.4	0.84	0.52
PV [h]	PV Layer	0.236	0.4	0.071	0.6	0.4	0.08	0.6	0	0.84	0.4	0.52
	Air	0.5										0.028
	Clear	0.236	0.775	0.071	0.071	0.881	0.08	0.08	0	0.84	0.84	0.52

[c] Window design for cold climates.
[h] Window Design for hot climates.
D is the glazing layer-thickness in meters.
Tsol is the solar transmittance percentage.
Rsol is the solar reflectance percentage of the front and back (outward and inward) surfaces.
Tvis is the visible transmittance percentage.
Rvis is the visible reflectance percentage of the front and back (outward and inward) surfaces.
Tir is the hemispherical thermal-infrared transmittance.
Emissivity is the hemispherical thermal-infrared emittance of the front and back (outward and inward) surfaces.
Keff is the thermal conductivity.

4.4 Resource Assessment

This section presents the results of the electricity production of the PV material and the effects of shading on the PV production. In addition, the shading reports that were output from the DOE-2 program, hourly reports of the percent of the wall that is shaded and the results of the PV F-Chart simulation are also discussed.

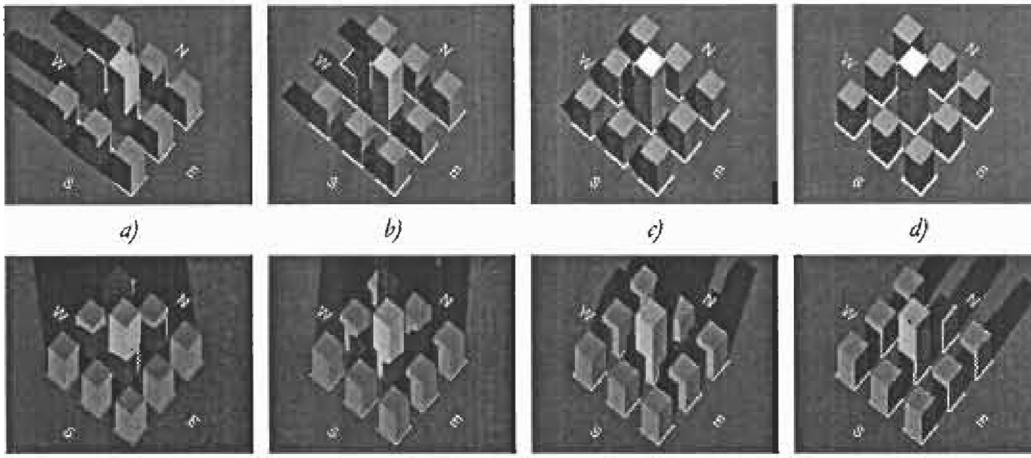


Figure 4-9. Shading Validation of PV Façade

The diagram compares the simulated shading results of 3D Studio Max software for the summer solstice (June 21) and winter solstice (December 21) in Houston, Texas. The top row shows the morning hours for the summer solstice at: a) 9:00 a.m., b) 10:00 a.m., c) 11:00a.m and d) 12:00 noon, and the bottom row shows the winter solstice at the similar times.

Table 4-12. Hourly Percent Shading Values

Solstice	*9:00*		*10:00*		*11:00*		*12:00*	
	South	*East*	*South*	*East*	*South*	*East*	*South*	*East*
Summer	—	0.33	—	0.28	—	0.12	—	—
Winter	0.41	0.31	0.30	0.34	0.20	0.27	0.29	—

The diagram shows the hourly values for the percent of the wall shaded for the summer and winter Solstice in Houston, Texas. Those portions of the table without a shading value indicate that the façade was not receiving direct solar radiation at that time.

4.4.1 Determining the Shading Effect

To validate the average monthly shaded data obtained from DOE-2, this study used simulated visual observations created with 3D Studio Max software for the winter (December 21) and summer (June 21) solstice. In general, the images show that the south façade receives the most direct sunlight during the winter and the least sunlight during the summer. For the east and west facades the shading is relatively the same for the winter and summer solstice. Thus, a comparison between the images in Figure 4-9 and values in Table 4-12 show an agreement between the DOE-2 hourly report values for the north and east facades and the visual simulations.

4.4.2 DOE-2 Hourly Report for the Shaded Percent

For this experiment, all the glass material was considered including spandrel glass areas. To account for the shading effects of the surrounding buildings, an hourly report-block for the variable type AGOLGE was used in the DOE-2 input file. This variable, when used in the HOURLY-REPORT of LOADS, calculated the hourly shaded percent and the average monthly shading for each exterior wall for one year. Within DOE-2 each façade was divided into forty equal segments using the SHADING-DIVISIONS command in the input file. Overall, an input file representing a simple description of the building's shape was used to simulate each site for the South, East and West facades and the roof. See Appendix.

Figure 4-10, Figure 4-11, Figure 4-12, and Figure 4-13 show the shading percentage of each façade. For the first half of the year, all months from January and June are labeled and plotted using solid lines. For the second half of the year, all months from July and December are labeled and plotted using dashed lines. In review, the South façade had a higher shading percent and was shaded for longer periods of time during the winter months when the solar altitude angle is smallest. Also visible in the data are shading reductions cause by the roadways between the buildings which are mostly visible during the winter months. On the other hand, it is important to note that no shading occurs during the months of May, June, July and August due to the high solar altitude of the sun.

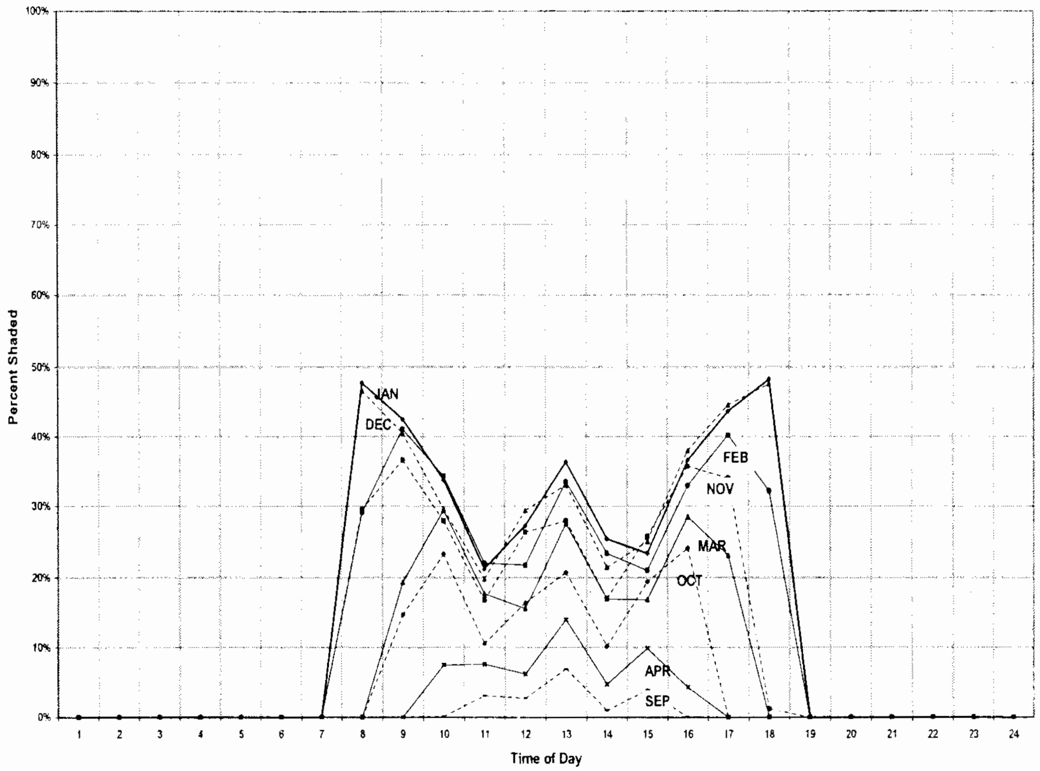


Figure 4-10. Percent Hourly Shading of South Façade for Houston

The diagram above shows the hourly percent shading value for a year. In the diagram, January has the highest peak shading of 47% at 7:30 AM and September has the lowest. For the months from May through August, there is no shading of the south façade caused by direct sunlight.

Figure 4-11 shows that shadowing of the north facade occurs only for the months of June, July and August for early morning and late evening hours. During these months, the solar altitude angle is at its highest.

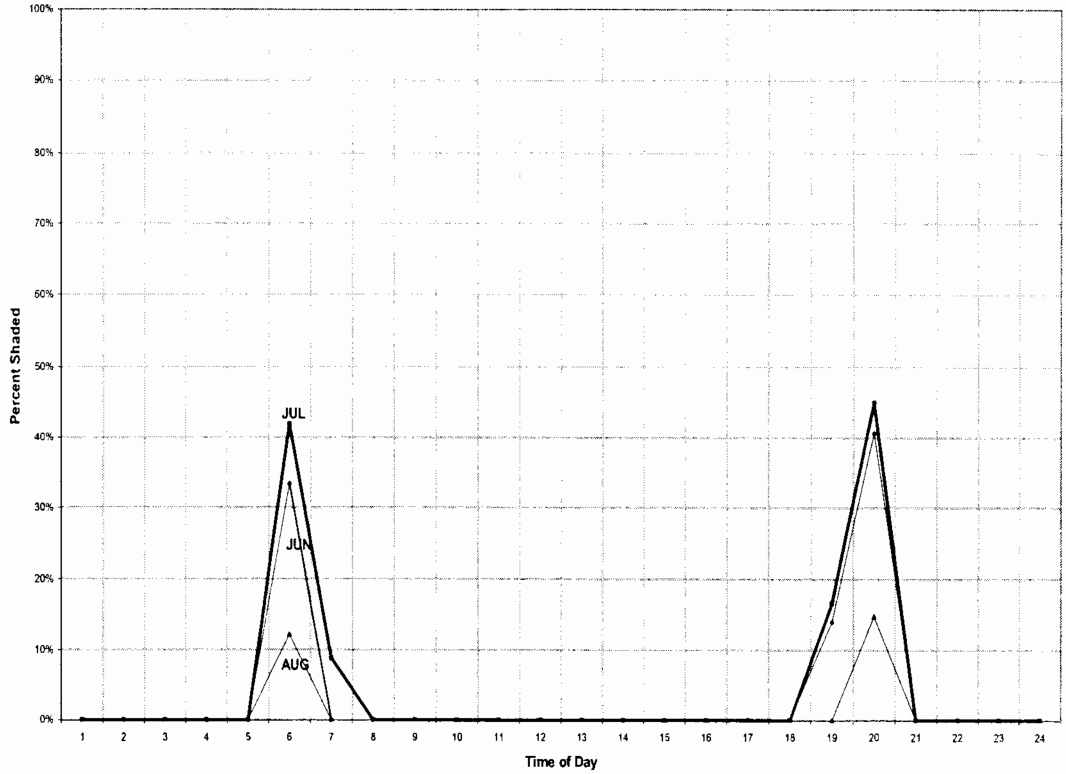


Figure 4-11. Percent Hourly Shading of North Façade for Houston

The diagram above shows the hourly percent shading value for one year. In the diagram, July has the highest peak shading of 42% at 6:30 AM and August at 13% has the lowest. For the months from January through May and September through December, there direct sunlight striking the North facade.

For the east and west façade, the maximum shading occurs during the months of September and April and then slowly reduces. The shading for these facades is very sensitive to the length of the day (Figure 4-12 and Figure 4-13). Likewise, the sun passes the east facade between noon and 1:00 p.m. and begins to affect the west facade between 1:00 and 2:00p.m.

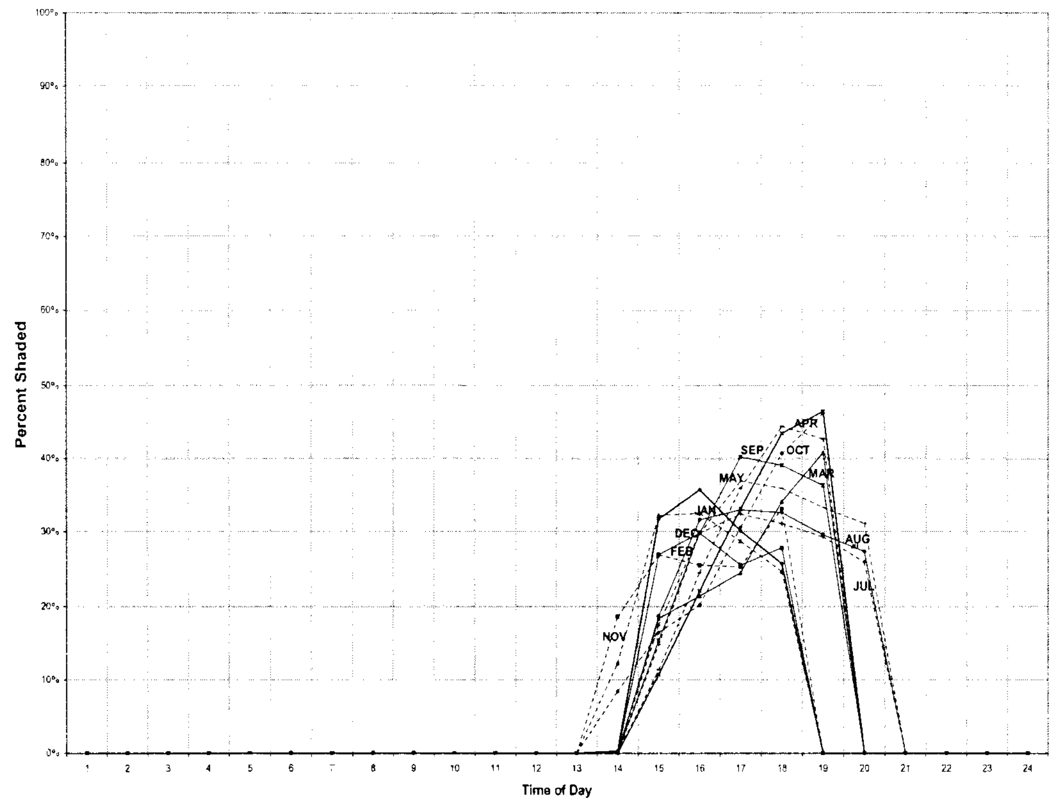


Figure 4-12. Percent Hourly Shading of West Façade for Houston

The diagram above shows the hourly percent shading value for one year. In the diagram, April has the highest peak shading of 45% of the west facade at 7:30 PM and July has the lowest. There is minimum shading percent of 35% for the entire year.

In summary, when looking at the average monthly performance of each facade, the shading behavior of the buildings becomes evident (Figure 4-14). For the south facade, the average monthly shading of the wall decreases from winter to spring and increases from fall to winter. Additionally, there is no shading during summer due to the high incidence angles of the sun. The east and west facade shading remains constant for the entire year. Due to the orientation the North facade, it receives little direct light and subsequently has minimal annual shading, which occurs only during the summer months.

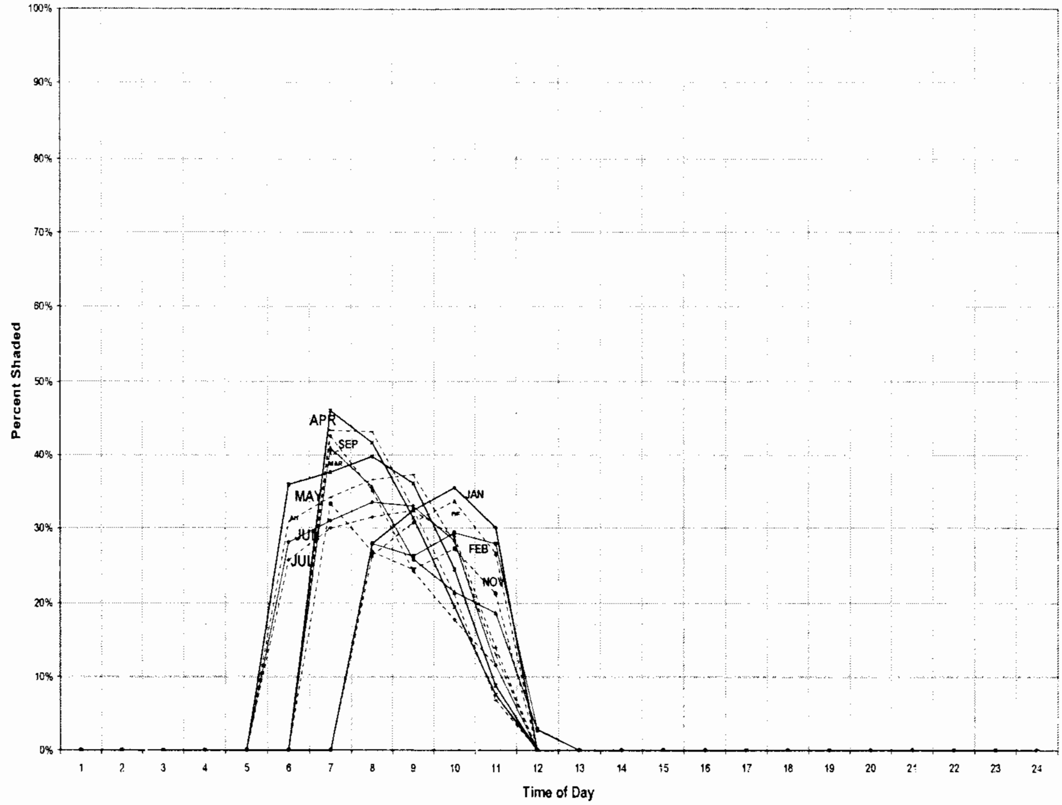


Figure 4-13. Hourly Shading of East Façade for Houston

The diagram above shows the hourly percent shading value for one year. In the diagram, April has the highest peak shading of 45% of the west facade at 6:30 AM and July has the lowest peak. Also, there is minimum shading percent of 35% for the entire year.

4.4.3 Prediction of PV Production

The area of the façade was divided into spandrel and vision glass. PV elements were used in both cases. While the entire area of the spandrel glass is considered productive, only the opaque component of the vision glass (60%) was used. In both cases, the area of the mullions was subtracted from the total PV façade area (Table 4-13).

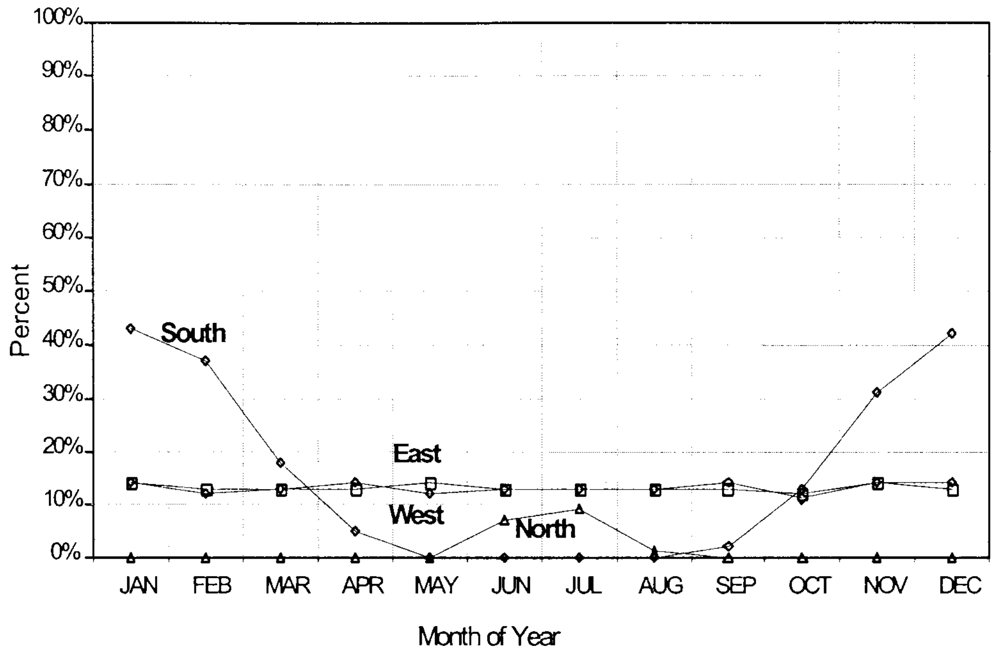


Figure 4-14. Annual Average Monthly Shading

The diagram shows the annual monthly shading percent of each façade for the city of Houston. A comparison of all sites shows minimal fluctuations of 1% to 2%. Therefore, values for Houston were used to determine the shading effect for all sites.

Table 4-13. PV Surface Area Calculation

	Vision Glass (Per Façade)	Spandrel (Per Façade)	Roof
Number of floors	40	40	1
Total Surface Area	40,000	20,000	10,000
Transmittance (40%)	-16,000	NA	NA
Mullions [a]	-3,232.5	-2,332.5	-845.6
Net Surface Area	20,767.5	17,667.5	9,154.4

[a] Values subtracted from total PV electricity production. Note: DOE-2 recommends specifying the thermal conductance of the frame when it is more than 10% of the window area. In this study, the frame is 9% of the window area. Therefore, no conductance was specified.

When conducting a reasonableness check for the PV production, five values are used in the calculation - the PV area, maximum solar irradiation, the rated cell efficiency, the number of hours per year and the annual cell efficiency. As shown above, the PV area is multiplied by the product of the PV efficiency and the solar insolation. The PV output is then multiplied by the number of hours in a year to get a gross annual kWh. PV panels produce no more than 20% of their rated output for a horizontal orientation. To account for the reduced output of vertical surfaces, the rated output of the PV facades has been reduced by 50%. See reasonableness check for PV in Figure 4-15.

$$124{,}459m^2 \times \left(1000\frac{w}{m^2} \times 12\%\right) \times 8760hr \times 10\% = 1{,}215{,}466kWh$$

Figure 4-15. Reasonableness Check for PV Production

In summary, panels are predicted to produce no more than 10% of their rated output over a 24-hour period as a yearly average (Martel and Presnell, 1999). Thus, a quick calculation of the potential PV output for this study shows an annual estimated PV electrical production of 1,215,466kWh, which compares favorably to the simulated values discussed in the following sub-section.

4.4.4 Result of Resource Assessment

The simulation was conducted using PV F-Chart for all conditions. This study simulated a south, east and west facing façade with 12% efficient solar cells for all sites. The spandrel glass of the building was considered opaque while the vision glass had a 40% transmittance and was adjusted accordingly. Three input files were created, representing site conditions for the roof, spandrel glass and the PV glazing.

Each input file varied the site location and façade, if necessary. In all, six sets of data were produced by each file representing sites in Detroit, Houston, Los Angeles and New York, and the south, east and west orientations of the façade. The study only considered electricity production and does not include energy savings due to reclaimed or ventelated heat from the double glazed window.

The results show that BIPV systems performed best for the unshaded condition as compared to the shaded condition for all sites. As shown in Figure 4-16, Los Angeles shows the greatest electricity production of all sites; Houston was next and then Detroit; and last, New York shows the lowest electricity production levels. In agreement with estimated BIPV productions of 1,2154,66 kWh, the non-shaded and shaded PV annual averages are 1,128,766 kWh and 982,951kWh respectively. The annual average for all conditions is 1,055,859kWh.

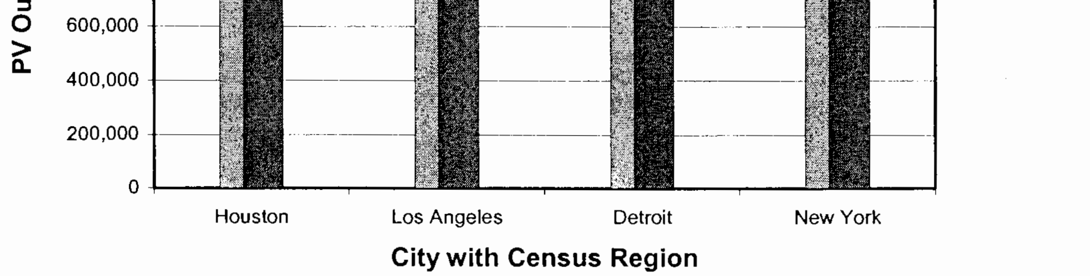


Figure 4-16. Annual PV Production

The diagram shows the electricity production for the shaded and unshaded effects of the PV system for all facades.

4.5 Energy Simulation

In this study, a DOE-2 energy simulation evaluated the reduction in electricity and the heating and cooling reductions due to the effects of the glazing type. Using the calculated window properties and PV resource assessment values, the energy consumption was determined for each site for the shaded and non-shaded conditions. In addition to the simulation results, this section discusses the DOE-2 input file and its modification.

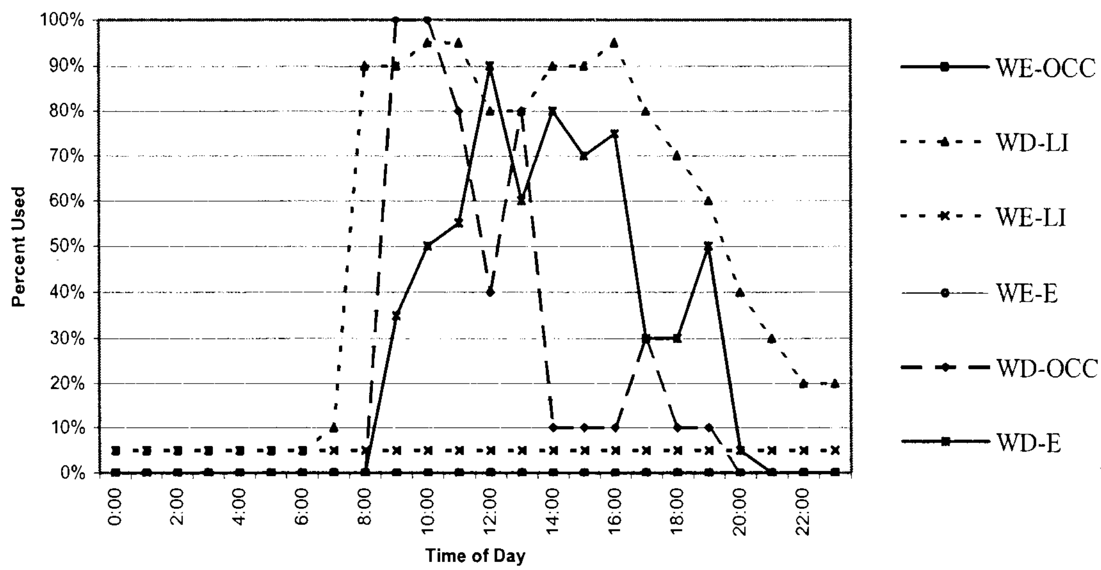


Figure 4-17. Building Schedules for DOE2 Sample File

The diagram shows the occupancy (OCC), lighting (LI), and equipment (E) schedules for the weekday (WD) and weekend days (WE)

4.5.1 DOE-2 Sample Input File

The DOE-2 programs provide several sample-input files of various types of buildings and their systems. For this study, the samp2.inp file was used as a basis for developing the case study input file. In general, the samp2.inp file is a 31-story office building with a steel frame, curtain walls, double-glazed tinted windows and built-up roofing. In the samp2.inp file, the FLOOR-MULTIPLIER command is used to define a plenum zone and five zones for each floor. The spaces are 13 feet floor-to-floor with 9 foot ceiling. In SYSTEMS, a single variable-air-volume system serves the entire building. This system has cooling and heating design temperatures of 78 degrees and 70 degrees respectively. The PLANT input uses a chilled water storage system to provide cooling while taking advantage of low nighttime rates. Last, in the ECONOMIC input, uniform rates for gas and electricity are used with a nominal flat rate for electric demand charge.

To evaluate the reliability of the samp2.inp file, the building schedules for lighting, equipment and occupancy (Figure 4-17) and the BEPS report were plotted. A plot of the building schedules for lighting, equipment and occupancy are presented in and the tabulated results from the BEPS's report are in Table 4-14. In this plot, it is evident that the building is almost completely shutdown during unoccupied periods. As a result, the samp2.inp file produced an unreasonable low energy use that is not characteristic of typical high-rise commercial buildings.

4.5.2 DOE-2 Sample Input File Modifications

The unreasonably low energy use of the samp2.inp file made it necessary to increase the gross energy intensity and energy consumption of the building to reflect that of comparable buildings shown in Table 4-14 and Table 4-15. The buildings in these tables were selected from the LoanSTAR database at Texas A&M University (Turner et al., 1998) based on their gross square footage and building characteristics. Included in the national average, these buildings represent mid-rise buildings with 8 to 20 floors and low-rise buildings with 3 to 8 floors. Overall, the low-rise buildings had the larger square footages while the mid-rise buildings had the smaller square footages.

Table 4-14. Comparison of Gross Energy Consumption for Selected Sites

Site	*Size (sq.ft.)*	*Electric (kWh)*	*Heating (MMBtu)*	*Cooling (MMBtu)*	*Total (MMBtu)*
S.F. Austin	470,000	17,801,615	11,580[1]	27,195	99,514
W.B. Travis	491,000	8,469,982	12,098[1]	35,220	76,217
L.B. Johnson	308,080	12,425,650	7,591[1]	45,454	95,441
Capitol Building	282,499	6,964,998	14,202[2]	50,568	88,534.57
Capitol Extension	592,781	8,368,989	14,931[2]	46,469	89,954
Texas Dept. Of Health	298,700	6,825,605	18,022[2]	22,658	63,968
DOE-2 Sample Buidling	640,000	6,287,719	1,894	5,460	28,808
DOE ADJUSTED	640,000	18,781,828	25,443	10,332	99,858

[1] There is a single gas meter for the S.F. Austin, W.B. Travis, and L.B. Johnson that used 31,270 MMBtu per year. Total usage was divided by the total square footage proportioned to each building.
[2] Steam used for heating was assumed 80% efficient.

Table 4-15. Comparison of Gross Energy Intensity for Selected Sites

Site	*Size (sq.ft.)*	*Electric (Btu/sq.ft)*	*Heating (Btu/sq.Ft)*	*Cooling (Btu/sq.ft)*	*Total (Btu/sq.ft)*
S.F. Austin	470,000	129,232	24,639	16,452	170,324
W.B. Travis	491,000	58,858	24,639	20,395	103,894
L.B. Johnson	308,080	137,614	24,639	41,950	204,204
Capitol Building	282,499	84,122	62,840	50,896	197,859
Capitol Extension	592,781	48,171	31,485	22,289	101,945
Texas Dept. Of Health	298,700	77,967	75,418	21,568	174,954
DOE-2	640,000	33,521[1]	2,960[2]	8,532[3]	45,013
DOE ADJUSTED	640,000	100,130	39,754	16,143	156,029
National Average	—	—	—	—	100,000

[1] Electricity consumption includes the DOE-2 BEPS totals for area lights, miscellaneous equipment, heat rejection, pumps and miscellaneous, vent fans, and domestic hot water.
[2] Heating is the sum of electricity and natural gas for space heating.
[3] Cooling energy is the electricity used for space cooling.

In summary, Table 4-15 shows that there is a 55 kBtu/sq.ft difference between the original samp2.inp file and the national average energy intensity of 100 kBtu/sq.ft (EIA, 1992). Additionally, there is a 105 kBtu/sq.ft difference between the samp2.inp file run for Houston, Texas and the average energy intensity of the

LoanSTAR buildings in Austin, Texas. Because of these differences, the energy consumption of the building was increased using the modifications discussed in the following paragraphs.

Overall, in the LOADS portion of the samp2.inp file, the building description and windows were the only areas of major modification. The SYSTEMS and ECONOMICS descriptions were only modified to reflect changes in the LOADS input and average energy costs, while the PLANT description required no modifications.

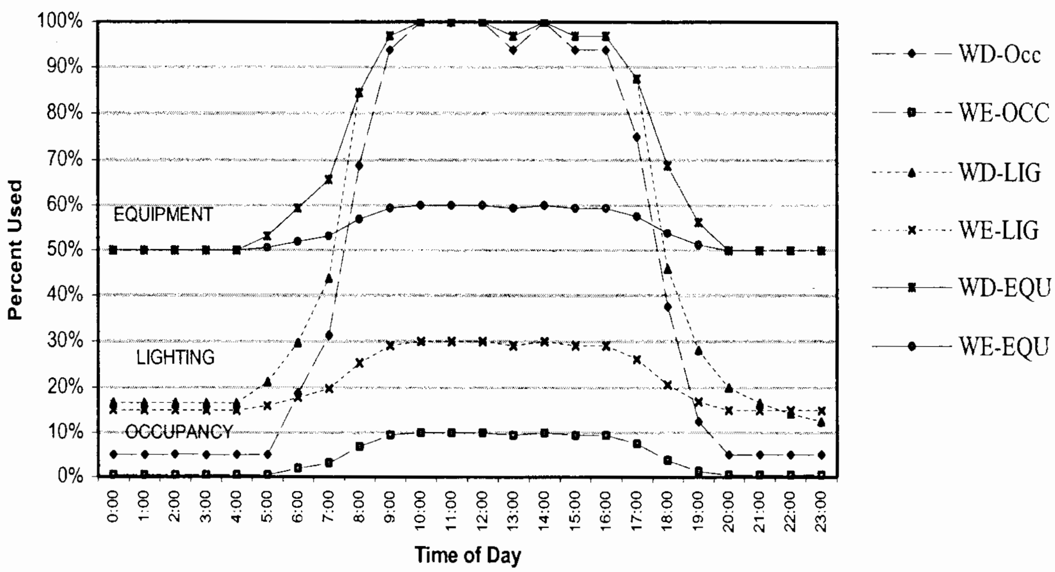


Figure 4-18. Building Schedules for the Texas Department of Health

The diagram shows the occupancy (OCC), lighting (LI), and equipment (E) schedules for the weekday (WD) and weekend days (WE)

In LOADS because the input was written for Chicago, Illinois, the atmospheric moisture and turbidity values were removed. In addition, the occupancy, lighting and equipment schedules of the samp2.inp file were modified to be more representative of buildings in the Texas LoanStAR database (Figure 4-18). The Appendix contains additional plots of other buildings). Using these data, the weekday and weekend schedules for occupancy, lighting and equipment were modified. The window-shading schedule that simulated the use of blinds in the windows was deleted and removed from the SET-DEFAULT for the windows.

In the SYSTEMS portion of the input file the following modification were made: 1) The temperatures for the heating schedule were changed from their various inputs to a constant 72 degrees Fahrenheit in order to reflect continuous building operation, which is typical of office buildings in the LoanSTAR database; 2) the temperatures for the cooling schedules were changed to a constant 75 degrees Fahrenheit; 3) the temperatures for the weekend set back schedules were also changed from 90 degrees Fahrenheit (summer) and 55 degrees Fahrenheit (winter) to constant summer and winter set points; 4) the fan schedules were also modified to provide constant operation of the fans; 5) the heating schedules for the weekday and weekend were set to a constant temperature of 72 degrees Fahrenheit and the cooling were set to a constant temperature of 75 degrees Fahrenheit, 6) the cooling coil set point schedule, in all areas, was set to a constant temperature of 55 degrees Fahrenheit. Note that this could also be accomplished by setting a COOL-SET-TEMP of 55 degrees; 7) the design heating and cooling temperatures were also adjusted to be 72 and 75 degrees respectively from 78 and 70 degrees. ZONE-AIR was set to an OA-CHANGE of 0.25, as compared to OA-CFM/PER of 20; 8) the damper position was set to be open constantly; and 9) humidification was eliminated.

The results of these changes yielded an energy intensity of 156,029 MMBtu/sq.ft, as shown in Table 4-15. The modified DOE-2 samp2.inp file is included in the Appendix.

Table 4-16. Energy Cost Data for Commercial Users

Source	**Service Description**	**Electricty (kWh)**	**Demand (kW)**	**Gas**
Estimated Prices[1]	——————	$0.734000		$5.18 (mcf)
Detroit [2]	Primary Supply Service	$0.028100	$14.25	
Los Angeles [3]	General Service A2, Rate A	$0.021810	$13.20	
Houston [4]	Large General Services	$0.025486		
New York [5]	General Commercial, Large	$0.054250	$19.27	0.489 (therm)
Average Costs		**$0.032412**	**$15.57**	**$5.18**

[1] Source: Energy User News (1998).
[2] Source: Detroit Edison (1997). Energy Choices, 1997 Detroit Edison, Detroit, MI
[3] Source: Department of Water and Power, City of Los Angeles (1997).
[4] Source: Houston Lighting and Power Company (1995).
[5] This data was obtain in 1997 through interview with Kelvin Colvin, an employee of Consolidated Edison of New York.

The DOE-2 ECONOMICS input reflects the simplest calculation possible and was modified to use uniform rates for both electricity and gas. In the input file, the fixed monthly rate and rate limitation were deleted and the national average electric and gas charges were used instead, remaining constant for each case study (Table 4-16). In addition, the peak demand charge was deleted. Only, a flat rate for the electric demand of the building was used. In summary, a comparison of the energy use between the modified prototype building and comparison buildings from the LoanSTAR database are shown below.

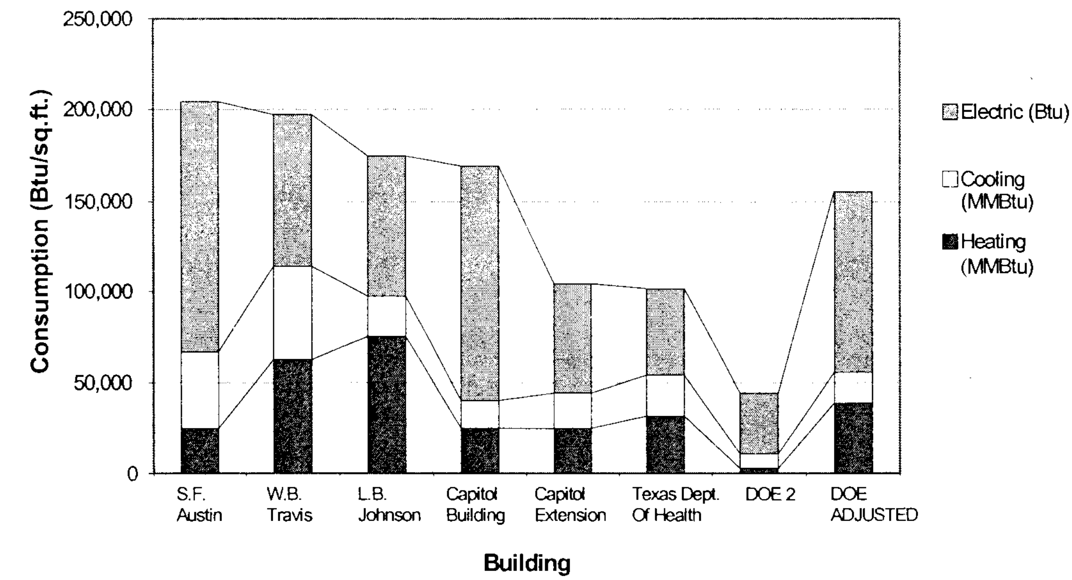


Figure 4-19. Comparison of Annual Energy Consumption

The figure is a comparison of annual energy consumption for the buildings chosen from the LoanSTAR database and the samp2.inp file using the Houston TMY weather file (Energy Soft, 1994).

In Figure 4-19, the electric, cooling, and heating energy are shown. In summary, the energy performance of the unmodified DOE-2 samp2.inp file was unreasonably low and therefore produced results that were not applicable to a typical high-rise commercial building. After modification, the adjusted DOE-2 file shows a consumption that has moved to a level comparable to LoanSTAR buildings that are considered representative of typical buildings in the four census regions.

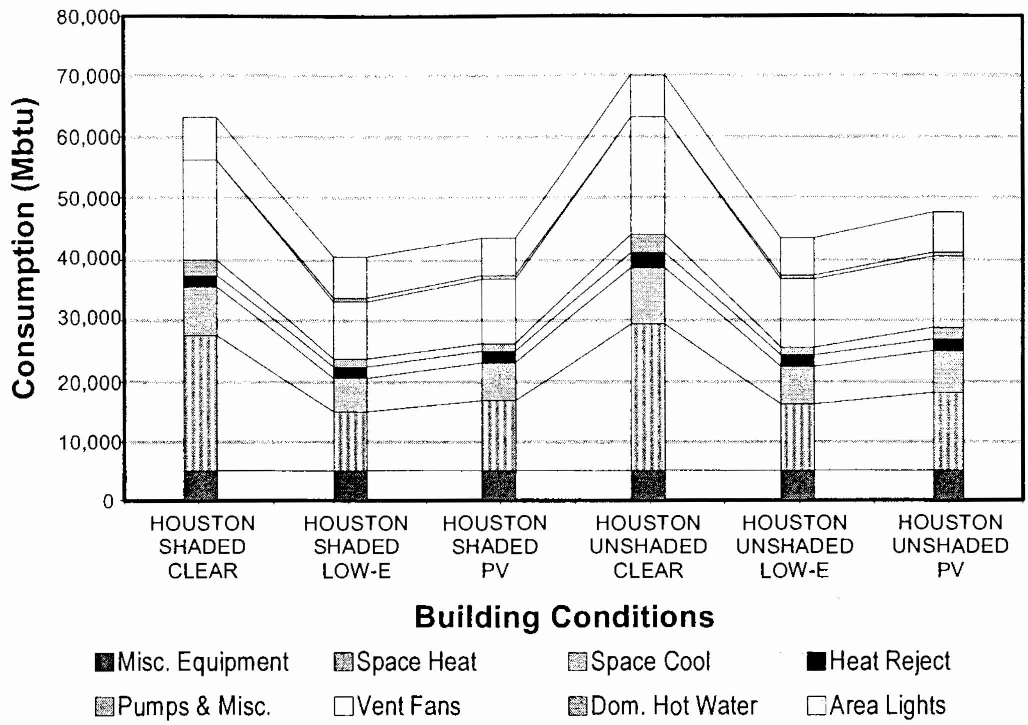


Figure 4-20. Annual Energy Totals for Houston

The figure shows the annual energy consumption for the three window treatments for the shaded and non-shaded effect in Houston. The legend is read by associating, from left to right, the first entry in the upper row in the legend entry with the bottom division in the figure. This association should be repeated for all legend entries reading from left to right and for the figure reading from bottom to top. The Appendix contains the BEPS results used to produce this figure.

4.5.3 Results

After development of the modified DOE-2 input file, the weather and site data were changed and the prototype building was simulated for the selected sites. Figure 4-20 shows the results of the energy consumption by category from the DOE-2 BEPS report. In this figure, the shaded and unshaded conditions for Houston are plotted for single-pane clear, double-pane Low-E and double-pane PV glazing. As expected, the results show that the buildings using single-pane clear glazing were consumed the most energy for the shaded and unshaded conditions. The Low-E and

PV glazed buildings showed similar results for the shaded and unshaded cases. The PV glazing shows a slightly higher consumption that the Low-E due to increases in the SPACEHEAT and VENTFAN energy. However, it is important to note that the PV electricity production is not factored into the results shown in Figure 4-20.

An analysis of Figure 4-21 and Figure 4-22 shows the annual building energy use and the simulated PV electricity production. In this figure it is evident that the electricity produced by the PV makes the building slightly less consumptive than the Low-E (Figure 4-21 and Figure 4-22).

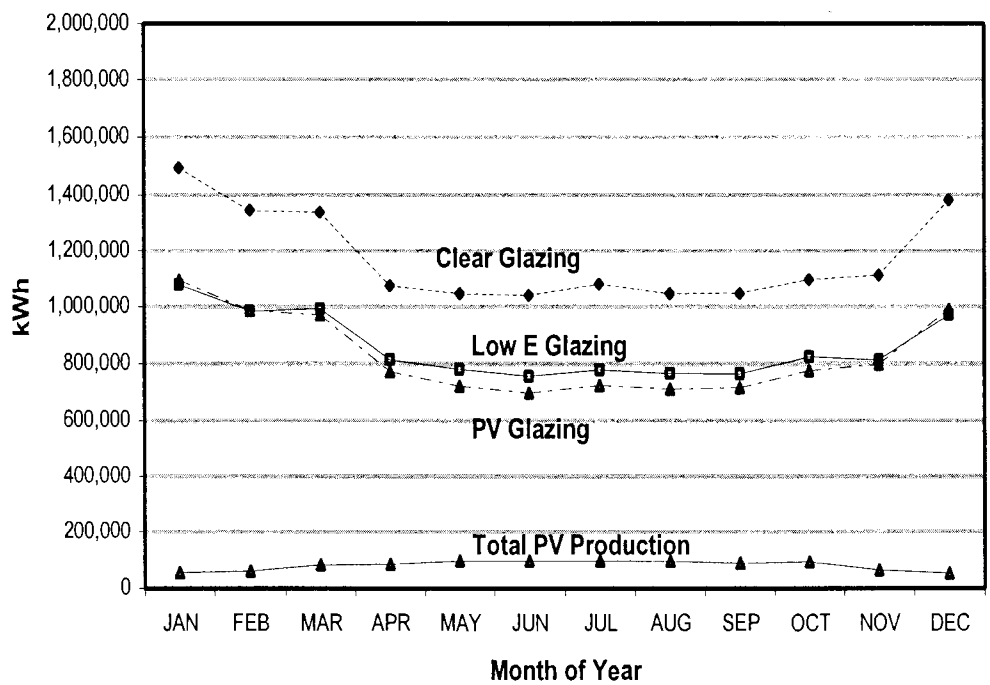


Figure 4-21. Shaded Monthly Electric for Houston

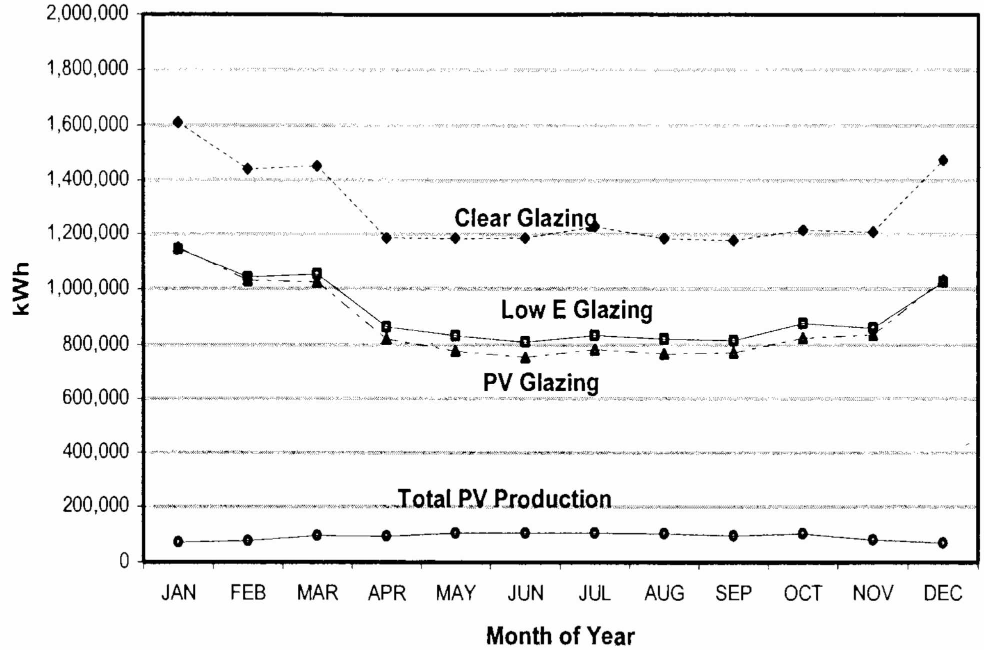


Figure 4-22. Unshaded Monthly Electric for Houston

In Figure 4-23 the shaded and unshaded cases are shown with and without the PV production. Overall, the data shows that buildings in Houston, Los Angeles, and New York have similar reductions in energy consumption, despite the production of the PV glazing. Further analysis of Figure 4-23 shows that the unshaded condition with PV production is the same as the shaded condition with no PV. The results for Detroit, on the other hand, shows that there is a linear decrease in consumption between cases and that the PV glazing has a larger effect on the energy consumption than the buildings in the other cities.

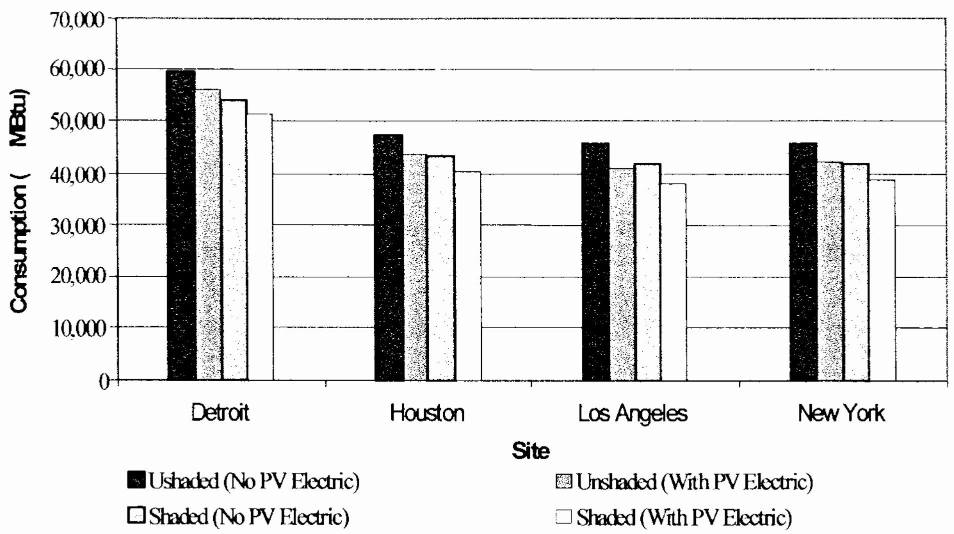


Figure 4-23. Annual Energy Consumption for PV Glazing

The figure shows the shaded and unshaded results of the PV glazing for all sites. In summary, the first column is the building's energy use for the unshaded condition and does not consider the electricity production of the PV glazing, while the second column includes the PV electricity production. The third column is the building energy use for the shaded condition that does not consider the electricity production of the PV glazing, while the fourth column does factor in the PV electricity production.

In summary, the samp2.inp file produced unreasonably low results mainly due operation and temperature schedules, which completely shut down the building during unoccupied periods. However, the energy use of the building increased to levels comparable to buildings from the LoanSTAR database after modification of the samp2.inp file. The results, which are based the modified DOE.2 samp2.inp file, show that buildings using single pane clear glazing were the most consumptive for both conditions and that Low –E and PV glazed buildings perform similarly. In review of the electric production for all conditions, the electricity produced by the PV glazing made the building slightly less consumptive than Low-E. Overall, shaded buildings using PV glazing with no electric production perform similar to unshaded buildings using PV glazing and its electricity production.

4.6 Economics

Using energy costs acquired for the DOE2.1E simulations, simple payback analyses were conducted. In this analysis, wiring and power conditioning costs of the PV systems were not considered, but should be studied further. In all cases, first costs were determined using glazing costs published by Kiss (1995). The following paragraphs discuss the application of this method for four cases: 1) no capitol recovery, 2) capitol recovery, 3) 10% tax credit, and 4) a 5-year depreciation.

Table 4-17. Total Energy Costs for All Sites

	Shaded			*UnShaded*		
	Clear	Low-E	PV	Clear	Low-E	PV
Detroit	$1,237,728	$823,399	$861,725	$1,332,126	$867,536	$906,502
Houston	$1,096,055	$773,389	$790,696	$1,205,770	$839,071	$868,160
Los Angeles	$1,031,966	$769,990	$781,067	$1,113,520	$829,545	$833,574
New York	$1,031,949	$769,985	$791,085	$1,113,468	$829,529	$845,676

Table 4-18. System Costs Factors

	clear	*low-e*	*pv (vision)*	*pv (spandrel)*	*north façade*
Façade Area (sq.ft)	60,000	60,000	40,000	30,000	60,000
Mullion Area (sq.ft)	-(5,565)	-(5,565)	-(3,235)	-(2,333)	-(5,565)
Total Glazing Area (sq.ft)	217,740.00	217,740.00	110,303	83,003	54,435
Glazing Cost sq.ft	$3.50	$6.90	$14.35	57.26	$6.90
			$1,582,840.88	$4,752,522.68	$375,601.50
Total Cost	**$762,090.00**	**$1,502,406.00**			**$6,710,965.05**

For the PV calculation, the spandrel glass and the rooftop costs were estimated using high efficiency silicon modules and is included in the spandrel calculation. In addition, the north façade was designed to be Low-E glazing.

Table 4-19. Sample Worksheet Calculation for Houston

	Shaded			*Unshaded*		
First Costs (Windows)	$762,090.00	$1,502,406.00	$6,710,965.05	$762,090.00	$1,502,406.00	$6,710,965.05
Annual Energy Costs	$1,096,055.00	$773,389.00	$790,696.84	$1,205,770.00	$839,071.00	$868,160.97
Savings 1st yr.	$0.00	$322,666.00	$305,358.16	$0.00	$366,699.00	$337,609.03
Simple Payback	NA	4.66	21.98	NA	4.10	19.88

Simple payback equals the first cost divided by the first year savings

First, a simple payback with no capitol recovery was determined. In the payback the energy cost simulated by DOE-2 was offset PV resources (Table 4-17). These costs are assumed to be the annual energy costs. In addition, the PV area of the facades was calculated by treating the vision and spandrel glass as independent systems. As stated earlier, an amorphous silicon module was selected for the vision glass and a crystalline high efficiency module was selected for the spandrel areas and the roof (Table 4-18). Table 4-19 shows a sample worksheet calculation and the results for all cases are presented in Table 4-20. The results show the longest payback for New York and the shortest payback for Detroit. You should note that this remains true for all cases. On average, the PV glazing in this case shows a payback that is 4.7 times that of the Low-E glazing for the shaded and unshaded conditions.

Table 4-20. Simple Payback with No Capitol Recovery

	Shaded			*Unshaded*		
	Clear	Low-E	PV	Clear	Low-E	PV
Detroit	NA	3.63	17.85	NA	3.23	15.77
Houston	NA	4.66	21.98	NA	4.10	19.88
Los Angeles	NA	5.73	26.75	NA	5.29	23.97
New York	NA	5.73	27.86	NA	5.29	25.06
National Average	NA	4.94	23.61	NA	4.48	21.17

Next, the reduction in chiller size was factored. To factor the capitol recovery of the chiller size, DOE-2 output data were reviewed. Because DOE-2 was automatically sizing the equipment, no difference in the system sizes was detected, except for hot water usage. Because of such unknown effects in the SYSTEMS and PLANT input, the chiller was sized using 25 Btu/sq.ft. for this analysis. Translating into 854 tons, the chiller costs were then determined at a rate of $1,830 per ton. Therefore, for the Low-E and PV strategies, the chiller size and subsequent costs was offset by 20% (Table 4-21). Overall, the payback only reduced by approximately 1 year when compared to no capitol recovery.

Next, this study applied a tax. Table 4-22 shows the payback for a 10% investment tax credit for investments in solar energy property. In this case, the payback again only reduced by approximately 1 year when compared to the capitol recovery.

Table 4-21. Simple Payback Analysis with Capitol Recovery

Site	*Shaded*			*Unshaded*		
	Clear	Low-E	PV	Clear	Low-E	PV
Detroit	NA	2.868	17.01	NA	2.558	15.03
Houston	NA	3.683	20.95	NA	3.241	18.95

New York	NA	4.537	26.56	NA	4.185	23.89
National Average	NA	3.906	22.51	NA	3.542	20.18

Table 4-22. Simple Payback Analysis with Investment Tax Credit

	Shaded			*Unshaded*		
	Clear	Low-E	PV	Clear	Low-E	PV
Detroit	NA	2.868	16.11	NA	2.558	14.23
Houston	NA	3.683	19.83	NA	3.241	17.94
Los Angeles	NA	4.536	22.96	NA	4.185	21.63
New York	NA	4.537	25.14	NA	4.185	22.62
National Average	NA	3.906	21.01	NA	3.542	19.11

Last, in Table 4-23, a 5-year depreciation schedule for solar energy equipment was used. As shown, the depreciation is based on 95% of the original cost of the solar system over a five-year period. In total, the study shows a 41.8% saving from the original investment paid by the Federal Government. As result, the average payback for Low-E glazing is 3.72 years and for PV glazing it was 12 years (Table 4-24).

Table 4-23. Depreciation Schedule for Solar Energy

Year	*Deduction*	*Tax Bracket*	*% Depreciation*	*Savings*
1	20.00%	34.00%	6.80%	$433,528.34
2	32.00%	34.00%	10.88%	$693,645.35
3	19.20%	34.00%	6.53%	$416,187.21
4	11.52%	34.00%	3.92%	$249,712.33
5	11.52%	34.00%	3.92%	$249,712.33
6	5.76%	34.00%	1.96%	$124,856.16
Totals	100.00%	N/A	34.37	$2,167,641.71

Table 4-24. Simple Payback Analysis with 5-Year Depreciation

	Shaded			*Unshaded*		
	Clear	Low-E	PV	Clear	Low-E	PV
Detroit	NA	2.87	9.55	NA	2.56	8.44
Houston	NA	3.68	11.76	NA	3.24	10.64
Los Angeles	NA	4.54	14.91	NA	4.19	13.41
New York	NA	4.54	14.32	NA	4.18	12.83
National Average	NA	3.91	12.64	NA	3.54	11.33

In summary, PV glazing showed the quickest payback in Detroit and Houston for both shaded and unshaded effects. Also, the PV glazing performed similar to Low-E glazing with a greater reduction in electric energy use due the solar shading than the electric production of the system. With no capitol recovery, the payback for the building using PV glazing is 22.4 years and 4.7 years for Low-E glazing. With capitol recovery included, the payback reduces to an average of 21.3 years for the PV system as compared to 3.6 years for the Low-E glazing. Last, the average payback reduced to approximately 20 years when considering all government tax incentives. Specifically, the 5-year depreciation schedule had the greatest effect on the payback of the PV system.

4.7 Summary of Results

In this section, a summary is presented for each part of this study. Overall, this section summarizes the results of the human assessment, the PV resources assessment, the energy simulation, and the economic analysis.

4.7.1 Human Assessment

In the final study of the human assessment, the mean result for arousal shows that the subjects were only slightly aroused. In the case of the view shown, the students preferred a sitting position facing the window to one facing the door. In addition, the students preferred the spaces using the clear glass windows to the spaces using windows with 40% transmittance. The analysis of variance for the final experiment showed that that all the treatment means at levels of VIEW, LOCATION, and GLAZING were significantly different. That is, the variations in the test stimuli were being detected.

For the pleasure response, the overall mean result shows that the subjects were only slightly pleased. In addition, the students preferred a sitting position facing the window to one facing the door and spaces using the clear glass windows to those using windows with 40% transmittance. In the analysis of variance for the final study, only VIEW had significantly different treatment means, while levels of LOCATION and GLAZING did not. Overall, people prefer clear windows to those with 40% transmittance. However, windows with 40% transmittance do not create significantly stressful or unpleasant feelings in people.

4.7.2 Window Properties

The results of the experiment show a calculated transmittance of 42% and a measured transmittance of 44%. Since there is only a 2% difference, it was felt that the experiment indicates good agreement between the calculated and the measured transmittances of the prototype PV glazing.

4.7.3 PV Resource Assessment

In the resource assessment, the results show that the PV glazing performed best for the unshaded condition as compared to shaded. Specifically, Los Angeles shows the greatest electricity production of all sites; Houston was next and then Detroit; and last, New York shows the lowest production levels. In view of these urban centers, it is important to note that undesirable atmospheric conditions caused by air pollution and smog may significantly affect the available solar irradiation and should be studied further. Nonetheless, in this study the shading caused by the adjacent buildings significantly reduced the electricity production of the PV glazing by 13%.

In agreement with the simulated electricity production of the PV glazing, the estimated PV production of the reasonableness check was 1,215,466 kWh, while the simulated annual average for the non-shaded and shaded conditions is 1,055,859 kWh. Thus, reasonably close estimates of PV production using the reasonableness check can quickly be determined when designing buildings using PV glazing. However, further development is required to produce a more accurate calculation that factors shading caused by adjacent buildings. In the work of Pearsall and Hill (1994) it was shown that the entire electric demand of an urban area could be met using BIPV systems on the rooftops of buildings. In this study, the PV glazing did produce a significant amount of cost-effective energy when used in vertical facades but was not able to match the entire electric energy demand of the buildings.

4.7.4 Energy Simulation

In this study, the DOE-2 samp2.inp file produced unreasonably low results mainly due to the operation and temperature schedules, which completely shut down the building during unoccupied periods. After modification of the samp2.inp file, the energy use of the building increased to levels comparable to buildings from the

LoanSTAR database. Based on the modified samp2.inp file of DOE-2, the results show that buildings using single pane clear glazing were most consumptive for both conditions. In addition, this study also shows that Low–E and PV glazed buildings perform similarly, which agrees with current research (EIA, 1992) [36].

The electricity produced by the PV glazing made the building slightly less consumptive than buildings using Low-E glazing. Overall, Ashley (1992) states that BIPV systems can supply up to 70% of the electric demand of the building. In this study, the mostly vertical PV glazing, with no shading effects of surrounding buildings, met 21% of the electricity needs of the building, while the PV glazing that considered shading from surrounding buildings satisfied only 14% of the electric needs of the building. Thus, the shading by surrounding buildings reduced the electricity production of the PV glazing by 34%.

4.7.5 Economics

PV glazing showed the quickest payback in Detroit and Houston for both shaded and unshaded effects. In addition, the PV glazing performs similar to Low-E glazing with a greater reduction in electricity consumption use due to the solar shading and the electric production of the system. When the reduced sized of the chiller are not considered, the simple payback for the building using PV glazing is 22.4 years and 4.7 years for Low-E glazing. With discounting included, the payback reduces to an average of 21.3 years for the PV system as compared to 3.6 years for the Low-E glazing. Last, when factoring a 5-year depreciation allowed by the

---

[36] Current research shows that commercial buildings using solar glazing have similar energy patterns regardless of location.

government, the payback time for the PV glazing reduced to 12 years. Please note that other cost factors, such as wiring, framing and power conditioning, should be considered. Furthermore, future study is required to develop more accurate and reliable cost data that reflect our current technologies and their application.

5 CONCLUSIONS

5.1 Conclusions

It is well known that people prefer daylight and windows in their environments. However, the primary function of windows is overshadowed by economic factors associated with their thermal performance, which may adversely affect the human satisfaction of office workers. Consistent with this, architects must avoid presumptuous decisions that are based on obsolete market standards. By obtaining information on the current preferences of building occupants, architects expand their search of excellence by relating human acceptance to window or glazing types. More importantly, effects of windows on worker performance and preference, as indicated by this study, may be linearly related to the amount of light they transmit, either due to the size or the transmittance of the window.

A "science-wise" architect avoids designing to minimum window standards by employing human assessment methods and basing his decision on external design factors that influence the use and operation of the building. When considering the use of PV windows, there is an inverse relationship between window performance and human satisfaction as discussed earlier. When using PV glazing, window performance is a function of the windows thermal properties and their effects on the building's energy budget, the electrical output of the PV glazing and the transparency of the window. In addition to this, potential users of PV glazing must now consider the electrical output of the window system. That is, with lower window transmittances of PV glazing, there is reduced daylight entering the space, possibly resulting in a lower level of human satisfaction. In contrast, there is an increase in electricity to meet the energy demands of the building and reduce operating costs.

Understanding what levels of window transparency are acceptable by office workers allows the architect to maximize the contribution of electricity of the PV glazed windows. Thus, the design of better windows is a function of the allowable tolerance to the independent variable window transparency. In summary, preference is a control rather than an impulse when the architect factors these variables.

Providing additional benefits, PV systems affect the time of day rates by providing peak electric output at times of peak electric demand by the building. However, the peak production time of the vertical PV glazing changes and is dependent upon its orientation. This condition should be studied further to determine how the PV glazing affects the peak energy demand, which is used by electric companies to determine demand charges.

In the design and use of PV windows in high-rise commercial buildings, there are many questions that have been asked by the building community. Although many of their concerns are quantitative, qualitative issues continually arise. In all developing a better understanding about the effects of PV windows on owning and operating costs in buildings, this research produced a comprehensive model to assess the effects PV glazing on the energy use of commercial buildings, which includes the shading effects of adjacent buildings, and human satisfaction of office workers within spaces using PV glazing.

There are several obstacles preventing the widespread adoption of solar PVs as a power source on buildings in the world today. Listed by priority, these obstacles are 1) public awareness, 2) system costs and 3) code requirements. Although the congress of the United States has mandated research of PV systems, application of these system have been minimal. Whether influenced by Corporate forces that want maintain their monopoly on fossil fuels as the major provider of electricity or the lack of relevant research that would facilitate the immediate application of PV systems, the reasons for this condition are unknown. In 1993, a general survey of the building community (Kiss, 1993) indicated that the results of such research - or lack thereof - is reaching the relevant professions in a slow and controlled manner. Consequently, we must answer the question of the building community in the areas of thermal analysis, life cycle and energy costs of buildings using PV glazing. Specifically, these concerns are about market incentives, safety and liability, reliability, maintenance, thermal and physical characteristics of PV's. Nonetheless, the answer to many of these questions presented will only come with the application of PV glazing in buildings. In general, we are faced with an age-old paradigm - *'what comes first, the chicken or the egg'*. In our situation, can or should we know all the information about a particular technology before its application, even if there are obvious benefits, or should we apply the technology knowing the long-term economical and social benefits, and answer the questions as we go.

Another factor affecting the widespread use of BIPV systems is their costs. The cost of PV systems is higher than conventional materials they replace. Because of increases in owning costs of buildings, the energy and thermal benefits of the BIPV system are often ignored. This condition is due to the desires of the general public to reduce their initial investment costs, despite the high operation and maintenance costs. However, when considering the laws of supply and demand, the cost of PV systems will only decrease as architects and builders continue to use them.

Overall, according to the suggested practices of the National Electric Code (NEC, many PV systems that are installed today may not comply with the NEC and other local codes, regardless of size. Major contributing factors to this condition are stated to be 1) inexperience of PV dealers and PV installers, 2) inexperience of electrical inspectors and 3) non-technical presentation of PV system to the public which has lead them to a "*do-it-yourself*" attitude. Nonetheless, electrical contractors who are familiar with all sections of the NEC can install reliable PV systems that meet the National Electrical Code (NREL, 1993).

5.2 Future Work

Results from this study show that there is much work to be done to effectively model the effects of PV glazing in buildings. Thus, this section discusses the recommended future work to improve the simulation of PV glazing in commerical buildings.

Although the assessment measures in this study have been proven reliable, more studies should be conducted for spaces that are used by the elderly or people who are psychologically stressed. Such studies should investigate the effect of age on human preference to PV glazing and the effect of low transmittance on the well being of hospital patients.

With respect to the window properties, this study has validated and created preliminary information to begin modeling BIPV glazing within energy simulation software. However, testing of the actual PV element is required to accurately define the thermal and optical properties of double glazed PV windows.

For the resource assessment, the PV electricity generated was reduced by 34% due to the vertical orientation. Thus, studies using alternative façade designs, such as those by Kiss (1993) are expected to improve the PV production. In this case, the façade design must reduce the angle between the incident light of the sun and the face of the module. Another method to improve the effectiveness of the PV indicated in the literature review is the reclamation heat generated within the double glazed system. This is expected to be beneficial to cold climates.

Concerning energy simulation, the study has shown that real building data and descriptions are required to produce reliable energy simulations. Thus, future work in this area should develop input data representative of buildings within various census and climatic region.

In terms of economics, the PV systems in this study did not compare well with Low-E glazing for the simple payback analysis, indicating the need for integrating selective solar glazing within the PV system. Consequently, further study should investigate using a less expensive PV material and investigate the development of a hybrid Low-E/PV glazed window system. In addition, with the continual production of electricity, other future study should conduct a lifecycle cost analysis and factor maintenance and repair, power conditioning, and construction requirements of the PV system.

REFERENCES

Ashley, S. 1992. Solar Photovoltaics: Out of the Lab and Onto the Production Line. *Mechanical Engineering*. 114 (1): 48-55.

ASHRAE 1997. *ASHRAE Handbook-Fundamentals*. Chapter 29, Fenestration. Atlanta: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

Autodesk. 1996. *3D Studio Max User's Guide. Concept and Modeling*. San Rafael, CA: Autodesk, Inc.

Ayres, J. M. and E. Stamper. 1995. Historical Development of Building Energy Calculations. *ASHRAE Transactions*. 101: 841-849.

Bechtel, R., Marans, R. and W. Michelson. 1987. *Methods in Environmental and Behavioral Research*. New York:Van Nostrand Reinhold Company, Inc. pp. 162-190.

Beckman, W.A., Broman, L., Fiksel, A., Klein, S.A., Lindberg, E., Schuler, M., Thornton, J., 1994. TRNSYS - The Most Complete Solar Energy System Modeling and Simulation Software. World Renewable Energy Congress in Reading, United Kingdom.

Bendel, C., Rudolph, U., and M. Vioto. 1994. Experimental PV Façade. *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Biner, P. M., and D. L. Butler. 1989. Effects of Setting on Window Preferences and Factors Associated with Those Preferences. *Environment & Behavior*. 21 (1): 17-31.

Brown, L., Renner, M. and B. Halweil. 1999. *Vital Signs 1999: The Environment Trends That Are Shaping Our Future.* New York: W.W. Norton & Company, Inc.

Clarke, J. Kely, N. and P. Strachan. 1997. The Simulation of Photovoltaic-Integrated Building Facades. *Proceedings of the First International Building Performance Simulation Association*. Prague, Czech Republic. pp. 189-196.

Cochran, J. 1997. Micro PV Inverter under Development Could Reduce Price of PV Systems. *UPVG Record.* Washington DC: Utility Photovoltaic Group.

Collins. B. L., 1975. Windows and People: A Literature Survey. Psychological Reaction to Environments with and without Windows. Washington, DC: Department of Commerce and the National Bureau of Standards.

Commercial Service Electric Rates for Commercial and Industrial Customers. 1997. Los Angeles, CA: Department of Water and Power, City of Los Angeles.

Danford, S. and P. Williams. 1975. Subjective Responses to Architectural Displays: A Question of Validity. *Environment and Behavior*. 7: 486-516.

Detroit Edison. 1997. Energy Choices. Detroit, MI: Detroit Edison.

DOE. 1993. Profiles in Renewable Energy: Case Studies of Successful Utility Sector Projects. DOE/Ch10093-206, DE93000081. NREL. pp. 14-17.

Duffie, A. and W. Beckman. 1991. *Solar Engineering of Thermal Processess*. New York: John Wiley & Sons, Inc.

EIA. 1994. *Commercial Characteristics 1992: Commercial Buildings Energy Consumption Survey*. Office of Energy Markets and End Use, Washington, DC: U.S. Department of Energy.

EIA. 1992. *Commercial Buildings Energy Consumption and Expenditures 1989*. Office of Energy Markets and End Use. Washington, DC: U.S. Department of Energy.

Energy Soft. 1994. *DOE-2 Weather CD-ROM*. Novato, CA: Energy Soft.

Energy Users News. 1998. Current Prices Estimated. 1998. *Energy Users News*. 23: 40.

EPA. 1990. An Evaluation of the Potential Carcinogenicity of Electromagnetic Fields (EMFs). Summary and Conclusions of EPA's EMF Cancer Report. Washington, DC: U.S. Environmental Protection Agency.

F-Chart Software, Inc. 1997. *PV F-Chart User's Manual*. Middleton, WI: F-Chart Software, Inc.

Goethe, R. 1994. To Convince the Architect – PV People Love Integration Anyway, *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Green, M., Zhao, J., and A. Wang. 1998. *23% Module and Other Silicon Cell Advances*. Photovoltaics Special Research Center. University of New South Wales. Sydney, Australia.

Gutschker, O. and H. Roga. Simulation of a Photovoltaic Hybrid Façade. The Simulation of Photovoltaic-Integrated Building Facades. *Proceedings of the First International Building Performance Simulation Association*. Prague, Czech Republic. pp. 197-202.

Hittle, D.C., 1979. *Building Loads Analysis and System Thermodynamics (BLAST) Users Manual*. Version 2.0, Vol. 1 and 2 Technical Report E-153. Champaign, IL : U.S. Army Construction Engineering Research Laboratory (USA-CERL).

HL&P. 1995. *Rate Schedules*. Houston, TX: Houston Lighting and Power Company.

IES. 1981. *IES Lighting Handbook. Application Volume*. New York : Illumination Engineering Society of North America.

Ishikawa, S. 1994. Building Integrated PV Mounting Technologies in Japan, *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Johnson, T. 1991. *Low-E Glazing Design Guide*. Stoneham, UK: Butterworth-Heinemann.

Keighly, E. C. 1973(a). Visual Requirements and Reduced Fenestration in Office: A Study of Window Shape. *Building Science*. 8: 311-320.

Keighly, E. C. 1973(b). Visual Requirements and Reduced Fenestration in Office: A Study of Multiple Apertures and Window Area. *Building Science*. 8: 321-331.

King, J. 1996. The Real Problem with Deregulation of the Utility Industry. *Electric Light and Power*. (Personal Collection, K. E. Sylvester).

Kiss, G. and J. Kinkead. 1996. Optimal Building-Integrated Photovoltaic Applications. *25th IEEE Photovoltaic Specialist Conference*. Washington DC.

Kiss, G., Kinkead, J. and M. Raman. 1995. *Building-Integrated Photovoltaics: A Case Study*. Springfield, VA. National Technical Information Service.

Kiss, G. 1993. *Architectural Design Opportunities for Commercial Buildings*. Springfield, VA: National Technical Information Service.

Kraushaar, J., and R. Ristinen. 1993. *Energy and Problems of a Technical Society*. New York: John Wiley & Sons, Inc.

LBL. 1997(a). *SPARK. Building Technologies Program*, Energy and Environment Division. Berkeley, CA: Lawrence Berkeley Laboratory.

LBL. 1997(b). *Window 4.1 Software. Building Technologies Program*. Energy and Environment Division. Berkeley, CA: Lawrence Berkeley Laboratory.

LBL. 1981. *DOE-2 Engineers Manual. Version 2.1A*. Lawrence Berkeley Laboratory and Los Alamos National Laboratory. Report No. LBL-11353 Rev. 2. DOE-2 User Coordination Office.

LBL. 1980(a). *DOE-2 User Guide. Version 2.1*. Lawrence Berkeley Laboratory and Los Alamos National Laboratory. Report No. LBL-8689 Rev. 2. Berkeley, CA: DOE-2 User Coordination Office.

LBL. 1980(b). *DOE-2 Supplement. Version 2.1E*. Lawrence Berkeley Laboratory. Report No. LBL-34947. Berkeley, CA: DOE-2 User Coordination Office.

Lee, E. J., J. H. Yoon and P. C. Thomas. 1997. Energy Simulation of a Commercial Building with Spectrally Controllable Solar Windows. (Personal Collection, K. E. Sylvester).

Lightscape. 1995. *Lightscape User's Guide*. San Jose, CA: Autodesk.

Markus, T. A. 1967. The Function of Windows: A Reappraisal. *Building Science*. 2: 97-121.

Martel, S. and K. Presnell. 1999. Stand Alone PV. *Renewable World Energy*. 2 (3): 99-100.

Morgan, G. 1989. *Electric and Magnetic Fields from 60-Hertz Electric Power: What Do We Know About Possible Health Risks?* Department of Engineering and Public Policy. Pittsburgh, PA: Carnegie Mellon University.

Munger, B. 1997. An Improved Multipyronameter Array for the Measurement of Direct and Diffuse Radiation. M.S. Thesis. Texas A&M University. College Station, TX.

Myers, D. 1997. Radiometric Instrumentation and Measurements Guide for Photovoltaic Testing. Berkeley, CA: National Renewable Energy Laboratory.

Science News. 1999. Nighttime hormone helps starve cancers. *Science News*. 156 (10): 221.

Pearsall, N. and R. Hill. 1994. Calculation of Potential Resource from Building-integrated Photovoltaics. *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Photovoltaic Power Systems and The National Electrical Code. 1993. Las Cruces, New Mexico: Southwest Region Experiment Station and Southwest Technology Development Institute.

Piotrowski, C. 1985. Use of the Semantic Differential Technique in Research on Disaster: A Methodological Note. *Psychological Reports*. 56 (4): 527-30.

Posnansky, M. and S. Gnos. 1994. Building Integrated Photovoltaic Systems: PV Power Plants with Specially Conceived PV-Modules for Building Integration. *Proceedings of the Joint Solar Engineering Conference*. ASME. pp. 421-423.

Rosenfeld, J. 1998. *Measuring the Optical Properties of Advanced Glazing.* (Personal Collection, K. E. Sylvester).

Russell, J.A., Weiss, A. And G. A. Mendesohn. 1989. Affect Grid: A Single-Item Scale of Pleasure and Arousal. *Journal of Personality and Social Psychology*. 57 (3): 493-502.

Russell, J. A. and G. Pratt. 1980. A Description of the Affective Quality Attributed to Environments. *Journal of Personality and Social Psychology*. 38 (2): 311-322.

SAS Institute, Inc. 1993. *SAS/STAT User's Guide*. Version 6. Cary, NC: SAS Institute.

Schoen, J. N. and S. Blum. 1994. An Introduction to Photovoltaics in Buildings, *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Sloan, M. 1995. Texas Renewable Energy Resource Assessment: Survey, Overview & Recommendations. Austin, TX: Virtus Energy Research Associates.

Strand, R., Liesen, R., Pedersen, C., Fisher, D., Taylor, R., Winkelmann, F., Buhl F., Huang, J., Crawley, D. and L. Lawrie. 1999. Enhancing and Extending the Capabilities of the Building Heat Balance Simulation Technique for Use in Energy Plus. (Personal Collection, K. E. Sylvester)

Strong, S. 1994. World Overview of Development Activity in Building-Integrated Photovoltaics. *Proceedings of the Third International Workshop on Photovoltaics in Buildings*. Cambridge, MA.

Turner, W.D., Claridge, D., O'Neal, D., Haberl, J., Heffington, W., Harvey, T., and T. Sifuentes. 1998. Program Overview: The Texas LoanSTAR Program. *Proceedings of the Eleventh Symposium on Improving Building Systems in Hot and Humid Climates*. Ft. Worth, TX: Texas Building Institute. pp. 99-112.

UPG. 1997. Request for Proposals: 1997 TEAM-UP Program. Washington DC: Utility Photovoltaic Group.

Ward, Gregory J., The Radiance Lighting Simulation and Rendering System. Computer Graphics. *Proceedings of '94 SIGGRAPH Conference.* pp. 459-72.

Watson, D. 1993. *The Energy Design Handbook.* Washington, DC: The American Institute of Architects.

Watson, D., Clark, L. A. and A. Tellegen. 1988. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *Journal of Personality and Social Psychology.* 54 (6): 1063-1070.

Wotton, E. and B. Barkow. 1983. An Investigation of the Effects of Windows and Lighting in Offices. *Proceedings of the 1983 Daylighting Conference.* Phoenix, AZ.

APPENDIX A

Notes

This Appendix contains terms used within this dissertation and within documents produced by EIA (1994). Some terms have been developed specifically for this dissertation while others have been taken directly from the EIA documents.

Air-Handling Unit: A type of heating and/or cooling distribution equipment that channels warm or cool air to different parts of a building. This process of channeling the conditioned air often involves drawing air over heating or cooling coils and forcing it from a central location through ducts or air-handling units. Air-handling units are hidden in the walls or ceilings, where they use steam or hot water to heat or chill water to cool the air inside the ductwork.

Baseboard: A type of heating distribution equipment in which either electric resistance coils or finned tubes carrying steam or hot water are mounted behind shallow panels along baseboards. Baseboards rely on passive convection to distribute heated air in the space. Electric baseboards are an example of an Individual Space Heater.

Boiler: A type of space-heating equipment consisting of a vessel or tank where heat produced from the combustion of such fuels as natural gas, fuel oil, or coal is used to generate hot water or steam. Many buildings have their own boilers, while other buildings have steam or hot water piped in from a central plant.

Building: A structure totally enclosed by walls extending from the foundation to the roof, containing over 1,000 square feet of floorspace and intended for human occupancy. Included in the survey as a specific exception were structures erected on pillars to elevate the first fully enclosed level but leaving the sides at ground level open.

Building Shell (Envelope): The thermal envelope of the building, that is, the roof, exterior walls, and bottom floors that enclose conditioned space through which thermal energy may be transferred to or from the exterior.

Building Shell Conservation Features: Features designed to reduce the energy loss or gain through the shell or envelope of the building. This category includes roof, ceiling or wall insulation; storm windows or double-or-triple-paned glass (multiple glazing); tinted or reflecting glass or shading films; and exterior or interior shadings or awnings.

Built-Up Roof: A roof covering consisting of several successive layers (each of which is called a "ply"), usually of roofing felt, with mopping of hot asphalt between layers and topped by a mineral-surfaced layer or by gravel embedded in a heavy coat of asphalt.

Commercial: Neither residential, manufacturing/industrial, nor agricultural.

Commercial Building: A building with more than 50% of its floorsapce used for commercial activities. Commercial buildings include, but are not limited to, the following: stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings were included except for buildings on sites with restricted access, such as some military bases. Agricultural buildings, parking garages, residences, and manufacturing/industrial buildings were excluded from the survey. In 1995, commercial buildings on manufacturing sites were also excluded.

Compact Fluorescent Light Bulb: A light bulb designed to replace screw-in incandescent light bulbs, they are often found in table lamps, wall sconces, and hall and ceiling fixtures of commercial buildings with residential type lights. They combine the efficiency of fluorescent lighting with the convenience of standard incandescent bulbs. Light is produced the same way as with other fluorescent lamps. Compact fluorescent bulbs have either electronic or magnetic ballasts.

Computer Room with Separate Air-Conditioning System: An energy-related function that has space specifically designed and equipped to meet the needs of computer equipment. The air-conditioning system for this area controls the temperature and/or humidity and is separate from that used to control the environment in other parts of the building. Walls and doors usually separate the space. Sometimes such rooms have raised floors with ventilation equipment located under the floor.

Cooling: As an energy end use, the conditioning of air in a room for human comfort by a refrigeration unit (such as an air conditioner or heat pump) or by a central cooling or district cooling system that circulates chilled water. Excluded is the use of fans or blowers by themselves, without chilled air or water.

Cooling Degree-Days (CDD): A measure of how hot a location was over a period of time, relative to a base temperature. In this report, the base temperature is 65 degrees Fahrenheit, and the period of time is one year. The cooling degree-day is the difference between that day's average temperature and 65 degrees if the daily average is greater than 65; it is zero if the daily average temperature is less than or equal to 65. Cooling degree-days for a year are the sum of the daily cooling degree-days for that year.

Cooling Distribution Equipment: The part of a cooling system that distributes conditioned water and/or air throughout a building by means of pipes, ducts, or fans. Often the distribution serves both heating and cooling.

Cooling Equipment: The equipment used for cooling room air in the building for human comfort.

Census Regions: Census Regions divide the United States into four geographic regions, each with nine to 16 states in each. They are:

Region	State(s)
Northeast Region	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont
Midwest Region	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin
South Region	Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana. Maryland. Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
West Region	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon. Utah. Washington, and Wyoming

Climate Zone: The United States is divided into five climatically distinct areas (climate zones) that are defined by long-term weather conditions, which affect heating and cooling loads in buildings. The zones are based on the 45-year average annual number of degree-days (with a 65 degree Fahrenheit base). Annual heating degree-days (HDD) are a measure of how cold a building location is relative to the base temperature. The HDD is the numerical difference between the 45-year average temperature and 65 degrees (if less than 65; otherwise it is zero); annual HDD is the sum of the daily HDD for the reference year. Annual cooling degree-days (CDD) are a measure of how warm a building location is relative to the base temperature. The CDD is the numerical difference between the 45 year average temperature and 65 degrees (if greater than 65; otherwise it is zero); annual CDD is the sum of the daily CDD for the reference year. Temperature data from the National Oceanic and Atmospheric Administration were used to define five climate zones for the United States. The zones are oriented roughly east-west, with Zone 1 the northernmost (and coldest) and Zone 5 the southernmost (and warmest).

Climate Zone	*Description*	*Cities*
1	Fewer than 2,000 average annual CDD; more than 7,000 average annual HDD	Billings, Montana; Casper, Wyoming; Minneapolis, Minnesota; Augusta, Maine
2	Fewer than 2,000 average annual CDD; 5,500 to 7,000 average annual HDD	Reno, Nevada; Omaha, Nebraska; Des Moines, Iowa; Indianapolis, Indiana; Boston, Massachusetts
3	Fewer than 2,000 average annual CDD; 4,000 to 5,499 average annual HDD	Seattle, Washington; Albuquerque, New Mexico; Wichita, Kansas; Lexington, Kentucky; Baltimore, Maryland
4	Fewer than 2,000 average annual CDD; fewer than 4,000 average annual HDD	San Francisco, California; Lubbock, Texas; Memphis, Tennessee; Raleigh, North Carolina
5	2,000 or more average annual CDD; fewer than 4,000 average annual HDD	Honolulu, Hawaii; Las Vegas, Nevada; Dallas, Texas; New Orleans, Louisiana; Miami, Florida

Central Chiller: A type of cooling equipment that is centrally located and that produces chilled water in order to cool air. The chilled water or cold air is then distributed throughout the building using pipes or air ducts, or both. These systems are also commonly known as "chillers," "centrifugal chillers," "reciprocating chillers" or "absorption chillers." Chillers are generally located in, or just outside, the building they serve. Chillers located at central plants are included under district chilled water.

Compact Fluorescent Light Bulb: A light bulb designed to replace screw-in incandescent light bulbs, they are often found in table lamps, wall sconces and hall and ceiling fixtures of commercial buildings with residential type lights. They combine the efficiency of fluorescent lighting with the convenience of standard incandescent bulbs. Light is produced the same way as other fluorescent lamps. Compact fluorescent bulbs have either electronic or magnetic ballasts.

District Chilled Water: Water chilled outside of the building in a central plant and piped into the building as an energy source for cooling. Chilled water may be purchased from a utility or provided by a central physical plant in a separate building that is part of the same multibuilding facility (for example, a hospital complex or university).

District Heat: Steam or hot water produced outside of the building in a central plant and piped into the building as an energy source for space heating or another end use. The district heat may be purchased from a utility or provided by a central physical plant in a separate building that is part of the same multibuilding facility (for example, a hospital complex or university.) District heat includes district steam and/or district hot water.

DOE-2 Software: DOE-2 is a public-domain computer program that performs an hour-by-hour simulation of a building's expected energy use and energy cost given a description of the building's climate, architecture, materials, operating schedules, and HVAC equipment. DOE-2 is widely used in the United States and in 42 other countries to design energy-efficient buildings, to analyze the impact of new technologies, and to develop energy conservation standards.

Distributed Water-Heating System: A type of water-heating system for heating water for other than space-heating purposes which is located at more than one place within a building. Often called a "point-of-use" water heating system, the water heater is located at the faucet and heats water only as required for immediate use. Because water is not heated until it is required, this equipment is more energy efficient.

Duct: A type of heating and/or cooling distribution equipment that is a passageway made of sheet metal or other suitable material to convey air from the heating, ventilating, and cooling system to and from the point of utilization.

Economizer Cycle: A heating, ventilation, and cooling (HVAC) conservation feature consisting of indoor and outdoor temperature and humidity sensors, dampers, motors, and motor controls for the ventilation system to reduce the air-conditioning load. Wherever the temperature and humidity of the outdoor air are more favorable (lower heat content) than the temperature and humidity of the return air, more outdoor air is brought into the building.

Electric Baseboard: An individual space heater with electric resistance coils mounted behind shallow panels along baseboards. Electric baseboards rely on passive convection to distribute heated air to the space.

Electricity: Electric energy supplied to a building by a central utility via power lines or from a central physical plant in separate building that is part of the same multibuilding facility. Electric power generated within a building for exclusive use in that building is specifically excluded from the definition of electricity as an energy source.

Electricity Generation: As an energy end use, the onsite production of electricity by mean of electricity generators on either a regular or emergency basis.

Emissivity: Emissivity is a spectrally dependent surface property that defines the radiative heat that is emitted from a surface within a particular spectrum. The higher the emissivity, the more heat is radiated from the surface of a material. Conversely, lower emissivity signifies less heat is radiated.

Energy Audit: An energy management practice consisting of an evaluation to provide information on the physical and operating characteristics of a building and its energy uses and processes. The energy audit is conducted at the premise or facility by trained auditors. Audit services vary from simple walk-through to building management training programs and site-specific process and efficiency evaluations. Audits can be initiated or sponsored and performed by a local utility; a Federal, State or local government; a building owner; or an energy service contractor.

Energy Source: A type of energy or fuel consumed in the building. In this survey, information about the use of electricity, natural gas, fuel oil, district heat, district chilled water, propane, wood, coal, and solar thermal panels in commercial buildings was obtained from the building respondent. In most tables, wood, coal, and solar thermal panels are included in "Other" in the Energy Sources category.

Evaporative Cooler (Swamp Cooler): A type of cooling equipment that turns air into moist, cool air by saturating the air with water vapor. It does not cool air by use of a refrigeration unit. This type of equipment is commonly used in warm, dry climates.

Exterior or Interior Shadings or Awnings: A building shell conservation feature designed to reduce the flow of light into a building. Exterior shadings or awnings include any type of shading (including architectural) or awning on the outside of the building designed to limit solar penetration. Interior shadings are drapes, horizontal or vertical shades, mini blinds, or any other means of covering a window from the inside to limit the amount of solar or thermal penetration.

Electrochromatic Glazing uses the phenomenon of electrochromism (ion and electron injection/ejection) to color the window. Application of an electrical signal changes the thermal, solar and visible transmittance.

F-Chart is an authoritative solar system analysis and design program written by Professors Klein and Beckman at the University of Wisconsin, the originators of the F-Chart method.

Framing: Framing requirements for electrical wiring of photovoltaic modules require redesign to function as an electrical conduit that allows serial or parallel connection of photovoltaic modules.

Furnace: A type of space-heating equipment with an enclosed chamber where fuel is burned or electrical resistance is used to heat air directly, without using steam or hot water. The heated air is then distributed throughout the building, typically by air ducts.

Fluorescent Light Bulb: These are usually long, narrow, white tubes made of glass coated on the inside with fluorescent material that are connected to an electric fixture at both ends of the light bulb; the tubes may also be circular or U-shaped. The light bulb produces light by passing electricity through mercury vapor, causing the fluorescent coating to glow or fluoresce. Excluded are compact fluorescent light bulbs, which are a separate category . Fluorescent light bulbs are included in "Standard Fluorescent" in the Lighting Equipment category.

Fan-Coil Unit: A type of heating and/or cooling distribution equipment that circulates hot or chilled water with fans but without ducts. Fan-coil units have thermostatically controlled built-in fans that draw air from the room and then carry the air across finned tubes containing hot water, steam, or chilled water. The hot water, steam, or chilled water can be produced by equipment within the building or can be piped into the building as part of a district heating or cooling system.

Floors: The number of levels in the tallest section of a building that are actually considered a part of the building, including parking areas, basements, or other floors below ground level.

Floorspace: All the area enclosed by the exterior walls of a building, including indoor parking facilities, basements, hallways, lobbies, stairways, and elevator shafts. For aggregate floorspace statistics, floorspace was summed or aggregated over all buildings in a category (such as all office buildings in the United States).

Fluorescent Lamp: This is usually a long, narrow, white tube made of glass coated on the inside with fluorescent material that is connected to an electric fixture at both ends of the light bulb; the tube may also be circular or U-shaped. The light bulb produces light by passing electricity through mercury vapor, causing the fluorescent coating to glow or fluoresce. Excluded are compact fluorescent light bulbs, which are listed in a separate category. Fluorescent light bulbs are included in Standard Fluorescent in the Lighting Equipment category.

Fuel Oil: A liquid petroleum product used as an energy source that is less volatile than gasoline. Fuel oil includes distillate fuel oil (Nos. 1, 2, and 4), residual fuel oil (Nos. 5 and 6), and kerosene.

Furnace: A type of space-heating equipment with an enclosed chamber where fuel is burned or electrical resistance is used to heat air directly without steam or hot water. The heated air is then distributed throughout the building, typically by air ducts.

Geothermal Heat Pump: A renewable energy feature that uses the natural heat storage ability of the earth and/or the earth's groundwater to heat and/or cool the building. The earth has the ability to absorb and store heat energy from the sun. To use that stored energy, heat is extracted from the earth through a liquid medium (groundwater or an anti-freeze solution) and is pumped to the heat pump or heat exchanger. There, the heat is used to heat the building. In the summer, the process is reversed and indoor heat is extracted from the building and transferred to the earth through the liquid. The geothermal heat pump is more efficient than an air-source heat pump.

Government Owned: A building owned by a Federal, State, or local government agency. The building may be occupied by agencies of more than one government and may also be shared with non-government establishment.

Glazing Cost Factors: Glazing cost factors as defined by Kiss (1993) for standard curtain wall systems are listed below: 1) type and quality of framing desired such as structural silicon or pressure plate detailing, interior of exterior glazed, tabular or I-beam framing, etc., 2) desired thermal characteristics such as thermal breaks, insulated glass, etc., 3) type of glazing material used, such as tempered glass, laminated glass, stone, spandrel panels, etc., 4) finish of the framing, 5) dimensions of the framing members and panels, 6) manufacturer's flexibility, for example, custom designs, specialty products, 7) field installation vs. prefabrication, 8) location / climate, 9) geometry of the wall surface, for example, number of individual elements, 10) size of the building, and 11) desired quality, tolerances and standards.

High-Intensity Discharge (HID) Light Bulb: A lamp that produces light by passing electricity through gas, which causes the gas to glow. Examples of HID lamps are mercury vapor lamps, metal halide lamps, and high- and low-pressure sodium lamps. HID lamps have an extremely long life and emit many more lumens per fixture than do fluorescent lights.

Halogen Light Bulb: A type of incandescent light bulb that lasts much longer and is more efficient than the common incandescent light bulb. The light bulb uses a halogen gas, usually iodine or bromine, that causes the evaporating tungsten to be redeposited on the filament, thus prolonging its life.

Heating Degree-Days (HDD): A measure of how cold a location was over a period of time, relative to a base temperature. In this report, the base temperature used is 65 degrees Fahrenheit, and the period of time is one year. The heating degree-day is the difference between that day's average temperature and 65 degrees if the daily average is less than 65; it is zero if the daily average temperature is greater than or equal to 65. Heating degree-days for a year are the sum of the daily heating degree-days for days that year.

Heating Equipment: The equipment used for heating ambient air in the building such as a heat pump, furnace, boiler, packaged-heating unit, individual space heater, and district steam or hot water piped in from outside the building.

Heating, Ventilation, and Air Conditioning (HVAC): The system or systems that condition air in a building.

Heat mirror glass incorporates a double pane unit with a suspended film stretched between the panes of glass. It has a selective wavelength coating of metallic particles (i.e. metal oxides), which controls emissivity and thus re-radiates infrared heat back outside. It also controls UV transmission and visible light through varying degrees of reflectivity.

Heat Pump: A type of heating and/or cooling equipment that draws heat into a building from outside and, during the cooling season, ejects heat from the building to the outside. Heat pumps are vapor-compression refrigeration systems whose indoor-outdoor coils are used reversibly as condensers or evaporators, depending on the need for heating or cooling.

HVAC Conservation Features: A building feature designed to reduce the amount of energy consumed by the heating, cooling, and ventilating equipment. This category includes the presence of a variable air-volume (VAV) system, an economizer cycle, and HVAC maintenance programs.

HVAC Maintenance: An HVAC conservation feature consisting of a program of routing inspection and service for heating and/or cooling equipment. The inspection is performed on a regular basis, even if there are no apparent problems.

Incandescent Light Bulb: A light bulb that produces a soft warm light by electrically heating a tungsten filament so that it glows. Because so much of the energy is lost as heat, these are highly inefficient sources of light. Included in this category are familiar type of light bulbs which screw into sockets, as well as energy-efficient incandescent bulbs, such as Reflector or R-Lamps (accent and task lighting), Parabolic Aluminized Reflector (PAR) lamps (flood and spot lighting), and Ellipsoidal Reflector (ER) lamps (recessed lighting).

Individual Air Conditioner: A type of cooling equipment installed in either walls or windows (with heat-radiating condensers exposed to the outdoor air). These self-contained units are characterized by a lack of pipes or duct work for distributing the cool air; the units condition only air in the room or areas where they are located.

Individual Space Heater: A type of space heating equipment that is a free-standing or a self-contained unit that generates and delivers heat to a local zone within the building. The heater may be permanently mounted in a wall or floor or may be portable. Examples of individual space heaters include electric baseboards, electric radiant or quartz heaters, heating panels, gas- or kerosene-fired unit heaters, wood stoves, and infrared radiant heaters. These heaters are characterized by a lack of pipes or duct work for distributing hot water, steam, or warm air through the building.

Insulation: A building shell conservation feature consisting of material placed between the interior of a building (in the roof below the waterproofing layer or in the ceiling of the top floor in the building or between the exterior and interior walls of a building) and outdoor environment to reduce the rate of heat loss to the environment or heat gain from the environment. Examples include glass-wool fill and foam board.

Kerosene: A petroleum distillate with properties similar to those of No. 1 fuel oil; used primarily in space heaters, cooking stoves, and water heaters. In this report, no distinction is made between kerosene and fuel oil.

Lighting Conservation Features: A building feature or practice designed to reduce the amount of energy consumed by the lighting system. Lighting Conservation Features include natural lighting control sensors, manual dimmer switches, occupancy sensors, specular reflectors, time clocks or timed switchers, and energy-efficient ballasts.

Lighting Equipment: Light bulbs used to light a building's interior, such as incandescent light bulbs, standard and compact fluorescent light bulbs, high-intensity discharge (HID) lights, and halogen bulbs.

Manufacturing: As an energy end use, any of the energy-using operations required for manufacturing/industrial processes.

Mean: The simple average for a population characteristics is the sum of all the values in a population divided by the size of the population. For this report, population means are estimated by computing the weighted sum of the sample values, then dividing by the sum of the sample weights. For example, "Mean Hours per Week" is the weighted sum of the number of operating hours divided by the weighted sum of the number of buildings; "Mean Square Feet per Building" is the weighted sum of the total square feet divided by the weighted sum of the total square feet divided by the weighted sum of the total number of main shift workers.

Natural Gas: Hydrocarbon gas (mostly methane) supplied as an energy source to individual buildings by pipelines from a central utility company. Natural gas does not refer to liquefied petroleum gas (LPG) or to privately owned gas wells operated by a building owner.

Natural Lighting Control Sensors: A lighting conservation feature that takes advantage of sunlight to cut the amount of electric lighting used in a building by varying output of the lighting system in response to variations in available daylight. It is sometimes referred to as "daylighting controls" or "photocells."

Ownership and Occupancy: Ownership refers to the individual, agency, or organization that owns the building. In this report, building ownership is grouped into Government ownership (Federal, State, or local) and Nongovernment ownership (a private business or nonprofit organization owned by a group or an individual).

Occupancy refers to the individual, agency, or organization that leases or holds the space on a full-time basis.

Packaged Unit: A type of heating and/or cooling equipment that is assembled at a factory and installed as a self-contained unit. Packaged units are in contrast to engineer-specified units built up from individual components for use in a given building. Some type of electric packaged units are also called "Direct Expansion," or DX, units. Passive Solar Features: A renewable energy feature with a deliberate approach to designing buildings to make use of natural ways to heat buildings in the winter and keep them cool in the summer. No external mechanical power is used to move the collected solar heat. Passive solar design features include structuring the building on the lot so that large window areas face south to capture sunlight during the winter months; building "overhangs" on the south-facing windows to keep thesun from over heating the building during the summer; using certain types of building material to absorb heat during the day and release heat at night; and planting trees and vegetation to minimize heat gain in the building in the summer.

Packaged Heating Unit: A type of heating and/or cooling equipment that is assembled at a factory and installed as a self-contained unit. Packaged units are in contrast to engineer-specified units built up from individual components for use in a given building. Some types of electric packaged units are also called "Direct Expansion" or DX units.

Packaged Air-Conditioning Unit: A type of heating and/or cooling equipment that is assembled at a factory and installed as a self-contained unit. Packaged units are in contrast to engineer-specified units built up from individual components for use in a given building. Some types of electric packaged units are also called "Direct Expansion" or DX units.

Photovoltaic Glazed Windows are glass substrates layered with a photovoltaic (electricity producing) coating. These systems are constructed using typical window manufacturing processes, which have been redesigned with electrical circuitry.

PV F-Chart. PV F-CHART is a comprehensive photovoltaic system analysis and design program. The program provides monthly-average performance estimates. The calculations are based upon methods developed at the University of Wisconsin that uses solar radiation utilization to account for statistical variation of radiation and the load.

Swamp Cooler (Evaporative Cooler): A type of cooling equipment that turns air into moist, cool air by saturating the air with water vapor. It does not cool air by use of a refrigeration unit. This type of equipment is commonly used in warm, dry climates.

Space Heating Equipment: Boiler: A type of space-heating equipment consisting of a vessel or tank where heat produced from the combustion of fuels such as natural gas, fuel oil, or coal is used to generate hot water or steam. Many buildings have their own boilers, while other buildings have steam or hot water piped in from a central plant. For this survey, only boilers inside the building (or serving only that particular building) are counted as part of the building's heating system. Steam or hot water piped into a building from a central plant is considered district heat.

Solar Glazings: Low-E (low emittance) coating is a thin (<100mm) metal oxide or often multi-layer metal-oxide coating deposited on a glazing surface to reduce its thermal infrared emittance and thereby reduce radiative heat transfer at or near room temperature. Near infrared emittance may also be reduced depending on whether solar heat is to be rejected or admitted.

Space Heating: As an energy end use, the use of mechanical equipment (including wood stoves and active solar heating devices) to heat all, or part, of a building to at least 50 degrees Fahrenheit.

Square Footage: Floorspace, in units of square feet. One square foot is approximately equal to 0.0929 square meters.

Tinted or Reflective Glass, or Shading Film: A building shell conservation feature consisting of tinted or reflective glass or shading films installed on the exterior glazing of a building to reduce the rate of solar penetration into the building.

Variable Air-volume (VAV) System: An HVAC conservation feature usually referred to as "VAV" that supplies varying quantities of conditional (heated or cooled) air to different parts of a building according to the heating and cooling needs of those specific areas.

Variance: A measure of the variability of a set of observations that are subject to some chance variation, equal to the expected squared difference between a single observation and the average of all possible observations obtained in the same manner. The variance is the square of the standard error of estimates. The variance indicates the likely difference between the value computed from the CBECS sample and the average of the values that could have been computed from all possible samples that might have been obtained by the same sample selection process.

Weekly Operating Hours: The number of hours per week that a building is used, excluding hours when the building is occupied only by maintenance, security, or other support personnel. For buildings with a schedule that varied during the year, "Weekly Operating Hours" refer to the total weekly hours for the schedule most often followed. If operating hours varied throughout a building, the usual operating hours of the largest business in the building (based on floorspace) determined the operating hours for the building.

Weight: The number of buildings in the United States that a particular sample building represents. To estimate the total value of an attribute (such as square footage) in the U.S. commercial buildings population as a whole, each sample building's value is multiplied by the building's weight. Summing (aggregating) the weighted sample values provides an estimate of the national total.

Window or Vision Glass: An exterior wall construction material made of glass that can be seen through from the inside of the building, like the glass found in windows.

Walls that are glass-covered or constructed of non-transparent material are excluded from this category.

WINDOW 4.1 . Window 4.1 program is used worldwide by manufacturers and architects to determine window properties and ratings. To operate WINDOW 4.1, the user feeds information about window characteristics into the program. This includes descriptions of the glass to be used, the number of layers and their solar and infrared properties, the type of low-conductivity gas between the layers, and frame size, dimensions, and materials. In turn, WINDOW 4.1 determines rating numbers; the most important of which is the "U" value, a measure of heat transmission. It also specifies the solar heat gain coefficient, which influences cooling loads, and the visible transmittance--how much visible light comes through the window. All of these numbers relate to energy efficiency and tell manufacturers or designers if their windows comply with energy codes. WINDOW and DOE-2 have a link between them so that proposed windows can be analyzed and a data file created and fed from WINDOW 4.1 into DOE-2 as one of many factors it needs to analyze total energy use in a building.

Workers: The number of people working in a building during the main shift on a typical workday during the year. The main shift is the time when most people are in the building. Included in this definition are self-employed workers and volunteers. Excluded from this definition are customers, patients, and students, unless they are working for establishments in the building. Also excluded are employees who work out of the office, such as salespeople who report into the office, delivery people with routes, and messages.

APPENDIX B

Building Height Analysis

New York City	Floors	Year	Address
World Trade Building 1	110	1972	—
World Trade Building 2	110	1972	—
1 Battery Park Plaza	35	1971	24 State Street
One Bankers Trust Plaza	40	1974	130 Liberty Street
Building	40	—	15 Broad Street
Building	30	1986	33 Mansen Lane
Building	32	1912-1914	61 Broadway
Shearson Lehman Plaza	39	1989	388 Greenwich Street
Barciays Bank	33	1986	75 Wall Street
Emery Roth & Sons	26	1970	77 Water Street
Whitehall Building	31	1900-1910	West Street & Battery Plaza
1 State State Plaza	35	1969	White Hall & Water Street
Building	37	1931	19 Reltor Street
1 Financial Square	37	1987	33 Old Ship
Downtown Athletic Club	36	1930	19 West Street
Building	31	1967	55 Broad Street
Building	32	1959	2 Broadway
Building	28*	1971	22 Cortland Street
Building	48	1932	30 Broad Street
Goldman Sachs	29	1983	85 Broad Street
Federal Office Building	32	1994	290 Broadway
Building	33	1930	120 Wall Street
Building	28*	1983	175 Water Street
Building	32	1971	127 St. Johns Street
Building	40	1960	80 Pine Street
Building	53	1972	55 Water Street
1 Seaport Plaza	34	1983	199 Water Street
1 UN Plaza	40	1976	1st Avenue
2 UN Plaza	40	1983	1st Avenue
Building	29	1982	875 3rd Avenue
Building	40	1980	767 3rd Avenue
Building	31	1988	425 Lexington Avenue
Building	26	1986	527 Madison Avenue
Manhattan Tower	41	1985	101 East 52nd Street
Bell Atlantic	40	1970	1095 6th Avenue
Building	32	1987	137 East 57th Street
Building	38	1966	860 UN Plaza
Building	38	1966	870 UN Plaza
Building	39	1961	633 3rd Avenue
Building	30	1988	750 Lexington
Park Avenue Tower	36	1987	65 East 55th Street
Emery Roth & Sons	36	1982	535 Madison Avenue
Building	20	1962	104 West 40th Street
Tower 49	44	1984	12 East 49th Street
Building	42	1971	600 3rd Avenue
Ransom House	40	1969	825 3rd Avenue
Average Height for New York	**39**		

Los Angeles	Floors	Year	Address
First Interstate Bank Building	62	1973	707 Wilshire Boulevard
Building	36	1985-1987	865 South Figueroa Street
Building	24	1991-1992	801 South Figueroa Street
Citicorp/Seventh Market Place	41	1985-1988	725 South Figueroa Street
Citieorp/Seventh Market Place	53	1988-1990	777 South Figueroa Street
Sanwa Bank Plaza	52	1986-1989	601 South Figueroa Street
Union Bank Building	40	1968	445 South Figueroa Street
Atlantic Richfield Plaza	52	1972	515 & 555 Flower Street

Building	28	1941	550 South Hope Street
First Interstate World Center	73	1988-1990	633 West 5th Street
Gas Company Tower	52	1988-1991	555 West 5th Street
Building	48	1979	444 South Flower Street
Westin Bonaventure Hotel	32	1974-1976	404 South Flower Street
Wells Fargo Plaza	54	1982-1983	333 South Grand Avenue
IBM Tower South	45	1982-1983	355 South Grand Avenue
One California Tower	42	1985	300 South Grand Avenue
Two California Tower	52	1992	350 South Grand Avenue
Security Pacific Plaza	55	1973-1974	333 South Hope Street
Average Height for Los Angeles	**47**		

Houston	**Floors**	**Year**	**Address**
Republic Bank	56	1960	700 Louisiana Street
One Houston Center	—	1978	—
Two Houston Center	—	1974	—
Chevron Tower	—	1983	—
First City Tower	—	1981	—
Bank One Center	30*	1954-1993	—
Building	45*	1981	1100 Louisiana Street
Texas American Building	24	1920	—
First Interstate Bank Plaza	71	—	—
Average Height for Houston	**50**		
Detroit	**Floors**	**Year**	**Address**
Renaissance Center	45*	—	—

Overall Average **42**

APPENDIX C

Solar Irradiance Tables for the Human Assessment

Appendix Table 1. Solar Irradiance Values for Clear Glazing

Time	*Houston Solar*	*Sim. Sun*	*Refl. Light*	*Backg round*	*Los Angeles*	*Sim. Sun*	*Refl. Light*	*Backgr ound*	*Detroit*	*Sim. Sun*	*Refl. Light*	*Backg round*	*NY - CenP*	*Sim. Sun*	*Refl. Light*	*Backg round*
5- 6	4.19	6.06	1.82	0.02	5.86	8.47	2.54	0.03	8.79	12.70	3.81	0.05	8.02	11.59	3.48	0.05
6- 7	16.62	24.02	7.21	0.09	19.51	28.20	8.46	0.11	24.31	35.13	10.54	0.14	22.32	32.26	9.68	0.13
7- 8	44.20	63.88	19.16	0.25	56.13	81.12	24.34	0.32	53.50	77.32	23.20	0.30	48.72	70.41	21.12	0.28
8- 9	74.39	107.51	32.25	0.42	95.47	137.98	41.39	0.54	84.39	121.96	36.59	0.48	76.70	110.85	33.26	0.43
9-10	102.66	148.37	44.51	0.58	132.21	191.08	57.32	0.75	112.98	163.28	48.98	0.64	102.63	148.33	44.50	0.58
10-11	124.63	180.12	54.04	0.71	160.79	232.38	69.71	0.91	135.05	195.18	58.55	0.77	122.67	177.29	53.19	0.70
11-12	136.65	197.49	59.25	0.77	176.44	255.00	76.50	1.00	147.09	212.58	63.77	0.83	133.61	193.10	57.93	0.76
12-13	136.65	197.49	59.25	0.77	176.44	255.00	76.50	1.00	147.09	212.58	63.77	0.83	133.61	193.10	57.93	0.76
13-14	124.63	180.12	54.04	0.71	160.79	232.38	69.71	0.91	135.05	195.18	58.55	0.77	122.67	177.29	53.19	0.70
14-15	102.66	148.37	44.51	0.58	132.21	191.08	57.32	0.75	112.98	163.28	48.98	0.64	102.63	148.33	44.50	0.58
15-16	74.39	107.51	32.25	0.42	95.47	137.98	41.39	0.54	84.39	121.96	36.59	0.48	76.70	110.85	33.26	0.43
16-17	44.20	63.88	19.16	0.25	56.13	81.12	24.34	0.32	53.50	77.32	23.19	0.30	48.72	70.41	21.12	0.28
17-18	16.62	24.02	7.21	0.09	19.51	28.20	8.46	0.11	24.31	35.13	10.54	0.14	22.32	32.26	9.68	0.13
18-19	4.19	6.06	1.82	0.02	5.86	8.47	2.54	0.03	8.79	12.70	3.81	0.05	8.02	11.59	3.48	0.05

Appendix Table 2. Solar Irradiance Values for Glazing with 40% Transmissivity.

Time	*Houston Solar*	*Sim. Sun*	*Refl. Light*	*Los Angeles*	*Sim. Sun*	*Refl. Light*	*Backg round*	*Detroit*	*Sim. Sun*	*Refl. Light*	*NY - CenP*	*Sim. Sun*	*Refl. Light*
5- 6	4.19	2.42	0.73	5.86	3.39	1.02		8.79	5.08	1.52	8.02	4.64	1.39
6- 7	16.62	9.61	2.88	19.51	11.28	3.38		24.31	14.05	4.22	22.32	12.90	3.87
7- 8	44.20	25.55	7.67	56.13	32.45	9.73		53.50	30.93	9.28	48.72	28.17	8.45
8- 9	74.39	43.00	12.90	95.47	55.19	16.56		84.39	48.78	14.64	76.70	44.34	13.30
9-10	102.66	59.35	17.80	132.21	76.43	22.93		112.98	65.31	19.59	102.63	59.33	17.80
10-11	124.63	72.05	21.61	160.79	92.95	27.89		135.05	78.07	23.42	122.67	70.92	21.27
11-12	136.65	79.00	23.70	176.44	102.00	30.60		147.09	85.03	25.51	133.61	77.24	23.17
12-13	136.65	79.00	23.70	176.44	102.00	30.60		147.09	85.03	25.51	133.61	77.24	23.17
13-14	124.63	72.05	21.61	160.79	92.95	27.89		135.05	78.07	23.42	122.67	70.92	21.27
14-15	102.66	59.35	17.80	132.21	76.43	22.93		112.98	65.31	19.59	102.63	59.33	17.80
15-16	74.39	43.00	12.90	95.47	55.19	16.56		84.39	48.78	14.64	76.70	44.34	13.30
16-17	44.20	25.55	7.67	56.13	32.45	9.73		53.50	30.93	9.28	48.72	28.17	8.45
17-18	16.62	9.61	2.88	19.51	11.28	3.38		24.31	14.05	4.22	22.32	12.90	3.87
18-19	4.19	2.42	0.73	5.86	3.39	1.02		8.79	5.08	1.52	8.02	4.64	1.39

APPENDIX D

Survey Responses (Pilot Study)

This appendix shows survey responses and collected data for the human assessment. Sixteen subjects were surveyed and the written responses are given below. For the collection of data, the study used sixteen video segments for varying conditions based on view, site, and window treatment.

1. I did not notice a diffferences, except the effect of light. Both scenerios were presented very good and with enough time between.
2. enjoyable.
3. Personally no offense but I didn't think this exercise was very useful.
4. No comment except thanks for the extra credit.
5. Kind of vague, for fetched. Realy had to stretch to get any kind of emotion out of that. Not enough space. Bad view. Needs people or something (noise) to make realistic. Nobody's office is that quiet.
6. I noticed small differences in the amount of light let in by the different windows. I thought the more light the more pleasant and arousing it was. The less light, I felt a little less stimulated. The room was also boring. It was just a plain office with nothing on the desk. The furniture was very bland and uninspiring. There was nothing of interest in it.
7. The window views were much more stimulating, while the spaces without the windows were more relaxing. The only time I had unpleasant feeling is if there was too much light (stressful) or not enough (gloomy). For the most part, though, I experienced varying degrees of pleasant feelings.
8. Bright was positive but tobright was (stressful). Dark was gloomy.
9. The picture without the window was quite boring. In the beginning I thought the window animation was pretty neat but now (I) thought it was pretty boring. I thought repetition was also the cause of my boredom.
10. Some were more difficult to comment on since during the day the light would b e offensively bright and later very gloomy.
11. I could tell the difference in the window types. The on that allowed more light in was most pleasing and seems it could be a better morning environment.

12. At times it was hard to tell the difference between different simulations. None gave me strong feelings in any of the four directions.
13. The rooms with larger changes in the intensity of light were more stimulating. The rooms with lager amount of natural light seemed more pleasant. The offices in which you could see the cycle of the day were most pleasing and stimulation.
14. If I were in the office, facing the window would be more stimulating and arousing. Also, having more light come in and filter through the room is more arousing as long as the sunlight did not make it hot in the room. The pictures where it only got somewhat lighter in the room were pretty gloomy. Also, not being able to see the sunlight (facing the wall) was pretty depressing.
15. Lack of sunlight makes the office very boring and gloomy and would nt seem to be a productive environment.
16. While viewing these diffent settings I did notice them having some effect, but nothing major. Some did seem to be more pleasant than others while some were more gloomy and less attractive to the eye. Overall I feel this sheet gives a fairly valid description of how it effected me personally.
17. The effects looking in the backo fht e room were not visible for the most part. I really like more light.
18. One of the things that really turned me off to a specific setup was the hazy looking film on the windows. It made me feel like I was working in a cloud of smog. I also liked when the sun's light could reach across the room to the door and the natural light took over until the sun went down. However, when there are large sunny spots on the floor, I wanted to take a nap.

APPENDIX E

Survey Responses (Final Experiment)

1. I video of time laps with real sunlight would have been more accurate. The door was closed that's annoying. Sun spot in corner was nice. Could not see the building lit up at the night phase this was unpleasant
2. I thought the room chosen wasn't interesting enough to show the effect of light in offices. Most offices aren't entirely white with white furniture. There was a definite difference between pictures. The less lighting --- more sleepy/depressing response. The more lighting --- more of a relaxing/exciting response.
3. I used it when the office had more brighter light longer during the day. The rooms with the darker lights were more stressful. I like the numerous larger windows.
4. If your looking for the reaction to light, I think response to every window. Some windows were all the same, this giving a lot of .
5. The study was difficult to understand what the issues was – more explanation needed – changes in each were too vague not to pre-explain.
6. The majority of the simulations were not very different from each other, the few that were did change my feelings a little bit.
7. Video needed more color. Did not like the grid response. To many choices for answers. Responses should be more linear.
8. It was hard to see changes in wall without windows. Colors would of helped shade change-black/white to strange. We could have seen the simulation only once I have gotten the same response.
9. Cons: I didn't think the room was large enough to fully extenuate the lighting. The sunlight would have been more pleasant if there was a better scene in the background. Pros: I saw the lighting difference
10. You might learn something from this experiment.
11. Lighting in lecture hall kept from really seeing the difference in changes. Maybe bottom in smaller groups on a real tv. Computer was sort of blurry/screen did not do it justice. I think the survey is a great idea because working spaces are very important.
12. I liked the one that had no shadows on the inside (through the windows). The one that just lets the light in but did not have bright spots on the floor from the sun.
13. Was very interesting. Me personally do not like office spacing anyway.
14. Resolution wasn't clear enough. Time lapse needed to be longer period of time. Bigger space should have been utilized . Lighting seemed very similar on the projector.

15. I thought this was a unique way of surveying people about windows, thorough video. I liked it much better than reading a questionnaire and answering questions. The video resolution didn't do much justice to the video itself though. I though that could have been better.

16. Hard to distinguish black and white some of the simulations. The overhead projector was a little difficult to see because it was too small. It was a good survey, overall.

17. Video was not of good quality, and I did not see a great amount of change.

18. Light values were a little hard to tell the difference. There wasn't much of a difference between every simulation.

19. I understood th4e purpose the only thing is there were some pictures that you couldn't tell a difference in lighting. I don't think just looking at it that long gives you an accurate judgment of how it actually makes you feel. I think the office looked boring. I did like the grid response.

20. Many of the window lightings looked the same so it was hard to tell a difference. The best ones were where there was a fair amount of light from windows coming in and it lighted the whole room. Little light caused the room to be boring and sleepy.

21. The quality of the video/screen impaired the clarity of the differences between each simulation.

22. Overall, I noticed only slight variations in lighting and that itself was not greatly influential.

23. I really didn't like the experiment because I really couldn't judge each room. I felt obligated just to answer on one or two right in the middle.

24. The experiment overall was fine including the projection of the pictures.

25. I think the video showed what we needed to record an accurate response. It showed a different amount of light entering the room and gave me different feelings on each slide.

26. I thought the office space was a little small. I like the slides with brighten sunlight. All things being equal I thought the experiment was good.

27. The spaces were easy to see/understand. Video quality could have been better. Like the spaces that had light, but too much light made them too tense. Spaces with too little light were sleepy.

28. I thought the brighter light definitely enhanced the office space. The darker tones tend to make the office dreary. Overall quality of video could be a little better.

29. I think that the quality of the video and lighting was good enough to make a good evaluation.

30. I think it is very important to know how people are affected by windows and their place settings (and light).

31. Windows that show shadows in the room are generally more arousing. Quality of projection makes observing diff. Hard.

32. I did not think that this was worthless. I definitely see how lighting can affect a worker' Attitude, efficiency, etc. I think that the window itself is depressing. It is very bland and kind of had my mood down from the beginning.

33. The office space itself was depressing.

34. Some of the slides appeared the same. Maybe have a bigger change/variation. Show how paper or computer screen looks when the light changes.

35. I think this was a good exercise for this class because it made people pay attention to detail. I liked this experiment. Some views were hard to see a change.

36. I felt that some of the slides were more stimulating than others. However, I don't think the computer were of real life situations.

37. The lighting level was too high and the grid should have been larger and easier to read for easy reference.

38. A few of the slides looked different as far as the angle of the sun rays but there were only a few emotions . Sleepy, unpleasant or relaxing mainly sleepy.

39. Room seemed fake. Pictures seemed cloudy. Couldn't see city outside windows that well.

40. I thought a lot of the simulations were alike . . . it was hard to tell the differences between some of them. I didn't enjoy the room without the window too much; it was too bare and a bit dreary.

41. I thought that it was pointless, I don't think that the results will be accurate because I didn't really feel any emotions when the video was playing, they were all basically the same.

42. The high light in the viewing room made it hard to see different aspects. Up close (emersion) viewing may help to get more accurate results. Quality was fine.

43. I liked the settings, but the projector wasn't very good. The computer graphics were impressive.

44. I don't believe a computer simulation would have been the way to do this experiment. Computer simulations have a much more artificial feel to them than you would get in taping an actual office.

45. Disliked the non-existence of sun beams in certain scenarios. Disliked the lack of change of light in certain simulations.

46. Hard to tell difference between some of the pictures. Couldn't tell exact effect of lighting on the office

47. I don't like bright light. Bright light keeps me awake though I don't like offices.

48. Offices make me sleepy regardless of light, I am not an office person; however, the ones where the light changed dramatically were less sleepy.

49. The clarity wasn't great, a little out of focus sometimes it seemed (problem with machine?) hard to really see a lot of difference

50. The video was well done and the survey was very interesting. Thank you for letting us take part. I liked the graphics but the view toward the outside you could never focus on any of the objects outside even in the middle of the day to give a reference toward the time of day.

51. Some of the scenarios were so much a like I could hardly tell the difference and found myself mainly concentrating on differentiating them.

52. Many of the simulations looked the same. It was sometimes difficult to really say how I felt.

53. I only have one comment and that is you share with us your survey or the result of your information.

54. Realistic 3D modeling. Ambient interior lighting was too bright for the incident rays of the sun.

55. The screen was hard to see clearly. I think if I were watching it on a television or monitor it would have looked better.

56. There were noticeable differences in mood in the various scenes with different office lighting. The video was shaky at times, which may have made some spaces seem more stressful or exciting than others. The simulation seemed realistic, though, so the test was worthwhile. Unsure was to whether the grid answering system was effective in measurement, because it may be confusing for some.

57. I thought the simulation was a relatively accurate representation of the situation being tested. The lighting had a severe effect on my comfort in the simulation.

58. I really didn't see a big difference in the clips. Nothing was really arousing or exciting or were they sleepy or depressing.

59. It seemed like this survey would be a very vague study. Most people would not realize that their office lighting changed that much. I would have like more information of why we had to participate in the survey.

60. Like the bright lights. Didn't like the artificial light – sunlight good. The office itself was boring and depressing. Lighting helped it e more exciting, but there are many other tings (such as the decor) that can add to the excitement.

61. I would have used more than two offices. It started looking the same towards the end. The tree shadow did not change with the days shadow. It was an okay survey.

62. Picture was blurry (probably projector). Room could have been more exciting (more colors)

63. I thought that the simulations were not powerful enough to awake emotion. The simulations were also a little close. I felt I had too many response of emotion so pick how I felt.

64. The video did not influence much emotion because it was computer simulation. The view through the window influenced the general feeling too much – it was ugly.

65. I like moderate to high light but not to much. When its dark it makes me sleepy. Good project I thought was well put together.

66. I didn't like the bright glaring in on your eyes. Also the shot looking in at the shelf where no windows were seen was better at evaluating than the other shot was.

67. Room had no depth. Not sure of what test is for. Needed more wall fixtures (pictures, etc.) Computer simulation was excellent. If room contains natural wood. (dark) the room would have better depth and life.

68. I thought it was effective in its simulation of a typical day. The lighting worked well to illustrate the different levels projected through the window. I was mostly a positive interpretation.

69. It might have been easier to see difference is simulations if you could see them side by side.

70. I think test was put together with good quality. It wasn't the best picture for visual responses, but you could tell the difference between each picture just fine.

71. The space was legible. The last of A and the first of B were quite depressing. I would come in from a bad weekend, and leave in a worse more than the one I came in with. The simulation with immense light, was awesome. All the others would still work positive.

72. This was a good survey everything was legible. The light definitely made a difference in the way the room felt which can be seen in my marks.

73. Survey was interesting. The brightness caused my head to hurt, but that was due to scream. The shadow ply was what relaxed me the most leading to the gradual dimming of the lights.

74. I didn't like the ones with lots of light because it seemed almost hostile to me anyway. I didn't

75. like the two dim ones or the ones with very limited change during the day because they had a boring unappealing characteristic. My favorites were the ones with mid-level light and plenty of change throughout the day.

76. The video didn't really make me get real feelings so it may not have an accurate result.

77. I liked the office spaces that let more light through the windows. The more light that entered the room seemed to make it more pleasant and enjoyable. The less light was more depressing and sleepy to me.

78. The survey was and can be considered in my opinion a valid source of information. The presentation of the space was sufficient if not ideal and the idea of the study was portrayed accurately.

79. I think it was pretty worthless all of the spaces were basically the same. I don't think my opinion charged from clip to clip.

80. Computer simulation was a little unrealistic and distorted. Some scenes seemed repetitive at times. My survey might be rendered due to a long day and thus a sleepy state of mind. It seems appropriate to take this survey and I look forward to the answers.

81. I enjoyed the video – the simulation between night and day was very realistic with shadows and everything. The ones with lots of daylight were most enjoyable.

82. I really don't understand the video looking at lightness. The lightness viewed by looking through windows or at a corner of the room.

83. Room was very realistic and easy to understand the parts of it. The outside scene was also good. The "window" scene was better than the "bookshelf" scene because you could see the changes better. The experiment was easy to understand.

84. Typically the darker the room things were easier to see but not as pleasant. The room at times would get so bright one could not tell specifics.

85. The light/brightness of the video was hard to determine the difference between videos. Were we supposed to judge feeling during or after viewing. Confusing

86. I liked the ones where a lot of sunlight came in. I didn't like the ones where it looked foggy outside. That makes me sleepy.

87. In my opinion, the simulations were different, and I did fee/notice a difference in the way the light affected the environment. I quested the purpose of this study because it seems obvious which settings and amount of light is ideal for the environment.

88. I think that the space showed a good amount of difference in lighting. I think it gave a good idea.

89. I found it difficult to distinguish between some of the videos

90. I think this is an interesting experiment and I would be interested in the results

91. Some of them, I think, would have been a little better with higher quality video.

92. I think the survey was good for the purpose of the test. The computer simulation was really well done. The answering process was slightly confusing.

93. I think it did test the affects of light on space, but a lot of them were very subtle. I do think the projector had an effect on the picture. I also think there were too few choices of emotions but too many degrees of each.

94. The video looked like it was of good quality, especially for computer simulation, but it was difficult to see due to the light in the room. I did think the experiment was interesting. It was hard to tell the difference between slides.

95. Most of the lighting in the space seemed the same, but I think the brighter areas were better. For a better video I would think showing color outside the window would help with the evaluation.

96. Honestly, all of them had me feeling sleepy. The brighter lights definitely help make the space more vibrant and work/productivity conducive.

97. It was difficult to get a sense of a real life sense because it was computer simulated. And the video quality wasn't great. It was hard to judge the real effect the light has on the office.

98. I did not like it. It was boring and tedious. It did not have great quality and was very unamusing.

99. I thought that it did test what the lighting had to do with stress levels. I don't think that the clip were different enough to actually access the differences in the clips. The color quality was somewhat poor.

100. Visible light and constant change of light tones is more exciting than consistency of light.

101. The video was well simulated, but as far as the actual office space goes, it was a little dreary.

102. Hard to tell much difference sometimes except the most extreme simulations.

103. The spare was too sterile that's what made it uncomfortable the lighting was never too harsh or too soft. Without shades in the windows and color in the room – the spare was very "cell like". Granted, it was computer generated so that is partially to blame. But in regards to the purpose of the study the light is fine.

104. I'm not sure what the study was after, but it was pretty boring. I think the study was going after your attitude towards the amount of light that you receive in your office. I tried to be as positive as possible so this is what I came up with. This was difficult to judge. The words should have been either a yes or no and maybe one other selection instead of so many.

105. I believe the study was valid, but the quality of the video did not lend itself to the cause. Maybe we can try it again with a different video or try to enhance the quality in some way. Some of them looked to o similar. A little hard to see much of a difference on some of them. Maybe a different variety of windows or something. Couldn't really see out of the horizontal windows, need to put buildings in background or something. Office spaces were nice.

106. Maybe do a comparison of scenarios, to see which one we like better.

107. Need to see the grid with the possible responses better to see aroused/sleepy etc. only problem.

108. All things considered the think the experiment was controlled well. I see no problems with the procedure and physical properties of the room. The video was very realistic and a feel for a real life situation was given.

109. I don't think I was able to very accurately tell how the light made me feel because they all looked similar to me.

110. Everything seemed fine except the fact that the glazing made it seem foggy or overcast outside. Maybe make a note that the weather conditions are all the same.

111. Differences in some simulations were hard to tell apart

112. Video somewhat distracting – Length of seem good while intensity was negative. Visual restriction in seeing scale

113. The brighter time lapses were more pleasant but the quality of the simulation made it difficult to judge what lapses were too bright.

114. A unique project but I still cannot grasp how the results of this experiment can be used Video – fine

115. Chart – not see.

116. I felt this was hard to differentiate the different bright nesses and darkness' of the lighting. It was difficult to seethe lighting in this room.

117. The light quality of the room (Zach 102) was bad and made it difficult to see. Also the projection was bad.

118. Projection quality from projector was . Adding sound of different levels would add to the experience and aid in determining which type was most pleasant.

119. I thought the office space was too sterile looking. Maybe make it look more like an office. Pictures the desk facing door (for a client) blinds on side of windows. This would help the response be more accurate.

120. The preview was too lengthy. A quick instruction on what we were to look for with each example and two run throughs of the preview would have been sufficient enough to understand the purpose of the survey. Simulations could have been clearer. However, time constraints were quick and enough time to make a decision and move on.

121. I didn't like the ones with too much bright light. Simulation was accurate.

122. I really did not see a whole lot of differences in the pictures. I think some light is good, but a lot is distracting. The room gets too hot if there is a lot of sunlight.

123. Simulation was adequate, but the addition of weather conditions would help with determining a change of mood.

124. Most of the pictures shown were the same. Your eyes did not have the chance to register the difference between each clip.

125. I couldn't tell much difference in the simulations. I like the ones that let more light in. The computer animation looked real.

126. I didn't care for the really bright ones. I think that answers would be different depending on the mood of the person answering.

127. There were obvious changes in the lighting. I chose the answer that best suited my tastes.

128. I thought that the film was a little too dim – could be helped if the lights in front are turned off.

129. Maybe test would be more effective if film was in color.

130. The sequences all seemed to blend together perhaps if different office designs were used the different lighting sequences would have become more distinct. I believe that the computer simulation was accurate and the study achieved its desired effect.

131. I seemed to like the brighter office room where you could see the sun and if I had to work in an office that is what kind of room I would like. I would get more work done when I am aroused and pleasant.

132. Quality was kind of poor. However, you could tell the different lighting sequences but it was not very accurate. Color would be a nice additive I believe.

133. I did not like this experiment, because it was more the room's dullness that would put me in a bad mood than the window/lighting. It was hard to really hard to determine a feeling with the computer graphics.

134. I feel that most of the videos were too .; however, I believe that for me the brighter and shorter period of bright time would be the most aroused and most pleasing.

135. The quality of lighting was not well. Didn't like where the camera angle was (too high should be at eye level) liked the views with windows more than without a window

136. The simulations with more light definitely was more pleasant and arousing. There were a few that the light didn't change much and that made me sleepy, relaxed and depressed. And there were a few that seemed the same where my mood didn't change.

137. There wasn't enough variety between the pictures, but the computer simulation was pretty neat.

138. In the second scene, the shelves took up so much space on the wall that felt cluttered. When the first scene was lightened up you could see buildings out of the window this lead me to believe that this office was in a high rise when I liked. Brighter is better.

139. The simulation showed the contrast of the light and dark very well. Except the contrasts were better while viewing the desk and usual workplace not by the window.

140. Offices make me sleepy. I am an outside person and get tired and restless when cooped up.

141. Quality of the video was good, seemed to provide accurate interpretation of light during time lapse of day. Rooms without much light variation were the most non stressful working environments.

142. I can see what the survey is after, but I think its a little hard to see the affects since its computer generated.

143. It was much easier to see the lighting differential on the view looking into the room than the shots looking at the window (they looked much more similar). Very obviously a computer simulation, harder to gauge what it would look like in real life. Sunlight levels are so important if you're stuck inside all day. Too much sunlight will blind you but too little will depress you. Consider how it affects views.

144. This survey was almost boring. I was hoping to have more than two views. If I had to work in that place everyday, I think I'd go crazy. The rendering was okay

except that shadows were very sharp and lights seemed to flicker a lot on the last little segment.

145. The emptiness of the room provided a bleaker environment.

146. This survey was quite compelling, I never before thought of the effect upon light and mood in an office space. Now however I have a greatly different appreciation of light and it's use on effecting mood.

147. The darker the spaces, the more relaxed and sleepy I felt. But when the sun was shining on the space it gave me an exciting feeling. Overall I think they were mostly the same.

148. Didn't like the fact that it was just one room over and over again. Could have changed wall color, furniture, etc. The windows didn't even change.

149. I think the office space was too small I felt crammed into the space as If I had a hard time breathing and feeling comfortable. I also feel that the desk could be moved in order for the lighting to make you feel comfortable.

150. On the low light rooms, it is hard to see things in the room, but the pictures were legible. The low light rooms are depressing.

151. The screen quality was not very good. The dim lighting was not very good also, there should have been a blackout in the classroom for this simulation.

152. The video was of poor quality and there was some difficulty in determining all the variables. The video poorly delivered the appropriate light levels that I assume I was to evaluate.

153. I think the lighting in the room we were surveyed in should have been darker to get the effect of lighting change more effectively.

154. Didn't like drastic changes in lighting. Some poor quality in pictures.

155. It did seem similar when the rays of light hit the chair. I, therefore, could not tell space differences. Some of the lightness to darkness of the room as a whole were too bright for the room.

156. I thought the quality of the video was great – it was very realistic looking, especially with the sun coming through the windows. I do almost think one thing could be changed – for a different perspective of the video itself – If it was viewed from sitting in the desk chair itself, I might have gotten a better feel as if I personally was sitting within the space right now. This was pretty cool.

157. I felt that the video quality was poor, however sufficient to accurately judge the different window treatments. The one factor that I was unable to take into account was the color of light compared between the fluorescent bulb and natural window light.

158. I did not see enough difference to fully understand how I was supposed to respond. Lighting of windows is for the most part natural, so therefor why outside lighting?

159. I thought that this presentation was good because you could tell the quality by the shadows, the lights, the window glare and the detail outside the window. Great project. I hope it works out.

160. White walls are very interesting to use for simulation due to contrast reasons. Good luck with project

161. I could tell there was a difference in most of them. Some I thought looked the same. The grid was a little difficult to judge my reactions on each simulation.

162. Interesting survey. Job well done in trying to simulate the real world.

163. Its somewhat hard to get a real sense of things when the stimuli is only on a small screen a good distance in front of you. Probably a high quality video would be more convincing and be a better simulation than using the computer.

164. Video was not the best quality maybe because of the projector. I think it would have been a little more real had it not been computer simulated. Once you explained the grid system it was easy to understand.

165. The directions were a little hard to understand. The sun in simulation seemed whiter than it really is.

166. I liked the darker lighting, in some slides it looked like it was raining outside. I like rain so that could have swayed my preferences for the lighting.

167. I liked the office spaces that used more natural lighting. Sometimes the computer simulation was to bright not actually representing a real office space. Some of the dim lit office spaces were very depressing.

168. The experiment was somewhat confusing in the aspect of the way observations were recorded. All scenes were legible but the sharpness as somewhat off.

169. Video was good quality but most of the spaces looked the same. I believe this was an appropriate survey.

170. The film should have had something near the window to show the shadows given off by the sun. The lighting in the test room needed to be darker so we could see the contrast better.

171. It was very, very intellectually stimulating. Real simulations are better than computer though.

172. The spaces were more pleasurable when the lighting remained constant. The shadows produced in the computer simulation didn't change very well with the change in light.

173. The video was fine, but I think that the crowd you need to target is a crowd that uses office space regularly or in the past. I have an office job and deal with light problems daily so I believe that I have an upper hand on evaluating than somebody that never uses an office.

174. The window scenes were more enjoyable due to the scenery outside and the fact that you could see outside. The office scene was more boring or depressing.

175. I think windows are very important in the work place for workers to be more productive. The video was good ... good quality I thought.

176. I could see the differences in light but I didn't like the equality of the computer simulation it was a little fuzzy and it moved or jumped. But all things being equal I understood completely what you wanted.

177. The windows let in a lot of light when there was any. The computer simulation was amazing. I thought it was a real thing. The study or organized well.

178. The projection was good enough to create a feeling. More extra credit surveys of any kind should be done more frequent. Do you think Evans Library could be changed to give positive and relaxing emotions? Probably not.

179. Maybe the resolution was bad but ...there was a flicker from overhead and the plant flickered. The book shelves seemed to be at a strange angle. Besides that it was pretty impressive for a computer simulation the colors could have been a little more exciting.

180. Everything looked the same. The only difference I noted was that the pictures/scenes were rearranged. One time it was light getting lighter before dark getting lighter which would make a more drastic change. If one was depressed from a dark room and then exposed to a bright room.

181. The less lighting in a room it seemed more depressing. I envisioned sitting in the chair by the window when the light covered it I imagined taking a nap there. The computer imaging seemed good. I was able to envision everything the projector/film quality might have been better. The more light toward the rear of the room did aid in pleasantness.

182. There was too much white in the room it needed a contrast color somewhere other than that it was a good space to me.

183. If I was actually in the room personally experiencing the difference between the scenes I could give a more accurate opinion.

184. Kind of interesting but confusing concerning the purpose of the experiment. Curious to know about the results. Appreciative towards the extra credit.

185. Other than the projector quality, the study was good. The quality of the picture in the window could have improved or the picture more enjoyable.

186. Personally no offense but I didn't think this exercise was very useful.

187. No comment except thanks for the extra credit.

188. The overall quality was not great. The office space used with the window shown was

APPENDIX F

Appendix Table 3. Responses for Arousal and Pleasure (Pilot)

Window View								**Non Window**							
Houston		**Detroit**		**Los Angeles**		**New York**		**Houston**		**Detroit**		**Los Angeles**		**New York**	
HWC	HWF	DWC	DWF	LWC	LWF	NWC	NWF	HNWC	HNWF	DNWC	DNWF	LNWC	LNWF	NNWC	NNWF
5	3	3	4	5	4	7	6	4	5	3	5	7	4	6	4
7	6	8	5	6	3	7	4	7	5	7	5	7	8	6	6
5	6	9	6	7	5	9	8	6	5	4	5	2	5	3	2
5	4	6	5	5	5	6	4	4	4	4	4	4	4	4	5
7	4	8	4	4	4	7	3	7	4	3	1	3	1	8	4
7	2	8	2	6	7	8	7	4	2	2	6	6	2	2	2
5	6	9	8	8	7	8	6	7	5	7	4	8	4	7	4
7	5	7	5	6	5	6	4	6	4	7	5	6	4	5	5
4	5	5	5	4	6	6	5	6	4	3	4	4	3	4	5
4	3	6	6	7	5	7	5	7	2	6	4	8	3	4	4
9	9	6	9	8	9	5	6	5	5	2	5	5	5	5	4
5	2	6	3	7	7	2	2	1	5	8	6	8	2	3	2
7	7	8	7	8	8	7	7	5	3	4	4	6	3	4	4
6	5	6	5	6	4	7	4	6	4	5	4	6	4	4	5
8	4	7	7	7	7	7	8	4	3	7	4	7	3	7	4
5	2	8	3	5	7	8	8	5	2	8	7	8	3	2	5
Pleasure															
HWC	HWF	DWC	DWF	LWC	LWF	NWC	NWF	HNWC	HNWF	DNWC	DNWF	LNWC	LNWF	NNWC	NNWF
6	3	5	4	6	4	8	4	6	5	6	5	7	6	5	6
6	4	8	4	6	3	5	3	6	5	7	5	6	2	9	5
4	4	5	6	7	9	5	8	9	5	7	9	8	8	8	8
8	6	6	7	6	5	6	6	6	4	6	5	5	5	6	5
8	3	8	5	7	3	7	3	2	3	2	3	8	1	8	3
9	6	8	7	9	8	7	9	8	3	6	8	7	7	8	5
7	7	6	6	7	8	8	6	8	5	6	4	8	5	8	6
6	6	7	7	7	4	7	4	6	8	4	7	6	5	8	5
7	7	8	5	7	4	9	7	7	5	5	4	4	4	8	5
4	8	3	6	3	6	6	5	3	4	3	3	2	5	2	3
6	6	9	5	6	5	5	5	1	1	6	2	2	1	1	1
8	5	2	8	8	7	2	7	5	5	7	8	3	6	3	4
7	7	8	4	4	7	7	6	6	4	6	7	6	6	6	5
7	7	7	5	7	6	7	6	7	6	7	5	7	6	6	6
7	6	3	3	6	6	3	2	5	3	6	4	7	3	6	4
8	2	5	7	8	3	8	5	8	5	7	2	8	7	8	1

APPENDIX G

Appendix Table 4. Responses for Arousal

H-W-C	H-W-4	D-W-C	D-W-4	L-W-C	L-W-4	N-W-C	N-W-4	H-NW-C	H-NW-4	D-NW-C	D-NW-4	L-NW-C	L-NW-4	N-NW-C	N-NW-4
3	4	8	4	8	5	6	5	6	4	2	6	7	6	5	3
5	3	7	3	5	4	7	1	6	2	5	2	7	2	5	6
1	1	7	5	5	5	7	2	4	3	4	3	6	2	6	2
6	1	7	3	3	5	8	5	6	5	4	3	6	5	9	3
6	3	5	5	8	6	8	4	7	3	2	6	9	4	7	3
5	1	5	5	6	5	9	8	9	2	6	2	8	2	5	4
5	4	5	5	5	5	7	3	6	5	5	5	5	5	5	5
8	8	8	5	5	5	8	6	9	9	8	5	5	5	9	8
7	1	8	8	6	8	7	7	8	2	4	4	6	6	4	5
4	2	9	6	8	5	3	6	8	5	3	4	8	5	7	1
5	4	6	5	6	4	5	8	8	3	5	4	7	6	5	4
5	4	4	5	5	5	6	6	6	5	5	5	4	4	4	4
5	1	5	3	7	6	9	3	6	5	8	5	6	4	7	1
3	3	3	6	4	4	7	7	3	2	5	5	2	4	4	2
6	3	8	8	6	6	8	5	3	5	8	8	6	4	8	2
4	2	6	4	6	5	9	9	5	3	5	4	6	1	7	2
5	2	7	2	7	7	7	2	7	3	7	2	8	2	8	1
4	2	8	7	8	7	7	5	7	3	4	7	8	6	7	4
7	7	8	8	8	7	3	3	3	4	7	4	8	7	6	2
6	2	5	4	5	5	8	6	5	1	5	2	5	6	6	5
3	1	4	4	7	5	5	4	5	5	3	2	6	2	4	5
9	6	8	9	8	7	8	4	7	5	5	5	7	5	6	4
5	1	9	5	8	1	7	6	8	2	3	2	6	7	8	5
5	1	7	7	8	5	7	2	4	1	5	5	8	5	6	5
3	2	8	5	6	7	2	6	1	2	6	3	7	1	8	8
1	1	9	2	6	3	8	6	6	2	1	2	6	2	8	3
6	2	8	3	4	7	6	3	6	3	6	7	6	1	7	2
5	8	9	6	9	5	7	5	8	1	6	4	7	1	9	2
6	3	1	2	2	5	8	6	8	8	8	9	3	8	3	5
6	3	8	6	6	5	6	6	8	4	8	7	8	7	8	5
5	3	6	6	6	8	9	6	7	4	4	6	7	5	4	7
6	1	8	6	6	5	1	1	3	3	7	7	8	7	7	3
3	2	8	7	7	6	5	6	6	1	5	3	7	5	7	1
6	3	7	6	6	5	9	8	7	1	4	4	6	5	5	5
5	3	6	6	5	5	6	6	5	4	4	3	6	4	4	3
7	2	8	2	7	5	5	4	4	2	6	5	5	2	7	2
2	3	7	2	6	2	8	8	7	1	7	8	5	7	2	5
3	1	4	7	6	5	8	6	8	2	2	5	4	5	4	2
4	1	8	4	6	6	8	4	6	3	3	3	7	3	5	3
4	2	8	2	7	5	5	9	6	2	5	4	8	1	4	8
6	5	8	3	6	4	9	1	4	5	3	4	6	5	5	2
4	5	9	8	6	7	6	4	6	1	5	5	7	5	5	5
3	2	2	5	5	5	6	5	7	1	3	2	5	2	2	6
5	2	8	4	5	5	7	2	7	5	6	3	6	2	6	5
4	4	7	6	6	6	8	6	6	5	2	5	7	3	6	3
4	6	6	3	5	5	4	3	8	2	6	1	5	8	5	5
5	3	7	5	6	5	7	5	7	3	6	4	7	4	5	5
4	7	5	6	6	5	8	6	7	4	5	4	3	4	5	6
4	3	6	6	6	6	6	6	9	4	6	6	5	5	9	1
5	3	8	5	6	8	8	6	4	1	6	5	8	4	5	4
5	2	6	1	2	7	5	5	6	2	4	5	8	5	6	4
5	4	6	4	5	5	8	2	7	2	5	6	7	4	4	5
8	2	5	4	5	5	8	5	1	5	5	5	4	5	5	4
5	3	8	6	6	7	8	6	2	2	3	3	4	4	5	3
3	4	3	2	2	3	7	6	5	2	4	3	5	3	1	2
5	1	7	5	5	5	8	5	7	3	5	4	8	4	5	5
7	3	9	7	8	8	9	8	9	1	9	5	8	5	5	1
3	3	1	1	1	2	7	5	7	3	6	1	7	7	9	6
7	4	8	5	7	8	8	6	7	1	6	5	8	5	7	2
6	1	8	5	7	7	7	8	7	2	4	4	5	4	3	4
8	2	9	7	6	7	8	5	7	2	8	3	8	6	6	0
H-W-C	H-W-4	D-W-C	D-W-4	L-W-C	L-W-4	N-W-C	N-W-4	H-NW-C	H-NW-4	D-NW-C	D-NW-4	L-NW-C	L-NW-4	N-NW-C	N-NW-4
8	2	9	7	8	9	8	5	8	2	6	5	3	4	7	3
3	6	6	6	6	4	6	4	7	4	3	2	8	2	5	2

2	2	8	3	7	5	9	4	8	7	3	5	8	1	7	8
6	1	7	6	7	7	6	5	6	5	6	6	7	6	7	1
5	1	8	6	6	5	8	5	6	1	6	3	7	4	4	2
3	2	7	6	7	3	6	5	7	1	5	6	9	3	5	5
8	2	8	2	6	7	6	3	8	5	5	3	8	3	8	4
5	1	6	2	6	6	5	3	4	4	6	6	5	5	6	4
7	3	8	4	6	5	5	3	4	4	5	4	6	4	5	2
2	3	8	8	8	7	6	5	6	2	1	2	3	2	5	2
4	1	8	3	5	3	3	4	7	6	2	1	7	1	5	4
7	1	6	7	7	6	7	5	2	3	5	5	6	5	6	2
5	1	7	5	4	6	6	7	6	3	5	6	8	3	6	1
8	6	5	9	8	1	5	5	5	1	4	2	8	8	2	4
5	2	5	6	6	9	7	4	7	5	3	4	2	4	1	5
3	1	5	4	5	4	7	6	6	5	6	1	6	1	5	3
6	2	5	5	6	6	7	3	5	1	4	6	1	6	6	4
6	5	4	5	3	4	8	6	7	4	1	5	8	2	5	2
2	4	6	5	5	5	8	1	8	4	5	2	7	2	5	1
5	1	8	3	5	5	6	8	8	2	5	3	5	5	4	1
5	5	8	6	5	6	8	1	6	4	2	7	7	6	2	2
6	2	8	4	4	7	7	7	8	4	1	3	5	2	5	4
4	3	8	5	5	5	8	5	5	1	5	3	7	1	5	5
6	3	8	6	6	5	8	6	8	2	7	6	5	4	6	2
3	1	5	6	5	5	7	7	8	5	6	4	7	3	5	1
6	2	8	5	5	4	8	4	6	3	5	6	5	5	5	4
5	2	8	4	7	5	6	5	8	1	5	3	8	4	2	3
5	3	6	4	6	7	9	8	7	5	6	6	5	5	6	2
6	1	3	4	5	5	7	8	5	1	5	6	9	5	6	5
7	2	6	6	5	9	7	6	5	5	5	1	6	4	5	4
5	3	7	5	6	5	9	6	8	3	5	5	7	5	6	4
4	2	5	3	6	3	6	6	6	9	3	2	7	2	1	3
7	1	7	7	5	5	7	5	7	3	8	6	7	6	7	5
6	2	9	6	7	7	6	3	7	1	8	5	8	5	9	2
8	1	5	5	7	6	7	6	6	1	4	8	8	3	7	6
2	3	8	5	5	7	9	1	8	2	2	6	5	4	4	3
6	3	7	6	7	5	8	5	9	4	6	3	8	3	6	5
4	1	8	4	6	8	2	5	5	1	3	4	5	1	3	4
8	2	8	7	6	4	2	6	7	5	7	1	9	6	8	1
7	1	8	6	7	5	8	7	5	1	7	6	9	7	7	1
4	5	6	2	7	5	7	4	8	5	7	5	9	6	6	3
5	2	6	5	7	4	7	6	0	2	7	5	7	5	5	3
3	1	5	3	5	5	8	3	5	4	6	4	5	4	4	1
1	2	8	2	2	2	9	3	6	1	5	7	6	1	4	1
5	1	7	4	6	7	9	6	9	1	6	3	7	2	8	1
3	1	8	5	4	3	8	5	8	4	2	6	6	2	5	3
5	4	9	7	5	7	5	2	6	4	7	5	8	4	8	1
6	2	6	2	7	7	7	5	5	1	3	6	1	3	5	1
5	1	6	8	2	5	5	5	5	1	5	9	6	5	5	2
6	3	8	6	6	6	8	1	5	5	4	4	8	4	5	1
6	5	5	4	5	6	8	6	7	2	6	4	8	5	6	1
6	3	8	2	4	5	8	1	9	2	5	3	5	3	5	2
5	3	7	5	5	5	7	7	7	4	5	5	5	4	5	2
8	2	9	4	5	8	9	6	5	1	7	4	8	3	7	1
6	2	4	5	6	7	5	4	8	7	4	6	7	4	6	1
4	4	8	3	6	4	7	3	1	4	6	4	9	4	5	3
8	2	4	6	6	9	9	1	8	2	4	3	6	2	3	3
2	1	6	4	5	4	6	4	6	1	5	5	8	2	7	2
7	5	6	7	3	3	8	5	5	4	2	8	7	8	3	5
5	1	6	4	6	5	5	2	7	1	5	5	4	4	5	2
4	5	8	5	5	4	8	6	8	1	7	4	7	3	8	2
8	2	2	6	6	8	7	5	7	5	4	6	5	3	6	5
5	5	8	3	5	6	8	3	6	4	9	4	9	2	9	5
5	4	6	7	7	5	8	7	8	4	4	9	6	6	3	2
4	1	7	5	4	4	8	8	8	1	4	4	6	4	6	1
3	3	7	5	6	5	7	4	6	5	5	4	8	5	5	6
5	3	3	2	8	3	6	2	6	1	6	2	6	7	8	3
4	2	8	6	6	5	5	1	7	1	7	3	5	3	3	5
5	1	8	2	5	6	5	6	7	1	1	5	6	3	1	2
H-W-C	**H-W-4**	**D-W-C**	**D-W-4**	**L-W-C**	**L-W-4**	**N-W-C**	**N-W-4**	**H-NW-C**	**H-NW-4**	**D-NW-C**	**D-NW-4**	**L-NW-C**	**L-NW-4**	**N-NW-C**	**N-NW-4**
4	2	7	7	7	5	8	6	6	4	1	7	4	4	8	1
3	4	9	3	1	3	7	5	3	5	2	4	7	4	4	2

5	9	5	5	6	2	5	5	6	4	5	5	1	3	7	5
3	2	4	5	6	5	8	5	7	8	2	5	4	3	3	2
7	5	8	5	3	5	5	5	6	2	5	6	6	6	3	1
4	2	6	5	8	8	7	6	5	2	6	5	5	1	7	4
9	3	6	5	4	5	5	4	5	1	6	5	5	5	7	3
7	1	7	8	5	9	6	5	5	4	5	2	5	3	5	1
2	3	7	6	5	8	8	4	5	1	6	7	7	4	7	5
6	2	6	4	6	7	7	8	6	2	5	5	5	2	7	3
4	1	4	5	5	4	7	4	6	4	5	5	7	5	7	5
5	2	9	6	7	5	6	7	8	1	7	5	6	7	4	1
6	1	9	5	5	5	7	6	6	5	5	4	6	2	5	1
4	1	7	3	7	6	5	4	5	1	9	3	4	7	9	5
8	1	5	4	6	5	3	5	5	1	6	6	8	4	8	2
7	2	5	8	8	8	8	7	1	5	5	2	9	6	5	3
5	2	8	5	7	5	8	5	7	8	4	5	6	6	5	1
4	1	9	5	6	5	7	4	8	4	3	5	5	4	5	1
1	2	6	5	5	2	8	4	7	1	8	3	8	3	7	2
6	3	7	3	7	4	5	6	7	1	8	5	7	3	8	8
8	1	7	6	6	5	6	6	5	5	5	5	5	6	5	1
5	4	9	4	6	8	1	2	7	1	6	2	7	5	6	5
7	2	6	5	7	6	8	8	8	5	5	6	8	4	5	4
6	1	7	1	8	7	6	4	7	2	1	3	9	7	3	1
8	1	9	6	7	7	5	4	7	1	6	1	4	6	5	5
4	1	5	1	5	6	6	5	5	2	8	6	5	8	7	9
6	1	7	6	6	5	6	6	6	3	8	4	6	6	8	3
8	1	7	4	3	7	7	4	5	1	7	8	9	2	1	3
6	1	6	3	9	8	5	7	8	1	7	5	1	5	3	3
4	1	9	3	1	3	7	6	7	3	5	1	8	6	7	5
5	4	9	3	9	6	8	4	5	8	4	2	8	5	4	1
5	1	7	4	6	5	5	5	4	3	8	5	9	2	5	1
7	6	5	2	8	3	5	5	2	2	3	5	9	3	4	4
3	1	8	4	7	6	5	5	6	8	5	5	6	9	5	3
6	2	9	5	7	5	8	5	1	5	2	4	7	3	6	5
5	1	7	5	7	5	9	2	1	2	3	5	7	5	4	1
2	2	8	2	5	2	8	5	7	6	5	5	3	5	1	2
6	1	7	7	6	6	8	6	6	5	6	2	7	6	6	5
5	3	6	6	8	6	2	5	7	5	9	2	7	1	8	3
2	3	7	7	6	7	8	5	6	3	5	6	8	3	7	5
5	1	4	3	3	3	8	6	5	4	5	5	7	3	5	1
6	8	8	4	6	5	9	8	8	1	6	6	6	1	5	6
2	3	3	5	8	5	8	9	6	8	2	4	8	5	5	5
7	3	7	7	5	8	8	5	7	6	5	5	6	3	4	2
3	3	6	2	3	2	9	6	5	5	4	3	8	3	4	2
5	5	7	5	6	7	5	6	8	5	5	5	2	2	7	3
5	3	6	5	5	6	5	6	7	3	4	5	6	6	6	2
5	1	6	5	4	5	7	8	8	4	5	3	6	3	2	2
5	6	7	5	6	5	6	6	5	2	4	5	7	3	6	4
5.05	**2.58**	**6.72**	**4.79**	**5.78**	**5.41**	**6.77**	**5.00**	**6.13**	**3.17**	**4.98**	**4.41**	**6.35**	**4.10**	**5.47**	**3.22**

APPENDIX H

Appendix Table 5. Responses for Arousal

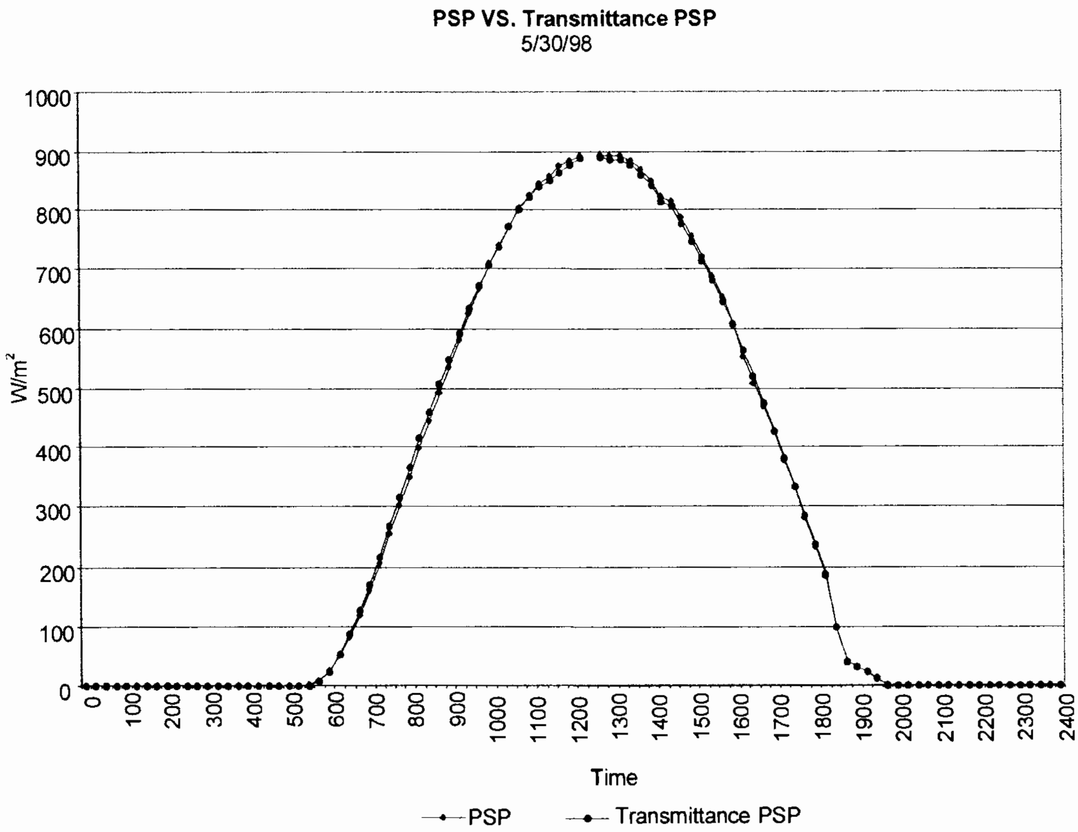
H-W-C	H-W-4	D-W-C	D-W-4	L-W-C	L-W-4	N-W-C	N-W-4	H-NW-C	H-NW-4	D-NW-C	D-NW-4	L-NW-C	L-NW-4	N-NW-C	N-NW-4
7	6	6	6	7	8	4	9	4	3	3	4	4	4	5	4
3	7	8	7	4	7	9	1	6	3	6	3	3	6	2	5
2	1	8	5	5	5	7	7	8	3	4	4	6	3	6	5
8	3	8	8	1	6	8	5	4	2	7	6	1	8	4	3
8	5	6	5	7	5	8	6	8	2	6	4	4	4	6	3
4	3	6	3	4	5	5	3	2	2	5	5	6	6	7	9
9	9	8	5	5	5	6	6	8	6	8	6	6	5	7	1
7	4	8	6	6	7	8	5	9	4	5	5	4	6	4	9
5	5	9	8	6	8	3	7	8	5	4	6	5	5	5	5
4	5	4	7	4	6	8	8	8	7	6	7	2	7	5	9
8	4	8	5	6	7	9	7	3	5	6	4	4	4	4	2
7	2	8	6	8	6	4	6	3	5	8	5	6	7	7	4
6	3	9	7	6	6	6	8	8	2	7	5	9	4	6	2
5	8	2	3	3	5	7	6	4	8	2	3	5	3	3	5
6	6	9	6	6	5	7	2	5	3	5	6	2	3	9	4
7	7	7	7	7	7	9	8	8	7	7	7	7	7	8	3
8	4	9	7	8	5	6	6	6	3	5	3	7	4	4	5
9	2	6	7	7	6	8	8	6	1	6	3	2	7	8	5
4	1	4	8	8	6	5	5	5	5	4	2	3	2	4	5
9	6	9	9	8	7	8	6	9	5	5	5	8	5	7	5
9	5	8	8	6	4	5	3	3	2	7	4	6	9	7	2
5	3	9	8	9	7	3	4	5	3	8	7	9	5	8	4
7	4	6	5	7	8	7	5	7	2	6	4	2	3	8	5
7	6	6	6	8	3	8	7	8	7	7	7	8	6	7	8
8	6	3	5	6	8	3	6	3	7	7	7	2	8	7	7

4	3	8	6	6	6	1	3	1	5	6	3	6	3	6	4
8	3	4	9	8	4	8	7	6	5	6	7	7	5	6	4
8	3	8	6	7	5	5	3	4	2	8	5	4	7	9	3
5	5	6	8	7	9	7	7	2	4	3	5	2	3	4	5
6	5	6	7	2	6	8	5	5	3	6	6	1	7	7	4
6	1	8	6	5	1	2	7	2	3	5	2	1	3	6	7
7	3	7	8	7	6	7	4	7	3	6	3	6	4	5	7
6	4	8	4	4	7	7	9	5	4	5	2	4	5	3	4
7	5	7	7	7	7	8	5	7	4	4	6	8	8	6	5
5	5	6	5	2	7	7	6	8	5	8	7	1	7	7	6
9	8	2	8	5	6	2	9	2	7	4	9	1	3	4	3
3	6	9	6	8	5	2	4	8	1	1	2	5	5	1	3
7	2	6	6	7	7	7	8	5	4	6	3	4	5	9	5
7	7	7	9	3	8	4	5	3	9	2	9	1	6	3	5
4	7	8	7	9	5	4	5	9	2	7	7	9	9	5	6
4	4	1	5	2	4	8	6	8	5	3	5	1	5	3	1
5	5	6	5	6	5	9	8	7	1	3	5	6	4	4	5
5	2	8	2	5	5	9	8	5	2	6	2	7	5	4	3
5	3	6	6	4	6	5	5	5	2	5	7	4	4	6	5
6	4	8	8	6	5	8	7	8	7	6	7	3	6	6	5
6	3	8	6	6	6	9	8	8	4	1	5	3	4	6	8
8	5	8	6	7	8	6	6	4	3	6	6	4	3	5	4
9	3	5	2	2	9	5	3	4	9	3	1	2	8	9	3
4	5	5	6	4	5	7	6	7	5	5	4	3	4	5	5
6	5	7	5	7	5	9	9	6	1	5	3	9	5	4	5
3	1	8	7	6	6	3	7	6	1	3	5	9	3	8	7
5	5	3	6	5	5	7	5	3	5	4	7	3	7	5	3
3	5	3	5	6	7	6	7	3	4	3	3	2	5	4	3
3	5	4	4	5	2	2	6	5	4	4	1	1	2	3	2
8	3	9	4	7	7	9	4	9	3	8	5	7	6	5	1
6	2	8	5	9	6	7	5	9	1	5	5	4	5	5	4
8	6	4	8	4	8	8	6	6	5	7	6	5	6	8	4
9	5	7	8	6	6	2	6	3	5	6	5	7	6	6	5
9	2	8	4	5	5	6	9	3	5	5	5	9	6	5	5
8	1	9	5	1	1	6	7	8	8	8	7	8	7	8	1
2	3	8	2	7	3	8	5	8	4	2	2	2	3	3	3
7	4	7	7	7	5	4	7	5	5	5	4	6	4	5	4
6	4	8	5	6	7	8	3	5	2	5	6	5	3	6	1
5	2	7	5	3	5	1	9	5	6	1	1	7	3	2	5
5	3	4	7	6	7	1	3	2	1	1	1	3	1	2	6
9	2	3	6	6	6	8	9	5	4	9	6	3	8	6	5
4	5	3	8	3	6	2	7	3	9	8	5	5	5	6	3
8	8	9	7	7	8	3	6	5	8	7	7	6	7	9	5
5	5	1	3	4	4	9	4	9	7	2	1	4	2	2	2
8	8	7	6	4	7	1	3	1	3	8	4	4	5	8	5
5	5	8	5	7	5	9	9	7	3	6	5	4	6	7	5
4	3	8	6	4	5	9	4	6	4	6	5	5	6	7	2
7	5	7	6	3	7	6	9	4	1	4	5	2	8	7	4
8	2	3	4	4	7	8	8	7	2	7	7	4	8	4	3
4	2	7	4	4	5	5	5	5	2	4	2	9	3	5	5
5	8	8	9	2	9	8	5	8	5	4	9	1	9	4	3
8	1	9	9	7	7	8	7	3	4	8	3	8	7	7	6
7	4	9	4	7	8	7	5	8	2	8	4	4	3	7	5
4	9	4	9	1	7	2	8	2	5	4	5	1	6	5	6
7	6	8	7	8	8	7	7	7	5	5	8	9	3	5	7
7	7	1	8	3	6	2	9	9	8	1	9	2	8	3	3
9	2	7	3	3	7	4	8	3	3	7	3	6	3	8	6
9	6	4	9	3	7	1	9	1	5	9	5	3	5	9	8
6	8	3	7	8	5	4	7	3	5	7	5	5	4	5	5
3	4	6	7	2	6	9	5	5	5	3	5	1	8	5	5
8	5	8	9	2	5	6	4	4	5	8	8	5	8	8	4
6	4	7	6	6	5	6	2	1	5	5	3	5	3	5	1
7	4	8	8	8	7	9	9	8	3	8	5	8	6	8	7
5	5	5	5	5	5	1	7	3	5	5	1	5	5	5	5
7	5	4	8	5	8	6	4	4	5	7	5	4	2	5	3
7	2	9	2	7	7	5	7	7	4	8	2	2	5	9	1
9	3	7	7	6	9	9	7	3	5	9	5	7	5	5	8
5	1	6	8	8	9	8	6	6	1	7	1	9	3	4	4
8	1	9	4	9	7	6	4	1	3	9	5	1	9	7	3
4	5	5	6	7	4	5	9	7	2	8	5	5	5	4	8
7	5	9	5	7	5	3	7	1	3	5	4	5	4	5	3
9	4	9	7	7	8	9	6	1	2	8	4	8	3	7	1
3	8	9	9	2	9	5	5	5	1	9	5	4	2	9	5
4	2	7	6	7	5	1	9	1	3	6	3	4	3	6	1
8	7	5	7	7	7	7	5	7	8	9	7	4	5	8	5
5	3	6	6	7	6	5	7	7	5	5	5	2	5	5	5
5	5	5	7	8	7	7	3	6	5	5	7	3	5	7	2
6	4	7	5	5	7	8	5	7	4	4	5	7	5	7	3
H-W-C	**H-W-4**	**D-W-C**	**D-W-4**	**L-W-C**	**L-W-4**	**N-W-C**	**N-W-4**	**H-NW-C**	**H-NW-4**	**D-NW-C**	**D-NW-4**	**L-NW-C**	**L-NW-4**	**N-NW-C**	**N-NW-4**
5	3	3	7	7	5	5	8	8	7	7	8	8	2	9	1
7	3	5	5	8	7	6	8	3	5	8	7	8	3	6	1

4	8	5	5	5	3	9	8	9	6	4	7	2	6	2	2
4	3	9	5	7	8	8	3	7	3	7	5	7	5	7	3
5	3	4	4	6	5	8	6	7	3	6	5	5	7	5	5
5	9	9	4	4	5	3	5	4	5	1	9	9	9	3	5
5	3	7	4	7	5	4	6	4	4	5	4	6	3	7	5
6	6	7	6	6	1	7	2	9	6	6	4	3	4	6	2
9	4	8	8	8	8	5	6	8	3	9	7	4	7	5	7
7	7	9	7	2	7	5	9	8	5	7	3	8	5	7	5
6	4	4	4	3	4	8	5	7	5	2	5	2	3	1	2
7	8	5	7	3	7	9	5	8	7	5	8	8	8	6	2
6.19	**4.6**	**6.51**	**6.14**	**5.64**	**6.15**	**5.97**	**6.09**	**5.49**	**4.27**	**5.63**	**5.1**	**4.9**	**5.18**	**5.7**	**4.36**

APPENDIX I

Polling and Calibration Procedures for Test Box Experiments



APPENDIX J

Window Library

Single Glazed Clear

```
WINDOW 4.1  DOE-2 Data File : Multi Band Calculation
Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : Single-clear
Window ID   : 1999
Tilt        : 90.0
Glazings    : 1
Frame       :  1 Al no break          10.790
Spacer      :  1 Class1                2.330  -0.010    0.138
Total Height: 3048.0 mm
Total Width : 30480.1 mm
Glass Height: 2933.7 mm
Glass Width : 30365.8 mm
Mullion     : None
Gap          Thick    Cond  dCond     Vis    dVis    Dens    dDens      Pr      dPr
1                0       0      0       0       0       0        0       0        0
2                0       0      0       0       0       0        0       0        0
3                0       0      0       0       0       0        0       0        0
4                0       0      0       0       0       0        0       0        0
5                0       0      0       0       0       0        0       0        0
Angle      0    10    20    30    40    50    60    70    80    90 Hemis
Tsol   0.850 0.850 0.848 0.844 0.835 0.814 0.766 0.652 0.399 0.000 0.770
Abs1   0.075 0.076 0.077 0.080 0.083 0.087 0.091 0.093 0.092 0.000 0.084
Abs2       0     0     0     0     0     0     0     0     0     0     0
Abs3       0     0     0     0     0     0     0     0     0     0     0
Abs4       0     0     0     0     0     0     0     0     0     0     0
Abs5       0     0     0     0     0     0     0     0     0     0     0
Abs6       0     0     0     0     0     0     0     0     0     0     0
Rfsol  0.075 0.074 0.075 0.076 0.082 0.099 0.144 0.255 0.509 1.000 0.136
Rbsol  0.075 0.074 0.075 0.076 0.082 0.099 0.144 0.255 0.509 1.000 0.136
Tvis   0.901 0.901 0.900 0.897 0.890 0.871 0.824 0.706 0.441 0.000 0.823
Rfvis  0.081 0.081 0.082 0.083 0.090 0.108 0.155 0.271 0.536 1.000 0.146
Rbvis  0.081 0.081 0.082 0.083 0.090 0.108 0.155 0.271 0.536 1.000 0.146
SHGC   0.870 0.870 0.868 0.865 0.857 0.837 0.790 0.677 0.423 0.000 0.792
SC: 1.00

Layer ID#             1        0        0        0        0        0
Tir               0.000        0        0        0        0        0
Emis F            0.840        0        0        0        0        0
Emis B            0.840        0        0        0        0        0
Thickness(mm)       2.5        0        0        0        0        0
Cond(W/m2-C     )360.0        0        0        0        0        0
Spectral File      None     None     None     None     None     None
Overall and Center of Glass Ig U-values (W/m2-C)
Outdoor Temperature                 -17.8 C       15.6 C       26.7 C       37.8 C
Solar      WdSpd  hcout hrout  hin
(W/m2)     (m/s)     (W/m2-C)
  0        0.00  12.25  3.43  8.23   5.32 5.32   4.99 4.99   4.98 4.98   5.59 5.59
  0        6.71  25.47  3.34  8.30   6.33 6.33   5.79 5.79   5.74 5.74   6.54 6.54
 783       0.00  12.25  3.47  8.18   5.30 5.30   4.76 4.76   5.24 5.24   5.70 5.70
 783       6.71  25.47  3.37  8.28   6.32 6.32   5.64 5.64   5.96 5.96   6.63 6.63
```

Low-E for Southern Census Regions

```
WINDOW 4.1  DOE-2 Data File : Multi Band Calculation
Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : Low-e-Sou
Window ID   : 2996
Tilt        : 90.0
Glazings    : 2
Frame       :  1 Al no break         10.790
Spacer      :  1 Class1               2.330  -0.010   0.138
Total Height: 3048.0 mm
Total Width : 30480.1 mm
Glass Height: 2933.7 mm
Glass Width : 30365.8 mm
Mullion     : None
Gap         Thick   Cond  dCond    Vis   dVis   Dens   dDens     Pr     dPr
1 Air        12.7 0.02410  7.600  1.730 10.000  1.290 -0.0044  0.720 0.00180
2               0       0      0      0      0      0       0      0       0
3               0       0      0      0      0      0       0      0       0
4               0       0      0      0      0      0       0      0       0
5               0       0      0      0      0      0       0      0       0
Angle     0    10    20    30    40    50    60    70    80    90 Hemis
Tsol  0.283 0.284 0.280 0.273 0.265 0.249 0.216 0.156 0.069 0.000 0.232
Abs1  0.558 0.564 0.570 0.573 0.570 0.566 0.565 0.542 0.412 0.001 0.550
Abs2  0.056 0.057 0.057 0.058 0.059 0.060 0.057 0.050 0.035 0.000 0.055
Abs3      0     0     0     0     0     0     0     0     0     0     0
Abs4      0     0     0     0     0     0     0     0     0     0     0
Abs5      0     0     0     0     0     0     0     0     0     0     0
Abs6      0     0     0     0     0     0     0     0     0     0     0
Rfsol 0.102 0.095 0.093 0.096 0.107 0.125 0.161 0.252 0.484 0.999 0.152
Rbsol 0.193 0.188 0.187 0.188 0.196 0.213 0.255 0.356 0.567 1.000 0.243
Tvis  0.442 0.445 0.439 0.430 0.419 0.396 0.346 0.251 0.116 0.000 0.368
Rfvis 0.055 0.047 0.045 0.048 0.060 0.081 0.121 0.221 0.465 0.999 0.110
Rbvis 0.122 0.116 0.115 0.119 0.133 0.162 0.224 0.367 0.631 1.000 0.201
SHGC  0.372 0.375 0.371 0.365 0.357 0.341 0.307 0.239 0.130 0.000 0.320
SC: 0.44


Layer ID#          451       3       0       0       0       0
Tir              0.000   0.000       0       0       0       0
Emis F           0.840   0.840       0       0       0       0
Emis B           0.100   0.840       0       0       0       0
Thickness(mm)      6.0     6.0       0       0       0       0
Cond(W/m2-C     )150.0   150.0       0       0       0       0
Spectral File     None    None    None    None    None    None

Overall and Center of Glass Ig U-values (W/m2-C)
Outdoor Temperature                 -17.8 C      15.6 C      26.7 C      37.8 C
Solar       WdSpd  hcout hrout  hin
(W/m2)      (m/s)    (W/m2-C)
   0        0.00  12.25  3.25  7.67  1.68 1.68  1.63 1.63  1.67 1.67  1.75 1.75
   0        6.71  25.47  3.22  7.70  1.78 1.78  1.70 1.70  1.74 1.74  1.83 1.83
 783        0.00  12.25  3.76  7.12  1.65 1.65  1.80 1.80  1.87 1.87  1.94 1.94
 783        6.71  25.47  3.50  6.52  1.69 1.69  1.84 1.84  1.90 1.90  1.96 1.96
```

Low-E for Northern Census Regions

```
WINDOW 4.1  DOE-2 Data File : Multi Band Calculation
Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : Low-E-North
Window ID   : 2997
Tilt        : 90.0
Glazings    : 2
Frame       :  1 Al no break          10.790
Spacer      :  1 Class1                2.330  -0.010    0.138
Total Height: 3048.0 mm
Total Width : 30480.1 mm
Glass Height: 2933.7 mm
Glass Width : 30365.8 mm
Mullion     : None
Gap        Thick    Cond  dCond     Vis   dVis    Dens   dDens     Pr     dPr
1 Air       12.7 0.02410  7.600   1.730 10.000   1.290 -0.0044  0.720 0.00180
2              0       0      0       0      0       0       0      0       0
3              0       0      0       0      0       0       0      0       0
4              0       0      0       0      0       0       0      0       0
5              0       0      0       0      0       0       0      0       0
Angle     0    10    20    30    40    50    60    70    80    90 Hemis
Tsol  0.281 0.282 0.278 0.271 0.262 0.246 0.213 0.152 0.067 0.000 0.230
Abs1  0.165 0.165 0.168 0.173 0.181 0.190 0.200 0.211 0.210 0.000 0.185
Abs2  0.427 0.430 0.433 0.432 0.423 0.408 0.381 0.315 0.170 0.000 0.385
Abs3      0     0     0     0     0     0     0     0     0     0     0
Abs4      0     0     0     0     0     0     0     0     0     0     0
Abs5      0     0     0     0     0     0     0     0     0     0     0
Abs6      0     0     0     0     0     0     0     0     0     0     0
Rfsol 0.127 0.123 0.121 0.124 0.134 0.156 0.206 0.322 0.554 1.000 0.190
Rbsol 0.209 0.203 0.201 0.204 0.213 0.230 0.261 0.342 0.546 0.999 0.252
Tvis  0.442 0.444 0.438 0.430 0.418 0.396 0.345 0.250 0.115 0.000 0.368
Rfvis 0.107 0.101 0.100 0.104 0.118 0.148 0.213 0.358 0.628 1.000 0.189
Rbvis 0.074 0.066 0.064 0.067 0.079 0.099 0.139 0.236 0.476 0.999 0.128
SHGC  0.492 0.495 0.492 0.485 0.474 0.451 0.407 0.316 0.163 0.000 0.424
SC: 0.56


Layer ID#            3       451        0        0        0        0
Tir              0.000     0.000        0        0        0        0
Emis F           0.840     0.840        0        0        0        0
Emis B           0.840     0.100        0        0        0        0
Thickness(mm)      6.0       6.0        0        0        0        0
Cond(W/m2-C      )150.0    150.0        0        0        0        0
Spectral File     None      None     None     None     None     None

Overall and Center of Glass Ig U-values (W/m2-C)
Outdoor Temperature                -17.8 C      15.6 C      26.7 C      37.8 C
Solar      WdSpd  hcout hrout  hin
(W/m2)     (m/s)     (W/m2-C)
   0        0.00  12.25  3.26  4.18  1.95 1.95  1.73 1.73  1.65 1.65  2.02 2.02
   0        6.71  25.47  3.23  4.22  2.07 2.07  1.82 1.82  1.73 1.73  2.14 2.14
 783        0.00  12.25  3.63  4.46  2.24 2.24  2.47 2.47  2.55 2.55  2.64 2.64
 783        6.71  25.47  3.43  4.23  2.29 2.29  2.57 2.57  2.66 2.66  2.76 2.76
```

PV for Northern Census Regions

```
WINDOW 4.1   DOE-2 Data File : Multi Band Calculation
Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : PV North
Window ID   : 2998
Tilt        : 90.0
Glazings    : 2
Frame       :  1 Al no break          10.790
Spacer      :  1 Class1                2.330  -0.010    0.138
Total Height: 3048.0 mm
Total Width : 30480.1 mm
Glass Height: 2933.7 mm
Glass Width : 30365.8 mm
Mullion     : None
Gap          Thick    Cond  dCond     Vis   dVis    Dens   dDens      Pr      dPr
1 Air         12.7 0.02410  7.600  1.730 10.000  1.290 -0.0044   0.720 0.00180
2                0       0      0      0      0      0       0       0        0
3                0       0      0      0      0      0       0       0        0
4                0       0      0      0      0      0       0       0        0
5                0       0      0      0      0      0       0       0        0
Angle      0    10    20    30    40    50    60    70    80    90 Hemis
Tsol   0.324 0.325 0.320 0.313 0.304 0.287 0.254 0.190 0.091 0.000 0.269
Abs1   0.229 0.230 0.233 0.240 0.248 0.258 0.266 0.268 0.246 0.000 0.248
Abs2   0.000 0.001 0.005 0.009 0.011 0.016 0.027 0.041 0.037 0.000 0.018
Abs3       0     0     0     0     0     0     0     0     0     0     0
Abs4       0     0     0     0     0     0     0     0     0     0     0
Abs5       0     0     0     0     0     0     0     0     0     0     0
Abs6       0     0     0     0     0     0     0     0     0     0     0
Rfsol  0.447 0.444 0.441 0.438 0.437 0.439 0.453 0.501 0.626 1.000 0.455
Rbsol  0.083 0.075 0.073 0.077 0.087 0.107 0.144 0.239 0.477 0.999 0.135
Tvis   0.370 0.372 0.367 0.361 0.352 0.336 0.301 0.230 0.118 0.000 0.315
Rfvis  0.569 0.566 0.565 0.565 0.568 0.576 0.594 0.644 0.758 1.000 0.586
Rbvis  0.093 0.086 0.084 0.087 0.098 0.117 0.155 0.250 0.486 0.999 0.145
SHGC   0.349 0.351 0.349 0.346 0.339 0.326 0.301 0.247 0.143 0.000 0.308
SC: 0.41


Layer ID#             3     6109        0        0        0        0
Tir               0.000    0.000        0        0        0        0
Emis F            0.840    0.400        0        0        0        0
Emis B            0.840    0.840        0        0        0        0
Thickness(mm)       6.0      6.0        0        0        0        0
Cond(W/m2-C      )150.0    150.0        0        0        0        0
Spectral File      None     None     None     None     None     None

Overall and Center of Glass Ig U-values (W/m2-C)
Outdoor Temperature                 -17.8 C      15.6 C       26.7 C       37.8 C
Solar      WdSpd  hcout hrout  hin
(W/m2)     (m/s)     (W/m2-C)
   0        0.00  12.25  3.27  7.79  2.12 2.12  2.16 2.16  2.21 2.21  2.37 2.37
   0        6.71  25.47  3.23  7.83  2.26 2.26  2.29 2.29  2.35 2.35  2.52 2.52
 783        0.00  12.25  3.46  7.60  2.12 2.12  2.22 2.22  2.36 2.36  2.47 2.47
 783        6.71  25.47  3.34  7.72  2.25 2.25  2.24 2.24  2.46 2.46  2.59 2.59
```

PV for Southern Census Regions

```
WINDOW 4.1  DOE-2 Data File : Multi Band Calculation
Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : PV South
Window ID   : 2999
Tilt        : 90.0
Glazings    : 2
Frame       :  1 Al no break          10.790
Spacer      :  1 Class1                2.330  -0.010   0.138
Total Height: 3048.0 mm
Total Width : 30480.1 mm
Glass Height: 2933.7 mm
Glass Width : 30365.8 mm
Mullion     : None
Gap         Thick   Cond  dCond    Vis   dVis   Dens   dDens      Pr     dPr
1 Air        12.7 0.02410  7.600  1.730 10.000  1.290 -0.0044  0.720 0.00180
2               0       0      0      0      0      0       0      0       0
3               0       0      0      0      0      0       0      0       0
4               0       0      0      0      0      0       0      0       0
5               0       0      0      0      0      0       0      0       0
Angle     0    10    20    30    40    50    60    70    80    90 Hemis
Tsol  0.324 0.325 0.320 0.313 0.304 0.287 0.254 0.190 0.091 0.000 0.269
Abs1  0.529 0.534 0.541 0.544 0.541 0.537 0.535 0.511 0.386 0.001 0.521
Abs2  0.064 0.065 0.065 0.066 0.068 0.069 0.067 0.061 0.046 0.000 0.064
Abs3      0     0     0     0     0     0     0     0     0     0     0
Abs4      0     0     0     0     0     0     0     0     0     0     0
Abs5      0     0     0     0     0     0     0     0     0     0     0
Abs6      0     0     0     0     0     0     0     0     0     0     0
Rfsol 0.083 0.075 0.073 0.077 0.087 0.107 0.144 0.239 0.477 0.999 0.135
Rbsol 0.447 0.444 0.441 0.438 0.437 0.439 0.453 0.501 0.626 1.000 0.455
Tvis  0.370 0.372 0.367 0.361 0.352 0.336 0.301 0.230 0.118 0.000 0.315
Rfvis 0.093 0.086 0.084 0.087 0.098 0.117 0.155 0.250 0.486 0.999 0.145
Rbvis 0.569 0.566 0.565 0.565 0.568 0.576 0.594 0.644 0.758 1.000 0.586
SHGC  0.428 0.431 0.426 0.420 0.411 0.395 0.360 0.289 0.165 0.000 0.372
SC: 0.49


Layer ID#           6108        3        0        0        0        0
Tir                0.000    0.000        0        0        0        0
Emis F             0.840    0.840        0        0        0        0
Emis B             0.400    0.840        0        0        0        0
Thickness(mm)        6.0      6.0        0        0        0        0
Cond(W/m2-C      )150.0    150.0        0        0        0        0
Spectral File       None     None     None     None     None     None

Overall and Center of Glass Ig U-values (W/m2-C)
Outdoor Temperature                 -17.8 C       15.6 C      26.7 C      37.8 C
Solar      WdSpd  hcout hrout  hin
(W/m2)     (m/s)     (W/m2-C)
   0       0.00  12.25  3.27  7.79  2.12 2.12  2.16 2.16  2.21 2.21  2.37 2.37
   0       6.71  25.47  3.23  7.83  2.26 2.26  2.29 2.29  2.35 2.35  2.52 2.52
 783       0.00  12.25  3.74  6.81  2.14 2.14  2.44 2.44  2.54 2.54  2.63 2.63
 783       6.71  25.47  3.50  7.04  2.25 2.25  2.51 2.51  2.62 2.62  2.73 2.73
```

APPENDIX K

PV F-Chart Input Files

Spandrel Glass

```
PR ON W ON PA OFF E 1 0 S 1 96 2 2 10 17667.5 12 0 R S 1 96 2 2 10 17667.5 12 90 R S
1 96 2 2 10 17667.5 12 -90 R S 1 121 2 2 10 17667.5 12 0 R S 1 121 2 2 10 17667.5 12
90 R S 1 121 2 2 10 17667.5 12 -90 R S 1 61 2 2 10 17667.5 12 0 R S 1 61 2 2 10
17667.5 12 90 R S 1 61 2 2 10 17667.5 12 -90 R S 1 149 2 2 10 17667.5 12 0 R S 1 149
2 2 10 17667.5 12 90 R S 1 149 2 2 10 17667.5 12 -90 R
```

Vision Glass

```
PR ON W ON PA OFF E 1 0 S 1 96 2 2 10 20767.5 12 0 R S 1 96 2 2 10 20767.5 12 90 R S
1 96 2 2 10 20767.5 12 -90 R S 1 121 2 2 10 20767.5 12 0 R S 1 121 2 2 10 20767.5 12
90 R S 1 121 2 2 10 20767.5 12 -90 R S 1 61 2 2 10 20767.5 12 0 R S 1 61 2 2 10
20767.5 12 90 R S 1 61 2 2 10 20767.5 12 -90 R S 1 149 2 2 10 20767.5 12 0 R S 1 149
2 2 10 20767.5 12 90 R S 1 149 2 2 10 20767.5 12 -90 R
```

Roof Tops

```
PR ON W ON PA OFF E 1 0 S 1 96 2 2 10 9154.375 12 0 R S 1 121 2 2 10 9154.375 12 0 R
S 1 61 2 2 10 9154.375 12 0 R S 1 149 2 2 10 9154.375 12 0 R
```

APPENDIX L

Sample Output for Hourly Shading

South	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.48	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.47
9.00	0.43	0.41	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.37	0.41
10.00	0.34	0.34	0.29	0.08	0.00	0.00	0.00	0.00	0.00	0.23	0.28	0.30
11.00	0.21	0.22	0.18	0.08	0.00	0.00	0.00	0.00	0.03	0.11	0.17	0.20
12.00	0.27	0.22	0.16	0.06	0.00	0.00	0.00	0.00	0.03	0.16	0.26	0.29
13.00	0.36	0.34	0.28	0.14	0.00	0.00	0.00	0.00	0.07	0.21	0.28	0.33
14.00	0.25	0.23	0.17	0.05	0.00	0.00	0.00	0.00	0.01	0.10	0.17	0.21
15.00	0.23	0.21	0.17	0.10	0.00	0.00	0.00	0.00	0.04	0.19	0.26	0.25
16.00	0.37	0.33	0.29	0.04	0.00	0.00	0.00	0.00	0.00	0.24	0.36	0.38
17.00	0.44	0.40	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.45
18.00	0.48	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.48
19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

East	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.36	0.28	0.26	0.31	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.41	0.46	0.38	0.31	0.30	0.34	0.43	0.43	0.33	0.00
8.00	0.28	0.28	0.36	0.42	0.40	0.34	0.32	0.37	0.43	0.35	0.27	0.26
9.00	0.32	0.26	0.26	0.31	0.36	0.33	0.32	0.37	0.33	0.24	0.25	0.31
10.00	0.36	0.29	0.22	0.20	0.25	0.28	0.29	0.28	0.21	0.18	0.27	0.34
11.00	0.30	0.28	0.19	0.08	0.09	0.12	0.14	0.13	0.07	0.12	0.21	0.27
12.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

West	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.19	0.12
15.00	0.32	0.27	0.18	0.11	0.15	0.19	0.18	0.15	0.11	0.17	0.27	0.32
16.00	0.36	0.30	0.21	0.22	0.30	0.32	0.30	0.30	0.25	0.20	0.26	0.33
17.00	0.30	0.26	0.25	0.33	0.40	0.33	0.32	0.37	0.36	0.31	0.25	0.29
18.00	0.26	0.28	0.34	0.44	0.39	0.33	0.31	0.36	0.44	0.41	0.33	0.25
19.00	0.00	0.00	0.41	0.47	0.36	0.30	0.29	0.33	0.43	0.46	0.00	0.00
20.00	0.00	0.00	0.00	0.00	0.00	0.27	0.26	0.31	0.00	0.00	0.00	0.00
21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

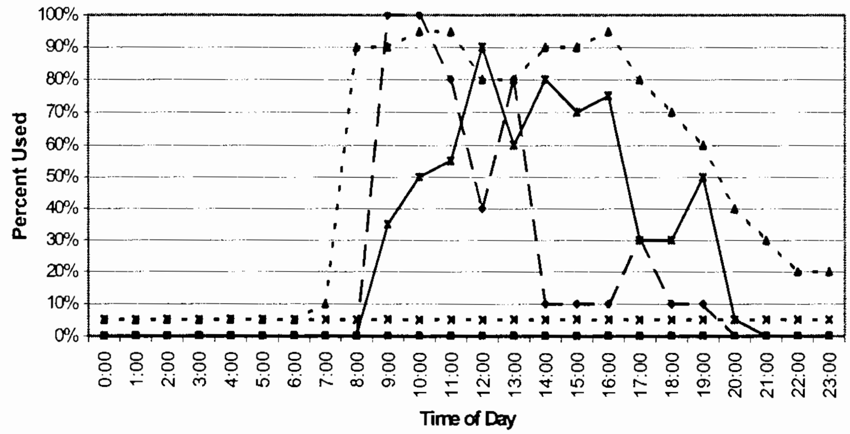
APPENDIX M

MONTHLY SHADING OF FACADES

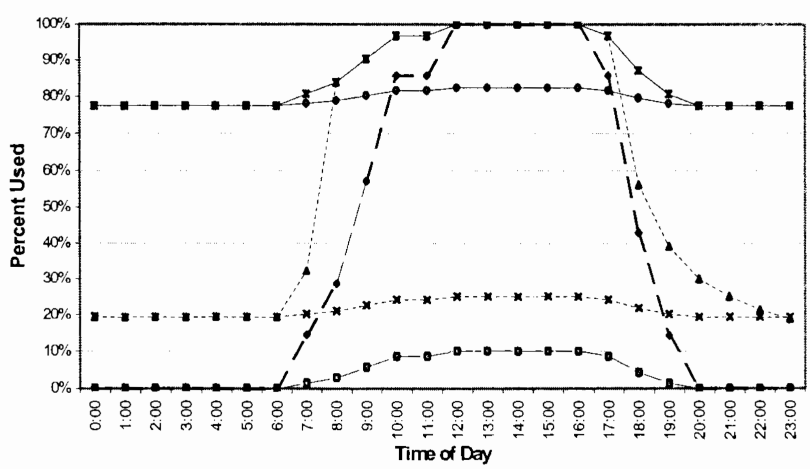
Detroit				
	South	East	North	West
JAN	0.43	0.14	0	0.14
FEB	0.37	0.13	0	0.12
MAR	0.18	0.13	0	0.13
APR	0.04	0.11	0	0.12
MAY	0	0.14	0	0.12
JUN	0	0.11	0.06	0.12
JUL	0	0.13	0.09	0.13
AUG	0	0.13	0.01	0.13
SEP	0.02	0.13	0	0.14
OCT	0.15	0.15	0	0.13
NOV	0.31	0.14	0	0.14
DEC	0.53	0.17	0	0.19
Houston				
JAN	0.43	0.14	0	0.14
FEB	0.37	0.13	0	0.12
MAR	0.18	0.13	0	0.13
APR	0.05	0.13	0	0.14
MAY	0	0.14	0	0.12
JUN	0	0.13	0.07	0.13
JUL	0	0.13	0.09	0.13
AUG	0	0.13	0.01	0.13
SEP	0.02	0.13	0	0.14
OCT	0.13	0.12	0	0.11
NOV	0.31	0.14	0	0.14
DEC	0.42	0.13	0	0.14
Los Angeles				
JAN	0.43	0.14	0	0.14
FEB	0.37	0.13	0	0.12
MAR	0.18	0.13	0	0.13
APR	0.05	0.13	0	0.14
MAY	0	0.14	0	0.12
JUN	0	0.13	0.07	0.13
JUL	0	0.13	0.09	0.13
AUG	0	0.13	0.01	0.13
SEP	0.02	0.13	0	0.14
OCT	0.13	0.12	0	0.11
NOV	0.31	0.14	0	0.14
DEC	0.42	0.13	0	0.14
New York				
JAN	0.43	0.14	0	0.14
FEB	0.37	0.13	0	0.12
MAR	0.18	0.13	0	0.13
APR	0.04	0.11	0	0.12
MAY	0	0.14	0	0.12
JUN	0	0.13	0.07	0.13
JUL	0	0.13	0.09	0.13
AUG	0	0.13	0.01	0.13
SEP	0.02	0.13	0	0.14
OCT	0.15	0.15	0	0.13
NOV	0.31	0.14	0	0.14
DEC	0.42	0.13	0	0.14

APPENDIX N

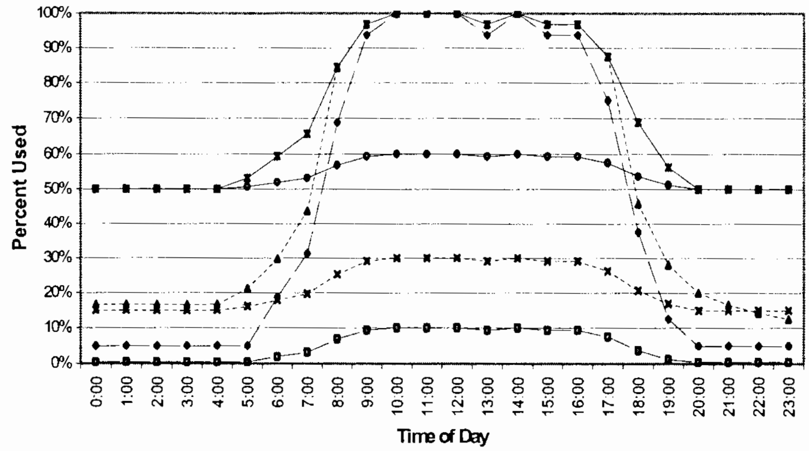
Building Schedules



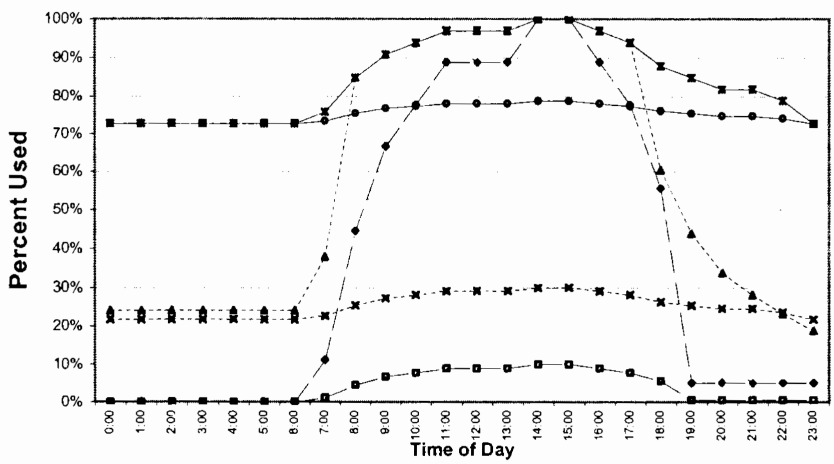
Appendix Figure 1. Building Schedules for DOE2 Sample



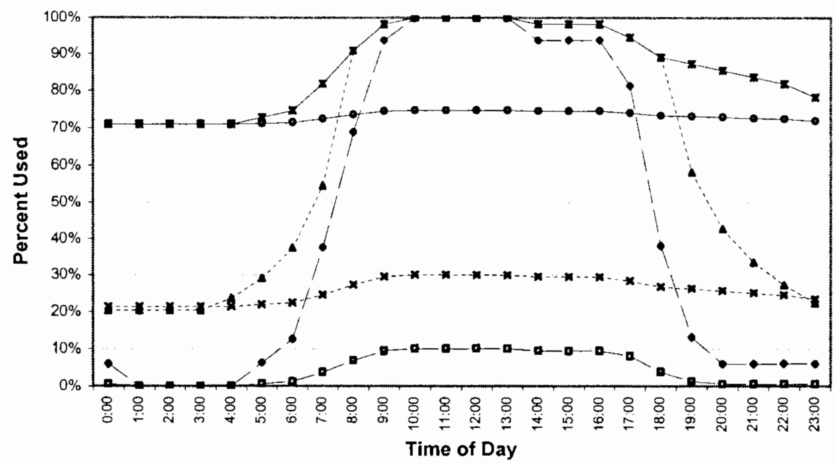
Appendix Figure 2. Building Schedules for the Capitol Building



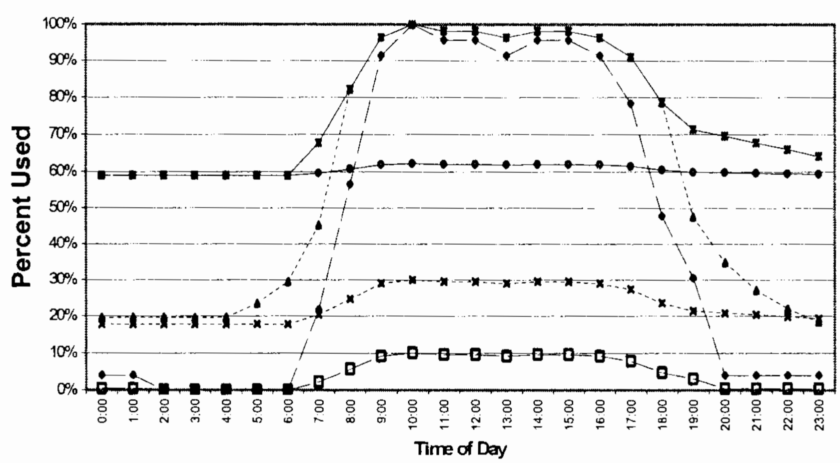
Appendix Figure 3. Building Schedules for the Texas Department of Health



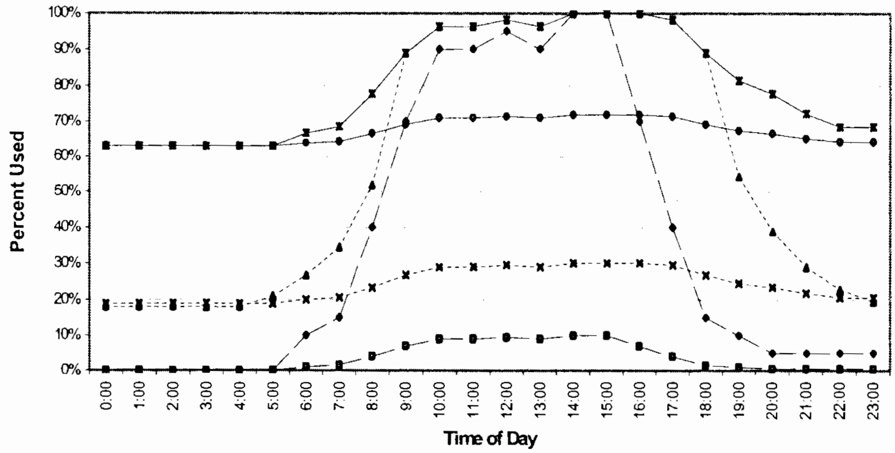
Appendix Figure 4. Building Schedules for the J.H. Winters



Appendix Figure 5. Building Schedules for the L.B. Johnson



Appendix Figure 6. Building Schedules for the W.B. Travis



Appendix Figure 7. Building Schedules for the S.F. Ausitn

APPENDIX O

Appendix Table 6. Building Schedules for DOE sample file

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0	0	0.05	0.05	0	0
1:00	0	0	0.05	0.05	0	0
2:00	0	0	0.05	0.05	0	0
3:00	0	0	0.05	0.05	0	0
4:00	0	0	0.05	0.05	0	0
5:00	0	0	0.05	0.05	0	0
6:00	0	0	0.05	0.05	0	0
7:00	0	0	0.1	0.05	0	0
8:00	0	0	0.9	0.05	0	0
9:00	1	0	0.9	0.05	0.35	0
10:00	1	0	0.95	0.05	0.5	0
11:00	0.8	0	0.95	0.05	0.55	0
12:00	0.4	0	0.8	0.05	0.9	0
13:00	0.8	0	0.8	0.05	0.6	0
14:00	0.1	0	0.9	0.05	0.8	0
15:00	0.1	0	0.9	0.05	0.7	0
16:00	0.1	0	0.95	0.05	0.75	0
17:00	0.3	0	0.8	0.05	0.3	0
18:00	0.1	0	0.7	0.05	0.3	0
19:00	0.1	0	0.6	0.05	0.5	0
20:00	0	0	0.4	0.05	0.05	0
21:00	0	0	0.3	0.05	0	0
22:00	0	0	0.2	0.05	0	0
23:00	0	0	0.2	0.05	0	0

Appendix Table 7. Building Schedules for S.F Austin

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.00	0.00	0.18	0.19	0.63	0.63
1:00	0.00	0.00	0.18	0.19	0.63	0.63
2:00	0.00	0.00	0.18	0.19	0.63	0.63
3:00	0.00	0.00	0.18	0.19	0.63	0.63
4:00	0.00	0.00	0.18	0.19	0.63	0.63
5:00	0.00	0.00	0.21	0.19	0.63	0.63
6:00	0.10	0.01	0.27	0.20	0.67	0.64
7:00	0.15	0.02	0.34	0.21	0.69	0.64
8:00	0.40	0.04	0.52	0.23	0.78	0.67
9:00	0.70	0.07	0.89	0.27	0.89	0.69
10:00	0.90	0.09	0.96	0.29	0.96	0.71
11:00	0.90	0.09	0.96	0.29	0.96	0.71
12:00	0.95	0.10	0.98	0.29	0.98	0.71
13:00	0.90	0.09	0.96	0.29	0.96	0.71
14:00	1.00	0.10	1.00	0.30	1.00	0.72
15:00	1.00	0.10	1.00	0.30	1.00	0.72
16:00	0.70	0.07	1.00	0.30	1.00	0.72
17:00	0.40	0.04	0.98	0.29	0.98	0.71
18:00	0.15	0.02	0.89	0.27	0.89	0.69
19:00	0.10	0.01	0.54	0.24	0.81	0.67
20:00	0.05	0.01	0.39	0.23	0.78	0.67
21:00	0.05	0.01	0.29	0.22	0.72	0.65
22:00	0.05	0.01	0.23	0.21	0.69	0.64
23:00	0.05	0.01	0.20	0.21	0.69	0.64

Appendix Table 8. Building Schedules for L.B. Johnson

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.06	0.01	0.20	0.21	0.71	0.71
1:00	0.00	0.00	0.20	0.21	0.71	0.71
2:00	0.00	0.00	0.20	0.21	0.71	0.71
3:00	0.00	0.00	0.20	0.21	0.71	0.71
4:00	0.00	0.00	0.24	0.21	0.71	0.71
5:00	0.06	0.01	0.29	0.22	0.73	0.71
6:00	0.13	0.01	0.37	0.22	0.75	0.71
7:00	0.38	0.04	0.55	0.25	0.82	0.72
8:00	0.69	0.07	0.91	0.27	0.91	0.74
9:00	0.94	0.09	0.98	0.29	0.98	0.74
10:00	1.00	0.10	1.00	0.30	1.00	0.75
11:00	1.00	0.10	1.00	0.30	1.00	0.75
12:00	1.00	0.10	1.00	0.30	1.00	0.75
13:00	1.00	0.10	1.00	0.30	1.00	0.75
14:00	0.94	0.09	0.98	0.29	0.98	0.74
15:00	0.94	0.09	0.98	0.29	0.98	0.74
16:00	0.94	0.09	0.98	0.29	0.98	0.74
17:00	0.81	0.08	0.95	0.28	0.95	0.74
18:00	0.38	0.04	0.89	0.27	0.89	0.73
19:00	0.13	0.01	0.58	0.26	0.87	0.73
20:00	0.06	0.01	0.43	0.26	0.85	0.73
21:00	0.06	0.01	0.33	0.25	0.84	0.73
22:00	0.06	0.01	0.27	0.25	0.82	0.72
23:00	0.06	0.01	0.22	0.23	0.78	0.72

Appendix Table 9. Building Schedules for W.B. Travis

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.04	0.00	0.20	0.18	0.59	0.59
1:00	0.04	0.00	0.20	0.18	0.59	0.59
2:00	0.00	0.00	0.20	0.18	0.59	0.59
3:00	0.00	0.00	0.20	0.18	0.59	0.59
4:00	0.00	0.00	0.20	0.18	0.59	0.59
5:00	0.00	0.00	0.24	0.18	0.59	0.59
6:00	0.00	0.00	0.29	0.18	0.59	0.59
7:00	0.22	0.02	0.45	0.20	0.68	0.60
8:00	0.57	0.06	0.82	0.25	0.82	0.61
9:00	0.91	0.09	0.96	0.29	0.96	0.62
10:00	1.00	0.10	1.00	0.30	1.00	0.62
11:00	0.96	0.10	0.98	0.29	0.98	0.62
12:00	0.96	0.10	0.98	0.29	0.98	0.62
13:00	0.91	0.09	0.96	0.29	0.96	0.62
14:00	0.96	0.10	0.98	0.29	0.98	0.62
15:00	0.96	0.10	0.98	0.29	0.98	0.62
16:00	0.91	0.09	0.96	0.29	0.96	0.62
17:00	0.78	0.08	0.91	0.27	0.91	0.62
18:00	0.48	0.05	0.79	0.24	0.79	0.61
19:00	0.30	0.03	0.48	0.21	0.71	0.60
20:00	0.04	0.00	0.35	0.21	0.70	0.60
21:00	0.04	0.00	0.27	0.20	0.68	0.60

22:00	0.04	0.00	0.22	0.20	0.66	0.60
23:00	0.04	0.00	0.18	0.19	0.64	0.59

Appendix Table 10. Building Schedules for J.H. Winters

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.00	0.00	0.24	0.22	0.73	0.73
1:00	0.00	0.00	0.24	0.22	0.73	0.73
2:00	0.00	0.00	0.24	0.22	0.73	0.73
3:00	0.00	0.00	0.24	0.22	0.73	0.73
4:00	0.00	0.00	0.24	0.22	0.73	0.73
5:00	0.00	0.00	0.24	0.22	0.73	0.73
6:00	0.00	0.00	0.24	0.22	0.73	0.73
7:00	0.11	0.01	0.38	0.23	0.76	0.73
8:00	0.44	0.04	0.85	0.25	0.85	0.75
9:00	0.67	0.07	0.91	0.27	0.91	0.77
10:00	0.78	0.08	0.94	0.28	0.94	0.77
11:00	0.89	0.09	0.97	0.29	0.97	0.78
12:00	0.89	0.09	0.97	0.29	0.97	0.78
13:00	0.89	0.09	0.97	0.29	0.97	0.78
14:00	1.00	0.10	1.00	0.30	1.00	0.79
15:00	1.00	0.10	1.00	0.30	1.00	0.79
16:00	0.89	0.09	0.97	0.29	0.97	0.78
17:00	0.78	0.08	0.94	0.28	0.94	0.77
18:00	0.56	0.06	0.60	0.26	0.88	0.76
19:00	0.05	0.01	0.44	0.25	0.85	0.75
20:00	0.05	0.01	0.34	0.25	0.82	0.75
21:00	0.05	0.01	0.28	0.25	0.82	0.75
22:00	0.05	0.01	0.23	0.24	0.79	0.74
23:00	0.05	0.01	0.19	0.22	0.73	0.73

Appendix Table 11. Building Schedules for Capitol Extension

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.00	0.00	0.20	0.20	0.79	0.79
1:00	0.00	0.00	0.20	0.20	0.79	0.79
2:00	0.00	0.00	0.20	0.20	0.79	0.79
3:00	0.00	0.00	0.20	0.20	0.79	0.79
4:00	0.00	0.00	0.20	0.20	0.79	0.79
5:00	0.00	0.00	0.20	0.20	0.79	0.79
6:00	0.86	0.09	0.33	0.25	0.97	0.81
7:00	0.86	0.09	0.67	0.25	0.97	0.81
8:00	0.29	0.03	0.88	0.22	0.85	0.80
9:00	0.57	0.06	0.94	0.23	0.91	0.80
10:00	0.71	0.07	0.97	0.24	0.94	0.81
11:00	0.86	0.09	1.00	0.25	0.97	0.81
12:00	0.86	0.09	1.00	0.25	0.97	0.81
13:00	0.86	0.09	1.00	0.25	0.97	0.81
14:00	0.71	0.07	0.97	0.24	0.94	0.81
15:00	0.71	0.07	0.97	0.24	0.94	0.81
16:00	0.71	0.07	0.97	0.24	0.94	0.81
17:00	0.57	0.06	0.94	0.23	0.91	0.80
18:00	0.43	0.04	0.60	0.23	0.88	0.80
19:00	0.29	0.03	0.44	0.22	0.85	0.80
20:00	1.00	0.10	0.41	0.26	1.00	0.81
21:00	0.86	0.09	0.33	0.25	0.97	0.81
22:00	0.14	0.01	0.24	0.21	0.82	0.79
23:00	0.14	0.01	0.21	0.21	0.82	0.79

Appendix Table 12. Building Schedules for Capitol Building

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.00	0.00	0.19	0.19	0.77	0.77
1:00	0.00	0.00	0.19	0.19	0.77	0.77
2:00	0.00	0.00	0.19	0.19	0.77	0.77
3:00	0.00	0.00	0.19	0.19	0.77	0.77
4:00	0.00	0.00	0.19	0.19	0.77	0.77
5:00	0.00	0.00	0.19	0.19	0.77	0.77
6:00	0.00	0.00	0.19	0.19	0.77	0.77
7:00	0.14	0.01	0.32	0.20	0.81	0.78
8:00	0.29	0.03	0.84	0.21	0.84	0.79
9:00	0.57	0.06	0.90	0.23	0.90	0.80
10:00	0.86	0.09	0.97	0.24	0.97	0.82
11:00	0.86	0.09	0.97	0.24	0.97	0.82
12:00	1.00	0.10	1.00	0.25	1.00	0.82
13:00	1.00	0.10	1.00	0.25	1.00	0.82
14:00	1.00	0.10	1.00	0.25	1.00	0.82
15:00	1.00	0.10	1.00	0.25	1.00	0.82
16:00	1.00	0.10	1.00	0.25	1.00	0.82
17:00	0.86	0.09	0.97	0.24	0.97	0.82
18:00	0.43	0.04	0.56	0.22	0.87	0.80
19:00	0.14	0.01	0.39	0.20	0.81	0.78
20:00	0.00	0.00	0.30	0.19	0.77	0.77
21:00	0.00	0.00	0.25	0.19	0.77	0.77
22:00	0.00	0.00	0.21	0.19	0.77	0.77
23:00	0.00	0.00	0.19	0.19	0.77	0.77

Appendix Table 13. Building Schedules for the Department of Health

HR	WD OCC	WE OCC	WD LI	WE LI	WD EQU	WE EQU
0:00	0.05	0.01	0.17	0.15	0.50	0.50
1:00	0.05	0.01	0.17	0.15	0.50	0.50
2:00	0.05	0.01	0.17	0.15	0.50	0.50
3:00	0.05	0.01	0.17	0.15	0.50	0.50
4:00	0.05	0.01	0.17	0.15	0.50	0.50
5:00	0.05	0.01	0.21	0.16	0.53	0.51
6:00	0.19	0.02	0.30	0.18	0.59	0.52
7:00	0.31	0.03	0.44	0.20	0.66	0.53
8:00	0.69	0.07	0.84	0.25	0.84	0.57
9:00	0.94	0.09	0.97	0.29	0.97	0.59
10:00	1.00	0.10	1.00	0.30	1.00	0.60
11:00	1.00	0.10	1.00	0.30	1.00	0.60
12:00	1.00	0.10	1.00	0.30	1.00	0.60
13:00	0.94	0.09	0.97	0.29	0.97	0.59
14:00	1.00	0.10	1.00	0.30	1.00	0.60
15:00	0.94	0.09	0.97	0.29	0.97	0.59
16:00	0.94	0.09	0.97	0.29	0.97	0.59
17:00	0.75	0.08	0.88	0.26	0.88	0.58
18:00	0.38	0.04	0.46	0.21	0.69	0.54
19:00	0.13	0.01	0.28	0.17	0.56	0.51
20:00	0.05	0.01	0.20	0.15	0.50	0.50
21:00	0.05	0.01	0.17	0.15	0.50	0.50
22:00	0.05	0.01	0.14	0.15	0.50	0.50
23:00	0.05	0.01	0.13	0.15	0.50	0.50

APPENDIX P

Appendix Table 14. Summarized PV F-Chart Simulation Results for All Sites (kwh)

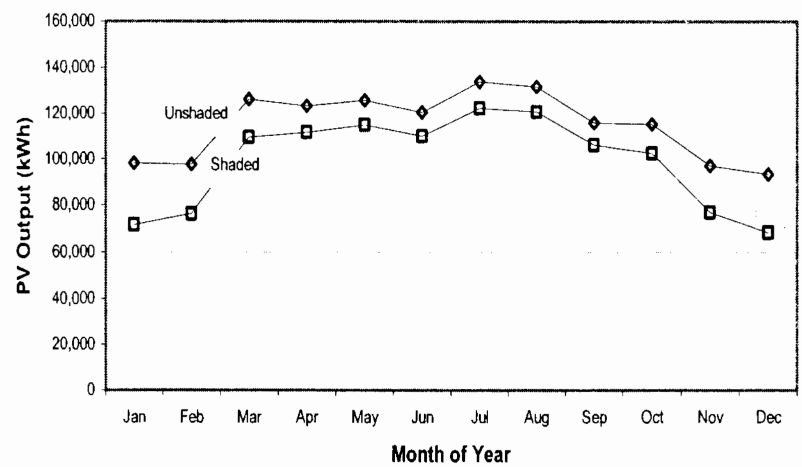
		South					Roof		
		Glass	Spandrel	Total N-SH	Shaded %	Total SH		Unshaded Total	Shaded Total
Houston	Jan	16,721.42	14,225.44	30,946.86	0.57	17639.7102	6580.26	71,528.44	53461.11
	Feb	16,236.05	13,812.44	30,048.49	0.63	18930.5487	7977.74	76,502.07	60574.65
	Mar	16,144.23	13,734.31	29,878.54	0.82	24500.4028	11044.48	95,066.77	82649.95
	Apr	12,796.65	10,886.45	23,683.10	0.95	22498.945	12403.00	93,350.98	84437.48
	May	11,540.89	9,818.17	21,359.06	1	21359.06	14711.30	104,981.16	96022.76
	Jun	10,777.16	9,168.44	19,945.60	1	19945.6	15106.81	104,440.13	95419.73
	Jul	11,143.08	9,479.70	20,622.78	1	20622.78	14866.70	104,827.17	95813.27
	Aug	12,359.51	10,514.59	22,874.10	1	22874.1	13623.86	102,381.46	93816.61
	Sep	14,929.39	12,700.88	27,630.27	0.98	27077.6646	11648.54	94,994.92	86920.64
	Oct	20,553.79	17,485.68	38,039.47	0.87	33094.3389	10497.60	102,924.35	91724.68
	Nov	18,665.01	15,878.94	34,543.95	0.69	23835.3255	7454.81	79,965.58	63941.60
	Dec	16,778.56	14,274.04	31,052.60	0.58	18010.508	6160.09	69,525.29	52121.00
	Total	**178,645.74**	**151,979.08**	**330,624.82**		**270,388.98**	**132,075.19**	**1,100,488.32**	**956903.45**
Los Angel	Jan	25,632.07	21,805.85	47,437.92	0.57	27039.6144	7674.2	98,186.75	71758.00
	Feb	22,654.07	19,272.44	41,926.51	0.63	26413.7013	9199.79	97,704.41	76368.21
	Mar	22,972.95	19,543.69	42,516.64	0.82	34863.6448	13910.52	126,119.84	109406.80
	Apr	17,428.76	14,827.18	32,255.94	0.95	30643.143	16204.45	123,208.09	111506.16
	May	13,580.19	11,553.12	25,133.31	1	25133.31	17609.09	125,743.20	114949.09
	Jun	12,305.74	10,468.86	22,774.60	1	22774.6	17570.36	120,488.48	110069.82
	Jul	13,270.05	11,289.26	24,559.31	1	24559.31	19560.44	133,829.10	122166.88
	Aug	15,975.14	13,590.57	29,565.71	1	29565.71	17349.68	131,648.81	120633.47
	Sep	19,342.67	16,455.33	35,798.00	0.98	35082.04	13581.57	115,790.61	106110.80
	Oct	24,460.89	20,809.54	45,270.43	0.87	39385.2741	10927.29	115,206.56	102535.39
	Nov	24,689.41	21,004.01	45,693.42	0.69	31528.4598	7956.14	97,108.70	76859.46
	Dec	25,086.89	21,342.10	46,428.99	0.58	26928.8142	6889.01	93,343.02	68440.44
	Total	**237,398.83**	**201,961.95**	**439,360.78**		**353,917.62**	**158,432.54**	**1,378,377.57**	**1190804.51**
Detroit	Jan	12,667.94	10,776.99	23,444.93	0.57	13363.6101	3652.12	49,430.51	36222.51
	Feb	15,071.33	12,821.58	27,892.91	0.63	17572.5333	5485.75	63,669.90	49563.12
	Mar	17,243.60	14,669.64	31,913.24	0.82	26168.8568	8925.98	88,452.50	76518.39
	Apr	16,575.82	14,101.50	30,677.32	0.96	29450.2272	11844.12	104,289.01	95960.08
	May	15,251.62	12,974.98	28,226.60	1	28226.6	14851.51	114,930.85	105586.56
	Jun	13,850.51	11,783.08	25,633.59	1	25633.59	15334.27	116,800.24	108081.37
	Jul	14,743.92	12,543.00	27,286.92	1	27286.92	15426.34	115,961.08	106438.86
	Aug	16,224.77	13,802.84	30,027.61	1	30027.61	13200.9	109,732.73	101087.18
	Sep	17,804.00	15,146.40	32,950.40	0.98	32291.392	10221.42	95,970.04	88183.27
	Oct	19,355.34	16,466.12	35,821.46	0.85	30448.241	7359.91	82,922.10	71983.28
	Nov	12,889.12	10,965.07	23,854.19	0.69	16459.3911	3938.62	51,230.11	40554.09
	Dec	10,073.58	8,569.90	18,643.48	0.47	8762.4356	2966.15	38,374.95	25476.15
	Total	**181,751.55**	**154,621.10**	**336,372.65**		**285,691.41**	**113,207.09**	**1,031,764.02**	**905654.85**
New York	Jan	15,203.81	12,934.28	28,138.09	0.57	16038.7113	4303.52	58,681.89	42908.87
	Feb	15,132.73	12,873.86	28,006.59	0.63	17644.1517	5758.21	65,039.12	50767.39
	Mar	17,169.86	14,606.89	31,776.75	0.82	26056.935	9162.2	89,283.07	77278.52
	Apr	15,347.40	13,056.50	28,403.90	0.96	27267.744	11539.16	98,944.92	91024.94
	May	14,128.40	12,019.50	26,147.90	1	26147.9	14019.02	108,046.26	99221.95
	Jun	12,811.31	10,898.95	23,710.26	1	23710.26	13909.92	103,139.64	94622.11
	Jul	13,478.09	11,466.24	24,944.33	1	24944.33	14049.1	105,577.43	96921.51
	Aug	14,705.64	12,510.46	27,216.10	1	27216.1	12290.2	101,185.18	93166.93
	Sep	16,358.96	13,917.02	30,275.98	0.98	29670.4604	9805.99	90,089.71	82733.15
	Oct	18,648.37	15,864.70	34,513.07	0.85	29336.1095	7513.12	81,468.39	70767.62
	Nov	13,852.02	11,784.32	25,636.34	0.69	17689.0746	4360.6	55,568.24	44040.99
	Dec	12,291.20	10,456.49	22,747.69	0.58	13193.6602	3431.75	47,410.76	34990.50
	Total	**179,127.79**	**152,389.21**	**331,517.00**		**278,915.44**	**110,142.79**	**1,004,434.61**	**878,444.47**

		East				West				
		Spandrel	Total N-SH	Shaded %	Total SH	Glass	Spandrel	Total N-SH	Shaded %	Total SH
Houston	Jan	7,814.73	17,000.66	0.86	14620.5676	9,185.93	7,814.73	17,000.66	0.86	14620.5676
	Feb	8,843.12	19,237.92	0.87	16736.9904	10,394.80	8,843.12	19,237.92	0.88	16929.3696
	Mar	12,504.34	27,202.66	0.87	23666.3142	14,556.99	12,384.10	26,941.09	0.87	23438.7483
	Apr	13,226.34	28,773.49	0.87	25032.9363	15,394.72	13,096.67	28,491.39	0.86	24502.5954
	May	15,838.20	34,455.40	0.86	29631.644	18,617.20	15,838.20	34,455.40	0.88	30320.752
	Jun	15,947.81	34,693.86	0.87	30183.6582	18,746.05	15,947.81	34,693.86	0.87	30183.6582
	Jul	16,017.21	34,844.83	0.87	30315.0021	18,637.44	15,855.42	34,492.86	0.87	30008.7882
	Aug	15,219.27	33,108.97	0.87	28804.8039	17,708.99	15,065.54	32,774.53	0.87	28513.8411
	Sep	12,805.55	27,858.10	0.87	24236.547	15,052.46	12,805.55	27,858.01	0.86	23957.8886
	Oct	12,500.16	27,193.64	0.88	23930.4032	14,693.48	12,500.16	27,193.64	0.89	24202.3396
	Nov	8,768.70	19,076.01	0.86	16405.3686	10,207.24	8,683.57	18,890.81	0.86	16246.0966
	Dec	7,426.64	16,156.30	0.87	14055.981	8,729.66	7,426.64	16,156.30	0.86	13894.418
	Total	**146,912.07**	**319,601.84**		**277,620.22**	**171,924.96**	**146,261.51**	**318,186.47**		**276,819.06**
Los Angel	Jan	9,947.91	21,641.36	0.86	18611.5696	11,581.01	9,852.26	21,433.27	0.86	18432.6122
	Feb	10,757.03	23,401.56	0.87	20359.3572	12,522.95	10,653.60	23,176.55	0.88	20395.364
	Mar	16,017.87	34,846.34	0.87	30316.3158	18,828.47	16,017.87	34,846.34	0.87	30316.3158
	Apr	17,262.75	37,554.40	0.87	32672.328	20,096.54	17,096.76	37,193.30	0.86	31986.238
	May	19,168.76	41,700.88	0.86	35862.7568	22,315.47	18,984.45	41,299.92	0.88	36343.9296
	Jun	18,509.72	40,267.23	0.87	35032.4901	21,546.28	18,330.01	39,876.29	0.87	34692.3723
	Jul	20,719.97	45,075.63	0.87	39215.7981	24,116.88	20,516.84	44,633.72	0.87	38831.3364
	Aug	19,570.74	42,575.41	0.87	37040.6067	22,779.14	19,378.87	42,158.01	0.87	36677.4687
	Sep	15,338.86	33,369.09	0.87	29031.1083	17,853.47	15,188.48	33,041.95	0.86	28416.077
	Oct	13,562.33	29,504.42	0.88	25963.8896	15,942.09	13,562.33	29,504.42	0.89	26258.9338
	Nov	9,988.45	21,729.57	0.86	18687.4302	11,741.12	9,988.45	21,729.57	0.86	18687.4302
	Dec	9,244.04	20,110.13	0.87	17495.8131	10,760.59	9,154.30	19,914.89	0.86	17126.8054
	Total	**180,088.43**	**391,776.02**		**340,289.46**	**210,084.01**	**178,724.22**	**388,808.23**		**338,164.88**
Detroit	Jan	5,133.07	11,166.73	0.86	9603.3878	6,033.66	5,133.07	11,166.73	0.86	9603.3878
	Feb	6,962.03	15,145.62	0.87	13176.6894	8,183.59	6,962.03	15,145.62	0.88	13328.1456
	Mar	10,943.24	23,806.64	0.87	20711.7768	12,863.40	10,943.24	23,806.64	0.87	20711.7768
	Apr	14,262.48	31,027.43	0.89	27614.4127	16,609.72	14,130.42	30,740.14	0.88	27051.3232
	May	16,593.36	36,098.27	0.86	31044.5122	19,319.14	16,435.33	35,754.47	0.88	31463.9336
	Jun	17,514.02	38,101.15	0.89	33910.0235	20,387.25	17,343.98	37,731.23	0.88	33203.4824
	Jul	16,834.98	36,623.91	0.87	31862.8017	19,788.93	16,834.98	36,623.91	0.87	31862.8017
	Aug	15,360.38	33,415.91	0.87	29071.8417	17,878.52	15,209.79	33,088.31	0.87	28786.8297
	Sep	12,134.95	26,399.11	0.87	22967.2257	14,264.16	12,134.95	26,399.11	0.86	22703.2346
	Oct	9,177.53	19,965.44	0.85	16970.624	10,685.17	9,090.12	19,775.29	0.87	17204.5023
	Nov	5,386.72	11,718.65	0.86	10078.039	6,331.93	5,386.72	11,718.65	0.86	10078.039
	Dec	3,853.30	8,382.66	0.83	6957.6078	4,529.36	3,853.30	8,382.66	0.81	6789.9546
	Total	**134,156.06**	**291,851.52**		**253,968.94**	**156,874.83**	**133,457.93**	**290,332.76**		**252,787.41**
New York	Jan	6,030.97	13,120.14	0.86	11283.3204	7,089.17	6,030.97	13,120.14	0.86	11283.3204
	Feb	7,187.95	15,637.16	0.87	13604.3292	8,449.21	7,187.95	15,637.16	0.88	13760.7008
	Mar	11,111.24	24,172.06	0.87	21029.6922	13,060.82	11,111.24	24,172.06	0.87	21029.6922
	Apr	13,624.42	29,639.43	0.89	26379.0927	15,865.34	13,497.09	29,362.43	0.88	25838.9384
	May	15,601.14	33,939.67	0.86	29188.1162	18,338.53	15,601.14	33,939.67	0.88	29866.9096
	Jun	15,132.92	32,921.11	0.87	28641.3657	17,613.79	14,984.56	32,598.35	0.87	28360.5645
	Jul	15,303.40	33,292.00	0.87	28964.04	17,988.60	15,303.40	33,292.00	0.87	28964.04
	Aug	14,176.06	30,839.44	0.87	26830.3128	16,663.38	14,176.06	30,839.44	0.87	26830.3128
	Sep	11,493.56	25,003.87	0.87	21753.3669	13,510.31	11,493.56	25,003.87	0.86	21503.3282
	Oct	9,109.05	19,816.37	0.85	16843.9145	10,604.37	9,021.46	19,625.83	0.87	17074.4721
	Nov	5,877.19	12,785.65	0.86	10995.659	6,908.46	5,877.19	12,785.65	0.86	10995.659
	Dec	4,879.71	10,615.66	0.87	9235.6242	5,735.95	4,879.71	10,615.66	0.86	9129.4676
	Total	**129,527.61**	**281,782.56**		**244,748.83**	**151,827.93**	**129,164.33**	**280,992.26**		**244,637.41**

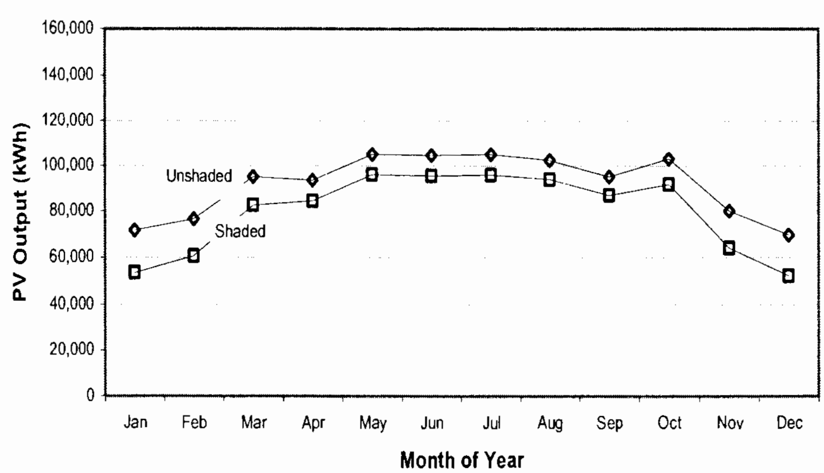
APPENDIX Q

Shaded vs. Non Shaded Effect on Photovoltaic Production

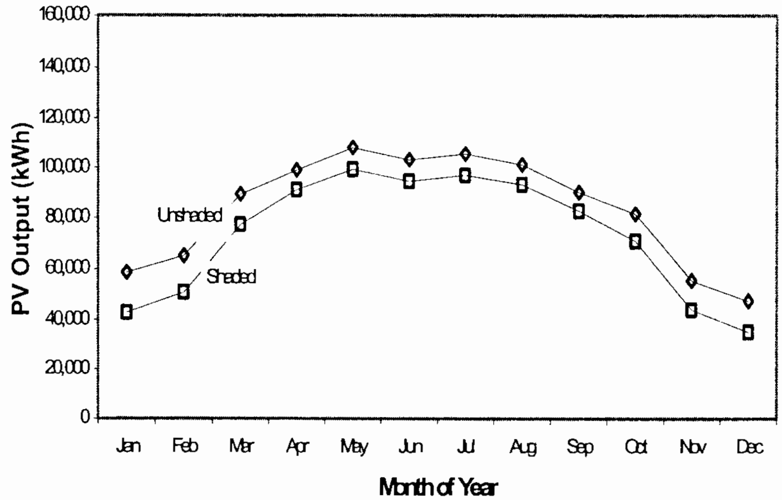
This appendix contains plots of the shaded effect on photovoltaic production of electricity for all sites.



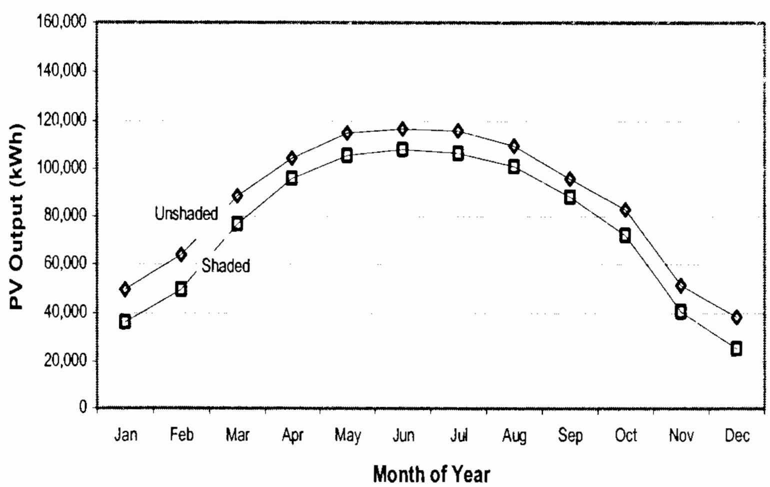
Appendix Figure 8. Shaded vs. Unshaded Effect for Los Angeles



Appendix Figure 9. Shaded vs. Unshaded Effect for Houston



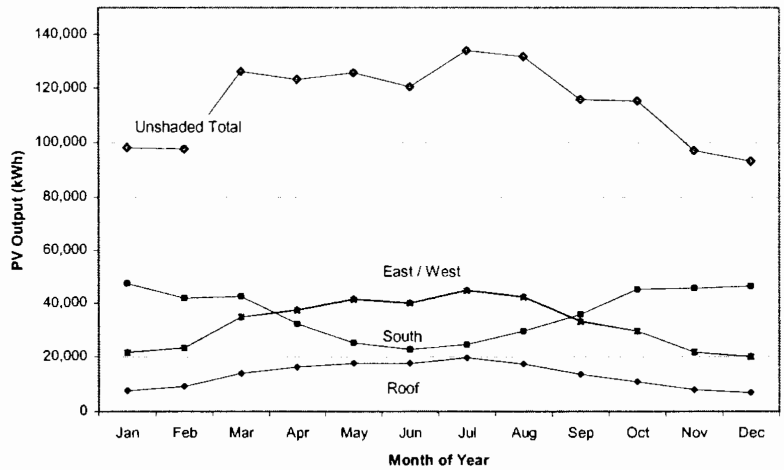
Appendix Figure 10. Shaded vs. Unshaded Effect for New York



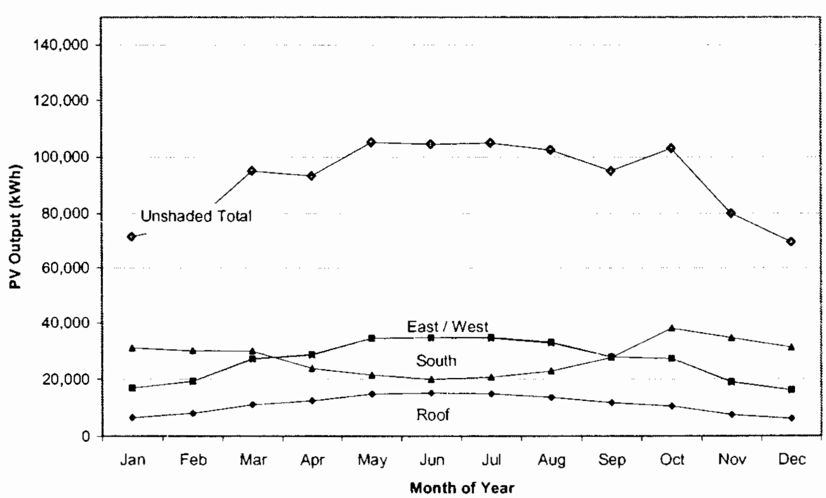
Appendix Figure 11. Shaded vs. Unshaded Effect for Detroit

APPENDIX R

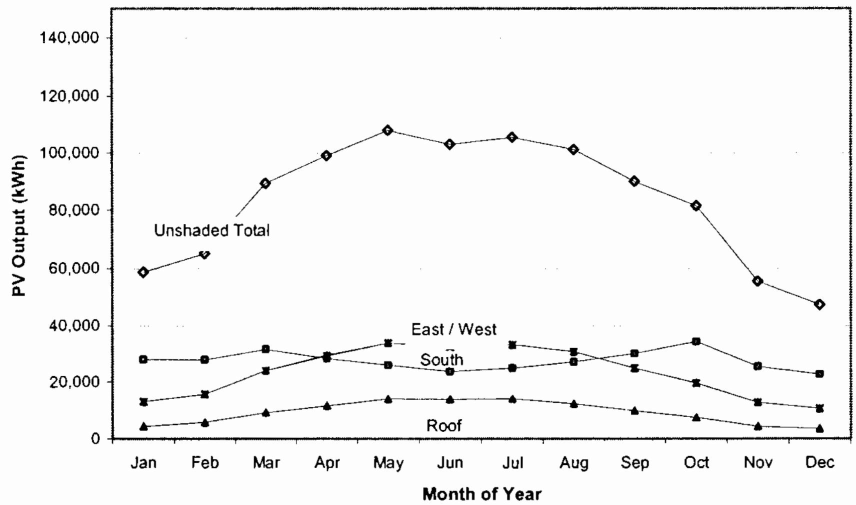
UNSHADED EFFECT ON PV PRODUCTION



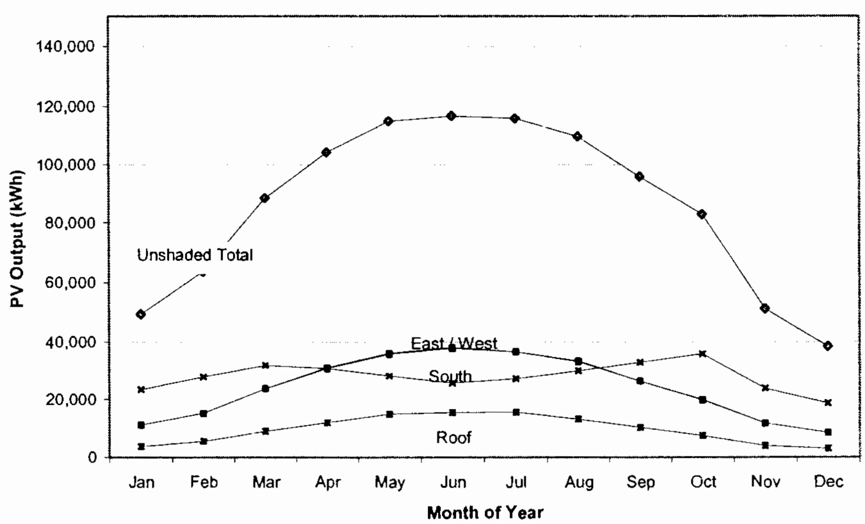
Appendix Figure 12. Unshaded Effect on Los Angeles



Appendix Figure 13. Unshaded Effect on Houston



Appendix Figure 14. Unshaded Effect on New York

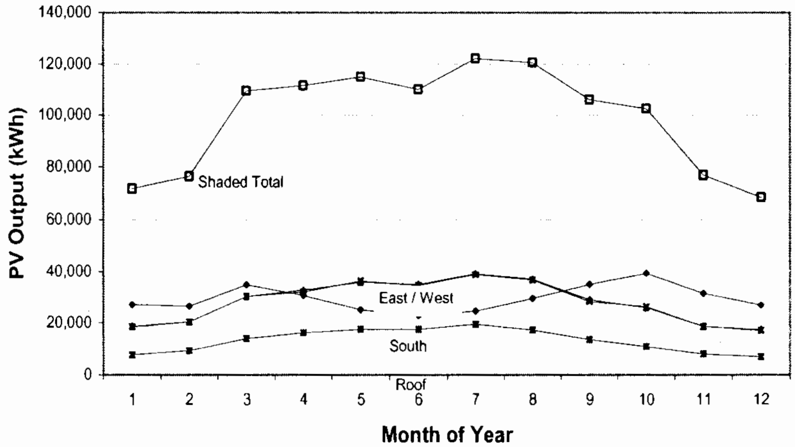


Appendix Figure 15. Unshaded Effect on Detroit

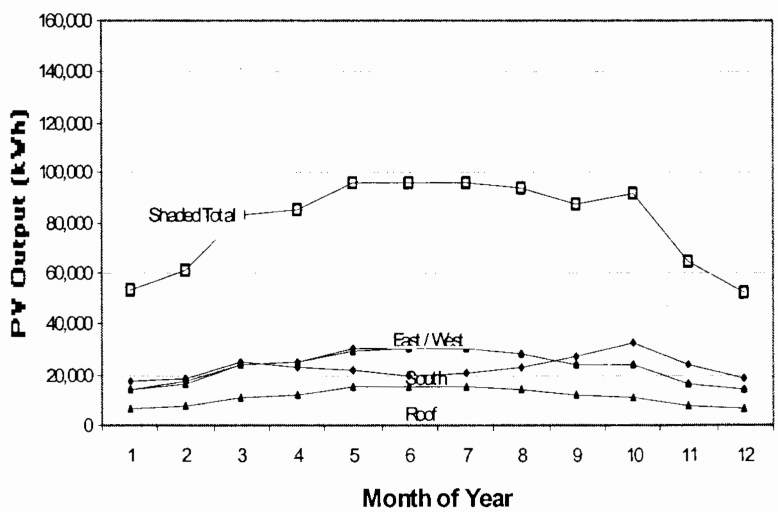
APPENDIX S

PV Production by Facades

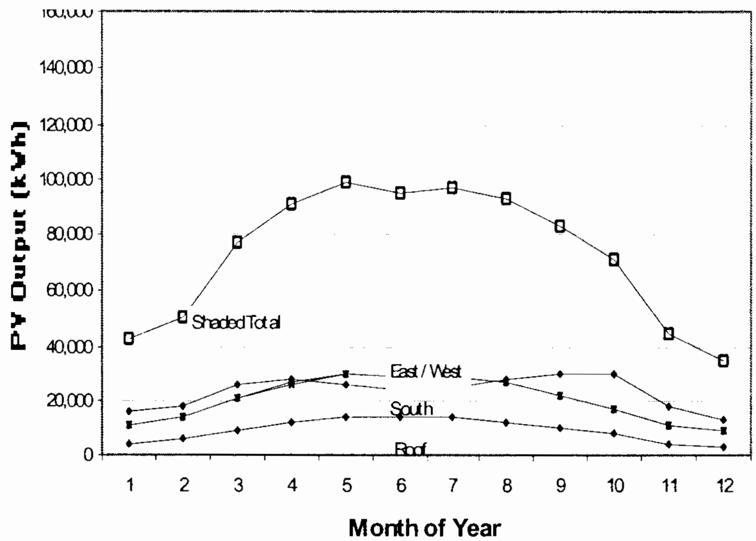
This appendix contains plots of the shaded effect on photovoltaic production of electricity for all sites.



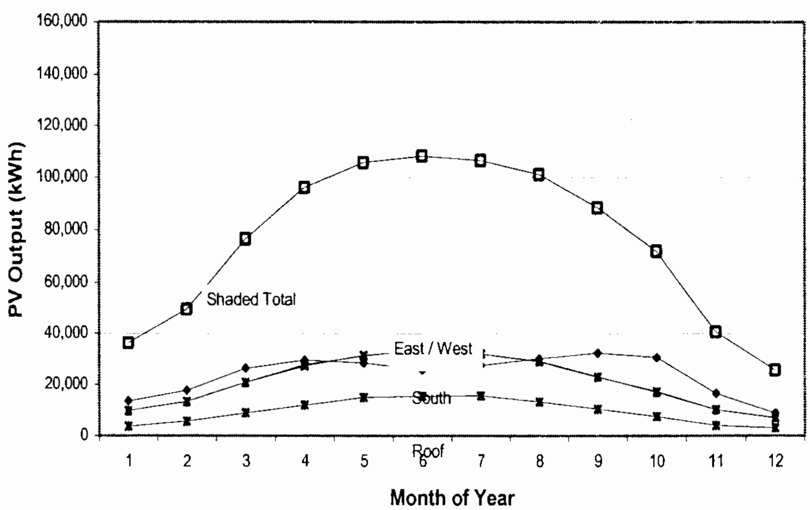
Appendix Figure 16. Shaded Effect on Los Angeles



Appendix Figure 17. Shaded Effect on Houston



Appendix Figure 18. Shaded Effect on New York



Appendix Figure 19. Shaded Effect on Detroit

APPENDIX T

Appendix Table 15. Annual Energy Consumption for Clear, Low-E, and PV Glazings.

Case Study	Size (sq.ft.)	Electric	Heating	Cooling	PV (kWh)	Total	Net PV Total
DOE ADJ	640,000	18,781,828.8	25,443.10	10,332.10		99,858.80	
DETROIT							
D-S-C	410,000	8,708,675.26	66,144.40	3,361.50		99,219.90	
D-S-L	410,000	6,506,154.75	22,392.50	2,537.10		47,128.60	
D-S-P	410,000	6,601,084.41	29,112.00	2,642.00	905654.85	51,186.81	54,276.90
D-U-C	410,000	9,703,604.92	71,890.90	3,939.00		108,938.60	
D-U-L	410,000	6,967,086.75	24,561.70	2,754.80		51,088.20	
D-U-P	410,000	7,352,872.22	31,624.80	2,889.10	1031764.02	56,081.52	59,601.90
HOUSTON							
H-S-C	410,000	8,806,242.67	22,470.60	8,214.10		60,731.60	
H-S-L	410,000	7,161,313.01	10,019.50	5,759.90		40,213.80	
H-S-P	410,000	7,520,779.60	11,971.30	6,051.60	956903.48	43,683.80	43,683.80
H-U-C	410,000	10,632,180.5	24,279.30	9,617.80		70,174.10	
H-U-L	410,000	7,682,092.61	11,289.40	6,188.90		43,689.60	
H-U-P	410,000	8,120,838.22	13,367.30	6,573.80	1100488.32	47,649.40	47,649.40
LOS							
L-S-C	410,000	8,911,488.86	23,050.10	6,352.70		59,808.80	
L-S-L	410,000	6,829,835.87	10,537.20	4,923.30		38,763.90	
L-S-P	410,000	7,129,308.32	12,717.50	5,119.00	1190804.51	42,161.70	42,161.70
L-U-C	410,000	9,918,845.25	24,711.10	7,274.70		65,828.90	
L-U-L	410,000	7,321,776.08	11,756.00	5,324.20		42,062.10	
L-U-P	410,000	7,691,324.74	14,045.10	5,564.80	1378377.57	45,852.70	45,852.70
NEW YORK							
N-S-C	410,000	8,911,225.09	23,050.50	6,352.10		59,807.70	
N-S-L	410,000	6,829,718.64	10,537.60	4,923.00		38,763.60	
N-S-P	410,000	7,128,780.77	12,717.80	5,118.70	878444	42,159.90	42,159.90
N-U-C	410,000	9,918,347.01	24,710.30	7,273.80		65,825.50	
N-U-L	410,000	7,321,629.54	11,756.30	5,323.90		42,061.60	
N-U-P	410,000	7,690,885.11	14,044.80	5,564.30	1004434.61	45,850.40	45,850.40

Appendix Table 16. Annual Gross Energy Intensities for Clear, Low-E, and PV Glazings.

Site	*Size*	*Electric (Btu/Sq.Ft)*	*Heating*	*Cooling*	*Total (Btu/Sq.Ft)*	*Net Total*
DOE ADJUSTED	640,000	100,130.63	39,754.84	16,143.91	156,029.38	
DETROIT						
D-S-C	410,000	72,473.17	161,327.80	8,198.78	241,999.76	
D-S-L	410,000	54,143.90	54,615.85	6,188.05	114,947.80	
D-S-P	410,000	54,933.90	71,004.88	6,443.90	124,845.87	132,382.68
D-U-C	410,000	80,752.93	175,343.66	9,607.32	265,703.90	
D-U-L	410,000	57,979.76	59,906.59	6,719.02	124,605.37	
D-U-P	410,000	61,190.24	77,133.66	7,046.59	136,784.20	145,370.49
HOUSTON						
H-S-C	410,000	73,285.12	54,806.34	20,034.39	148,125.85	
H-S-L	410,000	59,596.10	24,437.80	14,048.54	98,082.44	
H-S-P	410,000	62,587.56	29,198.29	14,760.00	98,582.55	106,545.85
H-U-C	410,000	88,480.49	59,217.80	23,458.05	171,156.34	
H-U-L	410,000	63,930.00	27,535.12	15,094.88	106,560.00	
H-U-P	410,000	67,581.22	32,603.17	16,033.66	107,059.84	116,218.05
LOS ANGELES						
L-S-C	410,000	74,160.98	56,219.76	15,494.39	145,875.12	
L-S-L	410,000	56,837.56	25,700.49	12,008.05	94,546.10	
L-S-P	410,000	59,329.76	31,018.29	12,485.37	92,923.60	102,833.41
L-U-C	410,000	82,544.15	60,270.98	17,743.17	160,558.29	
L-U-L	410,000	60,931.46	28,673.17	12,985.85	102,590.49	
L-U-P	410,000	64,006.83	34,256.34	13,572.68	100,365.06	111,835.85
NEW YORK						
N-S-C	410,000	74,158.78	56,220.73	15,492.93	145,872.44	
N-S-L	410,000	56,836.59	25,701.46	12,007.32	94,545.37	
N-S-P	410,000	59,325.37	31,019.02	12,484.63	95,518.65	102,829.02
N-U-C	410,000	82,540.00	60,269.02	17,740.98	160,550.00	
N-U-L	410,000	60,930.24	28,673.90	12,985.12	102,589.27	
N-U-P	410,000	64,003.17	34,255.61	13,571.46	103,471.39	111,830.24

APPENDIX U

BDL Input Files

This Appendix contain the original samp2.inp file, the modified samp2.inp file, and the final parametric input file used to generate the results of this study.

Doe2 Samp2 Input file

```
INPUT LOADS ..
TITLE      LINE-1 *31-STORY OFFICE BLDG, HOUSTON- LOAD2 *
        LINE-2 * CUSTOM WEIGHTING FACTORS & DAYLIGHTING *
        LINE-3 * * ..

        ABORT       ERRORS  ..
        DIAGNOSTIC  WARNINGS  ..

        LOADS-REPORT  V=(LV-K)  SUMMARY=(LS-C,LS-D,LS-I) ..
        RUN-PERIOD      JAN 1 1998 THRU  DEC 31 1998  ..
        BUILDING-LOCATION  LATITUDE=29.65  LONGITUDE=95.28
                TIME-ZONE=6  ALTITUDE=46
        ATM-MOISTURE=(.36,.32,.40,.53,.76,1.11,1.21,1.12,.88,.66,
              .43,.35)
        ATM-TURBIDITY=(.15,.18,.21,.18,.18,.19,.22,.16,.16,.14,.13,
              .15) ..

          $ BUILDING DESCRIPTION

$         THIS EXAMPLE HAS THREE SPECIAL FEATURES:

$        1 IT USES CUSTOM WEIGHTING FACTORS FOR THE EXTERIOR ZONES,
$          WHICH GIVES A BETTER SIMULATION
$          OF BUILDING MASS AND HVAC SYSTEM PERFORMANCE.
$          THE INTERIOR ZONES ARE INPUT
$          USING STANDARD ASHRAE WEIGHTING FACTORS WITH
$          A FLOOR WEIGHT OF 150LB/SQFT TO REPRESENT THE MASS OF ELEVATOR
$          SHAFT WALLS, WHICH ARE ASSUMED TO BE HEAVY REINFORCED
$          CONSTRUCTION FOR WIND BRACING.
$
$        2 IT DEMONSTRATES DAYLIGHTING AND ASSOCIATED ELECTRIC LIGHTING
$          CONTROLS. EACH 25 FT WIDE BAY ON
$          ALL FOUR EXPOSURES IS TREATED AS A SEPARATE ZONE.
$          THERE ARE 8 BAYS PER FLOOR ON THE EAST AND WEST EXPOSURES
$          AND 4 BAYS PER FLOOR ON THE NORTH AND SOUTH.
$
$        3 IT DEMONSTRATES HOW DOE-2 INPUT CAN BE SHORTENED BY
$          OMITTING U-NAMES FOR EVERY WALL AND FLOOR SURFACE.  THIS
$          MAKES THE VERIFICATION REPORTS LESS READABLE AS MOST SURFACES
$          ARE NOT IDENTIFIED.
$          IN ADDITION, AS ANOTHER WAY OF SHORTENING THE INPUT,
$          ABBREVIATIONS ARE USED EXTENSIVELY,
$          BUT THE FIRST INPUT ENTRY IS WRITTEN USING THE FULL KEYWORD
$          FOR CLARIFICATION.  EQUAL SIGNS ARE ALSO OMITTED IN MOST
$          CASES.

$    NOTE THAT THE FOLLOWING DESCRIPTION IS IDENTICAL TO
$    "31-STORY OFFICE BLDG - LOAD1" EXCEPT THAT:
$    (1) CEILING PLENUMS HAVE BEEN ADDED;
$    (2) DAYLIGHTING IS SPECIFIED; AND
$    (3) FOR THE DAYLIGHTING CALCULATION, THE PERIMETER ZONES HAVE BEEN
$       DIVIDED INTO INDIVIDUAL ROOMS, SO THAT RZ2, RZ4, TZ2, AND TZ4
$       NOW HAVE MULTIPLIER=8 AND RZ3,RZ5,TZ3, AND TZ5 HAVE MULTIPLIER=4
$       (AS BEFORE, THE TZ ZONES ALSO HAVE FLOOR-MULTIPLIER=30, SO THAT
$       THERE ARE 8X30=240 TZ2 AND TZ4 ZONES AND 4X30=120 TZ3 AND TZ5
```

```
$       ZONES).

$ STRUCTURE   STEEL FRAME WITH 4" CONCRETE FLOORS AND ROOF.  31 OCCUPIED
$         STORIES, 13FT FLOOR TO FLOOR HEIGHT, 9FT CEILINGS.  RETURN
$         AIR CEILING PLENUMS ARE DEFINED; ONE FOR THE TOP FLOOR AND ONE
$         FOR THE TYPICAL FLOORS.

$ CURTAIN WALL USING CODE-WORDS FROM DOE-2 LIBRARY (REFERENCE MANUAL, PART 2)
$         AND STARTING WITH OUTSIDE WORKING INWARD: 1/4IN SPANDREL GLASS
$         (NOT IN LIBRARY - SEE MATERIAL SPGL); 2IN POLYSTRENE INSUL
$         R-8 (IN35); STEEL BACKPANEL (AS01); 2IN AIRSPACE (AL21);
$         3/4IN GYPSUM BOARD FINISH (GP03) .

$ ROOF      ROOF GRAVEL (RG02); BUILT-UP ROOFING (BR01); 3IN ROOF INSUL R-8
$         (IN76); 4IN CONCRETE (CC03); INSIDE-FILM-RESISTANCE .76 .

$ WINDOWS     DOUBLE-GLAZED TINTED, SOLAR TRANSMITTANCE=.53, GLASS TYPE CODE=5.
$         WINDOWS HAVE INSIDE BLINDS THAT ARE PULLED WHENEVER TRANSMITTED
$         DIRECT SOLAR RADIATION EXCEEDS 40 BTUH PER SQFT AND IF THE WINDOW
$         GLARE INDEX EXCEEDS A VALUE OF 22.  THE BLINDS ARE CONSIDERED
$         TO BE REOPENED WITH A PROBABILITY OF .4 WHEN SOLAR EFFECT IS LESS
$         THAN 40 BTUH.

$ INTERIORS   CEILINGS ARE SUSPENDED ACCOUSTIC TILE.
$         PARTITIONS SIMULATE CONVECTIVE HEAT TRANSFER BETWEEN CORE AND
$         PERIMETER SPACES USING A U-VALUE OF 1.5.

$ SPACE LOADS  LIGHTING RECESSED FLUORSCENT AT 1.5 WATTS/SQFT.
$         OFFICE EQUIPMENT 1 WATTS/SQFT.
$         PEOPLE  100SQFT/PERSON FOR PERIMETER SPACES
$              200SQFT/PERSON FOR CORE AREAS.
$         INFILTRATION .3 AIR CHANGES/HR FOR PERIMETER AREAS WHEN FANS
$         ARE OFF -.06 AIR CHANGES/HR WHEN FANS ARE ON.

$ HVAC DESCRIPTIONS ARE TO BE FOUND WITH EACH INDIVIDUAL SYSTEM AND PLANT INPUT.

              $ MATERIALS NOT IN DOE-2 LIBRARY

SPGS=MATERIAL    TH=.0208  COND=.590  DENS=172.  S-H=.20  ..

              $ WALL CONSTRUCTIONS

ROOFER      =LAYERS  MAT (RG02,BR01,IN76,CC03)  I-F-R .76  ..
WALLER      =LAYERS  MAT (SPGS,IN35,AS01,AL21,GP03)  ..
FLR-UP      =LAYERS  MAT (CP01,CC03)  ..
FLR-DN      =LAYERS  MAT (CC03,CP01)  ..
PARTITION   =LAYERS  MAT (GP01,AL21,GP01)  ..

RF        =CONSTRUCTION      LAYERS=ROOFER  ..
WL1       =CONSTRUCTION      LAYERS=WALLER  ..
CEIL      =CONS  U=.20  ..
FLOOR-ABOVE  =CONS  LAYERS=FLR-UP  ..
FLOOR       =CONS  LAYERS=FLR-DN  ..
PA2       =CONS  LAYERS =PARTITION  ..
BW        =CONSTRUCTION      U=.05  ..
SB-U      =CONSTRUCTION      U=1.5  ..

              $ GLASS DESCRIPTION

GT1       =GLASS-TYPE  GLASS-TYPE-CODE=5  PANES=2  VIS-TRANS=.35  ..

              $ SCHEDULES

OC1       =DAY-SCHEDULE      (1,8) (0.)      (9,10) (1.)
                   (11,13) (.8,.4,.8)  (14,24) (1.,1.,1.,
                         .3,.1,.1,.1,0.,0.,0.,0.)  ..
OC2       =DAY-SCHEDULE      (1,24) (0.0)  ..
OCCUP       =SCHEDULE        THRU DEC 31  (WD) OC1  (WEH) OC2  ..

L1        =DAY-SCHEDULE      (1,6) (.05)      (7,24) (.1,.9,.9,
                   .95,.95,.95,.8,.8,.9,.9,.95,.8,.7,.6,
                   .4,.3,.2,.2)  ..
L2        =DAY-SCHEDULE      (1,24) (.05)  ..
LIGHTS      SCHEDULE         THRU DEC 31 (WD) L1  (WEH) L2  ..
```

```
ES1        =DAY-SCHEDULE       (1,8) (0.)         (9,20) (.35,.50,
                    .55,.9,.6,.8,.7,.75,.3,.3,.5,.05)
                    (21,24) (0.0)  ..
ES2        =DAY-SCHEDULE       (1,24) (0.0) ..
EQUIP       =SCHEDULE          THRU DEC 31 (WD) ES1  (WEH) ES2  ..

I1       =DAY-SCHEDULE       (1,7) (1.)        (8,18) (0.2)
                    (19,24) (1.)   ..
I2       =DAY-SCHEDULE       (1,24) (1.)  ..
INFIL       =SCHEDULE          THRU DEC 31  (WD)  I1  (WEH)  I2  ..

SHADE-MULT    =SCHEDULE THRU DEC 31 (ALL) (1,24) (.75)  ..
TRANS-MULT    =SCHEDULE THRU DEC 31 (ALL) (1,24) (.35)  ..
COND-MULT     =SCHEDULE THRU DEC 31 (ALL) (1,24) (.9)  ..
CLOSE-SHADE   =SCHEDULE THRU DEC 31 (ALL) (1,24) (40)  ..
REOPEN-PROB   =SCHEDULE THRU DEC 31 (ALL) (1,24) (.5)  ..

          $ SPACE DESCRIPTIONS

OFFICE      =SPACE-CONDITIONS   TEMPERATURE=(75)  FLOOR-WEIGHT=0  $ FOR CWF
                    LIGHTING-W/SQFT=1.5  EQUIPMENT-W/SQFT=1
                    PEOPLE-HEAT-GAIN=450
                    EQUIP-SCHEDULE=EQUIP  L-SCH=LIGHTS
                    PEOPLE-SCHEDULE=OCCUP  AIR-CHANGES/HR=.5
                    INF-SCHEDULE=INFIL  LIGHT-TO-SPACE=.80
                    INF-METHOD=AIR-CHANGE
                    LIGHTING-TYPE=REC-FLUOR-RV   ..

A-STORAGE    =SPACE           TEMPERATURE=(75)  FLOOR-WEIGHT=150
                    VOLUME=400000  AREA=20000
                    LIGHTING-W/SQFT=1.5
                    LIGHTING-SCHEDULE=LIGHTS   ..
         UNDERGROUND-WALL   AREA=12000  CONSTRUCTION=BW  ..
         UNDERGROUND-FLOOR  AREA=20000  CONSTRUCTION=BW  ..

         SET-DEFAULT FOR  EXTERIOR-WALL   HEIGHT=9.  AZIMUTH=180  ..
         SET-DEFAULT FOR  WINDOW   HEIGHT=6.5  GLASS-TYPE=GT1
                   MAX-SOLAR-SCH=CLOSE-SHADE
                   WIN-SHADE-TYPE=MOVABLE-INTERIOR
                   SHADING-SCHEDULE=SHADE-MULT
                   CONDUCT-SCHEDULE=COND-MULT
                   VIS-TRANS-SCH=TRANS-MULT
                   OPEN-SHADE-SCH=REOPEN-PROB
                   SUN-CTRL-PROB=.7  ..

RZ1        SPACE  SPACE-CONDITIONS OFFICE  VOLUME 107100  AREA 11900
             X 15  Y 15  Z 390  N-O-P 60  AIR-CHANGES/HR 0.01
             F-W 150  ..
       IN1  I-W   AREA 191  CONS SB-U  NEXT-TO RZ2  ..
       IN2  I-W   AREA 158   CONS SB-U  N-T RZ3  ..
          I-W   LIKE IN1  N-T RZ4  ..
          I-W   LIKE IN2  N-T RZ5  ..
       CL1   I-W   AREA 11900  CONS CEIL  TILT 0  NEXT-TO PLEN1  ..

RZ2        SPACE   S-C OFFICE  A 346.8  V 3114  N-O-P 4  M 8
             AZ -90  X 100  Y 87.5  Z 390
             DAYLIGHTING YES  LIGHT-REF-POINT1 (12.5,9,2.5)
             LIGHT-SET-POINT1 50  LIGHT-CTRL-TYPE1 CONTINUOUS
             MAX-GLARE 22  ..
       CU1   E-W   H 9  W 25  CONS WL1  .. $ EAST-FACING

$ FOR CU1, NOTE THAT THE SUM OF BUILDING AZIMUTH (0) + SPACE AZIMUTH (-90)
$ + WALL AZIMUTH (180, FROM SET-DEFAULT) = 90, SO THIS WALL FACES EAST

        W1    WI   W 25  Y 2.5  ..
       IN3   I-W    A 125  CONS PA2  I-W-TYPE ADIABATIC  ..
       IN4   I-W   LIKE IN3  ..
       FL1   I-W    A 347  CONS FLOOR  TILT 180  I-W-TYPE ADIABATIC  ..
       CL2   I-W    A 347  CONS CEIL   TILT 0  NEXT-TO PLEN1  ..

RZ3        SPACE   LIKE RZ2  A 319  V 2869  AZ 180  X 62.5  Y 200  M 4  ..
          E-W   LIKE CU1  ..  WI LIKE W1   .. $ NORTH-FACING
          I-W   LIKE IN3  ..  I-W LIKE IN3  ..
          I-W   LIKE FL1  ..  I-W LIKE CL2  ..
```

```
RZ4         SPACE  LIKE RZ2  AZ 90  X 0  Y 112.5  M 8 ..
           E-W  LIKE CU1 .. WI LIKE W1 .. $ WEST-FACING
           I-W  LIKE IN3 .. I-W LIKE IN3 ..
           I-W  LIKE FL1 .. I-W LIKE CL2 ..

RZ5         SPACE  LIKE RZ3  AZ 0  X 37.5  Y 0  M 4 ..
           E-W  LIKE CU1 .. WI LIKE W1 .. $ SOUTH-FACING
           I-W  LIKE IN3 .. I-W LIKE IN3 ..
           I-W  LIKE FL1 .. I-W LIKE CL2 ..

PLEN1        SPACE  ZONE-TYPE PLENUM T=(75) A 20000  V 60000  F-W 0
              Z 399 ..
       EW3  E-W  H 4  W 100  AZ 0  X 100  Y 200  CONS WL1 ..
       EW2  E-W  LIKE EW3  W 200  AZ 90  X 100  Y 0 ..
       EW5  E-W  LIKE EW3  AZ 180  X 0  Y 0 ..
       EW4  E-W  LIKE EW2  AZ 270  X 0  Y 200 ..
          ROOF  H 200  W 100  AZ 180  TILT 0  CONS RF  G-R 0 ..

TZ1         SPACE  LIKE RZ1  FLOOR-MULTIPLIER 30  Z 195 ..
           I-W  LIKE IN1  N-T TZ2 ..
           I-W  LIKE IN2  N-T TZ3 ..
           I-W  LIKE IN1  N-T TZ4 ..
           I-W  LIKE IN2  N-T TZ5 ..
           I-W  LIKE CL1  N-T PLEN2 ..

TZ2         SPACE  LIKE RZ2  F-M 30  Z 195 ..
           E-W  LIKE CU1 ..  WI LIKE W1 ..
           I-W  LIKE IN3 ..  I-W LIKE IN3 ..
           I-W  LIKE FL1 ..
       CL3 I-W  LIKE CL2  NEXT-TO PLEN2 ..

TZ3         SPACE  LIKE RZ3  F-M 30  Z 195 ..
           E-W  LIKE CU1 ..  WI LIKE W1 ..
           I-W  LIKE IN3 ..  I-W LIKE IN3 ..
           I-W  LIKE FL1 ..  I-W LIKE CL3 ..

TZ4         SPACE  LIKE RZ4  F-M 30  Z 195 ..
           E-W  LIKE CU1 ..  WI LIKE W1 ..
           I-W  LIKE IN3 ..  I-W LIKE IN3 ..
           I-W  LIKE FL1 ..  I-W LIKE CL3 ..

TZ5         SPACE  LIKE RZ5  F-M 30  Z 195 ..
           E-W  LIKE CU1 ..  WI LIKE W1 ..
           I-W  LIKE IN3 ..  I-W LIKE IN3 ..
           I-W  LIKE FL1 ..  I-W LIKE CL3 ..

PLEN2        SPACE  LIKE PLEN1  F-M 30  Z 204 ..
           E-W  LIKE EW3 ..
           E-W  LIKE EW2 ..
           E-W  LIKE EW5 ..
           E-W  LIKE EW4 ..
           I-W  A 20000  CONS FLOOR-ABOVE  I-W-TYPE ADIABATIC  TILT 0 ..

END ..
COMPUTE LOADS ..
INPUT SYSTEMS ..

     TITLE   LINE-2 *RUN 2 VARIABLE AIR VOLUME SYSTEM *
          LINE-4 *ELECTRIC THERMOSTATIC BASEBOARDS *
          LINE-5 *WARM-UP CYCLE USES GAS HEAT* ..

          $ HVAC SYSTEM DESCRIPTION

$ DESIGN TEMPS  COOLING 78F  HEATING 70F.
$ SYSTEM TYPE   A SINGLE VARIABLE AIR VOLUME SYSTEM SERVES THE ENTIRE BUILDING.
$        THE SYSTEM HAS A DRY BULB CONTROLLED ECONOMIZER WITH A LIMIT
$        TEMP OF 68F. THE FAN HAS INLET VANES.
$        THE VAV BOXES HAVE A MINIMUM STOP OF 25%.
$        ELECTRIC BASEBOARDS IN ALL PERIMETER SPACES ARE
$        SUFFICIENTLY LARGE TO HEAT THE SPACE BUT NOT PICK UP THE HEATING
$        LOAD ON A COLD WINTER MORNING; THEREFORE, A GAS WARM-UP CYCLE IS
$        IS PROVIDED WHICH MINIMIZES THE USE OF THE ELECTRIC BASEBOARDS
$        AND REDUCES THE ELECTRIC DEMAND CHARGES.  IT IS VERY DIFFICULT
$        TO SIMULATE THE DYNAMICS OF THIS CONTROL STRATEGY CORRECTLY AS
$        ON SOME MORNINGS SPACES ARE UNDERHEATED, AND ON OTHERS THEY ARE
```

```
$        OVERHEATED. THE OPERATOR OF THE BUILDING WOULD IN FACT NEED TO
$        TUNE THE SUPPLY AIR TEMPERATURE SETPOINT TO ELIMINATE THE
$        PROBLEM.

$        THE SUPPLY AIR TEMPERATURE IS SET AT 100F FOR ONE HOUR ON WINTER
$        MORNINGS AND THE CONTROL OF THE VAV BOXES OPENS THE BOXES
$        FULL FOR THOSE HOURS. THE SUPPLY AIR TEMPERATURE IS 60F AT ALL
$        OTHER TIMES. MINIMUM VENTILATION AIR IS 20 CFM/PERSON AND THE
$        FAN OPERATES FROM 7AM TO 6PM WEEKDAYS AND IS OFF ON WEEKENDS AND
$        HOLIDAYS. THERE IS A NIGHT LOW LIMIT SETTING FOR PERIMETER
$        THERMOSTATS TO HOLD SPACE AT 55F. THE FANS DO NOT RUN AT NIGHT
$        BUT CAN CYCLE ON AS EARLY 12 PM TO HOLD SETBACK. THE MINIMUM OA
$        DAMPERS ARE HELD CLOSED DURING MORNING STARTUP YEAR ROUND,
$        HOWEVER THE ECONOMIZER DAMPERS ARE ACTIVATED IF NEEDED.

    ABORT          ERRORS ..
    DIAGNOSTIC       WARNINGS ..
    SYSTEMS-REPORT    SUMMARY=(SS-A,SS-D,SS-J) ..

    $ SCHEDULES

 HRS1      = DAY-SCHEDULE (1,7) (0) (8,18) (1) (19,24) (0) ..
 HRS2      = DAY-SCHEDULE (1,24) (0) ..
 DAYS1      = WEEK-SCHEDULE (MON,FRI) HRS1 (WEH) HRS2 ..
 AHU-SCHED  = SCHEDULE THRU DEC 31 DAYS1 ..       $ FANS $

 HRSH1      = DAY-SCHEDULE (1,8) (55) (9,18) (70) (19,24) (55) ..
 HRSH2      = DAY-SCHEDULE (1,24) (55) ..
 DAYHEAT    = WEEK-SCHEDULE (MON,FRI) HRSH1 (WEH) HRSH2 ..
 THEAT      = SCHEDULE THRU DEC 31 DAYHEAT ..   $ HEATING $

 HRSC1      = DAY-SCHEDULE (1,7) (99) (8,18) (78) (19,24) (99) ..
 HRSC2      = DAY-SCHEDULE (1,24) (99) ..
 DAYCOOL    = WEEK-SCHEDULE (MON,FRI) HRSC1 (WEH) HRSC2 ..
 TCOOL      = SCHEDULE THRU DEC 31 DAYCOOL ..   $ COOLING $

COOLON      = SCHEDULE THRU DEC 31 (ALL) (1,24) (55) ..
HEATON      = SCHEDULE THRU DEC 31 (ALL) (1,24) (60) ..

REV-STAT-ACT = SCHEDULE THRU MAR 15 (ALL) (1,8)(1) (9,24)(-999)
               THRU DEC 15 (ALL) (1,24) (-999)
               THRU DEC 31 (ALL) (1,8)(1) (9,24)(-999) ..

SA1 = DAY-SCHEDULE (1,8)(110) (9,18)(60) (19,24)(110) ..
SA2 = DAY-SCHEDULE (1,8)(90) (9,18)(60) (19,24)(90) ..
SAT-SETPT = SCHEDULE THRU MAR 15 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(110)
            THRU MAY 15 (WD) SA2 (WEH) (1,24)(90)
            THRU SEP 15 (ALL) (1,24)(55)
            THRU OCT 15 (WD) SA2 (WEH) (1,24)(90)
            THRU DEC 31 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(110) ..

OA-DAMPER-POS = SCHEDULE THRU DEC 31 (ALL)(1,8)(.01)(9,18)(-999)(19,24)(.01) ..

    $ ZONE SUB-COMMANDS

 ZAIR      = ZONE-AIR    OA-CFM/PER=20 ..

 CONTROL    = ZONE-CONTROL DESIGN-HEAT-T=70 DESIGN-COOL-T=74
              HEAT-TEMP-SCH=THEAT COOL-TEMP-SCH=TCOOL
              BASEBOARD-CTRL=THERMOSTATIC
              THERMOSTAT-TYPE=REVERSE-ACTION ..

    $ ZONE DESCRIPTION

 RZ1    = ZONE          ZONE-AIR=ZAIR ZONE-CONTROL=CONTROL
              MIN-CFM-SCH=REV-STAT-ACT CFM/SQFT=1
              BASEBOARD-RATING=-55000 ..
 RZ2    = ZONE LIKE RZ1 BASEBOARD-RATING=-140000 ..
 RZ3    = ZONE LIKE RZ2 B-R=-69000 ..
 RZ4    = ZONE LIKE RZ2 ..
 RZ5    = ZONE LIKE RZ3 ..
 TZ1    = ZONE LIKE RZ1 ..
 TZ2    = ZONE LIKE RZ2 B-R=-120000 ..
 TZ3    = ZONE LIKE TZ2 B-R=-60000 ..
 TZ4    = ZONE LIKE TZ2 ..
```

```
TZ5    = ZONE  LIKE TZ3 ..
PLEN1  = ZONE  ZONE-TYPE=PLENUM S-O ADJUST-LOADS D-H-T 50 D-C-T 90 ..
PLEN2  = ZONE  ZONE-TYPE=PLENUM ..
A-STORAGE= ZONE  LIKE RZ1    AIR-CHANGES/HR=4  OA-CHANGES=0.5  ..

      $ SYSTEM SUB-COMMANDS

 S-CTRL  = SYSTEM-CONTROL    COOLING-SCHEDULE=COOLON
                 HEATING-SCHEDULE=HEATON COOL-CONTROL = SCHEDULED
                 HEAT-SET-T=100  COOL-SET-SCH=SAT-SETPT
                 MIN-SUPPLY-T=55  MAX-SUPPLY-T=100
                 MIN-HUMIDITY=25  ..

 S-FAN  = SYSTEM-FANS      FAN-SCHEDULE=AHU-SCHED  FAN-CONTROL=INLET
                 SUPPLY-STATIC=5.5  SUPPLY-EFF=0.55
                 RETURN-STATIC=2.0  RETURN-EFF=0.53 ..

 S-TERM  = SYSTEM-TERMINAL    REHEAT-DELTA-T=20  MIN-CFM-RATIO=0.25 ..

      $ SYSTEM DESCRIPTION

 BLDG   = SYSTEM          SYSTEM-TYPE=VAVS  SYSTEM-CONTROL=S-CTRL
                 SYSTEM-FANS=S-FAN  MIN-AIR-SCH=OA-DAMPER-POS
                 SYSTEM-TERMINAL=S-TERM
                 RETURN-AIR-PATH=PLENUM-ZONES
                 PLENUM-NAMES=(PLEN1,PLEN2)
                 BASEBOARD-SOURCE=ELECTRIC  PREHEAT=HOT-WATER
                 HEAT-SOURCE=HOT-WATER  HUMIDIFIER-TYPE=HOT-WATER
                 ECONO-LIMIT-T=68  ZONE-NAMES=(RZ1,RZ2,RZ3,RZ4,
                  RZ5,TZ1,TZ2,TZ3,TZ4,TZ5,PLEN1,PLEN2)  ..

BASMT-SYS = SYSTEM          SYSTEM-TYPE=SZRH  MAX-SUPPLY-T=105
                 MIN-SUPPLY-T=55   SUPPLY-STATIC=2.5
                 SUPPLY-EFF=.5    FAN-SCHEDULE=AHU-SCHED
                 HEATING-SCHEDULE=HEATON  HEAT-SOURCE=ELECTRIC
                 COOLING-SCHEDULE=COOLON
                 ZONE-NAMES=(A-STORAGE)  ..

PLANT1  = PLANT-ASSIGNMENT  SYSTEM-NAMES = (BLDG,BASMT-SYS)
                INT-ELEC-KW = 100  $ FOR ELEVATORS
                INT-ELEC-SCH = OCCUP
                DHW-SIZE=0
                DHW-GAL/MIN  = 2.22
                DHW-SCH     = OCCUP  ..

OC1        =DAY-SCHEDULE      (1,8) (0.)       (9,10) (1.)
                    (11,13) (.8,.4,.8)  (14,24) (1.,1.,1.,
                              .3,.1,.1,.1,0.,0.,0.,0.)  ..
OC2        =DAY-SCHEDULE      (1,24) (0.0)  ..
PEOPLE       =WEEK-SCHEDULE      (MON,FRI)  OC1     (WEH)  OC2  ..
OCCUP        =SCHEDULE          THRU DEC 31  PEOPLE    ..
END  ..
COMPUTE SYSTEMS   ..

INPUT PLANT  ..
PLANT1 = PLANT-ASSIGNMENT  ..

       PLANT-REPORT       SUMMARY=(PS-A,BEPS) ..

       $ EQUIPMENT DESCRIPTION

$ THE PLANT USES CHILLED WATER STORAGE. THE CHILLER CHARGES
$ THE TANKS AT NIGHT. STORED CHILLED WATER IS RELEASED FROM 12NOON TO 5PM,
$ WHICH IS THE ON-PEAK PERIOD OF THE TIME-OF-DAY RATE SCHEDULE.
$ THE CHILLER PROVIDES OFF-PEAK COOLING AND SUPPLEMENTS THE TANK
$ DURING THE ON-PEAK PERIOD IF NECESSARY.
$ DAYTIME HEATING IS DONE WITH ELECTRIC BASEBOARDS,
$ BUT FOR NIGHTTIME HEATING AND FOR EARLY MORNING
$ START-UP A GAS HOT WATER GENERATOR IS USED.

CMPC    =PLANT-EQUIPMENT    TYPE=HERM-CENT-CHLR  SIZE=13.5  I-N=2  ..

DHWH    =PLANT-EQUIPMENT    TYPE=ELEC-DHW-HEATER  SIZE -999  ..

HWG     =PLANT-EQUIPMENT    TYPE=HW-BOILER  SIZE=-999  ..
```

```
CTWR    =PLANT-EQUIPMENT    TYPE=COOLING-TWR  SIZE=-999  ..

CTANK   =PLANT-EQUIPMENT    TYPE=CTANK-STORAGE  SIZE=50  I-N=1  ..


ENERGY-STORAGE  COOL-STORE-RATE=13.5  COOL-SUPPLY-RATE=13.5
          COOL-STORE-SCH=TANK-CHG  CTANK-LOSS-COEF=50
          CTANK-BASE-T=54  CTANK-T-RANGE=10  CTANK-ENV-T=53  ..

TANK-CHG=SCHEDULE THRU MAY 1 (ALL) (1,24) (0)
           THRU OCT 1 (ALL) (1,7) (1) (8,24) (0)
           THRU DEC 31 (ALL) (1,24) (0)  ..

TANK-CHARGE =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=13.5
                  PLANT-EQUIPMENT=CMPC   N=1  ..

RELEASE-CHG =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                  PLANT-EQUIPMENT=CTANK  N=1
                  PLANT-EQUIPMENT=CMPC   N=1  ..

OFF-PEAK-CLG=LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                  PLANT-EQUIPMENT =CMPC  N=2  ..

CHW-CTRL =DAY-ASSIGN-SCH (1,7) (TANK-CHARGE)  (8,12) (OFF-PEAK-CLG)
               (13,17) (RELEASE-CHG) (18,24) (OFF-PEAK-CLG)  ..
WEH-CTRL =DAY-ASSIGN-SCH (1,24) (OFF-PEAK-CLG)  ..

CHILLER-CTRL=SCHEDULE THRU DEC 31 (WD) CHW-CTRL (WEH) WEH-CTRL  ..

LOAD-MANAGEMENT  PRED-LOAD-RANGE=999
          ASSIGN-SCHEDULE=(DEFAULT,CHILLER-CTRL,DEFAULT)  ..

END  ..
COMPUTE PLANT  ..
INPUT ECONOMICS ..
ECONOMICS-REPORT  S (ES-D,ES-E,ES-F)  ..

              $ ENERGY COST DESCRIPTION

$ THE INPUT FOR UTILITY RATES IS THE SIMPLEST POSSIBLE, USING UNIFORM RATES
$ FOR BOTH GAS AND ELECTRICITY.  THERE IS A FIXED MONTHLY CHARGE AND A RATE
$ LIMITATION ON ELECTRICITY OF 7 CENTS/KWH.  THE DEMAND CHARGE IS A NOMINAL
$ FLAT RATE OF 5 DOLLARS/KW YEAR-AROUND.

ELEC-RATE = UTILITY-RATE  RESOURCE=ELECTRICITY
                MONTH-CHGS = (2000)
                ENERGY-CHG = .055
                DEMAND-CHGS = (5)
                RATE-LIMITATION = .07  ..

GAS-RATE  = UTILITY-RATE  RESOURCE=NATURAL-GAS
                ENERGY-CHG =.70  ..  $ DOLLARS/THERM
END  ..
COMPUTE ECONOMICS  ..
STOP ..
```

Doe2 Samp2 Input file: Modified

```
INPUT LOADS ..
TITLE      LINE-1 *31-STORY OFFICE BLDG, HOUSTON - LOAD2 *
        LINE-2 * CUSTOM WEIGHTING FACTORS & DAYLIGHTING *
        LINE-3 * * ..

        ABORT      ERRORS ..
        DIAGNOSTIC   WARNINGS ..

        LOADS-REPORT SUMMARY=(LS-D,) ..
        RUN-PERIOD       JAN 1 1998 THRU  DEC 31 1998 ..

        BUILDING-LOCATION  LATITUDE=29.65  LONGITUDE=95.28
                  TIME-ZONE=6  ALTITUDE=46 ..

          $ BUILDING DESCRIPTION

$         THIS EXAMPLE HAS THREE SPECIAL FEATURES:

$        1 IT USES CUSTOM WEIGHTING FACTORS FOR THE EXTERIOR ZONES,
$          WHICH GIVES A BETTER SIMULATION
$          OF BUILDING MASS AND HVAC SYSTEM PERFORMANCE.
$          THE INTERIOR ZONES ARE INPUT
$          USING STANDARD ASHRAE WEIGHTING FACTORS WITH
$          A FLOOR WEIGHT OF 150LB/SQFT TO REPRESENT THE MASS OF ELEVATOR
$          SHAFT WALLS, WHICH ARE ASSUMED TO BE HEAVY REINFORCED
$          CONSTRUCTION FOR WIND BRACING.
$
$        2 IT DEMONSTRATES DAYLIGHTING AND ASSOCIATED ELECTRIC LIGHTING
$          CONTROLS. EACH 25 FT WIDE BAY ON
$          ALL FOUR EXPOSURES IS TREATED AS A SEPARATE ZONE.
$          THERE ARE 8 BAYS PER FLOOR ON THE EAST AND WEST EXPOSURES
$          AND 4 BAYS PER FLOOR ON THE NORTH AND SOUTH.
$
$        3 IT DEMONSTRATES HOW DOE-2 INPUT CAN BE SHORTENED BY
$          OMITTING U-NAMES FOR EVERY WALL AND FLOOR SURFACE.  THIS
$          MAKES THE VERIFICATION REPORTS LESS READABLE AS MOST SURFACES
$          ARE NOT IDENTIFIED.
$          IN ADDITION, AS ANOTHER WAY OF SHORTENING THE INPUT,
$          ABBREVIATIONS ARE USED EXTENSIVELY,
$          BUT THE FIRST INPUT ENTRY IS WRITTEN USING THE FULL KEYWORD
$          FOR CLARIFICATION.  EQUAL SIGNS ARE ALSO OMITTED IN MOST
$          CASES.

$    NOTE THAT THE FOLLOWING DESCRIPTION IS IDENTICAL TO
$    "31-STORY OFFICE BLDG - LOAD1" EXCEPT THAT:
$    (1) CEILING PLENUMS HAVE BEEN ADDED;
$    (2) DAYLIGHTING IS SPECIFIED; AND
$    (3) FOR THE DAYLIGHTING CALCULATION, THE PERIMETER ZONES HAVE BEEN
$       DIVIDED INTO INDIVIDUAL ROOMS, SO THAT RZ2, RZ4, TZ2, AND TZ4
$       NOW HAVE MULTIPLIER=8 AND RZ3,RZ5,TZ3, AND TZ5 HAVE MULTIPLIER=4
$       (AS BEFORE, THE TZ ZONES ALSO HAVE FLOOR-MULTIPLIER=30, SO THAT
$       THERE ARE 8X30=240 TZ2 AND TZ4 ZONES AND 4X30=120 TZ3 AND TZ5
$       ZONES).

$ STRUCTURE   STEEL FRAME WITH 4" CONCRETE FLOORS AND ROOF.  31 OCCUPIED
$         STORIES, 13FT FLOOR TO FLOOR HEIGHT, 9FT CEILINGS.  RETURN
$         AIR CEILING PLENUMS ARE DEFINED; ONE FOR THE TOP FLOOR AND ONE
$         FOR THE TYPICAL FLOORS.

$ CURTAIN WALL USING CODE-WORDS FROM DOE-2 LIBRARY (REFERENCE MANUAL, PART 2)
$         AND STARTING WITH OUTSIDE WORKING INWARD: 1/4IN SPANDREL GLASS
$         (NOT IN LIBRARY - SEE MATERIAL SPGL); 2IN POLYSTRENE INSUL
$         R-8 (IN35); STEEL BACKPANEL (AS01); 2IN AIRSPACE (AL21);
$         3/4IN GYPSUM BOARD FINISH (GP03) .

$ ROOF       ROOF GRAVEL (RG02); BUILT-UP ROOFING (BR01); 3IN ROOF INSUL R-8
$         (IN76); 4IN CONCRETE (CC03); INSIDE-FILM-RESISTANCE .76 .

$ WINDOWS     DOUBLE-GLAZED TINTED, SOLAR TRANSMITTANCE=.53, GLASS TYPE CODE=5.
```

```
$        WINDOWS HAVE INSIDE BLINDS THAT ARE PULLED WHENEVER TRANSMITTED
$        DIRECT SOLAR RADIATION EXCEEDS 40 BTUH PER SQFT AND IF THE WINDOW
$        GLARE INDEX EXCEEDS A VALUE OF 22.  THE BLINDS ARE CONSIDERED
$        TO BE REOPENED WITH A PROBABILITY OF .4 WHEN SOLAR EFFECT IS LESS
$        THAN 40 BTUH.

$ INTERIORS   CEILINGS ARE SUSPENDED ACCOUSTIC TILE.
$        PARTITIONS SIMULATE CONVECTIVE HEAT TRANSFER BETWEEN CORE AND
$        PERIMETER SPACES USING A U-VALUE OF 1.5.

$ SPACE LOADS  LIGHTING RECESSED FLUORSCENT AT 1.5 WATTS/SQFT.
$        OFFICE EQUIPMENT 1 WATTS/SQFT.
$        PEOPLE  100SQFT/PERSON FOR PERIMETER SPACES
$             200SQFT/PERSON FOR CORE AREAS.
$        INFILTRATION .3 AIR CHANGES/HR FOR PERIMETER AREAS WHEN FANS
$        ARE OFF -.06 AIR CHANGES/HR WHEN FANS ARE ON.

$ HVAC DESCRIPTIONS ARE TO BE FOUND WITH EACH INDIVIDUAL SYSTEM AND PLANT INPUT.

            $ MATERIALS NOT IN DOE-2 LIBRARY

SPGS=MATERIAL    TH=.0208  COND=.590  DENS=172.  S-H=.20  ..

            $ WALL CONSTRUCTIONS

ROOFER      =LAYERS  MAT (RG02,BR01,IN76,CC03)  I-F-R .76  ..
WALLER      =LAYERS  MAT (SPGS,IN35,AS01,AL21,GP03)  ..
FLR-UP      =LAYERS  MAT (CP01,CC03)  ..
FLR-DN      =LAYERS  MAT (CC03,CP01)  ..
PARTITION   =LAYERS  MAT (GP01,AL21,GP01)  ..

RF          =CONSTRUCTION     LAYERS=ROOFER  ..
WL1         =CONSTRUCTION     LAYERS=WALLER  ..
CEIL        =CONS  U=.20  ..
FLOOR-ABOVE  =CONS  LAYERS=FLR-UP  ..
FLOOR       =CONS  LAYERS=FLR-DN  ..
PA2         =CONS  LAYERS =PARTITION  ..
BW          =CONSTRUCTION     U=.05  ..
SB-U        =CONSTRUCTION     U=1.5  ..

            $ GLASS DESCRIPTION

GT1         =GLASS-TYPE  GLASS-TYPE-CODE=5  PANES=2  VIS-TRANS=.35  ..

            $ SCHEDULES

OC1         =DAY-SCHEDULE      (1,24) (.05,.05,.05,.05,.05,.05,
                 .19,.31,.69,.94,1,1,1,.94,1,.94,.94,
                 .75,.38,.13,.05,.05,.05,.05) ..

OC2         =DAY-SCHEDULE      (1,24) (0.01,.01,.01,.01,.01,.01,
                 .02,.03,.07,.09,.1,.1,.1,.09,.1,.09,
                 .09,.08,.04,.01,.01,.01,.01,.01)  ..

OCCUP       =SCHEDULE          THRU DEC 31  (WD) OC1  (WEH) OC2  ..

L1          =DAY-SCHEDULE      (1,24) (.17,.17,.17,.17,.17,.21,.3,
                 .44,.84,.97,1,1,1,.97,1,.97,.97,
                 .88,.46,.28,.2,.17,.14,.13)  ..

L2          =DAY-SCHEDULE      (1,24) (.15,.15,.15,.15,.15,.16,
                 .18,.2,.25,.29,.3,.3,.3,.29,.3,.29,
                 .29,.26,.21,.17,.15,.15,.15,.15) ..

LIGHTS      SCHEDULE           THRU DEC 31 (WD) L1  (WEH) L2  ..

ES1         =DAY-SCHEDULE      (1,24) (.5,.5,.5,.5,.5,.53,.59,.66,
                 .84,.97,1,1,1,.97,1,.97,.97,
                 .88,.69,.56,.5,.5,.5,.5)  ..

ES2         =DAY-SCHEDULE      (1,24) (.5,.5,.5,.5,.5,.51,.52,.53,
                 .57,.59,.6,.6,.6,.59,.6,.59,.59,
                 .58,.54,.51,.5,.5,.5,.5)  ..

EQUIP       =SCHEDULE          THRU DEC 31 (WD) ES1  (WEH) ES2  ..
```

```
I1       =DAY-SCHEDULE      (1,7) (1.)       (8,18) (0.2)
                   (19,24) (1.)   ..
I2       =DAY-SCHEDULE      (1,24) (1.)  ..
INFIL      =SCHEDULE        THRU DEC 31  (WD)  I1  (WEH)  I2  ..


           $ SPACE DESCRIPTIONS

OFFICE      =SPACE-CONDITIONS    TEMPERATURE=(75)  FLOOR-WEIGHT=0  $ FOR CWF
                  LIGHTING-W/SQFT=2.5  EQUIPMENT-W/SQFT=1
                  PEOPLE-HEAT-GAIN=450
                  EQUIP-SCHEDULE=EQUIP  L-SCH=LIGHTS
                  PEOPLE-SCHEDULE=OCCUP  AIR-CHANGES/HR=.25
                  INF-SCHEDULE=INFIL  LIGHT-TO-SPACE=.80
                  INF-METHOD=AIR-CHANGE
                  LIGHTING-TYPE=REC-FLUOR-RV   ..

A-STORAGE    =SPACE          TEMPERATURE=(73.5)  FLOOR-WEIGHT=150
                  VOLUME=400000  AREA=20000
                  LIGHTING-W/SQFT=1.5
                  LIGHTING-SCHEDULE=LIGHTS   ..
          UNDERGROUND-WALL   AREA=12000  CONSTRUCTION=BW  ..
          UNDERGROUND-FLOOR  AREA=20000  CONSTRUCTION=BW  ..

          SET-DEFAULT FOR  EXTERIOR-WALL   HEIGHT=9.  AZIMUTH=180  ..
          SET-DEFAULT FOR  WINDOW   HEIGHT=6.5  GLASS-TYPE=GT1  ..

RZ1         SPACE   SPACE-CONDITIONS OFFICE  VOLUME 107100  AREA 11900
              X 15  Y 15  Z 390  N-O-P 60  AIR-CHANGES/HR 0.25
              F-W 150  ..
        IN1  I-W   AREA 191  CONS SB-U  NEXT-TO RZ2  ..
        IN2  I-W   AREA 158  CONS SB-U  N-T RZ3  ..
           I-W   LIKE IN1  N-T RZ4  ..
           I-W   LIKE IN2  N-T RZ5  ..
        CL1  I-W   AREA 11900  CONS CEIL  TILT 0  NEXT-TO PLEN1  ..

RZ2         SPACE   S-C OFFICE  A 346.8  V 3114  N-O-P 4  M 8
              AZ -90  X 100  Y 87.5  Z 390 ..

        CU1  E-W   H 9  W 25  CONS WL1  .. $ EAST-FACING

$ FOR CU1, NOTE THAT THE SUM OF BUILDING AZIMUTH (0) + SPACE AZIMUTH (-90)
$ + WALL AZIMUTH (180, FROM SET-DEFAULT) = 90, SO THIS WALL FACES EAST

         W1   WI   W 25  Y 2.5  ..
        IN3  I-W   A 125  CONS PA2  I-W-TYPE ADIABATIC  ..
        IN4  I-W   LIKE IN3  ..
        FL1  I-W   A 347  CONS FLOOR  TILT 180  I-W-TYPE ADIABATIC  ..
        CL2  I-W   A 347  CONS CEIL   TILT 0  NEXT-TO PLEN1  ..

RZ3         SPACE   LIKE RZ2  A 319  V 2869  AZ 180  X 62.5  Y 200  M 4  ..
           E-W   LIKE CU1  ..  WI LIKE W1  .. $ NORTH-FACING
           I-W   LIKE IN3  ..  I-W LIKE IN3  ..
           I-W   LIKE FL1  ..  I-W LIKE CL2  ..

RZ4         SPACE   LIKE RZ2  AZ 90  X 0  Y 112.5  M 8  ..
           E-W   LIKE CU1  ..  WI LIKE W1  .. $ WEST-FACING
           I-W   LIKE IN3  ..  I-W LIKE IN3  ..
           I-W   LIKE FL1  ..  I-W LIKE CL2  ..

RZ5         SPACE   LIKE RZ3  AZ 0  X 37.5  Y 0  M 4  ..
           E-W   LIKE CU1  ..  WI LIKE W1  .. $ SOUTH-FACING
           I-W   LIKE IN3  ..  I-W LIKE IN3  ..
           I-W   LIKE FL1  ..  I-W LIKE CL2  ..

PLEN1         SPACE   ZONE-TYPE PLENUM T=(75) A 20000   V 60000  F-W 0
               Z 399  ..
        EW3  E-W   H 4  W 100  AZ 0  X 100  Y 200  CONS WL1  ..
        EW2  E-W   LIKE EW3  W 200  AZ 90  X 100  Y 0  ..
        EW5  E-W   LIKE EW3  AZ 180  X 0  Y 0  ..
        EW4  E-W   LIKE EW2  AZ 270  X 0  Y 200  ..
           ROOF   H 200  W 100  AZ 180  TILT 0  CONS RF  G-R 0  ..

TZ1         SPACE   LIKE RZ1  FLOOR-MULTIPLIER 30  Z 195  ..
```

```
            I-W   LIKE IN1  N-T TZ2  ..
            I-W   LIKE IN2  N-T TZ3  ..
            I-W   LIKE IN1  N-T TZ4  ..
            I-W   LIKE IN2  N-T TZ5  ..
            I-W   LIKE CL1  N-T PLEN2  ..

TZ2          SPACE   LIKE RZ2  F-M 30  Z 195  ..
            E-W   LIKE CU1  ..  WI LIKE W1  ..
            I-W   LIKE IN3  ..  I-W LIKE IN3  ..
            I-W   LIKE FL1  ..
         CL3 I-W   LIKE CL2  NEXT-TO PLEN2  ..

TZ3          SPACE   LIKE RZ3  F-M 30  Z 195  ..
            E-W   LIKE CU1  ..  WI LIKE W1  ..
            I-W   LIKE IN3  ..  I-W LIKE IN3  ..
            I-W   LIKE FL1  ..  I-W LIKE CL3  ..

TZ4          SPACE   LIKE RZ4  F-M 30  Z 195  ..
            E-W   LIKE CU1  ..  WI LIKE W1  ..
            I-W   LIKE IN3  ..  I-W LIKE IN3  ..
            I-W   LIKE FL1  ..  I-W LIKE CL3  ..

TZ5          SPACE   LIKE RZ5  F-M 30  Z 195  ..
            E-W   LIKE CU1  ..  WI LIKE W1  ..
            I-W   LIKE IN3  ..  I-W LIKE IN3  ..
            I-W   LIKE FL1  ..  I-W LIKE CL3  ..

PLEN2          SPACE   LIKE PLEN1  F-M 30  Z 204  ..
            E-W   LIKE EW3  ..
            E-W   LIKE EW2  ..
            E-W   LIKE EW5  ..
            E-W   LIKE EW4  ..
            I-W   A 20000  CONS FLOOR-ABOVE  I-W-TYPE ADIABATIC  TILT 0 ..

END ..
COMPUTE LOADS  ..
INPUT SYSTEMS  ..

       TITLE    LINE-2 *RUN 2 VARIABLE AIR VOLUME SYSTEM *
              LINE-4 *ELECTRIC THERMOSTATIC BASEBOARDS *
              LINE-5 *WARM-UP CYCLE USES GAS HEAT*  ..

              $ HVAC SYSTEM DESCRIPTION

$ DESIGN TEMPS  COOLING 75F  HEATING 72F.
$ SYSTEM TYPE   A SINGLE VARIABLE AIR VOLUME SYSTEM SERVES THE ENTIRE BUILDING.
$          THE SYSTEM HAS A DRY BULB CONTROLLED ECONOMIZER WITH A LIMIT
$          TEMP OF 68F. THE FAN HAS INLET VANES.
$          THE VAV BOXES HAVE A MINIMUM STOP OF 25%.
$          ELECTRIC BASEBOARDS IN ALL PERIMETER SPACES ARE
$          SUFFICIENTLY LARGE TO HEAT THE SPACE BUT NOT PICK UP THE HEATING
$          LOAD ON A COLD WINTER MORNING; THEREFORE, A GAS WARM-UP CYCLE IS
$          IS PROVIDED WHICH MINIMIZES THE USE OF THE ELECTRIC BASEBOARDS
$          AND REDUCES THE ELECTRIC DEMAND CHARGES.  IT IS VERY DIFFICULT
$          TO SIMULATE THE DYNAMICS OF THIS CONTROL STRATEGY CORRECTLY AS
$          ON SOME MORNINGS SPACES ARE UNDERHEATED, AND ON OTHERS THEY ARE
$          OVERHEATED.  THE OPERATOR OF THE BUILDING WOULD IN FACT NEED TO
$          TUNE THE SUPPLY AIR TEMPERATURE SETPOINT TO ELIMINATE THE
$          PROBLEM.

$          THE SUPPLY AIR TEMPERATURE IS SET AT 100F FOR ONE HOUR ON WINTER
$          MORNINGS AND THE CONTROL OF THE VAV BOXES OPENS THE BOXES
$          FULL FOR THOSE HOURS. THE SUPPLY AIR TEMPERATURE IS 60F AT ALL
$          OTHER TIMES. MINIMUM VENTILATION AIR IS 20 CFM/PERSON AND THE
$          FAN OPERATES FROM 7AM TO 6PM WEEKDAYS AND IS OFF ON WEEKENDS AND
$          HOLIDAYS.  THERE IS A NIGHT LOW LIMIT SETTING FOR PERIMETER
$          THERMOSTATS TO HOLD SPACE AT 55F.  THE FANS DO NOT RUN AT NIGHT
$          BUT CAN CYCLE ON AS EARLY 12 PM TO HOLD SETBACK.  THE MINIMUM OA
$          DAMPERS ARE HELD CLOSED DURING MORNING STARTUP YEAR ROUND,
$          HOWEVER THE ECONOMIZER DAMPERS ARE ACTIVATED IF NEEDED.

       ABORT            ERRORS ..
       DIAGNOSTIC        WARNINGS  ..
       SYSTEMS-REPORT     SUMMARY=(SS-A) ..
```

```
$ SCHEDULES

HRS1      = DAY-SCHEDULE (1,7) (1) (8,18) (1) (19,24) (1) ..
HRS2      = DAY-SCHEDULE (1,24) (1) ..
DAYS1     = WEEK-SCHEDULE (MON,FRI) HRS1 (WEH) HRS2 ..
AHU-SCHED = SCHEDULE THRU DEC 31 DAYS1 ..     $ FANS $

HRSH1     = DAY-SCHEDULE (1,8) (72) (9,18) (72) (19,24) (72) ..
HRSH2     = DAY-SCHEDULE (1,24) (72) ..
DAYHEAT   = WEEK-SCHEDULE (MON,FRI) HRSH1 (WEH) HRSH2 ..
THEAT     = SCHEDULE THRU DEC 31 DAYHEAT ..   $ HEATING $

HRSC1     = DAY-SCHEDULE (1,7) (75) (8,18) (75) (19,24) (75) ..
HRSC2     = DAY-SCHEDULE (1,24) (75) ..
DAYCOOL   = WEEK-SCHEDULE (MON,FRI) HRSC1 (WEH) HRSC2 ..
TCOOL     = SCHEDULE THRU DEC 31 DAYCOOL ..   $ COOLING $

COOLON    = SCHEDULE THRU DEC 31 (ALL) (1,24) (55) ..
HEATON    = SCHEDULE THRU DEC 31 (ALL) (1,24) (60) ..

REV-STAT-ACT = SCHEDULE THRU MAR 15 (ALL) (1,8)(1) (9,24)(-999)
               THRU DEC 15 (ALL) (1,24) (-999)
               THRU DEC 31 (ALL) (1,8)(1) (9,24)(-999) ..

SA1 = DAY-SCHEDULE (1,8)(55) (9,18)(55) (19,24)(55) ..
SA2 = DAY-SCHEDULE (1,8)(55) (9,18)(55) (19,24)(55) ..
SAT-SETPT = SCHEDULE THRU MAR 15 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(55)
            THRU MAY 15 (WD) SA2 (WEH) (1,24)(55)
            THRU SEP 15 (ALL) (1,24)(55)
            THRU OCT 15 (WD) SA2 (WEH) (1,24)(55)
            THRU DEC 31 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(55) ..

OA-DAMPER-POS = SCHEDULE THRU DEC 31 (ALL)(1,8)(.01)(9,18)(.01)(19,24)(.01) ..

$ ZONE SUB-COMMANDS

ZAIR      = ZONE-AIR   OA-CHANGES=0.25 ..

CONTROL   = ZONE-CONTROL DESIGN-HEAT-T=72 DESIGN-COOL-T=75
            HEAT-TEMP-SCH=THEAT COOL-TEMP-SCH=TCOOL
            BASEBOARD-CTRL=THERMOSTATIC
            THERMOSTAT-TYPE=REVERSE-ACTION ..

$ ZONE DESCRIPTION

RZ1   = ZONE        ZONE-AIR=ZAIR ZONE-CONTROL=CONTROL
            MIN-CFM-SCH=REV-STAT-ACT CFM/SQFT=1
            BASEBOARD-RATING=-55000 ..
RZ2   = ZONE LIKE RZ1 BASEBOARD-RATING=-140000 ..
RZ3   = ZONE LIKE RZ2 B-R=-69000 ..
RZ4   = ZONE LIKE RZ2 ..
RZ5   = ZONE LIKE RZ3 ..
TZ1   = ZONE LIKE RZ1 ..
TZ2   = ZONE LIKE RZ2 B-R=-120000 ..
TZ3   = ZONE LIKE TZ2 B-R=-60000 ..
TZ4   = ZONE LIKE TZ2 ..
TZ5   = ZONE LIKE TZ3 ..
PLEN1 = ZONE ZONE-TYPE=PLENUM S-O ADJUST-LOADS D-H-T 50 D-C-T 90 ..
PLEN2 = ZONE ZONE-TYPE=PLENUM ..
A-STORAGE= ZONE LIKE RZ1   AIR-CHANGES/HR=4 OA-CHANGES=0.5 ..

$ SYSTEM SUB-COMMANDS

S-CTRL = SYSTEM-CONTROL   COOLING-SCHEDULE=COOLON
         HEATING-SCHEDULE=HEATON COOL-CONTROL = SCHEDULED
         HEAT-SET-T=100 COOL-SET-SCH=SAT-SETPT
         MIN-SUPPLY-T=55 MAX-SUPPLY-T=100 ..

S-FAN  = SYSTEM-FANS      FAN-SCHEDULE=AHU-SCHED FAN-CONTROL=INLET
         SUPPLY-STATIC=5.5 SUPPLY-EFF=0.55
         RETURN-STATIC=2.0 RETURN-EFF=0.53 ..

S-TERM = SYSTEM-TERMINAL  REHEAT-DELTA-T=20 MIN-CFM-RATIO=0.25 ..

$ SYSTEM DESCRIPTION
```

```
BLDG   = SYSTEM          SYSTEM-TYPE=VAVS SYSTEM-CONTROL=S-CTRL
                 SYSTEM-FANS=S-FAN MIN-AIR-SCH=OA-DAMPER-POS
                 SYSTEM-TERMINAL=S-TERM
                 RETURN-AIR-PATH=PLENUM-ZONES
                 PLENUM-NAMES=(PLEN1,PLEN2)
                 BASEBOARD-SOURCE=ELECTRIC PREHEAT=HOT-WATER
                 HEAT-SOURCE=HOT-WATER HUMIDIFIER-TYPE=HOT-WATER
                 ECONO-LIMIT-T=68 ZONE-NAMES=(RZ1,RZ2,RZ3,RZ4,
                 RZ5,TZ1,TZ2,TZ3,TZ4,TZ5,PLEN1,PLEN2) ..

BASMT-SYS = SYSTEM          SYSTEM-TYPE=SZRH MAX-SUPPLY-T=105
                 MIN-SUPPLY-T=55  SUPPLY-STATIC=2.5
                 SUPPLY-EFF=.5    FAN-SCHEDULE=AHU-SCHED
                 HEATING-SCHEDULE=HEATON HEAT-SOURCE=ELECTRIC
                 COOLING-SCHEDULE=COOLON
                 ZONE-NAMES=(A-STORAGE) ..

PLANT1  = PLANT-ASSIGNMENT  SYSTEM-NAMES = (BLDG,BASMT-SYS)
                INT-ELEC-KW = 100  $ FOR ELEVATORS
                INT-ELEC-SCH = OCCUP
                DHW-SIZE=0
                DHW-GAL/MIN  = 2.22
                DHW-SCH      = OCCUP ..

OC1      =DAY-SCHEDULE      (1,24) (.05,.05,.05,.05,.05,.05,
                  .19,.31,.69,.94,1,1,1,.94,1,.94,.94,
                  .75,.38,.13,.05,.05,.05,.05) ..

OC2      =DAY-SCHEDULE      (1,24) (0.01,.01,.01,.01,.01,.01,
                  .02,.03,.07,.09,.1,.1,.1,.09,.1,.09,
                  .09,.08,.04,.01,.01,.01,.01,.01) ..

PEOPLE     =WEEK-SCHEDULE      (MON,FRI) OC1    (WEH) OC2 ..
OCCUP      =SCHEDULE           THRU DEC 31 PEOPLE ..
END ..
COMPUTE SYSTEMS ..
INPUT PLANT ..
PLANT1 = PLANT-ASSIGNMENT ..

    PLANT-REPORT     SUMMARY=(PS-A,BEPS) ..

    $ EQUIPMENT DESCRIPTION

$ THE PLANT USES CHILLED WATER STORAGE. THE CHILLER CHARGES
$ THE TANKS AT NIGHT. STORED CHILLED WATER IS RELEASED FROM 12NOON TO 5PM,
$ WHICH IS THE ON-PEAK PERIOD OF THE TIME-OF-DAY RATE SCHEDULE.
$ THE CHILLER PROVIDES OFF-PEAK COOLING AND SUPPLEMENTS THE TANK
$ DURING THE ON-PEAK PERIOD IF NECESSARY.
$ DAYTIME HEATING IS DONE WITH ELECTRIC BASEBOARDS,
$ BUT FOR NIGHTTIME HEATING AND FOR EARLY MORNING
$ START-UP A GAS HOT WATER GENERATOR IS USED.

CMPC   =PLANT-EQUIPMENT   TYPE=HERM-CENT-CHLR  SIZE=13.5  I-N=2 ..

DHWH   =PLANT-EQUIPMENT   TYPE=ELEC-DHW-HEATER  SIZE -999 ..

HWG    =PLANT-EQUIPMENT   TYPE=HW-BOILER  SIZE=-999 ..

CTWR   =PLANT-EQUIPMENT   TYPE=COOLING-TWR  SIZE=-999 ..

CTANK  =PLANT-EQUIPMENT   TYPE=CTANK-STORAGE  SIZE=50  I-N=1 ..


ENERGY-STORAGE  COOL-STORE-RATE=13.5  COOL-SUPPLY-RATE=13.5
        COOL-STORE-SCH=TANK-CHG  CTANK-LOSS-COEF=50
        CTANK-BASE-T=54  CTANK-T-RANGE=10  CTANK-ENV-T=53 ..

TANK-CHG=SCHEDULE THRU MAY 1 (ALL) (1,24) (0)
         THRU OCT 1 (ALL) (1,7) (1) (8,24) (0)
         THRU DEC 31 (ALL) (1,24) (0) ..

TANK-CHARGE =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=13.5
              PLANT-EQUIPMENT=CMPC   N=1 ..
```

```
RELEASE-CHG =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                    PLANT-EQUIPMENT=CTANK  N=1
                    PLANT-EQUIPMENT=CMPC   N=1  ..

OFF-PEAK-CLG=LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                    PLANT-EQUIPMENT =CMPC  N=2  ..

CHW-CTRL =DAY-ASSIGN-SCH (1,7) (TANK-CHARGE)  (8,12) (OFF-PEAK-CLG)
                 (13,17) (RELEASE-CHG) (18,24) (OFF-PEAK-CLG)  ..
WEH-CTRL =DAY-ASSIGN-SCH (1,24) (OFF-PEAK-CLG)  ..

CHILLER-CTRL=SCHEDULE THRU DEC 31 (WD) CHW-CTRL (WEH) WEH-CTRL  ..

LOAD-MANAGEMENT  PRED-LOAD-RANGE=999
           ASSIGN-SCHEDULE=(DEFAULT,CHILLER-CTRL,DEFAULT)  ..

END  ..
COMPUTE PLANT  ..
INPUT ECONOMICS ..
ECONOMICS-REPORT  S (ES-D,ES-E,ES-F)  ..

               $ ENERGY COST DESCRIPTION

$ THE INPUT FOR UTILITY RATES IS THE SIMPLEST POSSIBLE, USING UNIFORM RATES
$ FOR BOTH GAS AND ELECTRICITY.  THERE IS A FIXED MONTHLY CHARGE AND A RATE
$ LIMITATION ON ELECTRICITY OF 7 CENTS/KWH.  THE DEMAND CHARGE IS A NOMINAL
$ FLAT RATE OF 5 DOLLARS/KW YEAR-AROUND.

ELEC-RATE = UTILITY-RATE  RESOURCE=ELECTRICITY
                 ENERGY-CHG =  032412
                 DEMAND-CHGS = (15.57) ..

GAS-RATE  = UTILITY-RATE  RESOURCE=NATURAL-GAS
                 ENERGY-CHG =.4886  ..  $ DOLLARS/THERM
END  ..
COMPUTE ECONOMICS  ..
STOP ..
```

Input for the Hourly report for Shading Values

```
INPUT   LOADS   ..
TITLE LINE-1 * EFFECT OF PHOTOVOLTAIC GLAZING *
      LINE-2 * ON OWNING AND OPERATION COSTS *
      LINE-3 * OF HIGH RISE COMMERCIAL BUILDINGS *
      LINE-4 * *
      LINE-5 * DETROIT- SHADED * ..


$ ABORT                 ERRORS   ..
$DIAGNOSTIC           WARNINGS    ..
            RUN-PERIOD          JAN 1 1998  THRU  DEC 31 1998  ..

            $DETROIT
            BUILDING-LOCATION  LATITUDE=42.23  LONGITUDE=83.33
                                   TIME-ZONE=5  ALTITUDE=663 ..


$       LOADS-REPORT        SUMMARY=(LS-D) ..
$


$ BUILDING DESCRIPTION

$             THE OFFICE BUILDING IS A 40 STORIES HIGH WITH 100% GLAZING.

$ STRUCTURE - THE BUILDING IS STEEL FRAME WITH 4IN CONCRETE
$             FLOORS AND ROOF.  10FT FLOOR TO CEILING HEIGHT, WITH A 5 FOOT
$             PLENUM BETWEEN EACH FLOOR. INPUT USES THE PLENUMS AS THE R-A-P.

$ CURTAIN WALL USING CODE-WORDS FROM DOE-2 LIBRARY ( REFERENCE MANUAL PART 2 )
$              AND STARTING WITH OUTSIDE WORKING INWARD; 1/4IN SPANDREL GLASS
$              ( NOT IN LIBRARY - SEE MATERIAL SPGL ); 2IN POLYSTRENE INSUL
$              R-8 (IN35); STEEL BACKPANEL (AS01); 2IN AIRSPACE (AL21);
$              3/4IN GYPSUM BOARD FINISH (GP03)

$ ROOF        ROOF GRAVEL (RG02); BUILT-UP ROOFING (BR01); 3IN ROOF INSUL R-8
$             (IN76); 4IN CONCRETE (CC03); INSIDE-FILM-RESISTANCE .76 .

$ WINDOWS     THE WINDOWS ARE 10' HIGH DOUBLE-GLAZED WINDOWS WITH ONE FOURTH
$             LITES AND ONE HALF INCH AIR SPACE USING AIR.  MULLIONS ARE
$             CONTINUOUS 3 INCH FRAME.

$ INTERIORS    CEILINGS ARE SUSPENDED ACCOUSTIC TILE.
$              PARTITIONS SIMULATE CONVECTIVE HEAT TRANSFER BETWEEN CORE AND
$              PERIMETER SPACES USING A U-VALUE OF 1.5.

$ SPACE LOADS  LIGHTING RECESSED FLUORSCENT AT 2 WATTS/SQFT.
$              OFFICE EQUIPMENT .18 WATTS/SQFT.
$              PEOPLE  100SQFT/PERSON FOR SPACES
$
$              INFILTRATION .3 AIR CHANGES/HR FOR PERIMETER AREAS WHEN FANS
$              ARE , AND .06 AIR CHANGES/HR WHEN FANS ARE ON.

$ MATERIALS NOT IN DOE-2 LIBRARY

SPGS=MATERIAL      TH=.0208  COND=.590  DENS=172.   S-H=.20   ..


                      $ CONSTRUCTIONS
$LAYERS
ROOF-TOP        =LAYERS         MAT=(RG02,BR01,IN76,CC03)  I-F-R=.76  ..
SUS-CLG         =LAYERS              MAT=(AC03) ..
CON-FLOOR       =LAYERS              MAT=(CC34,CP02) ..
PLEN-WALL       =LAYERS              MAT=(SPGS,IN35,AS01,AL21,GP03)   ..

$CONSTRUCTION
ROOF-1         =CONSTRUCTION         LAYERS=ROOF-TOP ..
EXTER-1        =CONSTRUCTION         U=.05 ..
INTER-1        =CONSTRUCTION         U=1.5 ..
PLEN-1         =CONSTRUCTION         LAYERS=PLEN-WALL ..
CLNG-1         =CONSTRUCTION         LAYERS=SUS-CLG ..
FLOOR-1        =CONSTRUCTION         LAYERS=CON-FLOOR ..
BW             =CONSTRUCTION         U=.05    ..


$ SCHEDULES

OC1            =DAY-SCHEDULE         (1,8) (0.)          (9,10) (1.)
                                     (11,13) (.8,.4,.8)  (14,24) (1.,1.,1.,
                                                .3,.1,.1,.1,0.,0.,0.,0.)   ..
OC2            =DAY-SCHEDULE         (1,24) (0.0)   ..
```

```
PEOPLE        =WEEK-SCHEDULE       (MON,FRI)  OC1       (WEH)  OC2  ..
OCCUP         =SCHEDULE            THRU DEC 31  PEOPLE    ..

L1            =DAY-SCHEDULE        (1,6) (.05)          (7,24) (.1,.9,.9,
                                   .95,.95,.95,.8,.8,.9,.9,.95,.8,.7,.6,
                                   .4,.3,.2,.2)    ..
L2            =DAY-SCHEDULE        (1,24) (.05)    ..
LIGHTS        =WEEK-SCHEDULE       (MON,FRI)  L1        (WEH)  L2    ..
LT1           =SCHEDULE            THRU DEC 31 LIGHTS    ..

ES1           =DAY-SCHEDULE        (1,8)  (0.)          (9,20) (.35,.50,
                                   .55,.9,.6,.8,.7,.75,.3,.3,.5,.05)
                                   (21,24) (0.0)    ..
ES2           =DAY-SCHEDULE        (1,24) (0.0)   ..
EQUIP         =WEEK-SCHEDULE       (MON,FRI)  ES1       (WEH)  ES2    ..
EQ1           =SCHEDULE            THRU DEC 31  EQUIP    ..

I1            =DAY-SCHEDULE        (1,7)  (1.)          (8,18)  (0.2)
                                   (19,24) (1.)     ..
I2            =DAY-SCHEDULE        (1,24)  (1.)    ..
INFILT        =WEEK-SCHEDULE       (MON,FRI)  I1        (WEH)  I2    ..
INF1          =SCHEDULE            THRU DEC 31  INFILT    ..

                   $ BUILDING SHADE BY ANOTHER BUILDING

$ FOR THIS RESEARCH WE HAVE ASSUMED THAT THERE ARE SURROUNDING BUILDINGS 1/2
$THE HEIGHT OF THE BUILDING.  THE BUILDINGS ARE 100' WIDE, 600' HIGH AND 100'
$APART.  THE INPUT TO REPRESENT THIS AS A SHADING SURFACE IS ..


BUILDING-SHADE  X=-200  Y=200  AZ=-180 H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=-100  Y=200  AZ=90   H=300  W=100  TILT 90   ..
BUILDING-SHADE  X= 0    Y=200  AZ=180  H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=200   Y=200  AZ=180  H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=200   Y=300  AZ=270  H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=200   Y=100  AZ=270  H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=200  Y=-100  AZ=270  H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=300  Y=-100  AZ=0    H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=100  Y=-100  AZ=0    H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=-100  Y=-200 AZ=90   H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=-100  Y=-100 AZ=0    H=300  W=100  TILT 90   ..
BUILDING-SHADE  X=-100  Y=0    AZ=90   H=300  W=100  TILT 90   ..
$
$PV ROOF SHADING
$BUILDING-SHADE  X=0   Y=0  Z=610 AZ=180    H=100  W=100  TILT 0  ..
$
$
$
$
                 $ SET DEFAULTS
SET-DEFAULT FOR EXTERIOR-WALL     WIDTH=100 HEIGHT=600 ..
$
$
$
  $ SPACE DESCRIPTIONS
$
OFFICE        =SPACE-CONDITIONS    TEMPERATURE=(75)   FLOOR-WEIGHT=70
                                   LIGHTING-W/SQFT=2  EQUIPMENT-W/SQFT=.18
                                   PEOPLE-HEAT-GAIN=450
                                   EQUIP-SCHEDULE=EQ1  LIGHTING-SCHEDULE=LT1
                                   PEOPLE-SCHEDULE=OCCUP  AIR-CHANGES/HR=.3
                                   INF-SCHEDULE=INF1  LIGHT-TO-SPACE=.80
                                   INF-METHOD=AIR-CHANGE
                                   LIGHTING-TYPE=REC-FLUOR-RV    ..
$
BASEMENT=SPACE              TEMPERATURE=(75)  FLOOR-WEIGHT=150
                                   VOLUME=400000   AREA=20000
                                   LIGHTING-W/SQFT=1
                                   LIGHTING-SCHEDULE=LT1    ..
$
     FRONT-B    =UNDERGROUND-WALL    X=0 Y=0 Z=-20 AZ=180 WIDTH=100 HEIGHT=20
                 AREA=8000  CONSTRUCTION=BW   ..
     RIGHT-B    =UNDERGROUND-WALL X=100 Y=0 Z=-20 AZIMUTH=90 WIDTH=100 HEIGHT=20
                 AREA=8000  CONSTRUCTION=BW   ..
     BACK-B     =UNDERGROUND-WALL X=100 Y=100 Z=-20 AZIMUTH=0 WIDTH=100 HEIGHT=20
                 AREA=8000  CONSTRUCTION=BW   ..
     LEFT-B  =UNDERGROUND-WALL X=100 Y=100 Z=-20 AZIMUTH=270 WIDTH=100 HEIGHT=20
                 AREA=8000  CONSTRUCTION=BW   ..
     FL-B        =UNDERGROUND-FLOOR  WIDTH=100 HEIGHT=100
                  X=0 Y=0 Z=0 AZ=180 TILT=0 AREA=10000 CONSTRUCTION=BW   ..
$
$FIRST FLOOR
$
SPACE1-1        =SPACE  SPACE-CONDITIONS=OFFICE AREA=10000 VOLUME=6000000
                 NUMBER-OF-PEOPLE=100 ..
    FRONT-1     =EXTERIOR-WALL AZIMUTH=180 X=0 Y=0 CONSTRUCTION=EXTER-1
                  SHADING-DIVISION=40 ..
    RIGHT-1      =EXTERIOR-WALL X=100 Y=0 AZIMUTH=90 CONSTRUCTION=EXTER-1
```

```
                SHADING-DIVISION=40 ..
    BACK-1       =EXTERIOR-WALL X=100 Y=100 AZIMUTH=0 CONSTRUCTION=EXTER-1
                SHADING-DIVISION=40 ..
    LEFT-1      =EXTERIOR-WALL X=0 Y=100 AZIMUTH=270 CONSTRUCTION=EXTER-1
               SHADING-DIVISION=40 ..
     TOP-1        =ROOF HEIGHT=100 WIDTH=100 AZ=180 CONSTRUCTION=ROOF-1
                 TILT=0 X=0 Y=0 Z=600 ..
$
R-SCHED=SCHEDULE  THRU DEC 31 (All)(1,24) (1) ..

    RB1=REPORT-BLOCK  VARIABLE-TYPE=FRONT-1
                      VARIABLE-LIST=(2) ..

    RB2=REPORT-BLOCK  VARIABLE-TYPE=RIGHT-1
                      VARIABLE-LIST=(2) ..

    RB3=REPORT-BLOCK  VARIABLE-TYPE=BACK-1
                      VARIABLE-LIST=(2) ..

    RB4=REPORT-BLOCK  VARIABLE-TYPE=LEFT-1
                      VARIABLE-LIST=(2) ..

REPORT1 = HOURLY-REPORT
          REPORT-SCHEDULE    =R-SCHED
          REPORT-BLOCK       =(RB1,RB2,RB3,RB4) ..
$
END ..
COMPUTE LOADS ..
INPUT SYSTEMS ..
$
          TITLE     LINE-2 * 2 VARIABLE AIR VOLUME SYSTEM *
                    LINE-4 *ELECTRIC THERMOSTATIC BASEBOARDS *
                    LINE-5 *WARM-UP CYCLE USES GAS HEAT*  ..
$
                     $ HVAC SYSTEM DESCRIPTION
$
$ DESIGN TEMPS  COOLING 76F  HEATING 70F.
$ SYSTEM TYPE   A SINGLE VARIABLE AIR VOLUME SYSTEM SERVES THE ENTIRE BUILDING.
$               THE SYSTEM HAS A DRY BULB CONTROLLED ECONOMIZER WITH A LIMIT
$               TEMPERATURE OF 68F AND THE FANS HAVE A SPEED CONTROLLER. THE VAV
$               BOXES HAVE A MINIMUM STOP OF 20%.  BASEBOARD RADIATION IS NOT
$               CONTROLLED BY SPACE THERMOSTATS BUT BY A RESET CONTROL THAT
$               IS A FUNCTION OF OA TEMP.  THEREFORE THE BASEBOARD IS ACTIVE
$               AT NIGHT BUT THE FAN SYSTEM CAN CYCLE ON IF NECESSARY TO HOLD
$               THE NIGHT LOW LIMIT SETTING OF 55F.  THE FANS CAN START AS
$               EARLY AS 5AM BUT ARE DELAYED AS LONG AS POSSIBLE (I.E. OPTIMUM
$               START).  FANS ARE OFF AFTER 6PM PLUS WEEKENDS AND HOLIDAYS.
$               THERE ARE REHEAT COILS IN THE VAV BOXES THAT ARE CONTROLLED BY
$               SPACE THERMOSTATS SINCE THE BASEBOARD RADIATION IS SIZED ONLY
$               FOR GLASS CONDUCTANCE.  THERE IS A HUMIDISTAT WHICH CONTROLS THE
$               RETURN AIR HUMIDITY AT 25% RH BY ADDING STEAM TO THE AIR. TO
$               PREVENT ADDING MOISTURE TO LARGE QUANITIES OF OUTSIDE AIR, WHICH
$               IS VERY COSTLY, THE ECONOMIZER DAMPERS ARE CLOSED BELOW OUTSIDE
$               AIR TEMPERATURES OF 45F.  THE FREE COOLING CYCLE ON THE CHILLERS
$               PROVIDES NECESSARY MECHANICAL COOLING, SINCE OUTSIDE AIR COOLING
$               IS LOCKED OUT.
$
$
          ABORT               ERRORS ..
          DIAGNOSTIC          WARNINGS  ..
$          SYSTEMS-REPORT      SUMMARY=(SS-A,SS-D) ..

                   $ SCHEDULES
$
HRS1         = DAY-SCHEDULE (1,5) (0) (6,7) (-999) (8,18) (1) (19,24) (0)   ..
HRS2         = DAY-SCHEDULE (1,24) (0)   ..
DAYS1        = WEEK-SCHEDULE  (MON,FRI)  HRS1   (WEH)  HRS2    ..
AHU-SCHED    = SCHEDULE THRU DEC 31    DAYS1   ..       $ FANS $
$
HRSH1        = DAY-SCHEDULE (1,7) (55)  (8,18) (70)  (19,24) (55)  ..
HRSH2        = DAY-SCHEDULE (1,24) (55)    ..
DAYHEAT      = WEEK-SCHEDULE (MON,FRI)   HRSH1   (WEH)   HRSH2   ..
THEAT        = SCHEDULE THRU DEC 31   DAYHEAT   ..     $ HEATING $
$
HRSC1        = DAY-SCHEDULE  (1,7) (99)  (8,18) (76)  (19,24) (99)   ..
HRSC2        = DAY-SCHEDULE  (1,24) (99)    ..
DAYCOOL      = WEEK-SCHEDULE  (MON,FRI)  HRSC1   (WEH)  HRSC2   ..
TCOOL        = SCHEDULE THRU DEC 31   DAYCOOL   ..     $ COOLING $
$
HEATON        = SCHEDULE THRU DEC 31 (ALL) (1,24) (60)    ..
$
SAT-FOA       = SCHEDULE THRU DEC 31 (ALL) SA1   ..
SA1           = DAY-RESET-SCH  SUPPLY-HI 65   SUPPLY-LO 55
                               OUTSIDE-LO 20  OUTSIDE-HI 75  ..
$
BASEB        = RESET-SCHEDULE  THRU MAR 15  (ALL)  BASE1
                                THRU DEC 15  (ALL)  BASE2
                                THRU DEC 31  (ALL)  BASE3  ..
```

```
$
BASE1        = DAY-RESET-SCH OUTSIDE-HI = 60  OUTSIDE-LO = 0
                             SUPPLY-HI  =  1  SUPPLY-LO  = 0     ..
BASE2        = DAY-RESET-SCH OUTSIDE-HI = 60  OUTSIDE-LO = 0
                             SUPPLY-HI  =  0  SUPPLY-LO  =  0  ..
BASE3        = DAY-RESET-SCH OUTSIDE-HI = 60  OUTSIDE-LO = 0
                             SUPPLY-HI  =  1  SUPPLY-LO  =  0  ..
$
         $ ZONE SUB-COMMANDS
ZAIR          = ZONE-AIR     OA-CFM/PER=7    ..
$
CONTROL      = ZONE-CONTROL  DESIGN-HEAT-T=70  DESIGN-COOL-T=74
                             HEAT-TEMP-SCH=THEAT  COOL-TEMP-SCH=TCOOL
                             BASEBOARD-CTRL=OUTDOOR-RESET
                             THERMOSTAT-TYPE=REVERSE-ACTION  ..
         $ ZONE DESCRIPTION
SPACE1-1       =ZONE      ZONE-AIR=ZAIR  ZONE-CONTROL=CONTROL
                          CFM/SQFT=.7 BASEBOARD-RATING=-25000 ..
$
BASEMENT       =ZONE      LIKE SPACE1-1 AIR-CHANGES/HR=4  OA-CHANGES=0.5  ..
$
$
$ SYSTEM SUB-COMMANDS
$
S-CTRL  = SYSTEM-CONTROL     HEATING-SCHEDULE=HEATON
                             BASEBOARD-SCH=BASEB  HEAT-SET-T=60
                             COOL-CONTROL=RESET  COOL-RESET-SCH=SAT-FOA
                             MIN-SUPPLY-T=55   MAX-SUPPLY-T=105
                             MIN-HUMIDITY=25  ..
$
S-FAN   = SYSTEM-FANS        FAN-SCHEDULE=AHU-SCHED  FAN-CONTROL=SPEED
                             SUPPLY-STATIC=5.5  SUPPLY-EFF=0.54
                             RETURN-STATIC=2.0  RETURN-EFF=0.51  ..
$
S-TERM  = SYSTEM-TERMINAL    REHEAT-DELTA-T=50  MIN-CFM-RATIO=0.2 ..
$
$
         $ SYSTEM DESCRIPTION
$
BLDG   = SYSTEM             SYSTEM-TYPE=VAVS  SYSTEM-CONTROL=S-CTRL
                             SYSTEM-FANS=S-FAN   ECONO-LOW-LIMIT 45
                             SYSTEM-TERMINAL=S-TERM  RETURN-AIR-PATH=DUCT
                             ECONO-LIMIT-T=68 ZONE-NAMES=(SPACE1-1) ..
$
BASMT-SYS = SYSTEM SYSTEM-TYPE=SZRH  MAX-S-T=105  MIN-S-T=55
                             SUPPLY-STATIC=2.5  S-E=.5  F-SCH=AHU-SCHED
                             H-SCH=HEATON  ZONE-NAMES=(BASEMENT)  ..
$
END  ..
COMPUTE SYSTEMS  ..
INPUT PLANT  ..
PLANT-REPORT  SUMMARY (PS-A)  ..
$
$ PLANT DESCRIPTION

$ THIS PLANT IS TYPICAL OF LARGE CITIES LIKE NEW YORK WHERE THE UTILITY
$ FURNISHES STEAM TO THE BUILDING, AND LIKE MANY OLDER BUILDINGS IT HAS AN
$ ABSORPTION CHILLER.  THIS WILL DEMONSTRATE THE USE OF THE ABSORPTION CHILLER
$ AS AN ELECTRIC PEAK SHAVING DEVICE TO ATTEMPT TO HOLD THE ELECTRIC DEMAND
$ BELOW 10 MBTUH OR 2930KW.

CHL  = PLANT-EQUIPMENT  TYPE=ABSORG-CHLR  SIZE -999  I-N 1  ..
DHW  = PLANT-EQUIPMENT  TYPE=DHW-HEATER  SIZE -999  I-N 1  ..
CTR  = PLANT-EQUIPMENT  TYPE=COOLING-TWR  SIZE -999   ..

END  ..
COMPUTE PLANT  ..
STOP ..
```

Parametric Input file for Final Simulations

```
INPUT  LOADS ..
TITLE LINE-1 * EFFECT OF PHOTOVOLTAIC GLAZING *
   LINE-2 * HOUSTON  *
   LINE-3 * 40-STORY OFFICE BLDG IN HOUSTON * ..
$ ABORT           ERRORS ..
$DIAGNOSTIC       WARNINGS  ..
$
$ LOADS-REPORT  V=(LV-K)  SUMMARY=(LS-D) ..
        RUN-PERIOD       JAN 1 1998  THRU  DEC 31 1998 ..
        BUILDING-LOCATION  LATITUDE=29.65  LONGITUDE=95.28
                    TIME-ZONE=6  ALTITUDE=46 ..

    PARAMETER        PERCENT=0
               GLAZING=1999 ..


$ BUILDING DESCRIPTION

$        THE OFFICE BUILDING IS A 40 STORIES HIGH WITH 100% GLAZING.

$ STRUCTURE - THE BUILDING IS STEEL FRAME WITH 4IN CONCRETE
$        FLOORS AND ROOF.  10FT FLOOR TO CEILING HEIGHT, WITH A 5 FOOT
$        PLENUM BETWEEN EACH FLOOR. INPUT USES THE PLENUMS AS THE R-A-P.

$ CURTAIN WALL USING CODE-WORDS FROM DOE-2 LIBRARY ( REFERENCE MANUAL PART 2 )
$         AND STARTING WITH OUTSIDE WORKING INWARD; 1/4IN SPANDREL GLASS
$         ( NOT IN LIBRARY - SEE MATERIAL SPGL ); 2IN POLYSTRENE INSUL
$         R-8 (IN35); STEEL BACKPANEL (AS01); 2IN AIRSPACE (AL21);
$         3/4IN GYPSUM BOARD FINISH (GP03)

$ ROOF      ROOF GRAVEL (RG02); BUILT-UP ROOFING (BR01); 3IN ROOF INSUL R-8
$        (IN76); 4IN CONCRETE (CC03); INSIDE-FILM-RESISTANCE .76 .

$ WINDOWS    THE WINDOWS ARE 10' HIGH DOUBLE-GLAZED WINDOWS WITH ONE FOURTH
$        LITES AND ONE HALF INCH AIR SPACE USING AIR.  MULLIONS ARE
$        CONTINUOUS 3 INCH FRAME.

$ INTERIORS    CEILINGS ARE SUSPENDED ACCOUSTIC TILE.
$         PARTITIONS SIMULATE CONVECTIVE HEAT TRANSFER BETWEEN CORE AND
$         PERIMETER SPACES USING A U-VALUE OF 1.5.

$ SPACE LOADS  LIGHTING RECESSED FLUORSCENT AT 2 WATTS/SQFT.
$         OFFICE EQUIPMENT .18 WATTS/SQFT.
$         PEOPLE  100SQFT/PERSON FOR SPACES
$
$         INFILTRATION .3 AIR CHANGES/HR FOR PERIMETER AREAS WHEN FANS
$         ARE , AND .06 AIR CHANGES/HR WHEN FANS ARE ON.

$ MATERIALS NOT IN DOE-2 LIBRARY

SPGS=MATERIAL    TH=.0208  COND=.590  DENS=172.  S-H=.20  ..


            $ CONSTRUCTIONS
$LAYERS
ROOF-TOP    =LAYERS       MAT=(RG02,BR01,IN76,CC03) I-F-R=.76 ..
SUS-CLG     =LAYERS         MAT=(AC03) ..
CON-FLOOR    =LAYERS           MAT=(CC03,CP01) ..
PLEN-WALL    =LAYERS           MAT=(SPGS,IN35,AS01,AL21,GP03) ..

$CONSTRUCTION
ROOF-1      =CONSTRUCTION      LAYERS=ROOF-TOP ..
EXTER-1      =CONSTRUCTION      U=100000 ..
INTER-1     =CONSTRUCTION      U=1.5 ..
PLEN-1      =CONSTRUCTION      LAYERS=PLEN-WALL ..
CLNG-1      =CONSTRUCTION      U=.20 ..
FLOOR-1      =CONSTRUCTION      LAYERS=CON-FLOOR ..
BW         =CONSTRUCTION     U=.05  .


$ GLASS DESCRIPTION

FACADE          =GLASS-TYPE   GLASS-TYPE-CODE=GLAZING ..

$ SCHEDULES

OC1       =DAY-SCHEDULE      (1,24) (.05,.05,.05,.05,.05,.05,
                    .19,.31,.69,.94,1,1,1,.94,1,.94,.94,
                    .75,.38,.13,.05,.05,.05,.05) ..

OC2       =DAY-SCHEDULE      (1,24) (0.01,.01,.01,.01,.01,.01,
                    .02,.03,.07,.09,.1,.1,.1,.09,.1,.09,
```

```
                  09,.08,.04,.01,.01,.01..01,.01) ..

OCCUP     =SCHEDULE       THRU DEC 31  (WD) OC1  (WEH) OC2  ..

L1      =DAY-SCHEDULE     (1,24) (.17,.17,.17,.17,.17,.21,.3,
                  .44,.84,.97,1,1,1,.97,1,.97,.97,
                  .88,.46,.28,.2,.17,.14,.13)  ..

L2      =DAY-SCHEDULE     (1,24) (.15,.15,.15,.15,.15,.16,
                  .18,.2,.25,.29,.3,.3,.3,.29,.3,.29,
                  .29,.26,.21,.17,.15,.15,.15,.15) ..

LIGHTS    SCHEDULE        THRU DEC 31 (WD) L1  (WEH) L2  ..

ES1      =DAY-SCHEDULE     (1,24) (.5,.5,.5,.5,.5,.53,.59,.66,
                  .84,.97,1,1,1,.97,1,.97,.97,
                  .88,.69,.56,.5,.5,.5,.5)  ..

ES2      =DAY-SCHEDULE     (1,24) (.5,.5,.5,.5,.5,.51,.52,.53,
                  .57,.59,.6,.6,.6,.59,.6,.59,.59,
                  .58,.54,.51,.5,.5,.5,.5)  ..

EQUIP     =SCHEDULE       THRU DEC 31 (WD) ES1  (WEH) ES2  ..

I1      =DAY-SCHEDULE     (1,7) (1.)      (8,18) (0.2)
                  (19,24) (1.)  ..
I2      =DAY-SCHEDULE     (1,24) (1.)  ..
INFIL     =SCHEDULE       THRU DEC 31  (WD) I1  (WEH) I2  ..


          $ BUILDING SHADE BY ANOTHER BUILDING

$ FOR THIS RESEARCH WE HAVE ASSUMED THAT THERE ARE SURROUNDING BUILDINGS 1/2
$THE HEIGHT OF THE BUILDING. THE BUILDINGS ARE 100' WIDE, 600' HIGH AND 100'
$APART. THE INPUT TO REPRESENT THIS AS A SHADING SURFACE IS ..


BUILDING-SHADE X=-200 Y=200 AZ=-180 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=-100 Y=200 AZ=90  H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X= 0  Y=200 AZ=180 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=200  Y=200 AZ=180 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=200  Y=300 AZ=270 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=200  Y=100 AZ=270 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=200 Y=-100 AZ=270 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=300 Y=-100 AZ=0  H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=100 Y=-100 AZ=0  H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=-100 Y=-200 AZ=90 H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=-100 Y=-100 AZ=0  H=300 W=100 TILT 90 TR=PERCENT ..
BUILDING-SHADE X=-100 Y=0  AZ=90 H=300 W=100 TILT 90 TR=PERCENT ..
$PV ROOF SHADING
BUILDING-SHADE X=0 Y=0 Z=610 AZ=180  H=100 W=100 TILT 0 TR=PERCENT ..
$
$
$
$
         $ SET DEFAULTS
SET-DEFAULT FOR EXTERIOR-WALL  WIDTH=100 ..
SET-DEFAULT FOR INTERIOR-WALL  HEIGHT=20 ..
SET-DEFAULT FOR WINDOW      WIDTH=100 HEIGHT=19.916 GLASS-TYPE=FACADE ..
$
$
 $ SPACE DESCRIPTIONS
$
OFFICE    =SPACE-CONDITIONS  TEMPERATURE=(75) $ FOR CWF
                  LIGHTING-W/SQFT=2.5 EQUIPMENT-W/SQFT=1
                  PEOPLE-HEAT-GAIN=450
                  EQUIP-SCHEDULE=EQUIP L-SCH=LIGHTS
                  PEOPLE-SCHEDULE=OCCUP AIR-CHANGES/HR=.25
                  INF-SCHEDULE=INFIL LIGHT-TO-SPACE=.80
                  INF-METHOD=AIR-CHANGE
                  LIGHTING-TYPE=REC-FLUOR-RV  ..
$
BASEMENT=SPACE      TEMPERATURE=(73.5) FLOOR-WEIGHT=150
                  VOLUME=200000 AREA=10000
                  LIGHTING-W/SQFT=1.5
                  LIGHTING-SCHEDULE=LIGHTS  ..
$
  FRONT-B  =UNDERGROUND-WALL  X=0 Y=0 Z=-20 AZ=180 WIDTH=100 HEIGHT=20
       AREA=8000 CONSTRUCTION=BW  ..
  RIGHT-B  =UNDERGROUND-WALL X=100 Y=0 Z=-20 AZIMUTH=90 WIDTH=100 HEIGHT=20
       AREA=8000 CONSTRUCTION=BW  ..
  BACK-B  =UNDERGROUND-WALL X=100 Y=100 Z=-20 AZIMUTH=0 WIDTH=100 HEIGHT=20
       AREA=8000 CONSTRUCTION=BW  ..
  LEFT-B  =UNDERGROUND-WALL X=100 Y=100 Z=-20 AZIMUTH=270 WIDTH=100 HEIGHT=20
       AREA=8000 CONSTRUCTION=BW  ..
  FL-B   =UNDERGROUND-FLOOR  WIDTH=100 HEIGHT=100
       X=0 Y=0 Z=0 AZ=180 TILT=0 AREA=10000 CONSTRUCTION=BW  ..
```

```
$
$FIRST FLOOR
$
SPACE1-1    =SPACE  SPACE-CONDITIONS=OFFICE AREA=1875 VOLUME=37500
         NUMBER-OF-PEOPLE=30 ..
  FRONT-1    =EXTERIOR-WALL HEIGHT=20
          AZIMUTH=180 X=0 Y=0 CONSTRUCTION=EXTER-1
          SHADING-DIVISION=40 ..
  WF-1      =WINDOW SHADING-DIVISION=40 ..
  C1-1      =INTERIOR-WALL AREA=1875 NEXT-TO PLENUM-1
          CONSTRUCTION=CLNG-1 TILT=0 ..
  F1-1      =INTERIOR-WALL AREA=1875 NEXT-TO BASEMENT
          CONSTRUCTION=FLOOR-1 TILT=0 ..
  SB12      =INTERIOR-WALL WIDTH=35.355339 X=100 Y=0 AZIMUTH=45
         NEXT-TO SPACE2-1 CONSTRUCTION=INTER-1 ..
  SB14      =INTERIOR-WALL WIDTH=35.355339 X=0 Y=0 AZIMUTH=135
          CONSTRUCTION=INTER-1  NEXT-TO SPACE4-1 ..
  SB15      =INTERIOR-WALL WIDTH=50 X=25 Y=25 AZIMUTH=180
          NEXT-TO SPACE5-1 CONSTRUCTION=INTER-1 ..
$
SPACE2-1      =SPACE  LIKE SPACE1-1 ..
  RIGHT-1    =EXTERIOR-WALL HEIGHT=20
          X=100 Y=0 AZIMUTH=90 CONSTRUCTION=EXTER-1
          SHADING-DIVISION=40 ..
  WR-1      =WINDOW SHADING-DIVISION=40 ..
  C2-1      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-1 ..
  F2-1      =INTERIOR-WALL LIKE F1-1 NEXT-TO BASEMENT ..
  SB23      =INTERIOR-WALL WIDTH=35.355339 X=75 Y=75 AZIMUTH=135
          CONSTRUCTION=INTER-1  NEXT-TO SPACE3-1 ..
  SB25      =INTERIOR-WALL WIDTH=50 X=75 Y=25 AZIMUTH=90
          CONSTRUCTION=INTER-1 NEXT-TO SPACE5-1 ..
$
SPACE3-1      =SPACE  LIKE SPACE1-1 ..
  BACK-1    =EXTERIOR-WALL HEIGHT=20
          X=100 Y=100 AZIMUTH=0 CONSTRUCTION=EXTER-1
          SHADING-DIVISION=40 ..
  WB-1      =WINDOW SHADING-DIVISION=40 ..
  C3-1      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-1 ..
  F3-1      =INTERIOR-WALL LIKE F1-1 NEXT-TO BASEMENT ..
  SB34      =INTERIOR-WALL WIDTH=35.355339 X=25 Y=75 AZIMUTH=45
          CONSTRUCTION=INTER-1  NEXT-TO SPACE4-1 ..
  SB35      =INTERIOR-WALL WIDTH=50 X=25 Y=75 AZIMUTH=180
          CONSTRUCTION=INTER-1 NEXT-TO SPACE5-1 ..
$
SPACE4-1      =SPACE  LIKE SPACE1-1 ..
  LEFT-1    =EXTERIOR-WALL HEIGHT=20
          X=0 Y=100 AZIMUTH=270 CONSTRUCTION=EXTER-1
          SHADING-DIVISION=40 ..
  WL-1      =WINDOW SHADING-DIVISION=40 ..
  C4-1      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-1 ..
  F4-1      =INTERIOR-WALL LIKE F1-1 NEXT-TO BASEMENT ..
  SB45      =INTERIOR-WALL WIDTH=50 X=25 Y=25 AZIMUTH=90
          CONSTRUCTION=INTER-1 NEXT-TO SPACE5-1 ..
$
SPACE5-1     =SPACE  SPACE-CONDITIONS=OFFICE AREA=2500 VOLUME=25000
         NUMBER-OF-PEOPLE=20 F-W=150 ..
  C5-1     =INTERIOR-WALL AREA=2500 NEXT-TO PLENUM-1 CONSTRUCTION=CLNG-1 ..
  F5-1     =INTERIOR-WALL AREA=2500 NEXT-TO BASEMENT CONSTRUCTION=FLOOR-1 ..
$
PLENUM-1      =SPACE  ZONE-TYPE=PLENUM T=(75) VOLUME=100000 AREA=10000 F-W=0 ..
   PL-F-1     =EXTERIOR-WALL HEIGHT=10
         X=0 Y=0 Z=20 AZIMUTH=180 CONSTRUCTION=PLEN-1 ..
   PL-R-1     =EXTERIOR-WALL HEIGHT=10
         X=100 Y=0  Z=20 AZIMUTH=90  CONSTRUCTION=PLEN-1 ..
   PL-B-1   =EXTERIOR-WALL HEIGHT=10
         X=100 Y=100 Z=20 AZIMUTH=0  CONSTRUCTION=PLEN-1
   PL-L-1    =EXTERIOR-WALL HEIGHT=10
         X=0  Y=100 Z=20 AZIMUTH=270  CONSTRUCTION=PLEN-1 ..
$
$ SECOND LEVEL
SPACE1-2     =SPACE LIKE SPACE1-1 ..
  FRONT-2    =EXTERIOR-WALL LIKE FRONT-1 Z=30 ..
  WF-2      =WINDOW SHADING-DIVISION=40 ..
  C1-2      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-2 ..
  F1-2      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-1 ..
  SB12-2     =INTERIOR-WALL LIKE SB12 Z=30 NEXT-TO SPACE2-2
  SB14-2     =INTERIOR-WALL LIKE SB14 Z=30 NEXT-TO SPACE4-2 ..
  SB15-2     =INTERIOR-WALL LIKE SB15 Z=30 NEXT-TO SPACE5-2 .
$
SPACE2-2      =SPACE  LIKE SPACE1-1 ..
  RIGHT-2    =EXTERIOR-WALL LIKE RIGHT-1 Z=30 ..
  WR-2      =WINDOW SHADING-DIVISION=40 ..
  C2-2      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-2 ..
  F2-2      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-1 ..
  SB23-2     =INTERIOR-WALL LIKE SB23 Z=30 NEXT-TO SPACE3-2
  SB25-2     =INTERIOR-WALL LIKE SB25 Z=30 NEXT-TO SPACE5-2
$
```

```
SPACE3-2     =SPACE  LIKE SPACE1-1 ..
   BACK-2    =EXTERIOR-WALL LIKE BACK-1 Z=30 ..
   WB-2      =WINDOW SHADING-DIVISION=40 ..
   C3-2      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-2 ..
   F3-2      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-1 ..
   SB34-2    =INTERIOR-WALL LIKE SB34 Z=30 NEXT-TO SPACE4-2 ..
   SB35-2    =INTERIOR-WALL LIKE SB35 Z=30 NEXT-TO SPACE5-2 ..
$
SPACE4-2     =SPACE  LIKE SPACE1-1 ..
   LEFT-2    =EXTERIOR-WALL LIKE LEFT-1 Z=30
   WL-2      =WINDOW SHADING-DIVISION=40 ..
   C4-2      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-2 ..
   F4-2      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-1 ..
   SB45-2    =INTERIOR-WALL LIKE SB45 Z=30 NEXT-TO SPACE5-2 ..
$
SPACE5-2     =SPACE  LIKE SPACE5-1 Z=30 ..
  C5-2       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-2 ..
  F5-2       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-1 ..
$
PLENUM-2     =SPACE  LIKE PLENUM-1 ..
    PL-F-2   =EXTERIOR-WALL LIKE PL-F-1 Z=50 ..
    PL-R-2   =EXTERIOR-WALL LIKE PL-R-1 Z=50 ..
    PL-B-2   =EXTERIOR-WALL LIKE PL-B-1 Z=50 ..
    PL-L-2   =EXTERIOR-WALL LIKE PL-L-1 Z=50 ..
$
$THIRD LEVEL
SPACE1-3     =SPACE  LIKE SPACE1-1 ..
   FRONT-3   =EXTERIOR-WALL LIKE FRONT-1 Z=60 ..
   WF-3      =WINDOW SHADING-DIVISION=40 ..
   C1-3      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-3 ..
   F1-3      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-2 ..
   SB12-3    =INTERIOR-WALL LIKE SB12 Z=60 NEXT-TO SPACE2-3 ..
   SB14-3    =INTERIOR-WALL LIKE SB14 Z=60 NEXT-TO SPACE4-3 ..
   SB15-3    =INTERIOR-WALL LIKE SB15 Z=60 NEXT-TO SPACE5-3 ..
$
SPACE2-3     =SPACE  LIKE SPACE1-1 ..
   RIGHT-3   =EXTERIOR-WALL LIKE RIGHT-1 Z=60 ..
   WR-3      =WINDOW SHADING-DIVISION=40 ..
   C2-3      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-3 ..
   F2-3      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-2 ..
   SB23-3    =INTERIOR-WALL LIKE SB23 Z=60 NEXT-TO SPACE3-3 ..
   SB25-3    =INTERIOR-WALL LIKE SB25 Z=60 NEXT-TO SPACE5-3 ..
$
SPACE3-3     =SPACE LIKE SPACE1-1 ..
   BACK-3    =EXTERIOR-WALL LIKE BACK-1 Z=60 ..
   WB-3      =WINDOW SHADING-DIVISION=40 ..
   C3-3      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-3 ..
   F3-3      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-2 ..
   SB34-3    =INTERIOR-WALL LIKE SB34 Z=60 NEXT-TO SPACE4-3 ..
   SB35-3    =INTERIOR-WALL LIKE SB35 Z=60 NEXT-TO SPACE5-3 ..
$
SPACE4-3     =SPACE LIKE SPACE1-1 ..
   LEFT-3    =EXTERIOR-WALL LIKE LEFT-1 Z=60 ..
   WL-3      =WINDOW SHADING-DIVISION=40 ..
   C4-3      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-3 ..
   F4-3      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-2 ..
   SB45-3    =INTERIOR-WALL LIKE SB45 Z=60 NEXT-TO SPACE5-3 ..
$
SPACE5-3     =SPACE LIKE SPACE5-1 Z=60 ..
   C5-3      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-3 ..
   F5-3      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-2 ..
$
PLENUM-3     =SPACE  LIKE PLENUM-1 ..
    PL-F-3   =EXTERIOR-WALL LIKE PL-F-1 Z=80 ..
    PL-R-3   =EXTERIOR-WALL LIKE PL-R-1 Z=80 ..
    PL-B-3   =EXTERIOR-WALL LIKE PL-B-1 Z=80 ..
    PL-L-3   =EXTERIOR-WALL LIKE PL-L-1 Z=80 ..
$
$FOURTH LEVEL
SPACE1-4     =SPACE LIKE SPACE1-1 ..
   FRONT-4   =EXTERIOR-WALL LIKE FRONT-1 Z=90 ..
   WF-4      =WINDOW SHADING-DIVISION=40 ..
   C1-4      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-4 ..
   F1-4      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-3 ..
   SB12-4    =INTERIOR-WALL LIKE SB12 Z=90 NEXT-TO SPACE2-4 ..
   SB14-4    =INTERIOR-WALL LIKE SB14 Z=90 NEXT-TO SPACE4-4 ..
   SB15-4    =INTERIOR-WALL LIKE SB15 Z=90 NEXT-TO SPACE5-4 ..
$
SPACE2-4     =SPACE LIKE SPACE1-1 ..
   RIGHT-4   =EXTERIOR-WALL LIKE RIGHT-1 Z=90 ..
   WR-4      =WINDOW SHADING-DIVISION=40 ..
   C2-4      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-4 ..
   F2-4      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-3 ..
   SB23-4    =INTERIOR-WALL LIKE SB23 Z=90 NEXT-TO SPACE3-4 ..
   SB25-4    =INTERIOR-WALL LIKE SB25 Z=90 NEXT-TO SPACE5-4 ..
$
SPACE3-4     =SPACE LIKE SPACE1-1 ..
```

```
  BACK-4     =EXTERIOR-WALL LIKE BACK-1 Z=90 ..
  WB-4       =WINDOW SHADING-DIVISION=40 ..
  C3-4       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-4 ..
  F3-4       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-3 ..
  SB34-4     =INTERIOR-WALL LIKE SB34 Z=90 NEXT-TO SPACE4-4 ..
  SB35-4     =INTERIOR-WALL LIKE SB35 Z=90 NEXT-TO SPACE5-4 ..
$
SPACE4-4     =SPACE LIKE SPACE1-1 ..
  LEFT-4     =EXTERIOR-WALL LIKE LEFT-1 Z=90 ..
  WL-4       =WINDOW SHADING-DIVISION=40 ..
  C4-4       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-4 ..
  F4-4       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-3 ..
  SB45-4     =INTERIOR-WALL LIKE SB45 Z=90 NEXT-TO SPACE5-4 ..
$
SPACE5-4     =SPACE LIKE SPACE5-1 Z=90 ..
  C5-4       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-4 ..
  F5-4       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-3 ..
$
PLENUM-4     =SPACE  LIKE PLENUM-1 ..
   PL-F-4    =EXTERIOR-WALL LIKE PL-F-1 Z=110 ..
   PL-R-4    =EXTERIOR-WALL LIKE PL-R-1 Z=110 ..
   PL-B-4    =EXTERIOR-WALL LIKE PL-B-1 Z=110 ..
   PL-L-4    =EXTERIOR-WALL LIKE PL-L-1 Z=110 ..
$
$FIFTH LEVEL
SPACE1-5     =SPACE LIKE SPACE1-1 ..
  FRONT-5    =EXTERIOR-WALL LIKE FRONT-1 Z=120 ..
  WF-5       =WINDOW SHADING-DIVISION=40 ..
  C1-5       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-5 ..
  F1-5       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-4 ..
  SB12-5     =INTERIOR-WALL LIKE SB12 Z=120 NEXT-TO SPACE2-5 ..
  SB14-5     =INTERIOR-WALL LIKE SB14 Z=120 NEXT-TO SPACE4-5 ..
  SB15-5     =INTERIOR-WALL LIKE SB15 Z=120 NEXT-TO SPACE5-5 ..
$
SPACE2-5     =SPACE LIKE SPACE1-1 ..
  RIGHT-5    =EXTERIOR-WALL LIKE RIGHT-1 Z=120 ..
  WR-5       =WINDOW SHADING-DIVISION=40 ..
  C2-5       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-5 ..
  F2-5       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-4 ..
  SB23-5     =INTERIOR-WALL LIKE SB23 Z=120 NEXT-TO SPACE3-5 ..
  SB25-5     =INTERIOR-WALL LIKE SB25 Z=120 NEXT-TO SPACE5-5 ..
$
SPACE3-5     =SPACE LIKE SPACE1-1 ..
  BACK-5     =EXTERIOR-WALL LIKE BACK-1 Z=120 ..
  WB-5       =WINDOW SHADING-DIVISION=40 ..
  C3-5       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-5 ..
  F3-5       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-4 ..
  SB34-5     =INTERIOR-WALL LIKE SB34 Z=120 NEXT-TO SPACE4-5 ..
  SB35-5     =INTERIOR-WALL LIKE SB35 Z=120 NEXT-TO SPACE5-5 ..
$
SPACE4-5     =SPACE LIKE SPACE1-1 ..
  LEFT-5     =EXTERIOR-WALL LIKE LEFT-1 Z=120 ..
  WL-5       =WINDOW SHADING-DIVISION=40 ..
  C4-5       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-5 ..
  F4-5       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-4 ..
  SB45-5     =INTERIOR-WALL LIKE SB45 Z=120 NEXT-TO SPACE5-5 ..
$
SPACE5-5     =SPACE LIKE SPACE5-1 Z=120 ..
  C5-5       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-5 ..
  F5-5       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-4 ..
$
PLENUM-5     =SPACE  LIKE PLENUM-1 ..
   PL-F-5    =EXTERIOR-WALL LIKE PL-F-1 Z=140 ..
   PL-R-5    =EXTERIOR-WALL LIKE PL-R-1 Z=140 ..
   PL-B-5    =EXTERIOR-WALL LIKE PL-B-1 Z=140 ..
   PL-L-5    =EXTERIOR-WALL LIKE PL-L-1 Z=140 ..
$
$SIXTH LEVEL
SPACE1-6     =SPACE LIKE SPACE1-1 ..
  FRONT-6    =EXTERIOR-WALL LIKE FRONT-1 Z=150 ..
  WF-6       =WINDOW SHADING-DIVISION=40 ..
  C1-6       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-6 ..
  F1-6       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-5 ..
  SB12-6     =INTERIOR-WALL LIKE SB12 Z=150 NEXT-TO SPACE2-6 ..
  SB14-6     =INTERIOR-WALL LIKE SB14 Z=150 NEXT-TO SPACE4-6 ..
  SB15-6     =INTERIOR-WALL LIKE SB15 Z=150 NEXT-TO SPACE5-6 ..
$
SPACE2-6     =SPACE LIKE SPACE1-1 ..
  RIGHT-6    =EXTERIOR-WALL LIKE RIGHT-1 Z=150 ..
  WR-6       =WINDOW SHADING-DIVISION=40 ..
  C2-6       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-6 ..
  F2-6       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-5 ..
  SB23-6     =INTERIOR-WALL LIKE SB23 Z=150 NEXT-TO SPACE3-6 ..
  SB25-6     =INTERIOR-WALL LIKE SB25 Z=150 NEXT-TO SPACE5-6 ..
$
SPACE3-6     =SPACE LIKE SPACE1-1 ..
  BACK-6     =EXTERIOR-WALL LIKE BACK-1 Z=150 ..
```

```
  WB-6      =WINDOW SHADING-DIVISION=40 ..
  C3-6      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-6 ..
  F3-6      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-5 ..
  SB34-6    =INTERIOR-WALL LIKE SB34 Z=150 NEXT-TO SPACE4-6 ..
  SB35-6    =INTERIOR-WALL LIKE SB35 Z=150 NEXT-TO SPACE5-6 ..
$
SPACE4-6     =SPACE LIKE SPACE1-1 ..
  LEFT-6    =EXTERIOR-WALL LIKE LEFT-1 Z=150 ..
  WL-6      =WINDOW SHADING-DIVISION=40 ..
  C4-6      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-6 ..
  F4-6      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-5 ..
  SB45-6    =INTERIOR-WALL LIKE SB45 Z=150 NEXT-TO SPACE5-6 ..
$
SPACE5-6     =SPACE LIKE SPACE5-1 Z=150 ..
  C5-6      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-6 ..
  F5-6      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-5 ..
$
PLENUM-6     =SPACE  LIKE PLENUM-1 ..
   PL-F-6   =EXTERIOR-WALL LIKE PL-F-1 Z=170 ..
   PL-R-6   =EXTERIOR-WALL LIKE PL-R-1 Z=170 ..
   PL-B-6   =EXTERIOR-WALL LIKE PL-B-1 Z=170 ..
   PL-L-6   =EXTERIOR-WALL LIKE PL-L-1 Z=170 ..
$
$LEVEL SEVEN
SPACE1-7     =SPACE LIKE SPACE1-1 ..
  FRONT-7   =EXTERIOR-WALL LIKE FRONT-1 Z=180 ..
  WF-7      =WINDOW SHADING-DIVISION=40 ..
  C1-7      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-7 ..
  F1-7      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-6 ..
  SB12-7    =INTERIOR-WALL LIKE SB12 Z=180 NEXT-TO SPACE2-7 ..
  SB14-7    =INTERIOR-WALL LIKE SB14 Z=180 NEXT-TO SPACE4-7 ..
  SB15-7    =INTERIOR-WALL LIKE SB15 Z=180 NEXT-TO SPACE5-7 ..
$
SPACE2-7     =SPACE LIKE SPACE1-1 ..
  RIGHT-7   =EXTERIOR-WALL LIKE RIGHT-1 Z=180 ..
  WR-7      =WINDOW SHADING-DIVISION=40 ..
  C2-7      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-7 ..
  F2-7      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-6 ..
  SB23-7    =INTERIOR-WALL LIKE SB23 Z=180 NEXT-TO SPACE3-7 ..
  SB25-7    =INTERIOR-WALL LIKE SB25 Z=180 NEXT-TO SPACE5-7 ..
$
SPACE3-7     =SPACE LIKE SPACE1-1 ..
  BACK-7    =EXTERIOR-WALL LIKE BACK-1  Z=180 ..
  WB-7      =WINDOW SHADING-DIVISION=40 ..
  C3-7      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-7 ..
  F3-7      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-6 ..
  SB34-7    =INTERIOR-WALL LIKE SB34 Z=180 NEXT-TO SPACE4-7 ..
  SB35-7    =INTERIOR-WALL LIKE SB35 Z=180 NEXT-TO SPACE5-7 ..
$
SPACE4-7     =SPACE LIKE SPACE1-1 ..
  LEFT-7    =EXTERIOR-WALL LIKE LEFT-1 Z=180 ..
  WL-7      =WINDOW SHADING-DIVISION=40 ..
  C4-7      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-7 ..
  F4-7      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-6 ..
  SB45-7    =INTERIOR-WALL LIKE SB45 Z=180 NEXT-TO SPACE5-7 ..
$
SPACE5-7     =SPACE LIKE SPACE5-1 Z=180 ..
  C5-7      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-7 ..
  F5-7      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-6 ..
$
PLENUM-7     =SPACE  LIKE PLENUM-1 ..
   PL-F-7   =EXTERIOR-WALL LIKE PL-F-1 Z=200 ..
   PL-R-7   =EXTERIOR-WALL LIKE PL-R-1 Z=200 ..
   PL-B-7   =EXTERIOR-WALL LIKE PL-B-1 Z=200 ..
   PL-L-7   =EXTERIOR-WALL LIKE PL-L-1 Z=200 ..
$
$LEVEL EIGHT
SPACE1-8     =SPACE LIKE SPACE1-1 ..
  FRONT-8   =EXTERIOR-WALL LIKE FRONT-1 Z=210 ..
  WF-8      =WINDOW SHADING-DIVISION=40 ..
  C1-8      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-8 ..
  F1-8      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-7 ..
  SB12-8    =INTERIOR-WALL LIKE SB12 Z=210 NEXT-TO SPACE2-8 ..
  SB14-8    =INTERIOR-WALL LIKE SB14 Z=210 NEXT-TO SPACE4-8 ..
  SB15-8    =INTERIOR-WALL LIKE SB15 Z=210 NEXT-TO SPACE5-8 ..
$
SPACE2-8     =SPACE LIKE SPACE1-1 ..
  RIGHT-8   =EXTERIOR-WALL LIKE RIGHT-1 Z=210 ..
  WR-8      =WINDOW SHADING-DIVISION=40 ..
  C2-8      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-8 ..
  F2-8      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-7 ..
  SB23-8    =INTERIOR-WALL LIKE SB23 Z=210 NEXT-TO SPACE3-8 ..
  SB25-8    =INTERIOR-WALL LIKE SB25 Z=210 NEXT-TO SPACE5-8 ..
$
SPACE3-8     =SPACE LIKE SPACE1-1 ..
  BACK-8    =EXTERIOR-WALL LIKE BACK-1 Z=210 ..
  WB-8      =WINDOW SHADING-DIVISION=40 ..
```

```
  C3-8      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-8 ..
  F3-8      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-7 ..
  SB34-8    =INTERIOR-WALL LIKE SB34 Z=210 NEXT-TO SPACE4-8 ..
  SB35-8    =INTERIOR-WALL LIKE SB35 Z=210 NEXT-TO SPACE5-8 ..
$
SPACE4-8      =SPACE LIKE SPACE1-1 ..
  LEFT-8    =EXTERIOR-WALL LIKE LEFT-1 Z=210 ..
  WL-8      =WINDOW SHADING-DIVISION=40 ..
  C4-8      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-8 ..
  F4-8      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-7 ..
  SB45-8    =INTERIOR-WALL LIKE SB45 Z=210 NEXT-TO SPACE5-8 ..
$
SPACE5-8      =SPACE LIKE SPACE5-1 Z=210 ..
  C5-8      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-8 ..
  F5-8      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-7 ..
$
PLENUM-8      =SPACE  LIKE PLENUM-1 ..
   PL-F-8    =EXTERIOR-WALL LIKE PL-F-1 Z=230 ..
   PL-R-8    =EXTERIOR-WALL LIKE PL-R-1 Z=230 ..
   PL-B-8    =EXTERIOR-WALL LIKE PL-B-1 Z=230 ..
   PL-L-8    =EXTERIOR-WALL LIKE PL-L-1 Z=230 ..
$
$LEVEL NINE
SPACE1-9      =SPACE LIKE SPACE1-1 ..
  FRONT-9   =EXTERIOR-WALL LIKE FRONT-1 Z=240 ..
  WF-9      =WINDOW SHADING-DIVISION=40 ..
  C1-9      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-9 ..
  F1-9      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-8 ..
  SB12-9    =INTERIOR-WALL LIKE SB12 Z=240 NEXT-TO SPACE2-9 ..
  SB14-9    =INTERIOR-WALL LIKE SB14 Z=240 NEXT-TO SPACE4-9 ..
  SB15-9    =INTERIOR-WALL LIKE SB15 Z=240 NEXT-TO SPACE5-9 ..
$
SPACE2-9      =SPACE LIKE SPACE1-1 ..
  RIGHT-9   =EXTERIOR-WALL LIKE RIGHT-1 Z=240 ..
  WR-9      =WINDOW SHADING-DIVISION=40 ..
  C2-9      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-9 ..
  F2-9      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-8 ..
  SB23-9    =INTERIOR-WALL LIKE SB23 Z=240 NEXT-TO SPACE3-9 ..
  SB25-9    =INTERIOR-WALL LIKE SB25 Z=240 NEXT-TO SPACE5-9 ..
$
SPACE3-9      =SPACE LIKE SPACE1-1 ..
  BACK-9    =EXTERIOR-WALL LIKE BACK-1 Z=240 ..
  WB-9      =WINDOW SHADING-DIVISION=40 ..
  C3-9      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-9 ..
  F3-9      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-8 ..
  SB34-9    =INTERIOR-WALL LIKE SB34 Z=240 NEXT-TO SPACE4-9 ..
  SB35-9    =INTERIOR-WALL LIKE SB35 Z=240 NEXT-TO SPACE5-9 ..
$
SPACE4-9      =SPACE LIKE SPACE1-1 ..
  LEFT-9    =EXTERIOR-WALL LIKE LEFT-1 Z=240 ..
  WL-9      =WINDOW SHADING-DIVISION=40 ..
  C4-9      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-9 ..
  F4-9      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-8 ..
  SB45-9    =INTERIOR-WALL LIKE SB45 Z=240 NEXT-TO SPACE5-9 ..
$
SPACE5-9      =SPACE LIKE SPACE5-1 Z=240 ..
  C5-9      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-9 ..
  F5-9      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-8 ..
$
PLENUM-9      =SPACE  LIKE PLENUM-1 ..
   PL-F-9    =EXTERIOR-WALL LIKE PL-F-1 Z=260 ..
   PL-R-9    =EXTERIOR-WALL LIKE PL-R-1 Z=260 ..
   PL-B-9    =EXTERIOR-WALL LIKE PL-B-1 Z=260 ..
   PL-L-9    =EXTERIOR-WALL LIKE PL-L-1 Z=260 ..
$
SPACE1-10     =SPACE LIKE SPACE1-1 ..
  FRONT-10   =EXTERIOR-WALL LIKE FRONT-1 Z=270 ..
  WF-10      =WINDOW SHADING-DIVISION=40 ..
  C1-10      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-10 ..
  F1-10      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-9 ..
  SB12-10    =INTERIOR-WALL LIKE SB12 Z=270 NEXT-TO SPACE2-10 ..
  SB14-10    =INTERIOR-WALL LIKE SB14 Z=270 NEXT-TO SPACE4-10 ..
  SB15-10    =INTERIOR-WALL LIKE SB15 Z=270 NEXT-TO SPACE5-10 ..
$
SPACE2-10     =SPACE LIKE SPACE1-1 ..
  RIGHT-10   =EXTERIOR-WALL LIKE RIGHT-1 Z=270 ..
  WR-10      =WINDOW SHADING-DIVISION=40 ..
  C2-10      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-10 ..
  F2-10      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-9 ..
  SB23-10    =INTERIOR-WALL  LIKE SB23 Z=270  NEXT-TO SPACE3-10 ..
  SB25-10    =INTERIOR-WALL LIKE SB25 Z=270 NEXT-TO SPACE5-10 ..
$
SPACE3-10     =SPACE LIKE SPACE1-1 ..
  BACK-10    =EXTERIOR-WALL LIKE BACK-1 Z=270 ..
  WB-10      =WINDOW SHADING-DIVISION=40 ..
  C3-10      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-10 ..
  F3-10      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-9
```

```
  SB34-10    =INTERIOR-WALL LIKE SB34 Z=270 NEXT-TO SPACE4-10 ..
  SB35-10    =INTERIOR-WALL LIKE SB35 Z=270 NEXT-TO SPACE5-10 ..
$
SPACE4-10     =SPACE LIKE SPACE1-1 ..
  LEFT-10    =EXTERIOR-WALL LIKE LEFT-1 Z=270 ..
  WL-10      =WINDOW SHADING-DIVISION=40 ..
  C4-10      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-10 ..
  F4-10      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-9 ..
  SB45-10    =INTERIOR-WALL LIKE SB45 Z=270 NEXT-TO SPACE5-10 ..
$
SPACE5-10     =SPACE LIKE SPACE5-1 Z=270 ..
  C5-10      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-10 ..
  F5-10      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-9 ..
$
PLENUM-10     =SPACE  LIKE PLENUM-1 ..
   PL-F-10   =EXTERIOR-WALL LIKE PL-F-1 Z=290 ..
   PL-R-10   =EXTERIOR-WALL LIKE PL-R-1 Z=290 ..
   PL-B-10   =EXTERIOR-WALL LIKE PL-B-1 Z=290 ..
   PL-L-10   =EXTERIOR-WALL LIKE PL-L-1 Z=290 ..
$
$LEVEL ELEVEN
$
SPACE1-11     =SPACE LIKE SPACE1-1 ..
  FRONT-11   =EXTERIOR-WALL LIKE FRONT-1 Z=300 ..
  WF-11      =WINDOW SHADING-DIVISION=40 ..
  C1-11      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-11 ..
  F1-11      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-10 ..
  SB12-11    =INTERIOR-WALL LIKE SB12 Z=300 NEXT-TO SPACE2-11 ..
  SB14-11    =INTERIOR-WALL LIKE SB14 Z=300 NEXT-TO SPACE4-11 ..
  SB15-11    =INTERIOR-WALL LIKE SB15 Z=300 NEXT-TO SPACE5-11 ..
$
SPACE2-11     =SPACE LIKE SPACE1-1 ..
  RIGHT-11   =EXTERIOR-WALL LIKE RIGHT-1 Z=300 ..
  WR-11      =WINDOW SHADING-DIVISION=40 ..
  C2-11      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-11 ..
  F2-11      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-10 ..
  SB23-11    =INTERIOR-WALL LIKE SB23 Z=300 NEXT-TO SPACE3-11 ..
  SB25-11    =INTERIOR-WALL LIKE SB25 Z=300 NEXT-TO SPACE5-11 ..
$
SPACE3-11     =SPACE LIKE SPACE1-1 ..
  BACK-11    =EXTERIOR-WALL LIKE BACK-1 Z=300 ..
  WB-11      =WINDOW SHADING-DIVISION=40 ..
  C3-11      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-11 ..
  F3-11      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-10 ..
  SB34-11    =INTERIOR-WALL LIKE SB34 Z=300 NEXT-TO SPACE4-11 ..
  SB35-11    =INTERIOR-WALL LIKE SB35 Z=300 NEXT-TO SPACE5-11 ..
$
SPACE4-11     =SPACE LIKE SPACE1-1 ..
  LEFT-11    =EXTERIOR-WALL LIKE LEFT-1 Z=300 ..
  WL-11      =WINDOW SHADING-DIVISION=40 ..
  C4-11      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-11 ..
  F4-11      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-10 ..
  SB45-11    =INTERIOR-WALL LIKE SB45 Z=300 NEXT-TO SPACE5-11 ..
$
SPACE5-11     =SPACE LIKE SPACE5-1 Z=300 ..
  C5-11      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-11 ..
  F5-11      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-10 ..
$
PLENUM-11     =SPACE  LIKE PLENUM-1 ..
   PL-F-11   =EXTERIOR-WALL LIKE PL-F-1 Z=320 ..
   PL-R-11   =EXTERIOR-WALL LIKE PL-R-1 Z=320 ..
   PL-B-11   =EXTERIOR-WALL LIKE PL-B-1 Z=320 ..
   PL-L-11   =EXTERIOR-WALL LIKE PL-L-1 Z=320 ..
$
$LEVEL TWELVE
SPACE1-12     =SPACE LIKE SPACE1-1 ..
  FRONT-12   =EXTERIOR-WALL LIKE FRONT-1 Z=330 ..
  WF-12      =WINDOW SHADING-DIVISION=40 ..
  C1-12      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-12 ..
  F1-12      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-11 ..
  SB12-12    =INTERIOR-WALL LIKE SB12 Z=330 NEXT-TO SPACE2-12 ..
  SB14-12    =INTERIOR-WALL LIKE SB14 Z=330 NEXT-TO SPACE4-12 ..
  SB15-12    =INTERIOR-WALL LIKE SB15 Z=330 NEXT-TO SPACE5-12 ..
$
SPACE2-12     =SPACE LIKE SPACE1-1 ..
  RIGHT-12   =EXTERIOR-WALL LIKE RIGHT-1 Z=330 ..
  WR-12      =WINDOW SHADING-DIVISION=40 ..
  C2-12      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-12 ..
  F2-12      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-11 ..
  SB23-12    =INTERIOR-WALL LIKE SB23 Z=330 NEXT-TO SPACE3-12 ..
  SB25-12    =INTERIOR-WALL LIKE SB25 Z=330 NEXT-TO SPACE5-12 ..
$
SPACE3-12     =SPACE LIKE SPACE1-1 ..
  BACK-12    =EXTERIOR-WALL LIKE BACK-1 Z=330 ..
  WB-12      =WINDOW SHADING-DIVISION=40 ..
  C3-12      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-12 ..
  F3-12      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-11 ..
```

```
  SB34-12    =INTERIOR-WALL  LIKE SB34 Z=330  NEXT-TO SPACE4-12 ..
  SB35-12    =INTERIOR-WALL LIKE SB35 Z=330 NEXT-TO SPACE5-12 ..
$
SPACE4-12      =SPACE LIKE SPACE1-1 ..
  LEFT-12    =EXTERIOR-WALL LIKE LEFT-1 Z=330 ..
  WL-12      =WINDOW SHADING-DIVISION=40 ..
  C4-12      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-12 ..
  F4-12      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-11 ..
  SB45-12    =INTERIOR-WALL LIKE SB45 Z=330 NEXT-TO SPACE5-12 ..
$
SPACE5-12      =SPACE LIKE SPACE5-1 Z=330 ..
  C5-12      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-12 ..
  F5-12      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-11 ..
$
PLENUM-12      =SPACE  LIKE PLENUM-1 ..
   PL-F-12    =EXTERIOR-WALL LIKE PL-F-1 Z=350 ..
   PL-R-12    =EXTERIOR-WALL LIKE PL-R-1 Z=350 ..
   PL-B-12    =EXTERIOR-WALL LIKE PL-B-1 Z=350 ..
   PL-L-12    =EXTERIOR-WALL LIKE PL-L-1 Z=350 ..
$
$LEVEL THIRTEEN
SPACE1-13      =SPACE LIKE SPACE1-1 ..
  FRONT-13    =EXTERIOR-WALL LIKE FRONT-1 Z=360 ..
  WF-13      =WINDOW SHADING-DIVISION=40 ..
  C1-13      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-13 ..
  F1-13      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-12 ..
  SB12-13    =INTERIOR-WALL LIKE SB12 Z=360 NEXT-TO SPACE2-13 ..
  SB14-13    =INTERIOR-WALL LIKE SB14 Z=360 NEXT-TO SPACE4-13 ..
  SB15-13    =INTERIOR-WALL LIKE SB15 Z=360 NEXT-TO SPACE5-13 ..
$
SPACE2-13      =SPACE LIKE SPACE1-1 ..
  RIGHT-13    =EXTERIOR-WALL LIKE RIGHT-1 Z=360 ..
  WR-13      =WINDOW SHADING-DIVISION=40 ..
  C2-13      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-13 ..
  F2-13      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-12 ..
  SB23-13    =INTERIOR-WALL LIKE SB23 Z=360 NEXT-TO SPACE3-13 ..
  SB25-13    =INTERIOR-WALL LIKE SB25 Z=360 NEXT-TO SPACE5-13 ..
$
SPACE3-13      =SPACE LIKE SPACE1-1 ..
  BACK-13    =EXTERIOR-WALL LIKE BACK-1 Z=360 ..
  WB-13      =WINDOW SHADING-DIVISION=40 ..
  C3-13      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-13 ..
  F3-13      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-12 ..
  SB34-13    =INTERIOR-WALL LIKE SB34 Z=360 NEXT-TO SPACE4-13 ..
  SB35-13    =INTERIOR-WALL LIKE SB35 Z=360 NEXT-TO SPACE5-13 ..
$
SPACE4-13      =SPACE LIKE SPACE1-1 ..
  LEFT-13    =EXTERIOR-WALL LIKE LEFT-1 Z=360 ..
  WL-13      =WINDOW SHADING-DIVISION=40 ..
  C4-13      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-13 ..
  F4-13      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-12 ..
  SB45-13    =INTERIOR-WALL LIKE SB45 Z=360 NEXT-TO SPACE5-13 ..
$
SPACE5-13      =SPACE LIKE SPACE5-1 Z=360 ..
  C5-13      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-13 ..
  F5-13      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-12 ..
$
PLENUM-13      =SPACE  LIKE PLENUM-1 ..
   PL-F-13    =EXTERIOR-WALL LIKE PL-F-1 Z=380 ..
   PL-R-13    =EXTERIOR-WALL LIKE PL-R-1 Z=380 ..
   PL-B-13    =EXTERIOR-WALL LIKE PL-B-1 Z=380 ..
   PL-L-13    =EXTERIOR-WALL LIKE PL-L-1 Z=380 ..
$
$LEVEL FOURTEEN
SPACE1-14      =SPACE LIKE SPACE1-1 ..
  FRONT-14    =EXTERIOR-WALL LIKE FRONT-1 Z=390 ..
  WF-14      =WINDOW SHADING-DIVISION=40 ..
  C1-14      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-14 ..
  F1-14      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-13 ..
  SB12-14    =INTERIOR-WALL LIKE SB12 Z=390 NEXT-TO SPACE2-14 ..
  SB14-14    =INTERIOR-WALL LIKE SB14 Z=390 NEXT-TO SPACE4-14 ..
  SB15-14    =INTERIOR-WALL LIKE SB15 Z=390 NEXT-TO SPACE5-14 ..
$
SPACE2-14      =SPACE LIKE SPACE1-1 ..
  RIGHT-14    =EXTERIOR-WALL LIKE RIGHT-1 Z=390 ..
  WR-14      =WINDOW SHADING-DIVISION=40 ..
  C2-14      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-14 ..
  F2-14      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-13 ..
  SB23-14    =INTERIOR-WALL LIKE SB23 Z=390 NEXT-TO SPACE3-14
  SB25-14    =INTERIOR-WALL LIKE SB25 Z=390 NEXT-TO SPACE5-14 ..
$
SPACE3-14      =SPACE LIKE SPACE1-1 ..
  BACK-14    =EXTERIOR-WALL LIKE BACK-1 Z=390 ..
  WB-14      =WINDOW SHADING-DIVISION=40 ..
  C3-14      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-14 ..
  F3-14      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-13 ..
  SB34-14    =INTERIOR-WALL LIKE SB34 Z=390 NEXT-TO SPACE4-14
```

```
  SB35-14     =INTERIOR-WALL LIKE SB35 Z=390 NEXT-TO SPACE5-14 ..
$
SPACE4-14      =SPACE LIKE SPACE1-1 ..
  LEFT-14     =EXTERIOR-WALL LIKE LEFT-1 Z=390 ..
  WL-14      =WINDOW SHADING-DIVISION=40 ..
  C4-14      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-14 ..
  F4-14      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-13 ..
  SB45-14     =INTERIOR-WALL LIKE SB45 Z=390 NEXT-TO SPACE5-14 ..
$
SPACE5-14      =SPACE LIKE SPACE5-1 Z=390 ..
  C5-14      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-14 ..
  F5-14      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-13 ..
$
PLENUM-14      =SPACE  LIKE PLENUM-1 ..
   PL-F-14    =EXTERIOR-WALL LIKE PL-F-1 Z=410 ..
   PL-R-14    =EXTERIOR-WALL LIKE PL-R-1 Z=410 ..
   PL-B-14    =EXTERIOR-WALL LIKE PL-B-1 Z=410 ..
   PL-L-14    =EXTERIOR-WALL LIKE PL-L-1 Z=410 ..
$
$LEVEL FIFTEEN
SPACE1-15      =SPACE LIKE SPACE1-1 ..
  FRONT-15    =EXTERIOR-WALL LIKE FRONT-1 Z=420 ..
  WF-15      =WINDOW SHADING-DIVISION=40 ..
  C1-15      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-15 ..
  F1-15      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-14 ..
  SB12-15     =INTERIOR-WALL LIKE SB12 Z=420 NEXT-TO SPACE2-15 ..
  SB14-15     =INTERIOR-WALL LIKE SB14 Z=420 NEXT-TO SPACE4-15 ..
  SB15-15     =INTERIOR-WALL LIKE SB15 Z=420 NEXT-TO SPACE5-15 ..
$
SPACE2-15      =SPACE LIKE SPACE1-1 ..
  RIGHT-15    =EXTERIOR-WALL LIKE RIGHT-1 Z=420 ..
  WR-15      =WINDOW SHADING-DIVISION=40 ..
  C2-15      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-15 ..
  F2-15      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-14 ..
  SB23-15     =INTERIOR-WALL LIKE SB23 Z=420 NEXT-TO SPACE3-15 ..
  SB25-15     =INTERIOR-WALL LIKE SB25 Z=420 NEXT-TO SPACE5-15 ..
$
SPACE3-15      =SPACE LIKE SPACE1-1 ..
  BACK-15     =EXTERIOR-WALL LIKE BACK-1 Z=420 ..
  WB-15      =WINDOW SHADING-DIVISION=40 ..
  C3-15      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-15 ..
  F3-15      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-14 ..
  SB34-15     =INTERIOR-WALL LIKE SB34 Z=420 NEXT-TO SPACE4-15 ..
  SB35-15     =INTERIOR-WALL LIKE SB35 Z=420 NEXT-TO SPACE5-15 ..
$
SPACE4-15      =SPACE LIKE SPACE1-1 ..
  LEFT-15     =EXTERIOR-WALL LIKE LEFT-1 Z=420 ..
  WL-15      =WINDOW SHADING-DIVISION=40 ..
  C4-15      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-15 ..
  F4-15      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-14 ..
  SB45-15     =INTERIOR-WALL LIKE SB45 Z=420 NEXT-TO SPACE5-15 ..
$
SPACE5-15      =SPACE LIKE SPACE5-1 Z=420 ..
  C5-15      =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-15 ..
  F5-15      =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-14 ..
$
PLENUM-15      =SPACE  LIKE PLENUM-1 ..
   PL-F-15    =EXTERIOR-WALL LIKE PL-F-1 Z=440 ..
   PL-R-15    =EXTERIOR-WALL LIKE PL-R-1 Z=440 ..
   PL-B-15    =EXTERIOR-WALL LIKE PL-B-1 Z=440 ..
   PL-L-15    =EXTERIOR-WALL LIKE PL-L-1 Z=440 ..
$
$LEVEL SIXTEEN
SPACE1-16      =SPACE LIKE SPACE1-1 ..
  FRONT-16    =EXTERIOR-WALL LIKE FRONT-1 Z=450 ..
  WF-16      =WINDOW SHADING-DIVISION=40 ..
  C1-16      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-16 ..
  F1-16      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-15 ..
  SB12-16     =INTERIOR-WALL LIKE SB12 Z=450 NEXT-TO SPACE2-16 ..
  SB14-16     =INTERIOR-WALL LIKE SB14 Z=450 NEXT-TO SPACE4-16 ..
  SB15-16     =INTERIOR-WALL LIKE SB15 Z=450 NEXT-TO SPACE5-16 ..
$
SPACE2-16      =SPACE LIKE SPACE1-1 ..
  RIGHT-16    =EXTERIOR-WALL LIKE RIGHT-1 Z=450 ..
  WR-16      =WINDOW SHADING-DIVISION=40 ..
  C2-16      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-16 ..
  F2-16      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-15 ..
  SB23-16     =INTERIOR-WALL LIKE SB23 Z=450 NEXT-TO SPACE3-16 ..
  SB25-16     =INTERIOR-WALL LIKE SB25 Z=450 NEXT-TO SPACE5-16 ..
$
SPACE3-16      =SPACE LIKE SPACE1-1 ..
  BACK-16     =EXTERIOR-WALL LIKE BACK-1 Z=450 ..
  WB-16      =WINDOW SHADING-DIVISION=40 ..
  C3-16      =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-16 ..
  F3-16      =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-15 ..
  SB34-16     =INTERIOR-WALL LIKE SB34 Z=450 NEXT-TO SPACE4-16 ..
  SB35-16     =INTERIOR-WALL LIKE SB35 Z=450 NEXT-TO SPACE5-16 ..
```

```
$
SPACE4-16      =SPACE LIKE SPACE1-1 ..
  LEFT-16      =EXTERIOR-WALL LIKE LEFT-1 Z=450 ..
  WL-16        =WINDOW SHADING-DIVISION=40 ..
  C4-16        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-16 ..
  F4-16        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-15 ..
  SB45-16      =INTERIOR-WALL LIKE SB45 Z=450 NEXT-TO SPACE5-16 ..
$
SPACE5-16      =SPACE LIKE SPACE5-1 Z=450 ..
  C5-16        =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-16 ..
  F5-16        =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-15 ..
$
PLENUM-16      =SPACE LIKE PLENUM-1 ..
   PL-F-16     =EXTERIOR-WALL LIKE PL-F-1 Z=470 ..
   PL-R-16     =EXTERIOR-WALL LIKE PL-R-1 Z=470 ..
   PL-B-16     =EXTERIOR-WALL LIKE PL-B-1 Z=470 ..
   PL-L-16     =EXTERIOR-WALL LIKE PL-L-1 Z=470 ..
$
$LEVEL SEVENTEEN
SPACE1-17      =SPACE LIKE SPACE1-1 ..
  FRONT-17     =EXTERIOR-WALL LIKE FRONT-1 Z=480 ..
  WF-17        =WINDOW SHADING-DIVISION=40 ..
  C1-17        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-17 ..
  F1-17        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-16 ..
  SB12-17      =INTERIOR-WALL LIKE SB12 Z=480 NEXT-TO SPACE2-17 ..
  SB14-17      =INTERIOR-WALL LIKE SB14 Z=480 NEXT-TO SPACE4-17 ..
  SB15-17      =INTERIOR-WALL LIKE SB15 Z=480 NEXT-TO SPACE5-17 ..
$
SPACE2-17      =SPACE LIKE SPACE1-1 ..
  RIGHT-17     =EXTERIOR-WALL LIKE RIGHT-1 Z=480 ..
  WR-17        =WINDOW SHADING-DIVISION=40 ..
  C2-17        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-17 ..
  F2-17        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-16 ..
  SB23-17      =INTERIOR-WALL LIKE SB23 Z=480 NEXT-TO SPACE3-17 ..
  SB25-17      =INTERIOR-WALL LIKE SB25 Z=480 NEXT-TO SPACE5-17 ..
$
SPACE3-17      =SPACE LIKE SPACE1-1 ..
  BACK-17      =EXTERIOR-WALL LIKE BACK-1 Z=480 ..
  WB-17        =WINDOW SHADING-DIVISION=40 ..
  C3-17        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-17 ..
  F3-17        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-16 ..
  SB34-17      =INTERIOR-WALL LIKE SB34 Z=480 NEXT-TO SPACE4-17 ..
  SB35-17      =INTERIOR-WALL LIKE SB35 Z=480 NEXT-TO SPACE5-17 ..
$
SPACE4-17      =SPACE LIKE SPACE1-1 ..
  LEFT-17      =EXTERIOR-WALL LIKE LEFT-1 Z=480 ..
  WL-17        =WINDOW SHADING-DIVISION=40 ..
  C4-17        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-17 ..
  F4-17        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-16 ..
  SB45-17      =INTERIOR-WALL LIKE SB45 Z=480 NEXT-TO SPACE5-17 ..
$
SPACE5-17      =SPACE LIKE SPACE5-1 z=480 ..
  C5-17        =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-17 ..
  F5-17        =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-16 ..
$
PLENUM-17      =SPACE  LIKE PLENUM-1 ..
   PL-F-17     =EXTERIOR-WALL LIKE PL-F-1 Z=500 ..
   PL-R-17     =EXTERIOR-WALL LIKE PL-R-1 Z=500 ..
   PL-B-17     =EXTERIOR-WALL LIKE PL-B-1 Z=500 ..
   PL-L-17     =EXTERIOR-WALL LIKE PL-L-1 Z=500 ..
$
$LEVEL EIGHTEEN
SPACE1-18      =SPACE LIKE SPACE1-1 ..
  FRONT-18     =EXTERIOR-WALL LIKE FRONT-1 Z=510 ..
  WF-18        =WINDOW SHADING-DIVISION=40 ..
  C1-18        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-18 ..
  F1-18        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-17 ..
  SB12-18      =INTERIOR-WALL LIKE SB12 Z=510 NEXT-TO SPACE2-18 ..
  SB14-18      =INTERIOR-WALL LIKE SB14 Z=510 NEXT-TO SPACE4-18 ..
  SB15-18      =INTERIOR-WALL LIKE SB15 Z=510 NEXT-TO SPACE5-18 ..
$
SPACE2-18      =SPACE LIKE SPACE1-1 ..
  RIGHT-18     =EXTERIOR-WALL LIKE RIGHT-1 Z=510 ..
  WR-18        =WINDOW SHADING-DIVISION=40 ..
  C2-18        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-18 ..
  F2-18        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-17 ..
  SB23-18      =INTERIOR-WALL LIKE SB23 Z=510 NEXT-TO SPACE3-18 ..
  SB25-18      =INTERIOR-WALL LIKE SB25 Z=510 NEXT-TO SPACE5-18 ..
$
SPACE3-18      =SPACE LIKE SPACE1-1 ..
  BACK-18      =EXTERIOR-WALL LIKE BACK-1 Z=510 ..
  WB-18        =WINDOW SHADING-DIVISION=40 ..
  C3-18        =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-18 ..
  F3-18        =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-17 ..
  SB34-18      =INTERIOR-WALL LIKE SB34 Z=510 NEXT-TO SPACE4-18 ..
  SB35-18      =INTERIOR-WALL LIKE SB35 Z=510 NEXT-TO SPACE5-18 ..
$
```

```
SPACE4-18      =SPACE LIKE SPACE1-1 ..
   LEFT-18     =EXTERIOR-WALL LIKE LEFT-1 Z=510 ..
   WL-18       =WINDOW SHADING-DIVISION=40 ..
   C4-18       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-18 ..
   F4-18       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-17 ..
   SB45-18     =INTERIOR-WALL LIKE SB45 Z=510 NEXT-TO SPACE5-18 ..
$
SPACE5-18      =SPACE LIKE SPACE5-1 Z=510 ..
   C5-18       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-18 ..
   F5-18       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-17 ..
$
PLENUM-18      =SPACE  LIKE PLENUM-1 ..
    PL-F-18    =EXTERIOR-WALL LIKE PL-F-1 Z=530 ..
    PL-R-18    =EXTERIOR-WALL LIKE PL-R-1 Z=530 ..
    PL-B-18    =EXTERIOR-WALL LIKE PL-B-1 Z=530 ..
    PL-L-18    =EXTERIOR-WALL LIKE PL-L-1 Z=530 ..
$
$LEVEL NINETEEN
SPACE1-19      =SPACE LIKE SPACE1-1 ..
   FRONT-19    =EXTERIOR-WALL LIKE FRONT-1 Z=540 ..
   WF-19       =WINDOW SHADING-DIVISION=40 ..
   C1-19       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-19 ..
   F1-19       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-18 ..
   SB12-19     =INTERIOR-WALL LIKE SB12 Z=540 NEXT-TO SPACE2-19 ..
   SB14-19     =INTERIOR-WALL LIKE SB14 Z=540 NEXT-TO SPACE4-19 ..
   SB15-19     =INTERIOR-WALL LIKE SB15 Z=540 NEXT-TO SPACE5-19 ..
$
SPACE2-19      =SPACE LIKE SPACE1-1 ..
   RIGHT-19    =EXTERIOR-WALL LIKE RIGHT-1 Z=540 ..
   WR-19       =WINDOW SHADING-DIVISION=40 ..
   C2-19       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-19 ..
   F2-19       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-18 ..
   SB23-19     =INTERIOR-WALL LIKE SB23 Z=540 NEXT-TO SPACE3-19 ..
   SB25-19     =INTERIOR-WALL LIKE SB25 Z=540 NEXT-TO SPACE5-19 ..
$
SPACE3-19      =SPACE LIKE SPACE1-1 ..
   BACK-19     =EXTERIOR-WALL LIKE BACK-1 Z=540 ..
   WB-19       =WINDOW SHADING-DIVISION=40 ..
   C3-19       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-19 ..
   F3-19       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-18 ..
   SB34-19     =INTERIOR-WALL LIKE SB34 Z=540 NEXT-TO SPACE4-19 ..
   SB35-19     =INTERIOR-WALL LIKE SB35 Z=540 NEXT-TO SPACE5-19 ..
$
SPACE4-19      =SPACE LIKE SPACE1-1 ..
   LEFT-19     =EXTERIOR-WALL LIKE LEFT-1 Z=540 ..
   WL-19       =WINDOW SHADING-DIVISION=40 ..
   C4-19       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-19 ..
   F4-19       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-18 ..
   SB45-19     =INTERIOR-WALL LIKE SB45 Z=540 NEXT-TO SPACE5-19 ..
$
SPACE5-19      =SPACE LIKE SPACE5-1 Z=540 ..
   C5-19       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-19 ..
   F5-19       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-18 ..
$
PLENUM-19      =SPACE  LIKE PLENUM-1 ..
    PL-F-19    =EXTERIOR-WALL LIKE PL-F-1 Z=560 ..
    PL-R-19    =EXTERIOR-WALL LIKE PL-R-1 Z=560 ..
    PL-B-19    =EXTERIOR-WALL LIKE PL-B-1 Z=560 ..
    PL-L-19    =EXTERIOR-WALL LIKE PL-L-1 Z=560 ..
$
$LEVEL TWENTY
SPACE1-20      =SPACE LIKE SPACE1-1 ..
   FRONT-20    =EXTERIOR-WALL LIKE FRONT-1 Z=570 ..
   WF-20       =WINDOW SHADING-DIVISION=40 ..
   C1-20       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-20 ..
   F1-20       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-19 ..
   SB12-20     =INTERIOR-WALL LIKE SB12 Z=570 NEXT-TO SPACE2-20 ..
   SB14-20     =INTERIOR-WALL LIKE SB14 Z=570 NEXT-TO SPACE4-20 ..
   SB15-20     =INTERIOR-WALL LIKE SB15 Z=570 NEXT-TO SPACE5-20 ..
$
SPACE2-20      =SPACE LIKE SPACE1-1 ..
   RIGHT-20    =EXTERIOR-WALL LIKE RIGHT-1 Z=570 ..
   WR-20       =WINDOW SHADING-DIVISION=40 ..
   C2-20       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-20 ..
   F2-20       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-19 ..
   SB23-20     =INTERIOR-WALL LIKE SB23 Z=570 NEXT-TO SPACE3-20 ..
   SB25-20     =INTERIOR-WALL LIKE SB25 Z=570 NEXT-TO SPACE5-20 ..
$
SPACE3-20      =SPACE LIKE SPACE1-1 ..
   BACK-20     =EXTERIOR-WALL LIKE BACK-1 Z=570 ..
   WB-20       =WINDOW SHADING-DIVISION=40 ..
   C3-20       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-20 ..
   F3-20       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-19 ..
   SB34-20     =INTERIOR-WALL LIKE SB34 Z=570 NEXT-TO SPACE4-20 ..
   SB35-20     =INTERIOR-WALL LIKE SB35 Z=570 NEXT-TO SPACE5-20 ..
$
SPACE4-20      =SPACE LIKE SPACE1-1 ..
```

```
  LEFT-20     =EXTERIOR-WALL LIKE LEFT-1 Z=570 ..
  WL-20       =WINDOW SHADING-DIVISION=40 ..
  C4-20       =INTERIOR-WALL LIKE C1-1 NEXT-TO PLENUM-20 ..
  F4-20       =INTERIOR-WALL LIKE F1-1 NEXT-TO PLENUM-19 ..
  SB45-20     =INTERIOR-WALL LIKE SB45 Z=570 NEXT-TO SPACE5-20 ..
$
SPACE5-20     =SPACE LIKE SPACE5-1 Z=570 ..
  C5-20       =INTERIOR-WALL LIKE C5-1 NEXT-TO PLENUM-20 ..
  F5-20       =INTERIOR-WALL LIKE F5-1 NEXT-TO PLENUM-19 ..
$
PLENUM-20     =SPACE  LIKE PLENUM-1 ..
   PL-F-20    =EXTERIOR-WALL LIKE PL-F-1 Z=590 ..
   PL-R-20    =EXTERIOR-WALL LIKE PL-R-1 Z=590 ..
   PL-B-20    =EXTERIOR-WALL LIKE PL-B-1 Z=590 ..
   PL-L-20    =EXTERIOR-WALL LIKE PL-L-1 Z=590 ..
   TOP-1      =ROOF HEIGHT=100 WIDTH=100 AZ=180 CONSTRUCTION=ROOF-1
         TILT=0 X=0 Y=0 Z=600 ..
$
END ..
COMPUTE LOADS ..
INPUT SYSTEMS ..
$
$
           $ HVAC SYSTEM DESCRIPTION
$
$ DESIGN TEMPS  COOLING 75F  HEATING 72F.
$ SYSTEM TYPE   A SINGLE VARIABLE AIR VOLUME SYSTEM SERVES THE ENTIRE BUILDING.
$         THE SYSTEM HAS A DRY BULB CONTROLLED ECONOMIZER WITH A LIMIT
$         TEMP OF 68F. THE FAN HAS INLET VANES.
$         THE VAV BOXES HAVE A MINIMUM STOP OF 25%.
$         ELECTRIC BASEBOARDS IN ALL PERIMETER SPACES ARE
$         SUFFICIENTLY LARGE TO HEAT THE SPACE BUT NOT PICK UP THE HEATING
$         LOAD ON A COLD WINTER MORNING; THEREFORE, A GAS WARM-UP CYCLE IS
$         IS PROVIDED WHICH MINIMIZES THE USE OF THE ELECTRIC BASEBOARDS
$         AND REDUCES THE ELECTRIC DEMAND CHARGES.  IT IS VERY DIFFICULT
$         TO SIMULATE THE DYNAMICS OF THIS CONTROL STRATEGY CORRECTLY AS
$         ON SOME MORNINGS SPACES ARE UNDERHEATED, AND ON OTHERS THEY ARE
$         OVERHEATED.  THE OPERATOR OF THE BUILDING WOULD IN FACT NEED TO
$         TUNE THE SUPPLY AIR TEMPERATURE SETPOINT TO ELIMINATE THE
$         PROBLEM.

$         THE SUPPLY AIR TEMPERATURE IS SET AT 100F FOR ONE HOUR ON WINTER
$         MORNINGS AND THE CONTROL OF THE VAV BOXES OPENS THE BOXES
$         FULL FOR THOSE HOURS. THE SUPPLY AIR TEMPERATURE IS 60F AT ALL
$         OTHER TIMES. MINIMUM VENTILATION AIR IS 20 CFM/PERSON AND THE
$         FAN OPERATES FROM 7AM TO 6PM WEEKDAYS AND IS OFF ON WEEKENDS AND
$         HOLIDAYS.  THERE IS A NIGHT LOW LIMIT SETTING FOR PERIMETER
$         THERMOSTATS TO HOLD SPACE AT 55F.  THE FANS DO NOT RUN AT NIGHT
$         BUT CAN CYCLE ON AS EARLY 12 PM TO HOLD SETBACK.  THE MINIMUM OA
$         DAMPERS ARE HELD CLOSED DURING MORNING STARTUP YEAR ROUND,
$         HOWEVER THE ECONOMIZER DAMPERS ARE ACTIVATED IF NEEDED.

     ABORT          ERRORS ..
     DIAGNOSTIC        WARNINGS ..
     SYSTEMS-REPORT    SUMMARY=(SS-A) ..

     $ SCHEDULES

 HRS1       = DAY-SCHEDULE (1,7) (1) (8,18) (1) (19,24) (1) ..
 HRS2       = DAY-SCHEDULE (1,24) (1) ..
 DAYS1      = WEEK-SCHEDULE  (MON,FRI)  HRS1  (WEH)  HRS2  ..
 AHU-SCHED  = SCHEDULE THRU DEC 31  DAYS1  ..      $ FANS $

 HRSH1      = DAY-SCHEDULE (1,8) (72)  (9,18) (72)  (19,24) (72) ..
 HRSH2      = DAY-SCHEDULE (1,24) (72)  ..
 DAYHEAT    = WEEK-SCHEDULE (MON,FRI)  HRSH1  (WEH)  HRSH2  ..
 THEAT      = SCHEDULE THRU DEC 31  DAYHEAT  ..   $ HEATING $

 HRSC1      = DAY-SCHEDULE  (1,7) (75)  (8,18) (75)  (19,24) (75)  ..
 HRSC2      = DAY-SCHEDULE  (1,24) (75)  ..
 DAYCOOL    = WEEK-SCHEDULE  (MON,FRI)  HRSC1  (WEH)  HRSC2  ..
 TCOOL      = SCHEDULE THRU DEC 31  DAYCOOL  ..   $ COOLING $

COOLON      = SCHEDULE THRU DEC 31 (ALL) (1,24) (55) ..
HEATON      = SCHEDULE THRU DEC 31 (ALL) (1,24) (60) ..

REV-STAT-ACT  = SCHEDULE THRU MAR 15 (ALL) (1,8)(1) (9,24)(-999)
               THRU DEC 15 (ALL) (1,24) (-999)
               THRU DEC 31 (ALL) (1,8)(1) (9,24)(-999) ..

SA1 = DAY-SCHEDULE  (1,8)(55) (9,18)(55) (19,24)(55) ..
SA2 = DAY-SCHEDULE  (1,8)(55)  (9,18)(55) (19,24)(55) ..
SAT-SETPT = SCHEDULE THRU MAR 15 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(55)
            THRU MAY 15 (WD) SA2 (WEH) (1,24)(55)
            THRU SEP 15 (ALL) (1,24)(55)
            THRU OCT 15 (WD) SA2 (WEH) (1,24)(55)
            THRU DEC 31 (MON) SA1 (TUE,FRI) SA2 (WEH) (1,24)(55) ..
```

```
OA-DAMPER-POS = SCHEDULE THRU DEC 31 (ALL)(1,8)(.01)(9,18)(.01)(19,24)(.01) .

      $ ZONE SUB-COMMANDS

 ZAIR       = ZONE-AIR     OA-CHANGES=0.25 .

 CONTROL     = ZONE-CONTROL  DESIGN-HEAT-T=72  DESIGN-COOL-T=75
                  HEAT-TEMP-SCH=THEAT  COOL-TEMP-SCH=TCOOL
                  BASEBOARD-CTRL=THERMOSTATIC
                  THERMOSTAT-TYPE=REVERSE-ACTION  ..
$
      $ ZONE DESCRIPTION
$
SPACE1-1      =ZONE     ZONE-AIR=ZAIR  ZONE-CONTROL=CONTROL
               MIN-CFM-SCH=REV-STAT-ACT  CFM/SQFT=1
               BASEBOARD-RATING=-60000  ..
$
SPACE2-1      =ZONE     LIKE SPACE1-1 BASEBOARD-RATING=-12000 ..
SPACE3-1      =ZONE     LIKE SPACE1-1 BASEBOARD-RATING=-60000 ..
SPACE4-1      =ZONE     LIKE SPACE1-1 BASEBOARD-RATING=-12000 ..
SPACE5-1      =ZONE     LIKE SPACE1-1  BASEBOARD-RATING=-55000  ..
PLENUM-1       =ZONE     ZONE-TYPE=PLENUM S-O ADJUST-LOADS
               D-H-T 50 D-C-T 90 ..
SPACE1-2      =ZONE     LIKE SPACE1-1 ..
SPACE2-2      =ZONE     LIKE SPACE2-1 ..
SPACE3-2      =ZONE     LIKE SPACE3-1 ..
SPACE4-2      =ZONE     LIKE SPACE4-1 ..
SPACE5-2      =ZONE     LIKE SPACE5-1 ..
PLENUM-2       =ZONE     LIKE PLENUM-1 ..
SPACE1-3      =ZONE     LIKE SPACE1-1 ..
SPACE2-3      =ZONE     LIKE SPACE2-1 ..
SPACE3-3      =ZONE     LIKE SPACE3-1 ..
SPACE4-3      =ZONE     LIKE SPACE4-1 ..
SPACE5-3      =ZONE     LIKE SPACE5-1 ..
PLENUM-3       =ZONE     LIKE PLENUM-1 ..
SPACE1-4      =ZONE     LIKE SPACE1-1 ..
SPACE2-4      =ZONE     LIKE SPACE2-1 ..
SPACE3-4      =ZONE     LIKE SPACE3-1 ..
SPACE4-4      =ZONE     LIKE SPACE4-1 ..
SPACE5-4      =ZONE     LIKE SPACE5-1 ..
PLENUM-4       =ZONE     LIKE PLENUM-1 ..
SPACE1-5      =ZONE     LIKE SPACE1-1 ..
SPACE2-5      =ZONE     LIKE SPACE2-1 ..
SPACE3-5      =ZONE     LIKE SPACE3-1 ..
SPACE4-5      =ZONE     LIKE SPACE4-1 ..
SPACE5-5      =ZONE     LIKE SPACE5-1 ..
PLENUM-5       =ZONE     LIKE PLENUM-1 ..
SPACE1-6      =ZONE     LIKE SPACE1-1 ..
SPACE2-6      =ZONE     LIKE SPACE2-1 ..
SPACE3-6      =ZONE     LIKE SPACE3-1 ..
SPACE4-6      =ZONE     LIKE SPACE4-1 ..
SPACE5-6      =ZONE     LIKE SPACE5-1 ..
PLENUM-6       =ZONE     LIKE PLENUM-1 ..
SPACE1-7      =ZONE     LIKE SPACE1-1 ..
SPACE2-7      =ZONE     LIKE SPACE2-1 ..
SPACE3-7      =ZONE     LIKE SPACE3-1 ..
SPACE4-7      =ZONE     LIKE SPACE4-1 ..
SPACE5-7      =ZONE     LIKE SPACE5-1 ..
PLENUM-7       =ZONE     LIKE PLENUM-1 ..
SPACE1-8      =ZONE     LIKE SPACE1-1 ..
SPACE2-8      =ZONE     LIKE SPACE2-1 ..
SPACE3-8      =ZONE     LIKE SPACE3-1 ..
SPACE4-8      =ZONE     LIKE SPACE4-1 ..
SPACE5-8      =ZONE     LIKE SPACE5-1 ..
PLENUM-8       =ZONE     LIKE PLENUM-1 ..
SPACE1-9      =ZONE     LIKE SPACE1-1 ..
SPACE2-9      =ZONE     LIKE SPACE2-1 ..
SPACE3-9      =ZONE     LIKE SPACE3-1 ..
SPACE4-9      =ZONE     LIKE SPACE4-1 ..
SPACE5-9      =ZONE     LIKE SPACE5-1 ..
PLENUM-9       =ZONE     LIKE PLENUM-1 ..
SPACE1-10      =ZONE     LIKE SPACE1-1 ..
SPACE2-10      =ZONE     LIKE SPACE2-1 ..
SPACE3-10      =ZONE     LIKE SPACE3-1 ..
SPACE4-10      =ZONE     LIKE SPACE4-1 ..
SPACE5-10      =ZONE     LIKE SPACE5-1 ..
PLENUM-10       =ZONE     LIKE PLENUM-1 ..
SPACE1-11      =ZONE     LIKE SPACE1-1 ..
SPACE2-11      =ZONE     LIKE SPACE2-1 ..
SPACE3-11      =ZONE     LIKE SPACE3-1 ..
SPACE4-11      =ZONE     LIKE SPACE4-1 ..
SPACE5-11      =ZONE     LIKE SPACE5-1 ..
PLENUM-11       =ZONE     LIKE PLENUM-1 ..
$
SPACE1-12      =ZONE     LIKE SPACE1-1 ..
SPACE2-12      =ZONE     LIKE SPACE2-1 ..
```

```
SPACE3-12     =ZONE    LIKE SPACE3-1 ..
SPACE4-12     =ZONE    LIKE SPACE4-1 ..
SPACE5-12     =ZONE    LIKE SPACE5-1 ..
PLENUM-12      =ZONE    LIKE PLENUM-1 ..
$
SPACE1-13     =ZONE    LIKE SPACE1-1 ..
SPACE2-13     =ZONE    LIKE SPACE2-1 ..
SPACE3-13     =ZONE    LIKE SPACE3-1 ..
SPACE4-13     =ZONE    LIKE SPACE4-1 ..
SPACE5-13     =ZONE    LIKE SPACE5-1 ..
PLENUM-13      =ZONE    LIKE PLENUM-1 ..
SPACE1-14     =ZONE    LIKE SPACE1-1 ..
SPACE2-14     =ZONE    LIKE SPACE2-1 ..
SPACE3-14     =ZONE    LIKE SPACE3-1 ..
SPACE4-14     =ZONE    LIKE SPACE4-1 ..
SPACE5-14     =ZONE    LIKE SPACE5-1 ..
PLENUM-14      =ZONE    LIKE PLENUM-1 ..
SPACE1-15     =ZONE    LIKE SPACE1-1 ..
SPACE2-15     =ZONE    LIKE SPACE2-1 ..
SPACE3-15     =ZONE    LIKE SPACE3-1 ..
SPACE4-15     =ZONE    LIKE SPACE4-1 ..
SPACE5-15     =ZONE    LIKE SPACE5-1 ..
PLENUM-15      =ZONE    LIKE PLENUM-1 ..
SPACE1-16     =ZONE    LIKE SPACE1-1 ..
SPACE2-16     =ZONE    LIKE SPACE2-1 ..
SPACE3-16     =ZONE    LIKE SPACE3-1 ..
SPACE4-16     =ZONE    LIKE SPACE4-1 ..
SPACE5-16     =ZONE    LIKE SPACE5-1 ..
PLENUM-16      =ZONE    LIKE PLENUM-1 ..
SPACE1-17     =ZONE    LIKE SPACE1-1 ..
SPACE2-17     =ZONE    LIKE SPACE2-1 ..
SPACE3-17     =ZONE    LIKE SPACE3-1 ..
SPACE4-17     =ZONE    LIKE SPACE4-1 ..
SPACE5-17     =ZONE    LIKE SPACE5-1 ..
PLENUM-17      =ZONE    LIKE PLENUM-1 ..
SPACE1-18     =ZONE    LIKE SPACE1-1 ..
SPACE2-18     =ZONE    LIKE SPACE2-1 ..
SPACE3-18     =ZONE    LIKE SPACE3-1 ..
SPACE4-18     =ZONE    LIKE SPACE4-1 ..
SPACE5-18     =ZONE    LIKE SPACE5-1 ..
PLENUM-18      =ZONE    LIKE PLENUM-1 ..
SPACE1-19     =ZONE    LIKE SPACE1-1 ..
SPACE2-19     =ZONE    LIKE SPACE2-1 ..
SPACE3-19     =ZONE    LIKE SPACE3-1 ..
SPACE4-19     =ZONE    LIKE SPACE4-1 ..
SPACE5-19     =ZONE    LIKE SPACE5-1 ..
PLENUM-19      =ZONE    LIKE PLENUM-1 ..
SPACE1-20     =ZONE    LIKE SPACE1-1 BASEBOARD-RATING=-69000 ..
SPACE2-20     =ZONE    LIKE SPACE1-1 BASEBOARD-RATING=-120000 ..
SPACE3-20     =ZONE    LIKE SPACE1-1 BASEBOARD-RATING=-69000 ..
SPACE4-20     =ZONE    LIKE SPACE1-1 BASEBOARD-RATING=-120000 ..
SPACE5-20     =ZONE    LIKE SPACE5-1 ..
PLENUM-20      =ZONE    LIKE PLENUM-1 ..

BASEMENT      =ZONE    LIKE SPACE5-1 AIR-CHANGES/HR=4  OA-CHANGES=0.5
$
$
$ SYSTEM SUB-COMMANDS

S-CTRL  = SYSTEM-CONTROL    COOLING-SCHEDULE=COOLON
              HEATING-SCHEDULE=HEATON  COOL-CONTROL = SCHEDULED
              HEAT-SET-T=100  COOL-SET-SCH=SAT-SETPT
              MIN-SUPPLY-T=55  MAX-SUPPLY-T=100 ..

S-FAN   = SYSTEM-FANS      FAN-SCHEDULE=AHU-SCHED  FAN-CONTROL=INLET
              SUPPLY-STATIC=5.5  SUPPLY-EFF=0.55
              RETURN-STATIC=2.0  RETURN-EFF=0.53 ..

S-TERM  = SYSTEM-TERMINAL    REHEAT-DELTA-T=20  MIN-CFM-RATIO=0.25 ..

    $ SYSTEM DESCRIPTION

BLDG    = SYSTEM          SYSTEM-TYPE=VAVS  SYSTEM-CONTROL=S-CTRL
              SYSTEM-FANS=S-FAN  MIN-AIR-SCH=OA-DAMPER-POS
              SYSTEM-TERMINAL=S-TERM
              RETURN-AIR-PATH=PLENUM-ZONES
              PLENUM-NAMES=(PLENUM-1,PLENUM-10,PLENUM-20)
              BASEBOARD-SOURCE=ELECTRIC  PREHEAT=HOT-WATER
              HEAT-SOURCE=HOT-WATER  HUMIDIFIER-TYPE=HOT-WATER
              ECONO-LIMIT-T=68
ZONE-NAMES=(SPACE1-1,SPACE2-1,SPACE3-1,SPACE4-1,SPACE5-1,SPACE1-2,
SPACE2-2,SPACE3-2,SPACE4-2,SPACE5-2,SPACE1-3,SPACE2-3,SPACE3-3,SPACE4-3,
SPACE5-3,SPACE1-4,SPACE2-4,SPACE3-4,SPACE4-4,SPACE5-4,SPACE1-5,SPACE2-5,
SPACE3-5,SPACE4-5,SPACE5-5,SPACE1-6,SPACE2-6,SPACE3-6,SPACE4-6,SPACE5-6,
SPACE1-7,SPACE2-7,SPACE3-7,SPACE4-7,SPACE5-7,SPACE1-8,SPACE2-8,SPACE3-8,
SPACE4-8,SPACE5-8,SPACE1-9,SPACE2-9,SPACE3-9,SPACE4-9,SPACE5-9,SPACE1-10,
SPACE2-10,SPACE3-10,SPACE4-10,SPACE5-10,SPACE1-11,SPACE2-11,SPACE3-11,
```

```
SPACE4-11,SPACE5-11,SPACE1-12,SPACE2-12,SPACE3-12,SPACE4-12,SPACE5-12,
SPACE1-13,SPACE2-13,SPACE3-13,SPACE4-13,SPACE5-13,SPACE1-14,SPACE2-14,
SPACE3-14,SPACE4-14,SPACE5-14,SPACE1-15,SPACE2-15,SPACE3-15,SPACE4-15,
SPACE5-15,SPACE1-16,SPACE2-16,SPACE3-16,SPACE4-16,SPACE5-16,SPACE1-17,
SPACE2-17,SPACE3-17,SPACE4-17,SPACE5-17,SPACE1-18,SPACE2-18,SPACE3-18,
SPACE4-18,SPACE5-18,SPACE1-19,SPACE2-19,SPACE3-19,SPACE4-19,SPACE5-19,
SPACE1-20,SPACE2-20,SPACE3-20,SPACE4-20,SPACE5-20, PLENUM-1,PLENUM-2,
PLENUM-3,PLENUM-4,PLENUM-5,PLENUM-6,PLENUM-7,PLENUM-8,PLENUM-9,
PLENUM-10,PLENUM-11,PLENUM-12,PLENUM-13,PLENUM-14,PLENUM-15,PLENUM-16,
PLENUM-17,PLENUM-18,PLENUM-19,PLENUM-20) ..
$
BASMT-SYS = SYSTEM        SYSTEM-TYPE=SZRH  MAX-SUPPLY-T=105
                 MIN-SUPPLY-T=55  SUPPLY-STATIC=2.5
                 SUPPLY-EFF=.5   FAN-SCHEDULE=AHU-SCHED
                 HEATING-SCHEDULE=HEATON  HEAT-SOURCE=ELECTRIC
                 COOLING-SCHEDULE=COOLON
                 ZONE-NAMES=(BASEMENT) ..
PLANT1  = PLANT-ASSIGNMENT  SYSTEM-NAMES = (BLDG,BASMT-SYS)
                INT-ELEC-KW = 100  $ FOR ELEVATORS
                INT-ELEC-SCH = OCCUP
                DHW-SIZE=0
                DHW-GAL/MIN  = 2.22
                DHW-SCH    = OCCUP ..

OC1       =DAY-SCHEDULE      (1,24) (.05,.05,.05,.05,.05,.05,
                  .19,.31,.69,.94,1,1,1,.94,1,.94,.94,
                  .75,.38,.13,.05,.05,.05,.05) ..

OC2       =DAY-SCHEDULE      (1,24) (0.01,.01,.01,.01,.01,.01,
                  .02,.03,.07,.09,.1,.1,.1,.09,.1,.09,
                  .09,.08,.04,.01,.01,.01,.01,.01) ..

PEOPLE    =WEEK-SCHEDULE    (MON,FRI) OC1   (WEH) OC2 ..
OCCUP     =SCHEDULE         THRU DEC 31  PEOPLE ..
$
$
END ..
COMPUTE SYSTEMS ..
INPUT PLANT ..
PLANT1 = PLANT-ASSIGNMENT ..

     PLANT-REPORT     SUMMARY=(PS-A,BEPS) ..

     $ EQUIPMENT DESCRIPTION

$ THE PLANT USES CHILLED WATER STORAGE. THE CHILLER CHARGES
$ THE TANKS AT NIGHT. STORED CHILLED WATER IS RELEASED FROM 12NOON TO 5PM,
$ WHICH IS THE ON-PEAK PERIOD OF THE TIME-OF-DAY RATE SCHEDULE.
$ THE CHILLER PROVIDES OFF-PEAK COOLING AND SUPPLEMENTS THE TANK
$ DURING THE ON-PEAK PERIOD IF NECESSARY.
$ DAYTIME HEATING IS DONE WITH ELECTRIC BASEBOARDS,
$ BUT FOR NIGHTTIME HEATING AND FOR EARLY MORNING
$ START-UP A GAS HOT WATER GENERATOR IS USED.

CMPC   =PLANT-EQUIPMENT   TYPE=HERM-CENT-CHLR  SIZE=13.5  I-N=2 ..

DHWH   =PLANT-EQUIPMENT   TYPE=ELEC-DHW-HEATER  SIZE -999 ..

HWG    =PLANT-EQUIPMENT   TYPE=HW-BOILER  SIZE=-999 ..

CTWR   =PLANT-EQUIPMENT   TYPE=COOLING-TWR  SIZE=-999 ..

CTANK  =PLANT-EQUIPMENT   TYPE=CTANK-STORAGE  SIZE=50  I-N=1 ..


ENERGY-STORAGE  COOL-STORE-RATE=13.5  COOL-SUPPLY-RATE=13.5
        COOL-STORE-SCH=TANK-CHG  CTANK-LOSS-COEF=50
        CTANK-BASE-T=54  CTANK-T-RANGE=10  CTANK-ENV-T=53 ..

TANK-CHG=SCHEDULE THRU MAY 1 (ALL) (1,24) (0)
          THRU OCT 1 (ALL) (1,7) (1) (8,24) (0)
          THRU DEC 31 (ALL) (1,24) (0) ..

TANK-CHARGE =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=13.5
                PLANT-EQUIPMENT=CMPC  N=1 ..

RELEASE-CHG =LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                PLANT-EQUIPMENT=CTANK  N=1
                PLANT-EQUIPMENT=CMPC  N=1 ..

OFF-PEAK-CLG=LOAD-ASSIGNMENT  TYPE=COOLING  LOAD-RANGE=27
                PLANT-EQUIPMENT =CMPC  N=2 ..

CHW-CTRL =DAY-ASSIGN-SCH (1,7) (TANK-CHARGE) (8,12) (OFF-PEAK-CLG)
            (13,17) (RELEASE-CHG) (18,24) (OFF-PEAK-CLG) ..
WEH-CTRL =DAY-ASSIGN-SCH (1,24) (OFF-PEAK-CLG) ..
```

```
CHILLER-CTRL=SCHEDULE THRU DEC 31 (WD) CHW-CTRL (WEH) WEH-CTRL ..

LOAD-MANAGEMENT  PRED-LOAD-RANGE=999
          ASSIGN-SCHEDULE=(DEFAULT,CHILLER-CTRL,DEFAULT) ..

END ..
COMPUTE PLANT ..
INPUT ECONOMICS ..
ECONOMICS-REPORT  S (ES-D,ES-E,ES-F) ..

              $ ENERGY COST DESCRIPTION

$ THE INPUT FOR UTILITY RATES IS THE SIMPLEST POSSIBLE, USING UNIFORM RATES
$ FOR BOTH GAS AND ELECTRICITY.  THERE IS A FIXED MONTHLY CHARGE AND A RATE
$ LIMITATION ON ELECTRICITY OF 7 CENTS/KWH   THE DEMAND CHARGE IS A NOMINAL
$ FLAT RATE OF 5 DOLLARS/KW YEAR-AROUND.

ELEC-RATE = UTILITY-RATE  RESOURCE=ELECTRICITY
               ENERGY-CHG = .032412
               DEMAND-CHGS = (15.57) ..

GAS-RATE  = UTILITY-RATE  RESOURCE=NATURAL-GAS
               ENERGY-CHG =.4886   $ DOLLARS/THERM
END ..
COMPUTE ECONOMICS ..
$
$
TITLE  LINE-1 * HOUSTON - SHADED LOW-E * ..
$
PARAMETRIC-INPUT LOADS ..
PARAMETER PERCENT=0
      GLAZING=2996 ..
END .
COMPUTE LOADS ..
COMPUTE SYSTEMS ..
COMPUTE PLANT ..
COMPUTE ECONOMICS ..
$
$
TITLE LINE-1 * HOUSTON - SHADED PV* ..
$
$
PARAMETRIC-INPUT LOADS ..
PARAMETER PERCENT=0
      GLAZING=2999 ..
END ..
COMPUTE LOADS ..
COMPUTE SYSTEMS ..
COMPUTE PLANT ..
COMPUTE ECONOMICS ..
$
$
TITLE   LINE-1 * HOUSTON - NON-SHADED CLEAR * ..
$
$
PARAMETRIC-INPUT LOADS ..
PARAMETER PERCENT=1
      GLAZING=1999 ..
END ..
COMPUTE LOADS ..
COMPUTE SYSTEMS ..
COMPUTE PLANT ..
COMPUTE ECONOMICS ..
$
$
TITLE LINE-1 * HOUSTON - NON-SHADED LOW-E* ..
$
$
PARAMETRIC-INPUT LOADS ..
PARAMETER PERCENT=1
      GLAZING=2996 ..
END ..
COMPUTE LOADS ..
COMPUTE SYSTEMS ..
COMPUTE PLANT ..
COMPUTE ECONOMICS ..

$
TITLE LINE-1 * HOUSTON - NON-SHADED PV* ..
$
$
PARAMETRIC-INPUT LOADS ..
PARAMETER PERCENT=1
      GLAZING=2999 ..
END ..
COMPUTE LOADS ..
COMPUTE SYSTEMS ..
```

```
COMPUTE PLANT ..
COMPUTE ECONOMICS ..
STOP ..
```

APPENDIX V

BEPS Reports

BEPS Report for DOE2 sample file and the adjusted file.

31-STORY OFFICE BLDG, HOUSTON- LOAD2 RUN 2 VARIABLE AIR VOLUME SYSTEM DOE-2.1E-084 07/11/99
22:27:47.02 PDL RUN 1
ELECTRIC THERMOSTATIC BASEBOARDS WARM-UP CYCLE USES GAS HEAT
REPORT- BEPS BUILDING ENERGY PERFORMANCE SUMMARY WEATHER FILE-
Houston, TX

ENERGY TYPE: / UNITS: MBTU / CATEGORY OF USE	ELECTRICITY	NATURAL-GAS
AREA LIGHTS	8699.8	0.0
MISC EQUIPMT	4029.1	0.0
SPACE HEAT	142.1	1752.6
SPACE COOL	5460.5	0.0
HEAT REJECT	1040.2	0.0
PUMPS & MISC	695.0	0.0
VENT FANS	6814.1	0.0
DOMHOT WATER	175.9	0.0
TOTAL	27056.6	1752.6

TOTAL SITE ENERGY 28809.16 MBTU 45.0 KBTU/SQFT-YR GROSS-AREA 45.0 KBTU/SQFT-YR NET-AREA

TOTAL SOURCE ENERGY 82930.49 MBTU 129.6 KBTU/SQFT-YR GROSS-AREA 129.6 KBTU/SQFT-YR NET-AREA

BEPS Report for DOE2 sample file and the adjusted file.

31-STORY OFFICE BLDG, HOUSTON - LOAD2 RUN 2 VARIABLE AIR VOLUME SYSTEM DOE-2.1E-058 07/13/99
16:47:54.94 PDL RUN 1
ELECTRIC THERMOSTATIC BASEBOARDS WARM-UP CYCLE USES GAS HEAT
REPORT- BEPS BUILDING ENERGY PERFORMANCE SUMMARY WEATHER FILE-
Houston, TX

ENERGY TYPE: / UNITS: MBTU / CATEGORY OF USE	ELECTRICITY	NATURAL-GAS
AREA LIGHTS	20540.4	0.0
MISC EQUIPMT	13223.8	0.0
SPACE HEAT	18735.9	6707.2
SPACE COOL	10332.1	0.0
HEAT REJECT	2062.6	0.0
PUMPS & MISC	3587.7	0.0
VENT FANS	24420.9	0.0
DOMHOT WATER	248.2	0.0
TOTAL	93151.6	6707.2

TOTAL SITE ENERGY 99858.81 MBTU 156.0 KBTU/SQFT-YR GROSS-AREA 156.0 KBTU/SQFT-YR NET-AREA

TOTAL SOURCE ENERGY 286189.94 MBTU 447.2 KBTU/SQFT-YR GROSS-AREA 447.2 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 68.6
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 2.3
NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

BEPS Report for Detroit – Clear Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                      WEATHER FILE- Flint, MI
---------------------------------------------------------------------------------------------------------
---------------

                              ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                              UNITS: MBTU
                           CATEGORY OF USE
                           ---------------
                               AREALIGHTS       6694.9          0.0
                              MISCEQUIPMT       4920.9          0.0
                                SPACEHEAT      18933.2      47211.2
                                SPACECOOL        3361.5          0.0
                               HEATREJECT        789.4          0.0
                               PUMPS&MISC       805.6          0.0
                                 VENTFANS      16180.3          0.0
                              DOMHOTWATER         322.9          0.0
                                             ----------   ----------
                                    TOTAL      52008.7      47211.2

                 TOTAL SITEENERGY      99219.91 MBTU     472.5 KBTU/SQFT-YR GROSS-AREA    472.5 KBTU/SQFT-YR NET-
AREA
                 TOTAL SOURCEENERGY  203252.89 MBTU     967.9 KBTU/SQFT-YR GROSS-AREA    967.9 KBTU/SQFT-YR NET-
AREA
                 PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 62.4
                 PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED              =  0.0
                 NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Detroit – Clear Unshaded

```
 EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                      WEATHER FILE- Flint, MI
---------------------------------------------------------------------------------------------------------
---------------

                              ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                              UNITS: MBTU
                           CATEGORY OF USE
                           ---------------
                               AREALIGHTS       6694.9          0.0
                              MISCEQUIPMT       4920.9          0.0
                                SPACEHEAT      18424.0      53466.9
                                SPACECOOL        3939.0          0.0
                               HEATREJECT        827.8          0.0
                               PUMPS&MISC       964.7          0.0
                                 VENTFANS      19377.5          0.0
                              DOMHOTWATER         322.9          0.0
                                             ----------   ----------
                                    TOTAL      55471.7      53466.9

                 TOTAL SITEENERGY     108938.63 MBTU     518.8 KBTU/SQFT-YR GROSS-AREA    518.8 KBTU/SQFT-YR NET-
AREA
                 TOTAL SOURCEENERGY  219898.76 MBTU    1047.1 KBTU/SQFT-YR GROSS-AREA   1047.1 KBTU/SQFT-YR NET-
AREA
                 PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 44.0
                 PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED              =  0.0
                 NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Detroit – Low-E Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                    DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                             WEATHER FILE- Flint, MI
------------------------------------------------------------------------------------------------------------------
----------------

                                   ENERGY TYPE:  ELECTRICITY   NATURAL-GAS
                                   UNITS: MBTU
                                CATEGORY OF USE
                                ---------------
                                    AREALIGHTS       6694.9         0.0
                                   MISCEQUIPMT       4920.9         0.0
                                     SPACEHEAT      11282.0     11110.5
                                     SPACECOOL       2537.1         0.0
                                    HEATREJECT        749.9         0.0
                                   PUMPS&MISC         450.5         0.0
                                      VENTFANS       9059.9         0.0
                                   DOMHOTWATER        322.9         0.0
                                                 ----------  ----------
                                         TOTAL      36018.1     11110.5

                    TOTAL SITEENERGY     47128.58 MBTU    224.4 KBTU/SQFT-YR GROSS-AREA   224.4 KBTU/SQFT-YR NET-
AREA
                    TOTAL SOURCEENERGY  119175.54 MBTU    567.5 KBTU/SQFT-YR GROSS-AREA   567.5 KBTU/SQFT-YR NET-
AREA
                    PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 29.1
                    PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.0
                    NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Detroit – Low-E Unshaded

```
 EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                    DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                             WEATHER FILE- Flint, MI
------------------------------------------------------------------------------------------------------------------
----------------

                                   ENERGY TYPE:  ELECTRICITY   NATURAL-GAS
                                   UNITS: MBTU
                                CATEGORY OF USE
                                ---------------
                                    AREALIGHTS       6694.9         0.0
                                   MISCEQUIPMT       4920.9         0.0
                                     SPACEHEAT      11323.6     13238.1
                                     SPACECOOL       2754.8         0.0
                                    HEATREJECT        760.0         0.0
                                   PUMPS&MISC         522.5         0.0
                                      VENTFANS      10550.5         0.0
                                   DOMHOTWATER        322.9         0.0
                                                 ----------  ----------
                                         TOTAL      37850.1     13238.1

                    TOTAL SITEENERGY     51088.27 MBTU    243.3 KBTU/SQFT-YR GROSS-AREA   243.3 KBTU/SQFT-YR NET-
AREA
                    TOTAL SOURCEENERGY  126799.93 MBTU    603.8 KBTU/SQFT-YR GROSS-AREA   603.8 KBTU/SQFT-YR NET-
AREA
                    PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 24.7
                    PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.0
                    NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Detroit – PV Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                   DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                           WEATHER FILE- Flint, MI
-----------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9         0.0
                                  MISCEQUIPMT       4920.9         0.0
                                    SPACEHEAT      13020.3     16091.7
                                    SPACECOOL       2642.0         0.0
                                   HEATREJECT        754.5         0.0
                                  PUMPS&MISC         510.2         0.0
                                     VENTFANS      10074.0         0.0
                                  DOMHOTWATER        322.9         0.0
                                                ----------  ----------
                                        TOTAL      38939.8     16091.7

                   TOTAL SITEENERGY     55031.45 MBTU    262.1 KBTU/SQFT-YR GROSS-AREA   262.1 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  132922.72 MBTU    633.0 KBTU/SQFT-YR GROSS-AREA   633.0 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 34.9
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Detroit – PV Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          DETROIT                                   DOE-2.1E-058  07/15/99
10:20:25.31 PDL RUN  1
 40-STORY OFFICEBLDG IN DETROIT
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                           WEATHER FILE- Flint, MI
-----------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9         0.0
                                  MISCEQUIPMT       4920.9         0.0
                                    SPACEHEAT      12946.5     18678.3
                                    SPACECOOL       2889.1         0.0
                                   HEATREJECT        765.8         0.0
                                  PUMPS&MISC         594.6         0.0
                                     VENTFANS      11788.9         0.0
                                  DOMHOTWATER        322.9         0.0
                                                ----------  ----------
                                        TOTAL      40923.6     18678.3

                   TOTAL SITEENERGY     59601.81 MBTU    283.8 KBTU/SQFT-YR GROSS-AREA   283.8 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  141461.19 MBTU    673.6 KBTU/SQFT-YR GROSS-AREA   673.6 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 26.9
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Houston – Clear Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                              DOE-2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                       WEATHER FILE- Houston,
TX
-------------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       7384.5      15086.1
                                    SPACECOOL        8214.1          0.0
                                   HEATREJECT       1952.3          0.0
                                  PUMPS&MISC       2474.1          0.0
                                     VENTFANS      16230.6          0.0
                                  DOMHOTWATER         248.2          0.0
                                                ----------    ----------
                                        TOTAL      48119.6      15086.1

                   TOTAL SITEENERGY     63205.74 MBTU    301.0 KBTU/SQFT-YR GROSS-AREA   301.0 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  159459.41 MBTU    759.3 KBTU/SQFT-YR GROSS-AREA   759.3 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 70.1
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.7
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Houston – Clear Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                              DOE 2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                       WEATHER FILE- Houston,
TX
-------------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       7162.1      17117.2
                                    SPACECOOL        9617.8          0.0
                                   HEATREJECT       2070.0          0.0
                                  PUMPS&MISC       2949.7          0.0
                                     VENTFANS      19393.3          0.0
                                  DOMHOTWATER         248.2          0.0
                                                ----------    ----------
                                        TOTAL      53057.0      17117.2

                   TOTAL SITEENERGY     70174.24 MBTU    334.2 KBTU/SQFT-YR GROSS-AREA   334.2 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  176304.26 MBTU    839.5 KBTU/SQFT-YR GROSS-AREA   839.5 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 63.5
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 1.4
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Houston – Low-E Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                                DOE-2.1E-058  07/15/99
10:09:48.94 EDL RUN  1
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                                DOE-2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                     WEATHER FILE- Houston,
TX
---------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                    AREALIGHTS       6694.9          0.0
                                   MISCEQUIPMT       4920.9          0.0
                                     SPACEHEAT       5032.6       4986.9
                                     SPACECOOL        5759.9          0.0
                                    HEATREJECT       1787.3          0.0
                                   PUMPS&MISC       1411.5          0.0
                                      VENTFANS       9371.6          0.0
                                   DOMHOTWATER        248.2          0.0
                                                 ----------   ----------
                                         TOTAL      35226.9       4986.9

                  TOTAL SITEENERGY     40213.78 MBTU    191.5 KBTU/SQFT-YR GROSS-AREA   191.5 KBTU/SQFT-YR NET-
AREA
                  TOTAL SOURCEENERGY  110678.16 MBTU    527.0 KBTU/SQFT-YR GROSS-AREA   527.0 KBTU/SQFT-YR NET-
AREA
                  PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 68.2
                  PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.2
                  NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Houston – Low-E Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                                DOE-2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                     WEATHER FILE- Houston,
TX
---------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                    AREALIGHTS       6694.9          0.0
                                   MISCEQUIPMT       4920.9          0.0
                                     SPACEHEAT       5106.7       6182.7
                                     SPACECOOL        6188.9          0.0
                                    HEATREJECT       1816.2          0.0
                                   PUMPS&MISC       1643.5          0.0
                                      VENTFANS      10887.6          0.0
                                   DOMHOTWATER        248.2          0.0
                                                 ----------   ----------
                                         TOTAL      37507.0       6182.7

                  TOTAL SITEENERGY     43689.65 MBTU    208.0 KBTU/SQFT-YR GROSS-AREA   208.0 KBTU/SQFT-YR NET-
AREA
                  TOTAL SOURCEENERGY  118714.88 MBTU    565.3 KBTU/SQFT-YR GROSS-AREA   565.3 KBTU/SQFT-YR NET-
AREA
                  PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 66.6
                  PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.4
                  NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Houston – PV Shaded

```
 EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                                  DOE-2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                               WEATHER FILE- Houston,
TX
--------------------------------------------------------------------------------------------------------------------
----------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       5551.3       6420.0
                                    SPACECOOL        6051.6          0.0
                                  HEATREJECT        1807.4          0.0
                                  PUMPS&MISC       1576.3          0.0
                                     VENTFANS      10413.2          0.0
                                  DOMHOTWATER         248.2          0.0
                                                -----------   ----------
                                        TOTAL      37263.9       6420.0

                    TOTAL SITEENERGY      43683.92 MBTU    208.0 KBTU/SQFT-YR GROSS-AREA   208.0 KBTU/SQFT-YR NET-
AREA
                    TOTAL SOURCEENERGY  118222.88 MBTU    563.0 KBTU/SQFT-YR GROSS-AREA   563.0 KBTU/SQFT-YR NET-
AREA
                    PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 68.8
                    PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.4
```

NOTE: ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.

BEPS Report for Houston – PV Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          HOUSTON                                  DOE-2.1E-058  07/15/99
10:09:48.94 PDL RUN  1
 40-STORY OFFICEBLDG IN HOUSTON
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                               WEATHER FILE- Houston,
TX
--------------------------------------------------------------------------------------------------------------------
----------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       5568.9       7798.4
                                    SPACECOOL        6573.8          0.0
                                   HEATREJECT       1841.5          0.0
                                  PUMPS&MISC       1842.3          0.0
                                     VENTFANS      12160.5          0.0
                                  DOMHOTWATER         248.2          0.0
                                                -----------   ----------
                                        TOTAL      39851.1       7798.4

                    TOTAL SITEENERGY      47649.44 MBTU    226.9 KBTU/SQFT-YR GROSS-AREA   226.9 KBTU/SQFT-YR NET-
AREA
                    TOTAL SOURCEENERGY  127363.51 MBTU    606.5 KBTU/SQFT-YR GROSS-AREA   606.5 KBTU/SQFT-YR NET-
AREA
                    PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 66.7
                    PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.5
                    NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – Clear Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING           LOSANGEL                                  DOE-2.1E-058  07/15/99
10:37:30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                              WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------------
---------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       9228.2      13821.9
                                    SPACECOOL        6352.7          0.0
                                   HEATREJECT       1642.8          0.0
                                  PUMPS&MISC       1192.2          0.0
                                     VENTFANS      15683.6          0.0
                                  DOMHOTWATER         271.6          0.0
                                                 ----------    ----------
                                        TOTAL     45987.0      13821.9
                   TOTAL SITEENERGY      59808.82 MBTU     284.8 KBTU/SQFT-YR GROSS-AREA   284.8 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  151796.53 MBTU     722.8 KBTU/SQFT-YR GROSS-AREA   722.8 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 52.2
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – Clear Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING           LOSANGEL                                  DOE-2.1E-058  07/15/99
10:37·30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                              WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------------
---------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       8627.2      16083.9
                                    SPACECOOL        7274.7          0.0
                                   HEATREJECT       1683.2          0.0
                                  PUMPS&MISC       1456.6          0.0
                                     VENTFANS      18815.9          0.0
                                  DOMHOTWATER         271.6          0.0
                                                 ----------    ----------
                                        TOTAL     49744.9      16083.9
                   TOTAL SITEENERGY      65828.79 MBTU     313.5 KBTU/SQFT-YR GROSS-AREA   313.5 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  165333.52 MBTU     787.3 KBTU/SQFT-YR GROSS-AREA   787.3 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 47.6
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – Low-E Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING           LOSANGEL                                    DOE-2.1E-058  07/15/99
10:37:30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                              WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------
----------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS      6694.9          0.0
                                  MISCEQUIPMT      4920.9          0.0
                                    SPACEHEAT      5873.3       4663.9
                                    SPACECOOL       4923.3          0.0
                                   HEATREJECT      1585.4          0.0
                                  PUMPS&MISC       621.3          0.0
                                     VENTFANS      9209.3          0.0
                                  DOMHOTWATER       271.6          0.0
                                               ----------   ----------
                                        TOTAL     34100.0       4663.9
                   TOTAL SITEENERGY     38763.90 MBTU    184.6 KBTU/SQFT-YR GROSS-AREA   184.6 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  106974.13 MBTU    509.4 KBTU/SQFT-YR GROSS-AREA   509.4 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 46.9
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – Low-E Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING           LOSANGEL                                    DOE-2.1E-058  07/15/99
10:37:30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                              WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------
----------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS      6694.9          0.0
                                  MISCEQUIPMT      4920.9          0.0
                                    SPACEHEAT      5946.6       5809.4
                                    SPACECOOL       5324.2          0.0
                                   HEATREJECT      1599.7          0.0
                                  PUMPS&MISC       730.2          0.0
                                     VENTFANS     10764.6          0.0
                                  DOMHOTWATER       271.6          0.0
                                               ----------   ----------
                                        TOTAL     36252.8       5809.4
                   TOTAL SITEENERGY     42062.24 MBTU    200.3 KBTU/SQFT-YR GROSS-AREA   200.3 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  114578.71 MBTU    545.6 KBTU/SQFT-YR GROSS-AREA   545.6 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 44.8
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                = 0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – PV Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          LOSANGEL                                   DOE-2.1E-058  07/15/99
10:37:30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                           WEATHER FILE-
LoSAngeles, CA
-----------------------------------------------------------------------------------------------------------
----------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       6691.1       6026.4
                                    SPACECOOL        5119.0          0.0
                                   HEATREJECT       1591.7          0.0
                                  PUMPS&MISC        670.4         0.0
                                     VENTFANS      10175.7          0.0
                                  DOMHOTWATER        271.6          0.0
                                              ----------    ----------
                                        TOTAL      36135.3       6026.4
                   TOTAL SITEENERGY     42161.69 MBTU     200.8 KBTU/SQFT-YR GROSS-AREA    200.8 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  114443.16 MBTU     545.0 KBTU/SQFT-YR GROSS-AREA    545.0 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 49.1
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for Los Angeles – PV Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          LOSANGEL                                   DOE-2.1E-058  07/15/99
10:37:30.49 PDL RUN  1
 40-STORY OFFICEBLDG IN LOSANGEL
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                           WEATHER FILE-
LoSAngeles, CA
-----------------------------------------------------------------------------------------------------------
----------------
                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                  UNITS: MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                  MISCEQUIPMT       4920.9          0.0
                                    SPACEHEAT       6670.1       7375.0
                                    SPACECOOL        5564.8          0.0
                                   HEATREJECT       1609.0          0.0
                                  PUMPS&MISC        799.0         0.0
                                     VENTFANS      11947.4          0.0
                                  DOMHOTWATER        271.6          0.0
                                              ----------    ----------
                                        TOTAL      38477.8       7375.0
                   TOTAL SITEENERGY     45852.74 MBTU     218.3 KBTU/SQFT-YR GROSS-AREA    218.3 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  122819.83 MBTU     584.9 KBTU/SQFT-YR GROSS-AREA    584.9 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 45.9
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                 =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for New York – Clear Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                                     DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFFICEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                                WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:  ELECTRICITY  NATURAL-GAS
                                  UNITS:MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS      6694.9         0.0
                                 MISCEQUIPMT      4920.9         0.0
                                    SPACEHEAT      9228.8     13821.7
                                    SPACECOOL       6352.1         0.0
                                   HEATREJECT      1642.8         0.0
                                  PUMPS&MISC      1191.9         0.0
                                     VENTFANS     15683.0         0.0
                                 DOMHOTWATER        271.6         0.0
                                                ----------  ----------
                                        TOTAL     45986.0     13821.7

                   TOTAL SITEENERGY     59807.76MBTU    284.8 KBTU/SQFT-YR GROSS-AREA   284.8 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  151793.60MBTU    722.8 KBTU/SQFT-YR GROSS-AREA   722.8 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 52.2
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                  =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for New York – Clear Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                                     DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFFICEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                                WEATHER FILE-
LoSAngeles, CA
---------------------------------------------------------------------------------------------------------------------
---------------

                                  ENERGY TYPE:  ELECTRICITY  NATURAL-GAS
                                  UNITS:MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS      6694.9         0.0
                                 MISCEQUIPMT      4920.9         0.0
                                    SPACEHEAT      8627.6     16082.7
                                    SPACECOOL       7273.8         0.0
                                   HEATREJECT      1683.2         0.0
                                  PUMPS&MISC      1456.3         0.0
                                     VENTFANS     18814.5         0.0
                                 DOMHOTWATER        271.6         0.0
                                                ----------  ----------
                                        TOTAL     49742.7     16082.7

                   TOTAL SITEENERGY     65825.48MBTU    313.5 KBTU/SQFT-YR GROSS-AREA   313.5 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  165325.88MBTU    787.3 KBTU/SQFT-YR GROSS-AREA   787.3 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 47.6
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                  =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for New York – Low-E Shaded

```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                              DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFFICEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                         WEATHER FILE-
LoSAngeles, CA
-----------------------------------------------------------------------------------------------------
---------------

                    ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                    UNITS:MBTU
                  CATEGORY OF USE
                  ---------------
                    AREALIGHTS        6694.9          0.0
                  MISCEQUIPMT        4920.9          0.0
                     SPACEHEAT        5873.6       4664.0
                     SPACECOOL         4923.0          0.0
                    HEATREJECT        1585.4          0.0
                   PUMPS&MISC         621.3          0.0
                      VENTFANS        9208.9          0.0
                   DOMHOTWATER          271.6          0.0
                                   ----------   ----------
                         TOTAL       34099.7       4664.0

          TOTAL SITEENERGY      38763.69MBTU     184.6 KBTU/SQFT-YR GROSS-AREA    184.6 KBTU/SQFT-YR NET-
AREA
          TOTAL SOURCEENERGY  106973.27MBTU     509.4 KBTU/SQFT-YR GROSS-AREA    509.4 KBTU/SQFT-YR NET-
AREA
          PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 46.9
          PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                =  0.0
          NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for New York – Low-E Unshaded

```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                              DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFFICEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                         WEATHER FILE-
LoSAngeles, CA
-----------------------------------------------------------------------------------------------------
---------------

                    ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                    UNITS:MBTU
                  CATEGORY OF USE
                  ---------------
                    AREALIGHTS        6694.9          0.0
                  MISCEQUIPMT        4920.9          0.0
                     SPACEHEAT        5946.9       5809.4
                     SPACECOOL         5323.9          0.0
                    HEATREJECT        1599.7          0.0
                   PUMPS&MISC         730.2          0.0
                      VENTFANS       10764.1          0.0
                   DOMHOTWATER          271.6          0.0
                                   ----------   ----------
                         TOTAL       36252.2       5809.4

          TOTAL SITEENERGY      42061.60MBTU     200.3 KBTU/SQFT-YR GROSS-AREA    200.3 KBTU/SQFT-YR NET-
AREA
          TOTAL SOURCEENERGY  114576.83MBTU     545.6 KBTU/SQFT-YR GROSS-AREA    545.6 KBTU/SQFT-YR NET-
AREA
          PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 44.8
          PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                =  0.0
```

BEPS Report for New York – PV Shaded

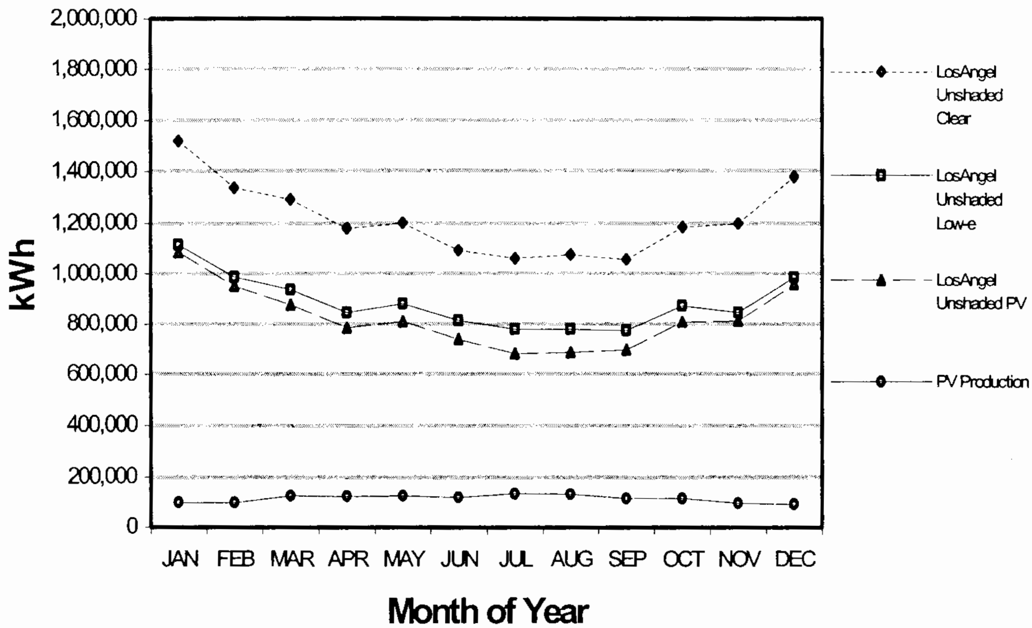
```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                                  DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFF1CEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                          WEATHER FILE-
LoSAngeles, CA
------------------------------------------------------------------------------------------------------
----------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                   UNITS:MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                 MISCEQUIPMT      4920.9          0.0
                                    SPACEHEAT       6691.5       6026.3
                                    SPACECOOL        5118.7          0.0
                                  HEATREJECT       1591.7          0.0
                                  PUMPS&MISC       670.3          0.0
                                     VENTFANS     10174.0          0.0
                                 DOMHOTWATER         271.6          0.0
                                                ----------   ----------
                                        TOTAL     36133.6       6026.3

                   TOTAL SITEENERGY     42159.95MBTU    200.8 KBTU/SQFT-YR GROSS-AREA   200.8 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  114438.06MBTU    544.9 KBTU/SQFT-YR GROSS-AREA   544.9 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 49.1
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                  =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

BEPS Report for New York – PV Unshaded

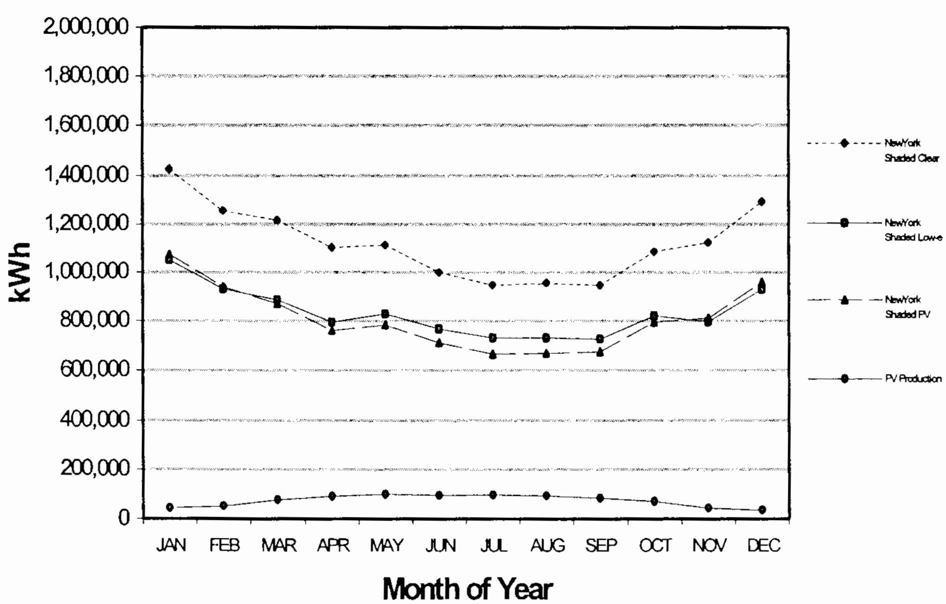
```
EFFECTOF PHOTOVOLTAICGLAZING          NEWYORK                                  DOE-2.1E-058  07/15/99
10:48:26.03 PDL RUN  1
 40-STORY OFFICEBLDG IN NEWYORK
REPORT- BEPS BUILDING ENERGY PERFORMANCESUMMARY                                          WEATHER FILE-
LoSAngeles, CA
------------------------------------------------------------------------------------------------------
----------------

                                  ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                                   UNITS:MBTU
                               CATEGORY OF USE
                               ---------------
                                   AREALIGHTS       6694.9          0.0
                                 MISCEQUIPMT      4920.9          0.0
                                    SPACEHEAT       6670.3       7374.5
                                    SPACECOOL        5564.3          0.0
                                  HEATREJECT       1609.0          0.0
                                  PUMPS&MISC       799.0          0.0
                                     VENTFANS     11945.9          0.0
                                 DOMHOTWATER         271.6          0.0
                                                ----------   ----------
                                        TOTAL     38476.0       7374.5

                   TOTAL SITEENERGY     45850.51MBTU    218.3 KBTU/SQFT-YR GROSS-AREA   218.3 KBTU/SQFT-YR NET-
AREA
                   TOTAL SOURCEENERGY  122814.02MBTU    584.8 KBTU/SQFT-YR GROSS-AREA   584.8 KBTU/SQFT-YR NET-
AREA
                   PERCENTOF HOURSANY SYSTEM ZONEOUTSIDEOF THROTTLING RANGE= 45.9
                   PERCENTOF HOURSANY PLANTLOAD NOTSATISFIED                  =  0.0
                   NOTE:  ENERGY ISAPPORTIONED HOURLY TO ALL END-USECATEGORIES.
```

APPENDIX W

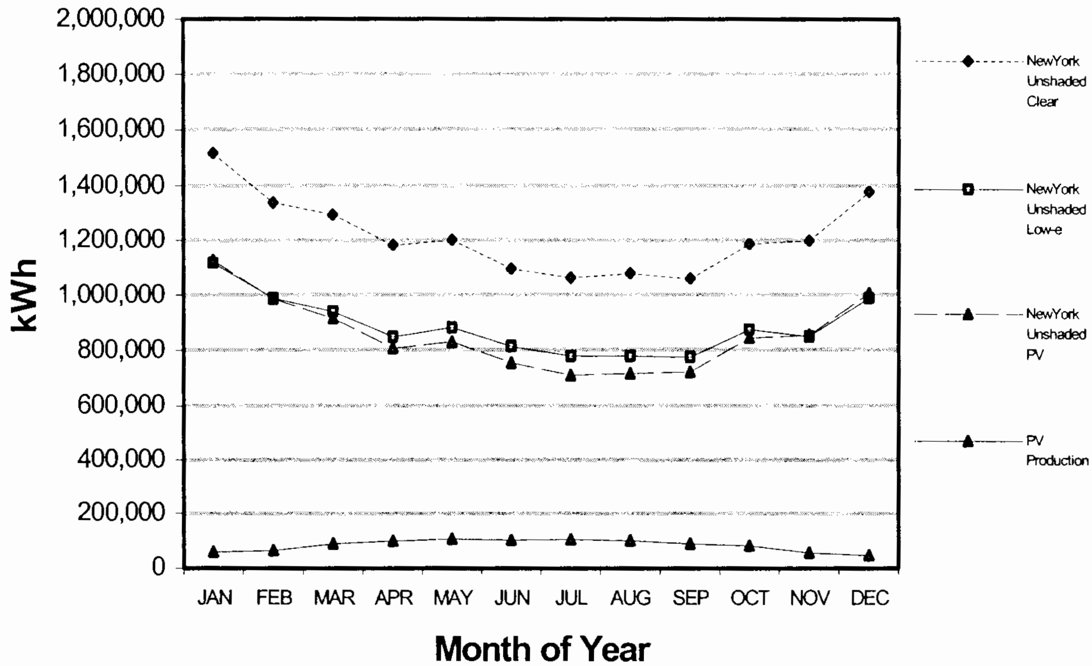
Monthly Electric Consumption



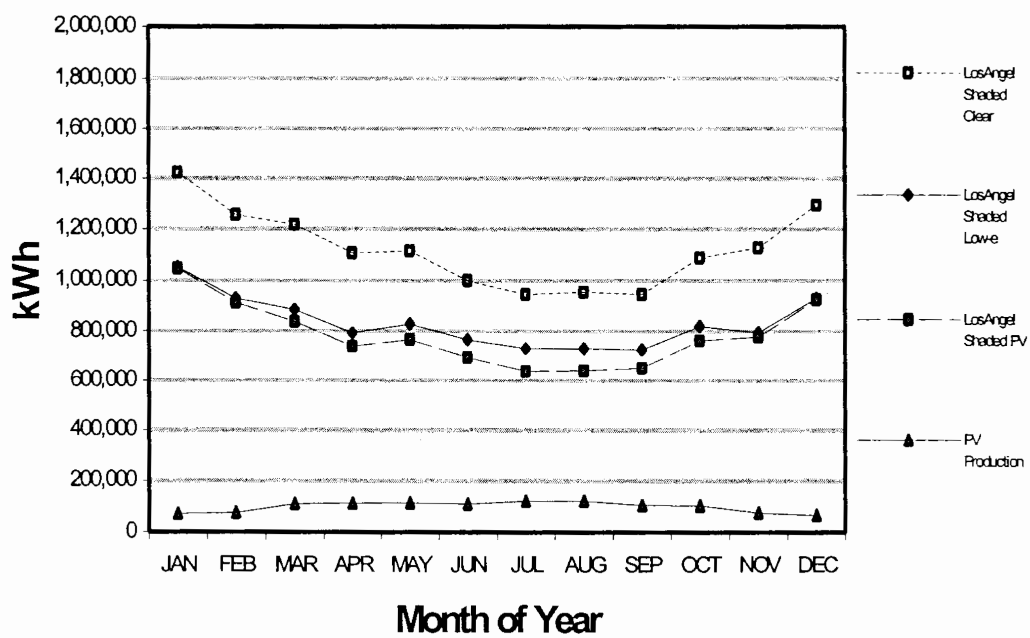
Appendix Figure 20. Monthly Electric for Los Angeles Unshaded



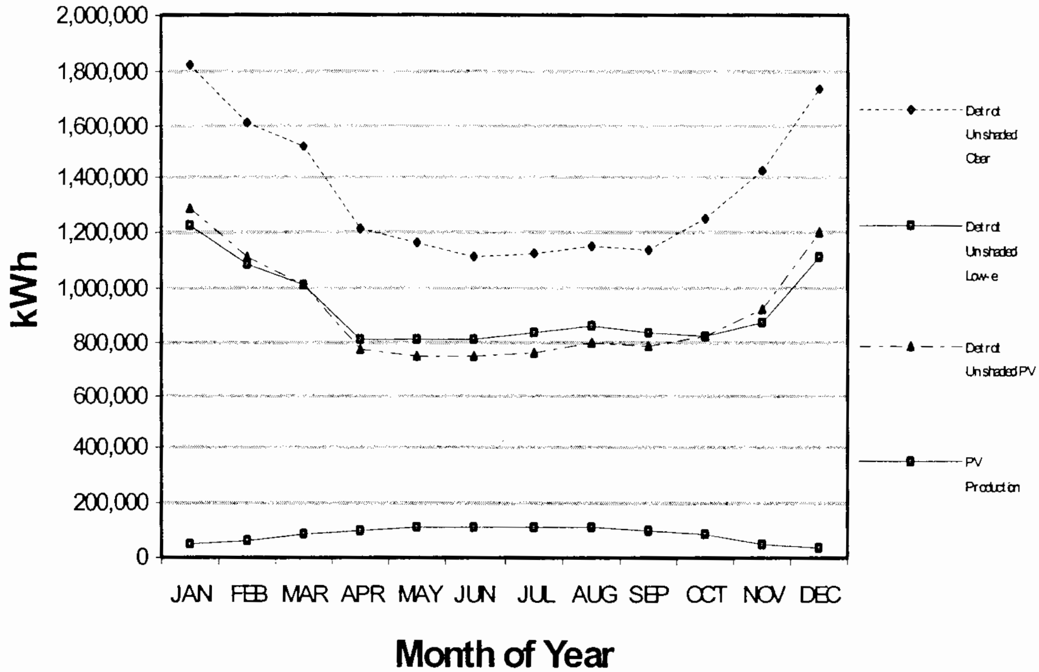
Appendix Figure 21. Monthly Electric for New York Shaded



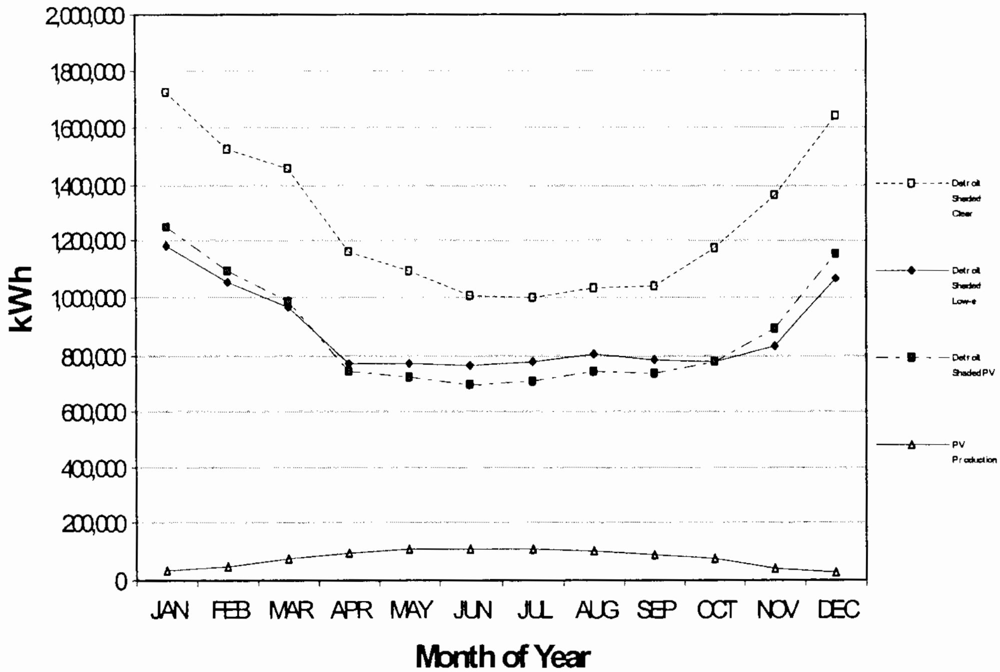
Appendix Figure 22. Monthly Electric for New York Unshaded



Appendix Figure 23. Monthly Electric for Los Angeles Shaded



Appendix Figure 24. Monthly Electric for Detroit Unshaded



Appendix Figure 25. Monthly Electric for Detroit Unshaded

APPENDIX X

Appendix Table 17. Economic Result for Low-E and PV Glazings

	Natural Gas	*Electricity*	*PV Resource*	*Total Consumption*
D-S-L	$54,286.00	$769,113.00		$823,399.00
D-S-P	$78,624.00	$812,456.00	$29,354.08	$861,725.92
D-U-L	$64,682.00	$802,854.00		$867,536.00
D-U-P	$91,262.00	$848,682.00	$33,441.54	$906,502.46
H-S-L	$24,366.00	$749,023.00		$773,389.00
H-S-P	$31,368.00	$790,344.00	$31,015.16	$790,696.84
H-U-L	$30,208.00	$808,863.00		$839,071.00
H-U-P	$38,103.00	$865,727.00	$35,669.03	$868,160.97
L-S-L	$22,788.00	$747,202.00		$769,990.00
L-S-P	$29,445.00	$790,219.00	$38,596.36	$781,067.64
L-U-L	$28,385.00	$801,160.00		$829,545.00
L-U-P	$36,034.00	$842,216.00	$44,675.97	$833,574.03
N-S-L	$22,788.00	$747,197.00		$769,985.00
N-S-P	$29,445.00	$790,113.00	$28,472.14	$791,085.86
N-U-L	$28,385.00	$801,144.00		$829,529.00
N-U-P	$36,032.00	$842,200.00	$32,555.73	$845,676.27