STRATEGIES AND RECOMMENDATIONS BASED ON ASHRAE'S ADVANCED ENERGY DESIGN GUIDE 50% SAVINGS TO ACHIEVE NET ZERO ENERGY FOR K-12 SCHOOL BUILDINGS IN THE STATE OF FLORIDA

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my family and friends

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Net Zero energy is a topic that is trending in the construction industry. A sector of this Net Zero movement garnering attention is K-12 public school construction. Compared to other buildings, schools can achieve Net Zero Energy status more readily. Few governments have established initiatives to incorporate and implement Net Zero strategies in school design and construction. There are already 20 Net Zero schools in the US and the number is increasing rapidly. The state of Florida has many energy efficient schools but a Net Zero energy school has not been achieved in this part of the country.

In this study, we discuss energy efficient design strategies for the schools and areas to be targeted in order to reduce the energy consumption based on ASHRAE's Advanced Energy Design Guide (Achieving 50% energy savings). Three case studies of popular Net Zero Schools in the country is also included. Energy performance of Alachua County's Meadowbrook Elementary School (K-5), which can achieve Net Zero Energy status with some proven and effective practices, is also discussed. Further recommendations could eliminate the gap between design and use with the help of

energy modelling and simulation. Renewable energy production is provided by taking advantage of the Florida climate zone. The suggestions reviewed and applied in this paper will establish guidelines to all the prospective Net Zero energy schools in general and the Florida based schools in particular.

CHAPTER 1
INTRODUCTION

Problem Statement

The planet Earth will have to encounter major challenges in near future. If you think it might be due to some extra-terrestrial reasons you are wrong. As the population of human beings increased by 7 times in the last 200 years, it is high time for us to conserve and put a stop to exhaustion of limited natural resources on this planet. World commission on environment and development in its report "Our Common Future" (1987) defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". If the consumption of resources continue to grow at same pace, then by 2030, we need two Earth's to support our needs.

In the statistical summary on Buildings and their impacts (2009), the U.S. Environmental Protection Agency (EPA) presented some key statistics on buildings and their significant impact on environment in United States. Below are some of the important observations:

- In the year 2005, Buildings consumed approximately 39% of the total US energy consumption.
- Buildings accounted for 72% of the total electricity consumption and is expected to reach 75% by 2025.
- They contribute 38.9% of the nation's total CO_2 emissions.

Construction industry has a key role to play in mitigating the energy consumption and thereby reducing the environmental impacts by adopting energy efficient strategies. The future of any civilization is predicted by the way their schools function. There are nearly 124,110 Colleges, Universities, primary and secondary schools where 84 million

Americans spend part of their weekdays. The design and operation of the school buildings and their value for sustainability will be reflected in day-to-day work of its occupants. Schools deserve a healthy environment and quality ambience to enable information exchange. Researches consistently showed that the students under good daylighting facilities score high on the tests compared to their peers. Improved environmental quality, low operating costs, faster payback period, enhanced learning curriculum are some of the many advantages of Net Zero Schools.

Research Objectives

The primary motivation for this study arose from the fact that NZE Schools are not a reality in the state of Florida. The main objective of this work is to analyze the energy efficient strategies implemented in the NZE schools across the country and recommending them to other schools which are near Net Zero or Net Zero ready schools in general and the schools in Florida in particular. In this process, three prominent Net Zero Schools in United States were chosen and their energy efficient strategies were discussed in detail. The efficient technologies suitable for Florida Climate zone based on the ASHRAE's Advanced Energy Design Guide for K-12 Schools were also discussed.

Another important goal of the study is to achieve Net Zero Energy Status to Alachua County's Meadowbrook Elementary School (K-5) by discussing and comparing the baseline EUI of the school since its completion and target opportunities to reduce energy usage.

Significance and Limitations

As Net Zero Schools are the next "Normal" in the construction industry, this study intended to assist any school board, owner or partner of the schools planning to achieve

Net Zero Energy status for the schools. The schools may not only conserve energy easily but have an opportunity to go Net Positive by 2030. Net Positive building is a building which exceeds its energy utilization and works as a source of energy for nearby buildings. Reasons supporting this statement are discussed in the later chapters. All the recommendations in this study are based on ASHRAE's Advanced Energy Design Guide for K-12 Schools. This work discusses the energy efficient policies in design, technology and operations of the school but the cost analysis of the projects are not carried out. The study is restricted only to School buildings but some strategies may also be very efficient when applied to commercial and residential buildings.

Organization of Study

The Chapter 2 reviews the literature on the Net Zero Schools ranging from definition to benefits of having them. Current trends for schools in United States and ASHRAE'S Advanced Energy Design Guide for K-12 Schools are also discussed in this chapter. The Chapter 3 deals with various phases involved in designing a Net Zero Energy School. Case studies of three prominent NZE Schools in USA namely Lady Bird Johnson Middle School, Richardsville Elementary School, and Richmond P.S.12 School are discussed in Chapter 4. In Chapter 5, strategies and resources for Net Zero Energy Schools in Florida and its advantages are discussed. Chapter 6 will explore all the possible strategies and recommendations involved in achieving Net Zero Status for Meadowbrook elementary school, Gainesville, Florida. Finally, Chapter 7 concludes this study.

CHAPTER 2
LITERATURE REVIEW

Background

Government and non-government organizations are dictating and supporting the rapid implementation of net zero energy strategies in the US. Net zero movement has gained momentum in the last five years as the economic recession moved out of the way. According to the Energy Independence and Security Act (EISA) of 2007 all new construction in the United States should be net zero energy by the year 2030. As President Obama said on June 2009, “By bringing more energy efficient technologies to American homes and businesses, we won’t just significantly reduce our energy demand—we’ll put more money back in the pockets of hardworking Americans.” As schools are serving as test platforms for measuring the technical and economic success of Net Zero Concept, they are leading the way by implementing of energy efficient strategies. Experts predict that there are at least 35 to 50 Net Zero or Net Zero Ready schools in USA and the number is expected to grow in the near future. Several government and Non-profit organizations like the U.S. Green Building Council (USGBC), National Renewable energy Laboratory (NREL), Florida Solar Research Center (FSEC), and Department of Energy (DOE) are playing key role in catalyzing the Net Zero Schools movement across the country. Importing huge amounts of foreign energy sources and plummeting energy prices are some significant factors which contributed to this movement.

The commercial and residential buildings use 40% of the total primary energy and almost 70% of the electricity in United States. Schools consume 17% of the total non-residential energy consumption. By the improving the energy efficiency in the K-12

Schools an amount of $2 billion can be saved (U.S. EPA, 2004b; U.S. DOE, 2006). The utility costs are only next to employee salaries thus taking huge toll on the schools exchequer. The average EUI of the schools in US is approximately 68.7 KBtu/sf/yr (U.S.EPA, 2008). Energy consumption should be reduced as much as possible to make a school Net Zero. Renewable energy technologies should be installed to offset that energy usage based on respective climatic advantages.

Definition of Net Zero Energy Building

There is no universal definition for a Net Zero School but various organizations across the world have defined NZEB. The framework of NZEB is still vaguely defined which is one of the reasons for it not having a generalized definition. Consideration of including embodied energy and the transportation energy in to the Net Zero framework is still not properly formulated. (Pless, et al 2010) Below are some of the definitions by various organizations

American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE)

A building which, on an annual basis, uses no more energy than is provided by the building's on-site renewable energy sources.

National Renewable Energy laboratory (NREL)

A residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.

Department of Energy (DOE)

A building that produces and exports at least as much emissions-free renewable energy as it imports and uses from emission-producing energy sources annually.

European Commission (EU)

The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

Net Zero Energy Building (NZEB):

Our definition: A building achieves the “Net Zero Energy” status, if the energy regenerated by the building with the help of renewable technologies compensate for its energy consumption in a year.

NZEB’s are categorized into 4 types based on their source of the renewable energy.

- **ZEB A**: The generated renewable energy is sourced within the building footprint.
- **ZEB B**: The generated renewable energy is sourced on-site
- **ZEB C**: The energy is generated on-site with the help of off-site resources
- **ZEB D**: Renewable energy is purchased from off-site sources

Other Definitions of Net Zero

Net Zero Site Energy

The energy generated by the renewable technologies installed on-site should compensate for the total energy used by the building in a year.

$$\text{Net Zero Site Energy} ----\mathrm{m} - \mathrm{r} \leq 0 \tag{2-1}$$

Where, m = end use consumption measured at the building’s utility meter(s)

r = renewable energy produced onsite

Net Zero Source Energy

The energy generated by the On-site renewable technologies should not only off-set the energy utilization of the building but also losses at the utility grid due to conversion and transmission.

$$\text{Net Zero Source Energy} ----\mathrm{m} + \mathrm{g} - \mathrm{r} \leq 0 \tag{2-2}$$

Where, m = end use consumption measured at the building's utility meter(s)

g = energy losses within the utility grid from the conversion and transmission losses

r = renewable energy produced onsite

Net Zero Energy Cost

The total amount paid by the owner to the utility grid for using the energy produced at the grid should be equal to the amount the utility grid pays to the owner for the importing the energy produced by the site or building.

$$\text{Net zero energy cost} ----\$\mathrm{m} - \$\mathrm{r} \leq 0 \tag{2-3}$$

Where, \$m = cost of purchased grid-based energy

\$r = income from renewable energy produced onsite

Net Zero Carbon Emissions

The on-site carbon neutral energy sources should off-set or avoid the amount of carbon emissions occurring at the utility source grid thereby making the sum total of carbon usage Zero.

$$\text{Net Zero Carbon} ------\mathrm{Cm} - \mathrm{Cr} \leq 0 \tag{2-4}$$

Where, Cm = amount of carbon emitted from grid-based energy sources

Cr = amount of carbon avoided by on-site carbon neutral sources

Benefits of having Net Zero School

Creating Net Zero Energy Schools will result in numerous benefits. As all the renewable technologies are purchased locally, they contribute a lot to the local economy and thereby creating employment in the neighborhood. According to American Solar Energy Society (ASES 2008), Energy efficient technologies created around 8 million jobs in the year 2006. The schools spend a lot on utility costs but having efficient operations and maintenance plan will reduce those expenses drastically and the huge amount saved can be spent on other purposes like books and study technology.

Education under healthy conditions keeps mind active and improves the performance of the students in the tests. Providing clean Indoor air quality for students is essential. Many studies suggest that students having good learning environment enhance their academic skills and score higher on tests compared to others. Comparatively, schools can achieve NetZero easily than other commercial and residential buildings. (Hutton, P. C. 2011) Some of the main reasons are:

- Less operation hours
- Long holiday break periods
- Minimal process loads
- Long term benefit oriented Owners

On the financial aspect, the Net Zero Energy Schools perform very well and are profitable in the long run. On contrast to general perception, the initial investment cost of an energy efficient school is on par with the conventional school building. But the savings on operations and maintenance are quite impressive. As average age of school buildings is 42 years, it is beneficial for the owners in long-run. Life cycle cost of the buildings suggests very fast payback periods and more return on investment. Schools like Lady Bird Johnson Middle School in Texas saves $250,000 through its NetZero initiatives. More about the School is discussed in later chapters.

Net Zero Energy Schools in USA

The rapid increase in the growth of number of Net Zero Energy buildings in US suggests that the market trend is towards the NetZero Concept. Net Zero energy schools create win-win situation to all the parties involved on the projects, ranging from owners to occupants. (Doo Consulting, October 1, 2013) Below table lists some of the Net Zero Schools in the Country.

Table 2-1. List of Net Zero Energy Schools in USA

Name	Location
Prairie Hill Learning Center	Roca, Nebraska
Putney School Field House	Putney, Vermont
Marin Country Day School – Learning Resources Center	Corte Madera, CA
Hayes Freedom High School	Camas, Washington
Evie Garrett Dennis PK-12 School	Denver, Colorado
Centennial PK-12 School	Centennial, Colorado
Richardsville Elementary School	Bowling Green, KY
Kiowa County K-12 School	Greensburg, Kansas
Sangre de Cristo PK-12 School	Mosca, Colorado
Lady Bird Johnson Middle School	Irving, Texas
Colonel Smith Middle School	Fort Huachuca, Arizona
George LeyVa Middle School Administration Building	San Jose, California
Hood River Middle School	Hood River, Oregon
Locust Trace AgriScience Farm	Lexington, Kentucky

Apart from the above mentioned schools there are many NetZero ready schools which are about to achieve Net Zero Energy status. Refer to Appendix B for more information regarding Net Zero Schools.

ASHRAE's Advanced Energy Design Guide for K-12 Schools

The Advanced Energy Design Guide for k-12 schools is developed to help the schools in achieving 50% energy savings if the building already complies with ASHRAE/IESNA 90.1-2004 standard. The AEDG-K12 school buildings guide is second 50% energy savings guide developed by ASHRAE along with AEDG for small to medium office buildings. This guide was developed by collaboration of ASHRAE, American Institute of Architects (AIA), Illuminating Engineering Society of North America (IESNA) and the USGBC with the support from Department of Energy (DOE).It provides design guidance and recommendations for elementary, middle and high school buildings. It also provides detailed recommendations based on the 8 primary climate zones of the country. These climate zones are categorized based on the seasonal metrics. Diligent study and thorough implementation of this guide would reduce the energy usage by 50% if the building already complies with ASHRAE/IESNA standard 90.1-2004. This can be applied not only to the new schools but also to those which are undergoing partial or major renovations.

The guide has various recommendations and detailed explanation for the ways to implement them. The recommendations applicable to envelope, daylighting, electric lighting, plug loads, kitchen equipment, service water heating, HVAC, quality assurance were made along with additional bonus savings. Whole building approach or integrated design process is the first and foremost step to be implemented in order to achieve energy savings as all the benefits of possible synergies can be taken into consideration. Refer to Appendix A for more information on ASHRAE Advanced Energy Design Guide.

CHAPTER 3
METHODOLOGY

Case Studies of Net Zero Energy Schools

From the existing Net Zero Schools, three schools were studied and analyzed in this study. Lady Bird Johnson Middle School, Richardsville Elementary School, and The P.S.62 School are the three schools considered in this study. Various energy efficient design strategies adopted by these schools have been discussed. Above mentioned schools are considered based on their location (climate zone), total area and the start year of operation. Lady Bird Johnson Middle School which is located in Irving, Texas is the largest Net Zero School in the country whereas Richardsville Elementary School located in Bowling green, Kentucky is the First Net Zero Energy School. The third school, the P.S.62 is located in New York and expected to start its operation in fall 2015. Various components of energy efficient designs ranging from envelope to HVAC system were detailed in the Chapter-4. Financial costs for installing renewable energy technologies were also mentioned. Considering the scarcity of data on Net Zero Schools at this point of time detailed study on economics of the schools were not evaluated.

Energy Modelling

In the later part of this study, energy performance of Meadowbrook Elementary School located in Gainesville has been analyzed. Energy modelling was done with the help of Trane Trace 700 software. Original energy usage of the school is compared to simulated data for its authenticity. Summer data of the school was not considered while checking the reliability as the data is inconsistent due to construction operations. The actual model was the taken as basis and three models are developed based on energy efficient design strategies recommended by various guides. ASHRAE 90.1-2007, ASHRAE Advanced Energy Design Guide and finally proposed model which consists of best practices from state-of-the-art were compared. As the school is already performing very efficiently, some of the components whose impact is high on energy usage were targeted. Finally, possibility of offsetting the energy consumption with Photovoltaic system was evaluated.

Recommendations

All the recommendations mentioned in this study are based on ASHRAE Advanced energy design guide for K-12 Schools. The proposed model developed for Meadowbrook elementary school was based on existing best practices already implemented in the schools. Data regarding existing state and amount of PV array installed on the Meadowbrook Elementary School was obtained from Solar Impact. Suggestions were made by considering not only the roof area but also parking lot near school building. NREL’s PV watts calculator was used to estimate the amount of array required to offset the energy consumption.

CHAPTER 4
DESIGNING A NET ZERO SCHOOL

There are several phases involved in designing a Net Zero School that are recommended in AEDG K-12 and other relevant guides are discussed below. “The initial investments are huge” is the general perception for the construction of Net Zero School. But Net Zero Schools like Lady Bird Johnson Middle School had only 10 to 20 percent more upfront costs. The additional investments are only due to installation of renewable energy technologies. The cost of these technologies can be reduced by mitigating the EUI of the building and thereby increasing the efficiency of the building.

Integrated Design Approach

The first step in this process is integrated design process or whole building approach. Design of NZE School is very challenging and demands highly dedicated team. Collaboration is involved in all the layers of the design, construction and operations phases of the building is known as integrated design approach. It takes skilled team and committed administration to reach the target of achieving Net Zero Status to the school. Charrette which is an intensive workshop to discuss all the issues regarding the building, should be conducted at the beginning of the design process.

The participants can range from architects, owners, stakeholders, facility managers, construction engineers, cost consultants, contractors, sub-contractors and the end users. The benefits of conducting the Charrette are very encouraging. It helps to understand the project inside out and various methods adopted to achieve Net Zero by all the people working on it. The advantages of energy synergies due to impact of one strategy on another can also be evaluated in this process.

Figure 4-1. Integrated Design Approach

Performance Targets by Adopting Energy Efficient Design

After thorough brain storming sessions, the target performance of the building should be reviewed. The design strategies mentioned in the ASHRAE AEGD K-12 should be implemented, which would decrease the EUI by 50% when compared to the ASHRAE 90.1-2004 standard. Based on case studies, the schools which restrict their EUI below 20KBtu/sf/yr can be a Net Zero energy school easily. Coordination in implementing the energy efficient strategies in well-designed building is critical. Important aspects like orientation, building envelope, HVAC system, day-lighting, electric lighting, plug loads, fenestration should be addressed with at most care. Using ENERGY STAR rated products, especially in the Kitchen, would reduce the utility costs substantially. According to U.S. EPA, 2008b, the schools which use products with

ENERGY STAR rating require 40% less cost to run when compared to conventional schools. High roof and wall insulation of the envelope along with efficient glazing components will have positive impact on the building performance. Daylight harvesting strategies with good electric lighting and productive HVAC system will also mitigate the energy consumption of the building.

Installation of Renewable Energy Technologies

Once the target EUI of the building is successfully achieved (<20KBtu/sf/yr), the energy needs can be covered with the help of Renewable Energy Technologies. The team should take advantage of the location of the project and its climate zone while selecting the technologies. ASHRAE’S AEDG for K-12 schools has categorized 8 climate zones based on their seasonal metrics. Each climate zone has its share of energy strategies and recommendations. Energy consultants can be very helpful in reviewing the installation process of technologies. Below are most common renewable energy technologies:

Solar photovoltaic panels

Photovoltaic panels are a widely used renewable energy system which captures energy from sunlight and converts it to electricity. Solar energy is the largest renewable energy source in the world. The solar cells in this system converts solar energy into direct current (DC). Then with the help of appropriate power conversion equipment the alternating current (AC) is produced. The solar cells are assembled in a series or parallel circuit to produce higher power levels. A typical module consists of 40 solar cells assembled together. The solar panel has one or more modules. Combination of the photovoltaic panels is called an Array. Basing on their operation and distribution, PV systems are classified into two types: Grid connected system and stand-alone system.

Considering the average age of the schools, i.e.42 years, payback periods of this technology is fast. It is less than 20 years after all the rebates and tax credits.

Figure 4-2. Renewable Energy Technologies (Nigeria Intel)

Geo exchange systems

This is a technology that should be implemented in HVAC system. The Geo exchange system is similar to any other electrically powered system which is used to heat and cool the interior spaces but it takes the Earth's energy to do that. Geo exchange heat pump present in this system releases heat into the earth when it is in cooling mode and extracts heat from the ground in heating mode. They are classified into various types based on their design and placement. Direct exchange, closed loop, open loop, horizontal and vertical geo-thermal heat pumps are some of those. Lady Bird

Johnson middle school uses this technology effectively by reducing 30% of the total energy consumption.

Wind turbines:

Wind turbines are used to generate electricity by converting kinetic energy of the wind to electric energy. Similar to solar PV panels, wind turbines can be connected to the electrical grid or used as stand-alone applications. They can also be connected to solar PV system in some cases. Large number of wind turbines are built closer to each other to form wind farm or wind plant. Wind power density (WPD) is the quantitative measure of the wind energy. It varies with height of the turbine, velocity and density of air.

Operations and Maintenance

Operation and Maintenance (O&M) and measurement and verification (M&V) are highly significant steps and crucial in achieving Net zero Energy. All the occupants of the building, ranging from teachers, students and employees should be well educated about the systems installed. Importance of conserving natural resources should be included in the course curriculum. A sense of ownership and the value of the project should be induced in to the culture of the organization thereby making everyone stewards of the Net Zero movement.

Proper digital monitoring systems should installed to review the performance of the building. First year performance determines the accurate efficiency of the building. It may happen that design occupancy do not comply with actual occupancy of the building. Frequent auditing will enable the facility to run according to design and meet its performance targets consistently. Periodic and preventive maintenance will have favorable effect on operational efficiency.

Below are some of the preventive maintenance activities:

- Minimizing the pressure drops by keeping the HVAC system clean.
- Fix broken sensors to get authentic feedback from automation systems.
- HVAC sensors should be inspected to have comfort air quality.
- Replacing bulbs which are meeting performance levels.
- Ensuring all pumps and fans are oiled and operating properly.

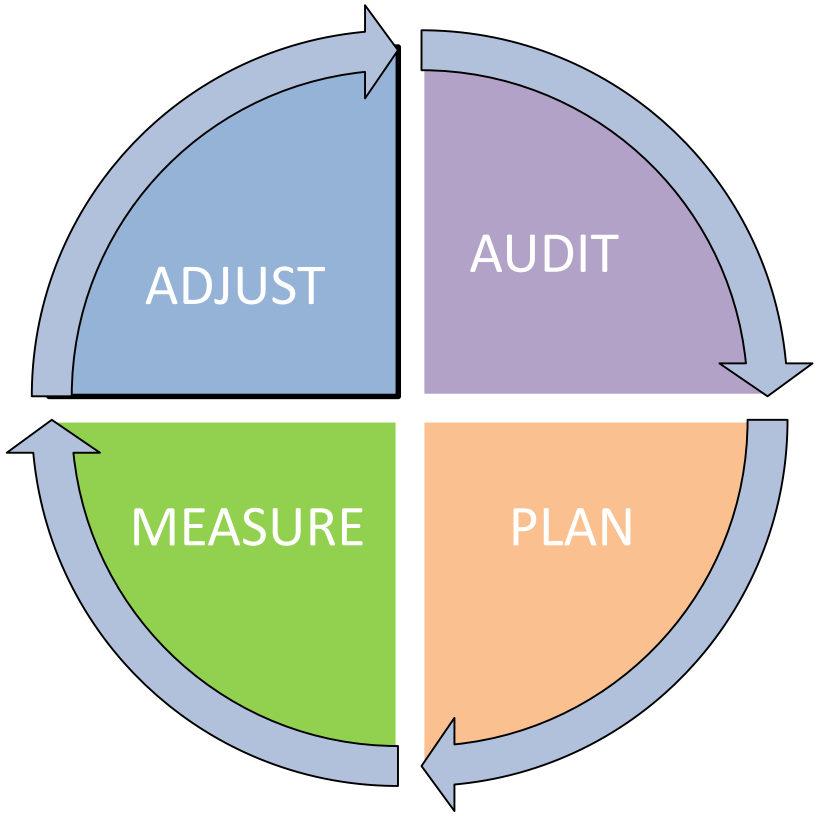

Figure 4-3. Operation and Maintenance cycle

Strictly implementing above mentioned strategies will play a crucial role in reducing energy consumption and thereby provides opportunity to achieve Net Zero Energy.

CHAPTER 5
CASE STUDIES

Lady Bird Johnson Middle School, Irving, Texas

Lady Bird Johnson Middle School is the first Net Zero School in the state of Texas and the largest in the country with the total area of 152,250 square-feet. This LEED Gold certified school was opened in the year 2011 and was awarded as the Best K-12 green school for the year 2013 by the Center for Green Schools at U.S. Green Building Council (USGBC). The idea of the school is to reduce, reuse, and recycle by educating future generations and making them stewards of environment.

Figure 5-1. Lady Bird Johnson Middle School is the largest Net Zero School in US (Source: Irving Independent school district)

Table 5-1. Lady Bird Johnson Middle School

SCHOOL AT GLANCE	
Architects	Corgan Associates, Inc.
Energy Consultant	Image Engineering Group
Contractor	Balfour Beatty Construction
EUI	22.8 KBtu/sf/yr
Gross square footage	152,250 SF
Occupancy	1000 students
Project Cost	$29,610,423

As a part of energy efficient strategies, the wall and roof insulation are above and beyond the code standards. Fabral wall panels on the exterior walls of the building and metal cladding covering the canopy keeps the building tightly insulated from outside air. The canopy provides the solar shading by covering the west and south facing windows of the building. Highly efficient glazing adopted helps the heat to pass through in winter to maintain the warmth of occupants and reflects the heat in summers. Considering the hot Texas summers, a highly reflective roof and bright silver color finishing were specified for all the products which helps in reducing the heat absorption and thereby improves the overall performance of the building.

Equipped with geo-thermal HVAC System and building automation systems the school's site energy use intensity (EUI) is 22.8 KBtu/sf/yr, which is very low compared to average EUI of conventional schools in U.S

To offset this energy usage, very efficient renewable energy technologies were employed. Lady Bird Johnson is one of those rare schools which have solar and wind renewable technologies on the same site. Solar PV panels with rating of 550kW were used to cover about 66,000 SF of roof area. Geo exchange systems or geo-thermal pumps which reduce 30% of the school's total energy usage are also installed. 468 geothermal wells, each 250 feet deep were connected to 105 heat water pumps for heating and cooling systems. The school also utilizes the wind energy by having 12 wind turbines with maximum rating of 28.8 kW. Important observation to be noted is the area of the school has been classified as no wind zone by NREL. The initial costs of the school were increased by 15% but the payback period is expected to be 12-15 years. While the initial costs have increased by $3.7million due to Net Zero Strategies, the school is saving $250,000 each year through utility bills

Rainwater harvesting, xeriscaping, grey water collection, LED lighting in hallways, GREENGUARD furniture and usage of ENERGY STAR kitchen equipment are among other energy efficient strategies.

Richardsville Elementary school, Bowling green, Kentucky

This 77,000 Square-foot elementary school is the first Net Zero School in United States and was built with construction costs of $14.2 million.

Figure 5-2. Richardsville Elementary School (Source: Sherman Carter Barnhart)

The two-story building accommodates 550 students and was designed to be a Net Zero school with the target EUI of 17 KBtu/sf/yr. This project represents the continuous energy successes of Warren County School district, Bowling Green, Kentucky. The project was completed in the year 2010. In the process of achieving NetZero Energy status, an integrated design process was implemented by involving school district officials, architectural and engineering design team, the state department of education and power companies around the area.

Table 5-2. Richardsville Elementary School

SCHOOL AT GLANCE	
Architects	Sherman, Carter, Barnhart, PSC
Energy Consultant	CMTA Engineering
Contractor	RG Anderson
EUI	17 Kbtu/sf/yr
Gross square footage	77,000 SF
Occupancy	550 students
Project Cost	$ 14.2 million
Single-ply membrane with rigid insulation on Metal decking	Overall R value=R-32, Reflectivity 95
ICF exterior walls	Overall R-value = R-28.6
View windows (center of glass)	U-factor – 0.29,SHGC – 0.40
Daylighting windows (center of glass)	U-factor – 0.47, SHGC – 0.78

Taking advantage of optimized orientation, Insulated concrete form walls, R-32 insulated roof high performance building envelope is designed. Richardsville elementary is the first school in the district to utilize the daylight harvesting. Light shelves, clerestories in each classroom and main hall, and skylights are some of their efficient lighting strategies. Substituting desktop with laptop computers and usage of ENERGY STAR rated kitchen have contributed to reduction in energy usage.

To mitigate the energy usage various energy efficient strategies technologies ranging from geo exchange systems, geothermal hot water and energy recovery are employed. Dedicated outside air system (DOAS) delivers the outside air directly into the classroom unrelated to heat pump system. Demand control ventilation is coupled with DOAS to further reduce the energy consumption. Richardsville Elementary School is one of the few schools which use thin film flexible PV instead of rigid panels. The total cost of the 394 KW PV panel system which covers roof and parking lot is $ 2,650,000. The school also boasts of some innovative technologies like mobile computer carts which eliminated the need for a separate computer lab area of 1200sf, thereby reducing the utility costs. To monitor and verify the building's performance a power monitoring system was also designed.

The School has themed some portions of the building based on various energy efficient techniques implemented as part of educational awareness. For example, the water conservation hallway is where students can see the amount of water collected through rain water harvesting and how much is utilized for flushing toilets. Likewise, they have solar, geo-thermal and recycling hallways.

With all the above mentioned strategies, the School has 75% energy reductions over ASHRAE 90.1-2004. Post-occupancy the EUI of the school is 1.55KBtu/sf/month which is close to the target performance (17KBtu/sf/yr). The school also sells the power generated by thin and crystalline solar panels to Tennessee Valley Authority, the local utility company, earning $ 37,000 every year. Efficient kitchen cooking strategies, operation and maintenance plan and materials reuse are among the other strategies.

The P.S.62 School, Staten Island, New York

Located on a 3.5 acre site area, P.S.62 Richmond is the first ever Net Zero Energy School in New York and Northeast United States. The construction and design of the school was launched in October 2012 and will open for use in fall 2015. It offers a

50% energy reduction over a New York City Standard Construction Authority (SCA) normal public school.

Figure 5-3. The P.S.62 School (Source: Skidmore, Owings & Merrill)

The building envelope is ultra-insulated with R-23 precast concrete walls and 4” rigid insulation between panels. Maximum benefits are gained by adopting optimized orientation and high performance envelope. By taking advantages of the sunlight, adequate daylighting strategies such as occupancy sensors, dimmable and skylight fixtures are designed. With open staircase between the two floors, the amount of light infiltration is improved. Highly efficient HVAC system with geo exchange systems, energy recovery ventilation (ERV) and demand control ventilation to specific areas are employed to maintain good indoor air quality and comfort ventilation. A vegetable and greenhouse garden, low energy kitchen equipment are some of the other energy conservation strategies.

Table 5-3. The P.S.62 School data

BUILDING AT GLANCE	
Architects	Skidmore, Owings & Merrill (SOM)
Energy Consultant	AKF Group, In Posse LLC
Contractor	Skidmore, Owings & Merrill (SOM)
Gross square footage	68,068 SF
Occupancy	444 Students
Project Cost	$58,000,000

A huge array of 2000 photovoltaic panels rating 606 kW will cover the roof and the South façade of the building is expected to generate 1.9 million KBtu of energy per year. . Solar thermal hot water system is designed to serve 80% of Domestic hot water (DHW) needs. This public funded school is completely built on a green space

CHAPTER 6
STRATEGIES AND RESOURCES FOR NET ZERO ENERGY SCHOOLS IN FLORIDA

The Sunshine State with its distinctive climate and superior levels of solar radiation can be the nationwide leader in implementation of Net zero energy schools. In 2011, the state ranked third in net electricity generation from solar energy. The government has been committed to implementing energy efficient strategies in the public schools in the last 10 years. But lacking proper initiatives and the participation of school boards, Net Zero Energy School is still not a reality in this part of the country. This chapter reviews the climatic advantages and energy efficient strategies that can be adopted in Florida.

Energy Strategies for Educational Facilities in Florida

Major energy end-uses in schools statewide are lighting and HVAC systems. Due to very hot summers, the cooling loads of the buildings are quite high. Beginning with orientation of the building to completely offset the energy usage with renewable energy technologies, various strategies should be implemented to make a school NetZero Energy. Some of them suitable strategies for Florida's climate zone are discussed below. Refer to Appendix A for ASHRAE's recommendation chart for Florida climate zone.

Orientation

The building orientation is the first step in the process of constructing energy efficient building. The East/ West axis building orientation to maximize north and south exposure is optimum for daylight harvesting and reducing heating and cooling loads of the building. The variation of $\pm 15^0$ is acceptable and has same efficiency of East/West orientation. This kind of orientation helps in reducing the heat gains in the summer while taking advantage of Sun’s warmth in winter.

Envelope

In order to gain maximum benefits the Envelope should be highly insulated making it air tight. Cool roofs with a high Solar Reflectance Index (SRI>=78) should be preferred in hot climates to dark roofs. Well insulated walls with high resistance value such as Insulated Concrete Form (ICF) walls will help in keeping the resistant from solar heat gains. Also glazing on the East and West facades of the building should be minimized by designing more openings on North and South exposure as sun control devices are not very effective. In Florida, North exposure gets less direct solar radiation which enables it to have less heat gains. Whereas south exposure gets intense heat but doesn’t last for long time in a day. On the other side, it helps to heat the building in winter thereby reducing the heating loads. Reflections from adjacent building surfaces, trees or walls should be considered at the design phase as they might have considerable impact on heat gain and shading strategies.

Harvesting the daylight should also be considered at the design face. Design team should consider putting clerestories, roof monitors for vertical fenestration of the building. If the sloped glazing opening is less than 70^0 then it falls under sky lighting category. The properties of glazing products such as visible transmittance (VT), solar heat gain Coefficient (SHGC) and U factor should be chosen based on the climate zone recommendations by AEDG. Refer to Appendix A for more information.

Massing

Decreasing the carbon footprint of the building is another very important target. Reduction in footprint and good orientation will reduce the energy consumption by 10%.

For example, a Two-story building is more efficient than one-story building given both has same foot area and orientation. But it should also be understood that massing will be counter-productive after three levels.

Lighting

Daylight harvesting and a high efficiency lighting system are common practices for all the new energy efficient schools. Adopting this strategy should be planned in the design stage of the project. Electrical lighting energy should be reduced by maximizing the natural lighting. Design should ensure that building is day lit for at least 60% of the hours of school operation (AEDG). Areas like classrooms, cafeterias, administrative offices and multipurpose rooms should be considered for daylighting. Minimum of 10ft high classrooms should be considered for daylighting.

Figure 6-1. Interior Daylighting (Source: CMTA Consulting Engineers)

Having clerestories in classrooms and main hall, dimmable fixtures, Skylights, LED site lighting, daylight and occupancy sensors will have huge impact in reducing the lighting loads. Daylight zones can be created inside the north and south facades of the building by placing the glazing in locations that reduce the need of lighting fixtures. With the help of Louvers direct solar radiation on the occupants can be eliminated. East and west orientation must be restricted to few windows and for effective results overhangs should be considered on the South façade of the building.

On the other side, increasing the glazing areas for excessive daylight may adversely affect the building by increasing the cooling loads. To avoid glare and discomfort for teachers and students, daylighting windows should be provided above the 7ft. At the same time, few view windows should be below 7ft allowing visual comfort for the occupants. Designing daylighting for rooms with AV system is bit challenging as it should not cause inconvenience for visual projections Therefore the balance between the controlled daylighting and cooling loads should be achieved which provides quality and controlled light for the occupants. Target light power densities (LPD) of various spaces in the building like classroom, gym, multi-purpose rooms, rest rooms, auditoriums, kitchen and cafeteria have been mentioned in the AEDG recommendations for Florida climate zone. Light colored interior finishes for spaces, high reflectance (>80%) should be considered for effective lighting. Using LED's and occupancy sensors would have positive impact on the energy savings. All the lighting in the exterior areas like parking lots and drives should be auto reduced to 25% at night.

HVAC System

Efficient HVAC system will help in reducing the heating and cooling loads of the building. According to AEDG for K-12 schools guide, 3 types of below mentioned HVAC systems can be used. 50% reduction in energy can also be achieved if the existing HVAC system performs better than the suggested systems.

HVAC 1: Ground source heat pump with dedicated outdoor air system for ventilation.

HVAC 2: Fan coils with a water chiller, a water boiler or electric resistance heat, and a dedicated outdoor air system for ventilation.

HVAC 3: Multiple zone, variable-air- volume (VAV) air handling units with a water chiller, a dedicated outdoor air system for ventilation, and perimeter or in-floor radiant heat located in the occupied spaces.

Ground Source Heat Pump System (GSHP)

It is also known as Geo-exchange system. This system uses Earth's temperature to cool or heat the building instead of cooling tower and boiler. In summer, when the temperature of the building is high, it rejects the heat to the ground. In winters, it takes the heat from the ground thereby reducing the heating loads of the building. Geo-exchange system is suitable for all climates according to AEDG guide. Though some people may rise doubts about its efficiency in Florida, actual performance of the system is yet to be tested. As mentioned in the earlier chapters, schools like Lady Bird Johnson Middle School reduces 30% of its energy consumption by making use of this system. They have installed 105 geo-thermal pumps for the school. All the components are factory assembled which includes refrigerant-to-air heat exchanger, refrigerant to water heat exchanger, compressor, fan and controls.

Fan-Coil System

In this system each thermal zone is equipped with separate fan coil unit. They are typically installed in the ceiling plenum above the corridor or in the adjacent closet to the space. Nevertheless, enough space should be provided for maintenance purposes. In this system, all the coils are connected to centralized water chiller. Centralized water chiller and centralized boiler provides the cooling and heating requirements respectively. For the Florida climate zone, it is recommended to use electric resistance heat instead of hot water heating due to minimal heating requirements.

Variable-air-Volume air handlers

In this system, recirculated air is cooled by central VAV air-handling unit and then distributed to several individually controlled systems. Dual duct VAV terminal unit is present in every thermal zone. One damper ensures proper ventilation by controlling the outside air from the outside air unit while other cools the primary air from VAV air-handling unit to maintain temperature in the respective thermal zone.

All the VAV units are connected to central air distribution system. Air handling units are connected to common water distribution system. Water chiller provides the cooling for the building while hot water coil or electric resistance heater is used for heating.

Dedicated Outdoor air systems (DOAS)

The DOAS can reduce the energy use by disconnecting cooling, heating and dehumidification of outside air (OA) unit for ventilation from sensible cooling and heating in the zone. A separate OA unit is designed to filter, heat, cool and dehumidify the outside air and deliver it. Terminal HVAC systems which are present will heat or cool recirculated indoor air to main temperature. Terminal HVAC system may include water source heat pump, fan-coil unit or dual duct VAV terminals. Apart from this, exhaust air energy recovery, demand controlled ventilation, temperature reset strategies can help in mitigating the overall energy use.

Plug Loads

Plug loads are energy consumption from electrical equipment such as computers, classroom technology, printers, copy machines, vending machines, and refrigerators. Plug loads have been challenging for the architects as their percentages increases when more energy efficient building technologies are adopted. They account for 10%-20% of total energy usage without considering the kitchen equipment. The technology design should explore the opportunities to switch off the servers, telecom and television systems when unoccupied. It is always good to have school's technology coordinator involved in the design process.

Practices like encouraging the use of laptop computers instead of desktops and using ENERGY STAR equipment for all the appliances would mitigate the plug loads significantly. Apart from some of the plug loads which are continuous, such as refrigerators, security equipment can be powered off or deactivated when not in use. A typical school has 180 working days, with a 8am to 3pm schedule, and it is unoccupied for 75% of the year. Regulating this loads will have a huge impact on the energy consumption of plug loads.

Some schools like Richardsville elementary school have a mobile computer lab which eliminates the area for the computer lab and thereby reducing the initial costs of the building. This innovation is possible by just having laptops with wireless network. Similar to lighting, occupancy sensors should be placed in each room to power off the coffee machines, printers, vending machines when not in use. ENERGY STAR rating equipment has this feature in it. It is also recommended for school boards to have policy which requires all the electric devices and appliances should be ENERGY STAR rated.

Another category in the plug loads are Phantom loads or Parasitic loads. The electronic clocks, VCR, office equipment with wall cubes contribute to phantom loads. Usually phantom loads consume up to 5% of the phantom loads. These loads can be decreased by directly switching off the devices or powering off the power strip to which the devices are connected. Occupancy sensor controlled power strips are highly effective to offset these loads.

Kitchen Equipment

Most of the K-12 schools have kitchens ranging from few appliances to whole kitchen equipment. It is recommended have food service manager on board at design phase to reduce the energy consumption of the Kitchen. Implementing the following strategies will provide an opportunity to conserve the energy:

Using Energy-Efficient Kitchen Equipment

All the heat producing appliances such as broilers, griddles should be replaced with combination oven steamers, conventional ovens, microwaves and tilting skillets. Using ENERGY STAR rated kitchen equipment is highly recommended in all categories which include Solid door freezers, dish washers, fryers, hot-food, ice machines, solid and glass door refrigerators and steamers.

Exhaust and ventilation design systems

To minimize the air flow, proper exhaust ventilation system should be designed for which placing of the cooking equipment and design of hood systems are critical. By reducing the ventilation adequate exhaust flow should not be compromised. Kitchen hood system which include exhaust hood, fan, and ductwork should be designed by food service consultant or mechanical engineer.

Reducing hot-water usage

Using low flow water flow fixtures will conserve both water and energy. The Hot-water design guide for commercial kitchens by FSTC will provide information on having maximum energy savings.

Highly efficient refrigeration systems

Energy efficiency measures in refrigerating systems like automatic door closers to make sure that refrigerator is completely closed, high insulation(R-25 and above), strip curtains to mitigate infiltration and productive internal lighting system should be considered for energy reduction. Impressive savings can be achieved by having the following system technologies in place:

- Floating head pressure controls
- Liquid pressure amplifier
- Sub-cooled liquid refrigerant
- Oversized condenser
- Mechanical sub-cooler
- Evaporative condensers

Operation and Maintenance

Operation of the equipment will also have significant impact on the energy. All the freezers and coolers should be shut down during long holiday periods like summer and Christmas breaks. Anticipating the quantity and the kind of food served in cafeteria and reducing the energy consumed to prepare that menu without compromising on the nutrition will have positive impact on the energy savings.

Commissioning

Commissioning gives an opportunity to inspect all the techniques adopted basing the design and review any chances of improvement. Selecting the design and construction team is very important step in process of having a successful project. Team dynamics have a very key role to play from start to close out of the project. Owner’s project requirements (OPR) is the basis of function and operation of the project which constitute team member roles, budgets, performance, schedule and other supporting information. All the key facility operators and users contribute to this document. Quality assurance (QA) and Basis of Design (BoD) follow this document.

The process of QA make sure that the building performs as per the designed norms. The evaluation process which was adopted for other team members should be applied in selection of the QA provider too. Making all the QA activities part of the construction schedule creates a critical path for successful completion of the project without any hiccups. Reviewing the strategies designed and executed by other team which will give broader perspective of the project. Strategies implemented on components like building envelope construction, daylighting, electric lighting, HVAC system, renewable energy technologies should be verified thoroughly before the final acceptance.

Teaching tool

A Net Zero Energy School serves as a great educational resource for the students who can relate it to day-to-day activities. Integrating the building design and its energy efficient strategies in the curriculum would make a strong statement about the importance of conserving the resources and protecting the nature. Richardsville elementary school in Kentucky have themed hallways where students can learn, play and operate with the renewable energy technologies. Students studying under good daylighting facilities and indoor air quality score high grades in tests. Proper energy design strategies have also proved to be enhancing the productivity of the occupants of the building. More than anything, next generation is well educated about the depletion of natural resources and well prepared to make this world a better place to live.

Renewable Energy Technologies

It does not require much imagination to guess that solar energy radiation is the major renewable energy resource in Florida. Tapping the solar energy by installing PV panels will help in offsetting the energy consumption of the school. On the economic side too solar panels are very productive. Considering the average age of School buildings in United States (i.e. 42), schools can save huge expenses on electricity in the long run. The payback period for Solar panels is less than 20 years.

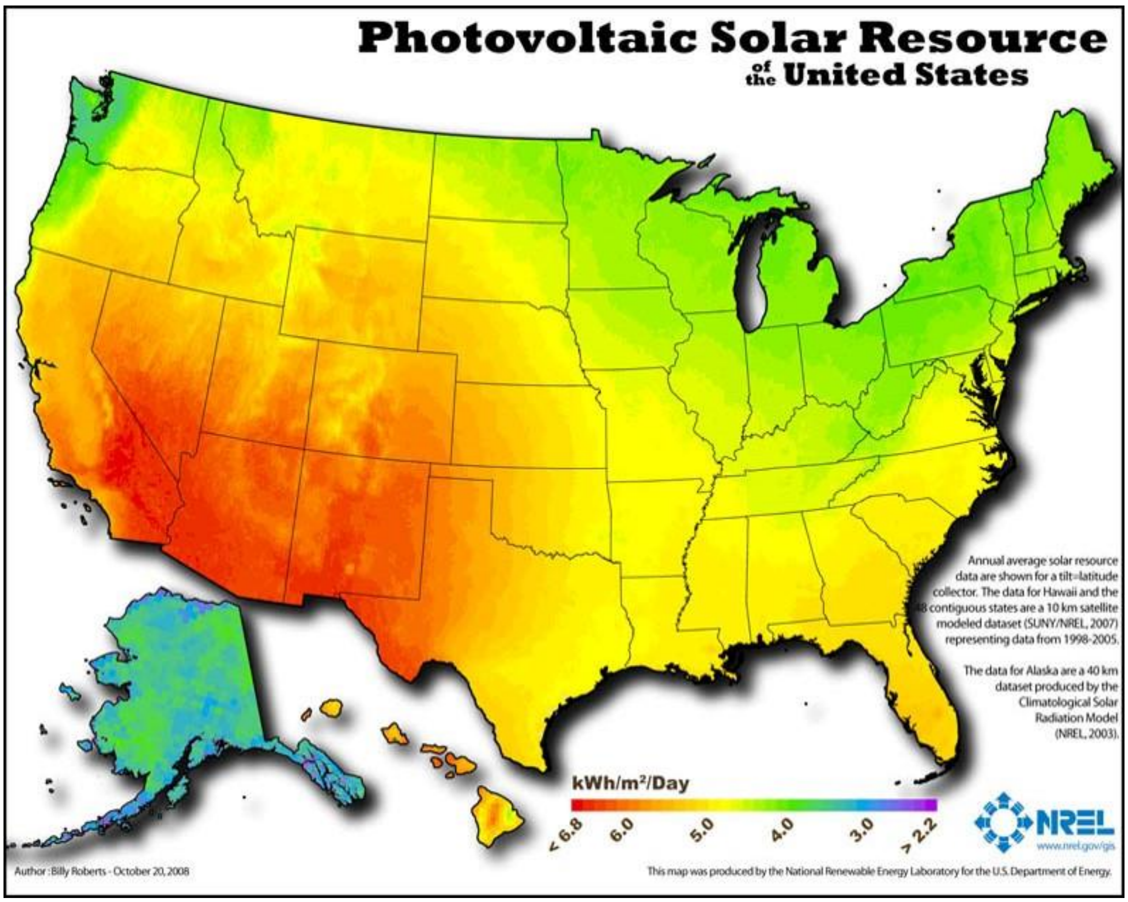

Figure 6-2. Photovoltaic Solar Resources of US (Sources: NREL)

PV systems can be installed on rooftops, on top of parking lots and also on ground. The ground mounted PV panels should be installed inside the site boundary. But it is highly recommended to restrict PV systems inside the building footprint. Unique funding opportunities are provided for the schools installing PV panels ranging from rebates by government and local utility firms to grants, loans, incentives and bonds. It is also easy to develop estimates of the panels and evaluating the energy production and payback periods

Wind energy is not very effective for Florida climate. Wind power density (WPD) is very low in this climate zone, therefore wind is not a productive option for generating renewable energy. Maps regarding other potential renewable energies by NREL can be found in Appendix A.

CHAPTER 7
ANALYSIS OF MEADOWBROOK ELEMENTARY SCHOOL ENERGY PERFORMANCE

Meadowbrook Elementary School is a public school located in Gainesville, FL with latitude of 29° 41' and longitude of -82° 27'. This school is one of the 39 public elementary schools in the Alachua County and began its operation in fall 2012. The school serves 600 students from preschool to 5th grade, and has an overall student-to-teacher ratio of 17:1. The school with the area of 101,476 square foot has a flexible design and is adaptable to be expanded to serve, 200 students for future needs. The building creates an educational community-based facility that covers wide areas of administration, a dining / multi-purpose space for community events, a media center, and classrooms.

Figure 7-1. Meadowbrook Elementary School (Parrish-McCall Constructors)

Meadowbrook has the site area of around 20 acres and was built throughout proper civil, architectural design, and preconstruction planning. The main part of the school includes a 2-story, concrete tilt wall building with bar joists and a mixture of standing seam metal roof and modified bituminous roofing systems.

Table 7-1. Meadowbrook Elementary School data

SCHOOL AT GLANCE	
Name	Meadowbrook Elementary School
Location	Gainesville, Florida
Owner	Alachua County Public Schools
Designer	Schenkel Shultz Architectural Firm
Contractor	Parrish-McCall Constructors
Principal Use	Elementary K-12 school
Occupants	Approximately 600 students, 50 employees
Gross Area	103,500 SF
Conditioned Area	Approximately 85,000 SF
Distinctions/Awards	4-Globes
Total Cost	$16.5 M
Cost Per Square Foot	$160 Per SF
Completion	July 2012

The tilt-up structure provides a fast approach mechanism with a reasonable cost and offers a durable system that is uniform and thus energy efficient. The panels are covered by several different finishes, including a clapboard (lap siding) profile, smooth profile, and real brick, set in form liners to simulate a running bond pattern. The MEP systems feature 2 - 160 ton chillers outfitted with bi-polar ionization modules that allow for less outside air leading to higher efficiencies. The school demonstrates its commitment to sustainability by designating green strategies that brought 4 Green Globes (equivalent of LEED Platinum) Certification.

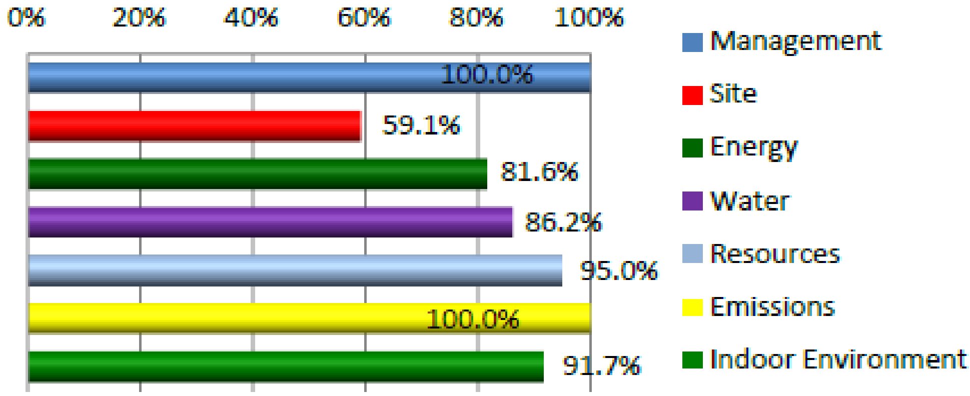

Figure 7-2. Summary of Achievement from Green Globes

Trane Trace 700 Software

Trace 700 is an extensive energy modelling software which has proven industry applications and wide range of customer base. TRACE 700 software is the complete load, system, energy and economic analysis program that compares the energy and economic impact of such building alternatives as architectural features, HVAC systems, building utilization or scheduling and economic options. Using this software various alternatives are created to check the efficiency of energy guides. The changes made in the alternative models are discussed in the later part of this chapter.

Actual Energy Usage vs Simulation Model

First and very important step in Energy Modelling is to calibrate simulated data to actual energy usage of the building. Several calibration standards and measurements are used to check the authenticity of the simulated data by comparing it with metered energy usage. In this process, coefficient of variance is calculated and if it falls in the tolerance range accepted by following methods then the simulation model is ready to use.

Following are some of the widely used techniques:

- ASHRAE Guidelines 14-2002: Measure of energy and demand savings (ASHRAE Standards Committee 2002)
- Measurement and verification (M&V) Guidelines for Federal Energy Projects, Federal Energy Management Program (FEMP 2008)
- International Performance Measurement and Verification Protocol (IPMVP 2002)

As measure of calibration, all the standards use Coefficient of Variance (CV) derived from Root Mean Square Error (RMSE). They are calculated based on equations 6-1 and 6-2.

$$RMSE_{MONTH} = \left[\frac{(M_{Month} - S_{Month})]^2}{N_{Month}}\right]^{\frac{1}{2}} \tag{7-1}$$

$$CV(RMSE_{MONTH})\% = \frac{RMSE_{MONTH}}{A_{MONTH}} \times 100 \tag{7-2}$$

Where,

M_{Month}, is Actual Energy Consumption of each month
N_{Month}, is Simulated Energy Consumption of each month
A_{Month}, is the Average monthly energy consumption

The range of tolerance for monthly data calibration of CV (RMSE) are ±5%,±10% and ±15% for IPMVP, FEMP and `ASHRAE respectively. For our study energy data from September to May is considered as summer energy information of the school is inconsistent. From the table 6-1 we can understand that CV ($RMSE_{Month}$) satisfies the tolerance range and the simulation data to be used in calibration is reliable. Now this model is considered as Baseline model for carrying out further simulations and comparing the results with various design guides. Finally, an efficient model have been proposed with all the best practices and high performance products. (Srinivasan, et al,2010).

Table 7-2. Actual and Simulated Monthly energy consumption and CV (RMSE) for Meadowbrook Elementary School

	Energy Consumption in KWh		
Month	Actual data (M)	Simulated data (S)	$(M\text{-}S)^2$
Sep	79281	70507	76983076
Oct	65840	59045	46172025
Nov	55840	52701	9853321
Dec	58960	58152	652864
Jan	59440	54483	24571849
Feb	54960	48257	44930209
Mar	54880	54610	72900
Apr	61840	60324	2298256
May	68480	64866	13060996
Total	693313	656737	13060996

$RMSE_{Month}$ 4928.325116

CV ($RMSE_{Month}$) 8%

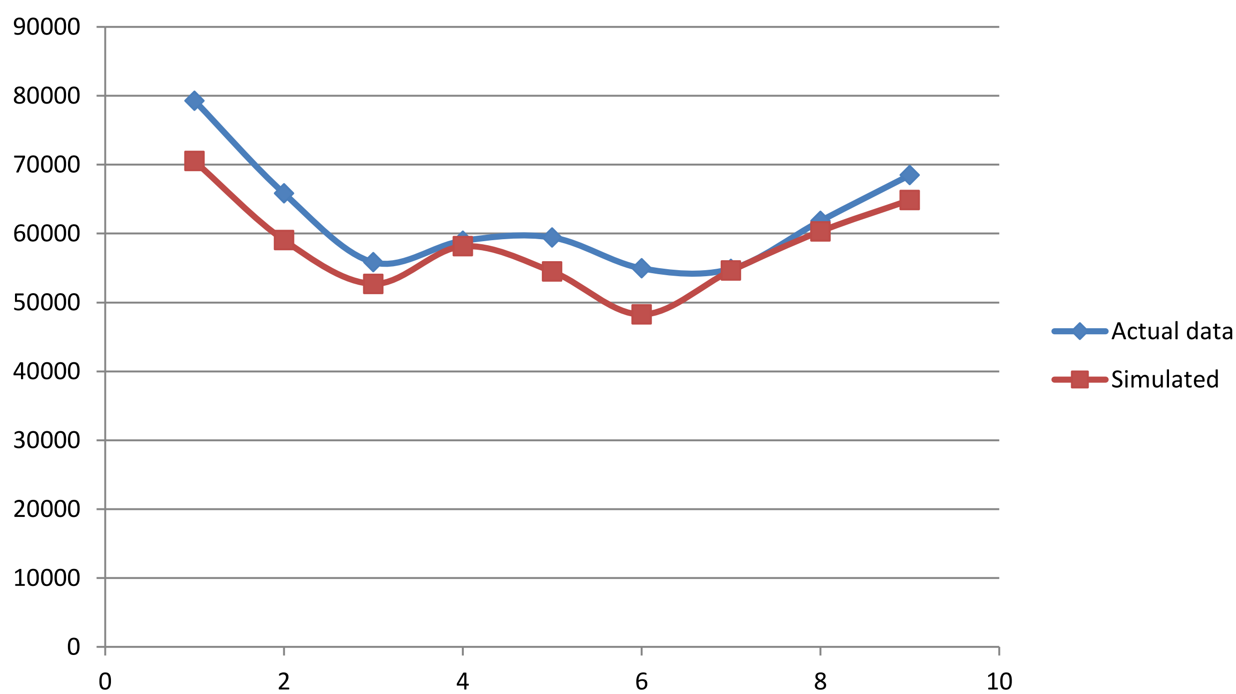

Figure 7-3. Actual data vs Simulation data of the school

Actual Model

As the actual model used in simulation is reliable, it was used to calibrate energy use for all the existing design strategies of the school. The type of HVAC, power of lighting systems and subsequent recommendations were established based on the mechanical, electrical plans. This calibration is carried out to determine the energy consumption of various end use categories. As shown in the figure below, auxiliary loads which include supply fans, pumps and stand-alone base utilizes consume 34% of the total energy. This is followed by plug loads at 27%, cooling at 19%, lighting at 15% and heating at 22%. The building EUI as determined by the simulation was 27.68 KBtu/ft2-year (292.04 MJ/m2-year). When compared to conventional school buildings, i.e. 68 KBtu/ft2-year or 717.43 MJ/m2-year (DOE Building energy databook, 2013) this value is very less. This supports the fact that Meadowbrook elementary school is already highly energy efficient..

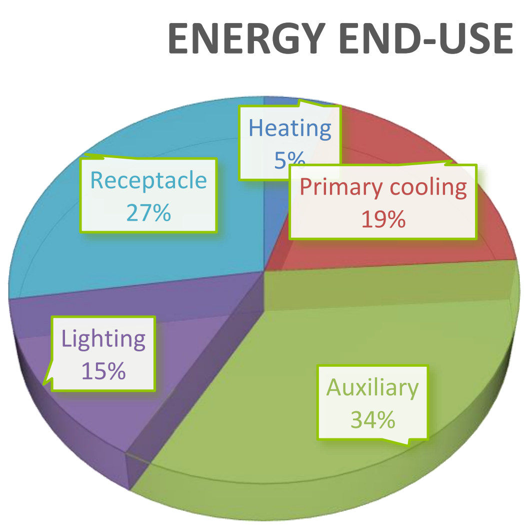

Figure 7-4. Energy End-use in Baseline or Existing Model

Model Inputs and Assumptions

Four major components of the building whose properties have significant impact on the energy consumption of the building are targeted. The components include building envelope, Lighting, HVAC system and plug loads. Applying energy efficient strategies for above mentioned components, based on various design guides, three additional models were developed to compare the performance of the building (Refer to below table). They are:

1) ASHRAE’s 90.1, 2007
2) ASHRAE’s AEDG 50% Savings
3) Proposed Model (State-of-the-Art Model)

For Models 1 & 2, values recommended in the design guides were used whereas proposed model was developed by considering all the best possible options to increase the performance of the school. State of art is taken as reference when developing this model. The existing design such as bipolar ventilation is retained in the proposed model as it is considered best possible option compared to others.

Envelope

Highly insulated envelope would have lower heat gains and thereby reduces cooling loads of the building. For the Florida climate zone, highly insulated cool roof with high Solar Reflective Index (SRI) is recommended to avoid heat absorption. Using R-40 with poly iso-cynurate for roof insulation will yield better results as it already being used in some of the other Net Zero Schools. Likewise, using Insulated Concrete Forms (ICF) and R-28 Spray foam insulation for walls is recommended. For window glazing, triple pane low-E windows should be preferred which has less U-value and Shading co-efficient (SC). It should also be remembered that after some point having high insulated envelope will yield diminishing results. For example, having using windows with high shading co-efficient would reduce the day lighting of the building. Therefore, perfect balance between building envelope and daylighting should be maintained.

HVAC

Meadowbrook has two Air-cooled chillers which supply chilled water to seven AHUs located in different parts of building. The efficiency of two chillers is 1.21kW/ton which is less in comparison to chillers available in market. This can be improved by using high efficiency centrifugal chillers with VFD controls having efficiencies in the range of 0.45kW/ton -1kW/ton. The school also uses a Bipolar Ionization system in order to purify air, remove mold, dust, odors and reduce gaseous contaminants like VOCs. The system is very efficient and has reduced the OA requirements to 5cfm/person. Other strategies such as energy recovery systems, demand control ventilation and dedicated outdoor air systems can also be implemented in order to make the school consistent with the Net Zero Energy goal.

Lighting

Lighting is one of the major factors contributing towards the energy consumption of Meadowbrook. Currently, the school uses a variety of fluorescent and HID lamps for internal lighting. Existing Light power densities of various rooms such as classrooms, conference halls, cafeteria, corridors, and storage rooms have been replaced with recommended LPD’s from design guides. However, energy savings can be observed in this area by retrofitting these lights with high efficient LED lamps having high lumens to watts ratio. Also, the amount of heat generated by LED lamps is much less than the existing ones which would further reduce the cooling loads. The lifespan of the LED lamps is much higher as compared to fluorescent lamps and thus requires less number of replacements. Tubular daylighting is another innovative design which can be adopted.

Plug Loads

Reducing plug loads in the Schools have been very challenging for the designers. As plug loads constitute for 27% of the total energy consumption in the actual model, it was addressed by trimming the plug load densities. Actual model of the School estimated the plug load densities as 1.4 W/ft2 which is very high. Benchmarked plug load densities were considered as existing approaches like NREL, ASHRAE 90.1 1989, COMNET are under or over estimating the same. (Ravi Srinivasan et al, 2011). Assuming 4 computers for each classroom, plug load density of 0.7 W/ft2 is considered for all the classrooms.

Also using ENERGY STAR equipment will mitigate the energy consumption of the building drastically. Apart from those systems which require continuous energy like refrigerators and security cameras, other equipment such as printers, coffee machines should be turned off when not in use.

Below table shows all the changes made to the existing model by applying the recommendations based on the respective energy guides

Table 7-3. Recommendations applied to existing baseline model in comparison with AEDG Guide and Proposed Model

Component	ASHRAE's 90.1, 2007	Baseline Model	ASHRAE's AEDG 50%Savings	Proposed Model
ENVELOPE				
Roof	U-0.048 6in. R-20 insulation above deck	Steel Sheet 4" Insulation U-0.0468	U-0.039 R-25 c.i.	R-40 with poly iso-cynurate insulation
Wall	U-0.124 3.5 in, R-13 steel framed wall	Tilt up Conc Panel 2.5in R-12 insulation U-0.0693	U- 0.064 R-13.0 + R-7.5 c.i.	R-28 Spray foam insulation. Insulated Concrete Form walls
Window	U-0.75 & SC-0.287	Viracon Glazing U-0.85 & SC-0.37	U-0.64, SHGC-0.456, SC-0.525	Low E, Triple pane U=0.25, SC=0.32
LIGHTING	LPD (W/sf) Classroom - 1.4 Restroom, Kitchen, Cafeteria, conference - 0.9 Corridor - 0.5 Office - 1.1 Storage - 0.8 Library - 1.2	LPD (W/sf) Classroom=0.5 Restroom=1.36 Corridor=1.46 Office=1.01 Storage=0.8 Cafeteria= 1 Kitchen=1.2	LPD (W/sf) Classrooms, art rooms, kitchens, media rooms - 0.8 Cafeteria, Lobby - 0.7 Offices - 0.60 Rest rooms - 0.5 Corridors & Mechanical rooms - 0.4	Usage of LED is recommended to mitigate energy consumption due to high efficacy and life of lamps.
PLUG LOADS	EPD Miscellaneous Loads=1.4 W/sf	EPD Miscellaneous Loads=1.4 W/sf		EPD 0.7 W/sf

Table 7-3. Continued

Component	ASHRAE's 90.1, 2007	Baseline Model	ASHRAE's AEDG 50%Savings	Proposed Model
HVAC	ASHRAE 62.1-2004/2007 10 cfm/person	Bipolar Ventilation 5cfm/person		
Chillers	No, Rooftop units	2-AC Chillers 1.21 KW/ton 0.662 IPLV	10 EER, 12.75 IPLV	11.6 EER, 19.8 IPLV with VFD and VEMA motors

Results

After calibrating the simulations for all the models, following data was observed.

Table 7-4. Final EUI'S of all the Models

ASHRAE's 90.1, 2007	Baseline Model	ASHRAE's AEDG 50%Savings	Proposed Model
35.83	27.68	25.7	22.71

The EUI of the Model have been reduced gradually. The proposed model is most efficient of all with EUI of 22.71 which is almost close to the average EUI of Net Zero Energy schools in US.

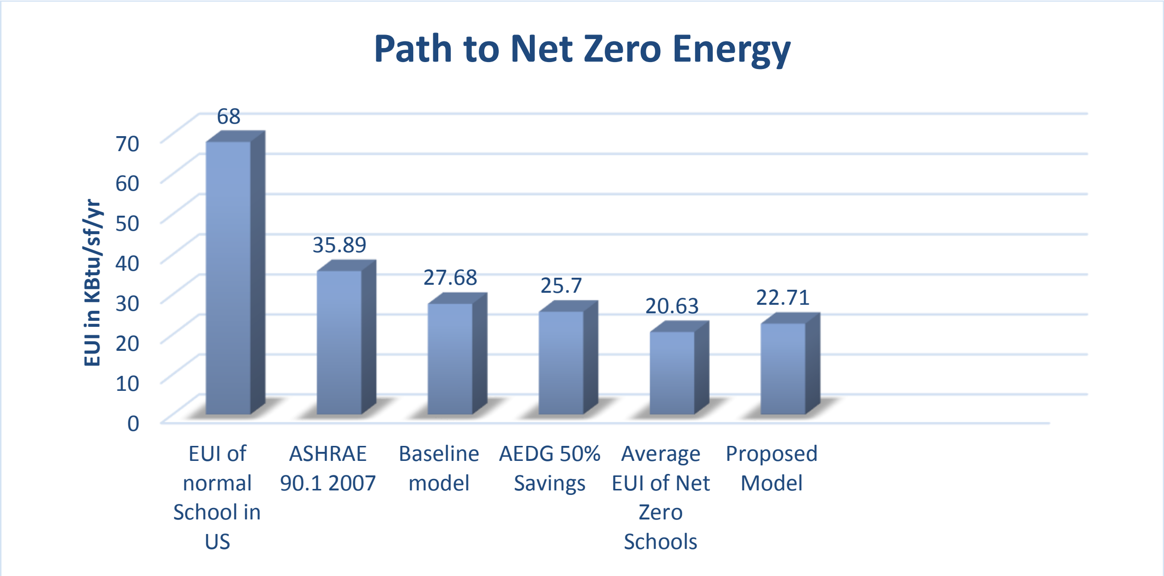

Figure 7-5. EUI's of Various Models

Proposed model is highly energy efficient and by adopting more recommendations energy consumption can be further reduced.

Scope of Photovoltaic Panels to Offset the Energy Consumption

The gap between the proposed target EUI and the net zero energy goal is eliminated by installing photovoltaic panels on the roof of the building. Meadowbrook currently has 183 kW PV array system consisting of 609 Hanwha panels with a capacity of 300W per panel, to produce the above mentioned power. Based on the results obtained from NREL PV Watts calculator, our target EUI of the proposed model requires 500 kW PV modules to completely offset energy consumption.

Potential Roof Area for PV array Installation

From the total roof area, six potential areas suitable for PV array installation were chosen based on their orientation which have maximum exposure to Sun. Sum of the six areas is 33,000 sf. Considering about 85% of the available area as some space is required for creating pathways to walk, maintenance and to avoid shading of panels, potential area for PV array installation is 28,050 sf.. (Refer to Figure 6-6 and Table 6-5). Therefore, the potential roof area which is suitable for installation of PV array is 26,400sf.

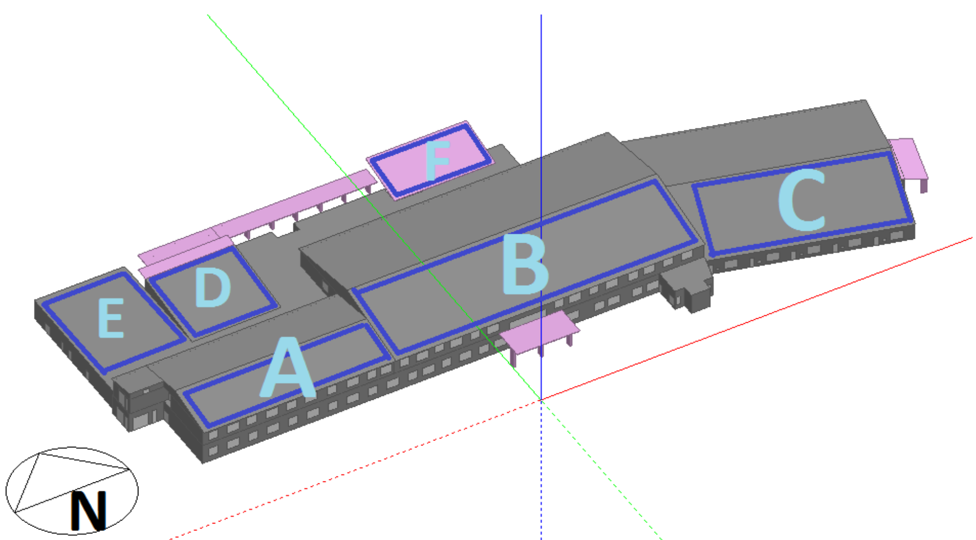

Figure 7-6. Design Builder model showing area suitable for PV array installation

Table 7-5. Potential PV array installation area

	Area	
A	4400	SF
B	11700	SF
C	7000	SF
D	3100	SF
E	4500	SF
F	2300	SF
Total:	33000	SF
Ratio of panel to total area: 80%		
PV Panel Area = (80%)(33000)= 26400 SF		

The current PV array installed on the roof has a low efficiency of about 14% and occupies approximately 18,000 sf. Thus, roughly 10,000 sf of south facing area is available for installing additional panels. The energy consumption of the school can be completely offset by installing an additional 317 kW array. Lesser number of panels will be required if higher efficiency modules are used. PV modules available today are about 20% efficient. Thus, using such high efficiency panels and adopting energy efficient strategies as suggested earlier, Meadowbrook has an opportunity to achieve a net zero energy status within the building footprint itself.

However, if the available roof area is insufficient, a solar carport can be created for the parking lot and could be used as PV system support. The solar carport will also provide shade, which not only protects the vehicles from the harsh effects of the sun but minimizes radiant heat transfer, which will require more of the car’s energy to cool down.

Having flat roof has more benefits when compared to existing pitched roof. More PV panels can be installed on a flat roof. For Meadowbrook, considering flat roof would increase the available area for PV array installation by 60%. If a flat roof is assumed

53,000 sf of roof area is available, that provides 20,000 sf more space than the current roof area.

Figure 7-7. Existing state of Solar panels (Source: Solar Impact)

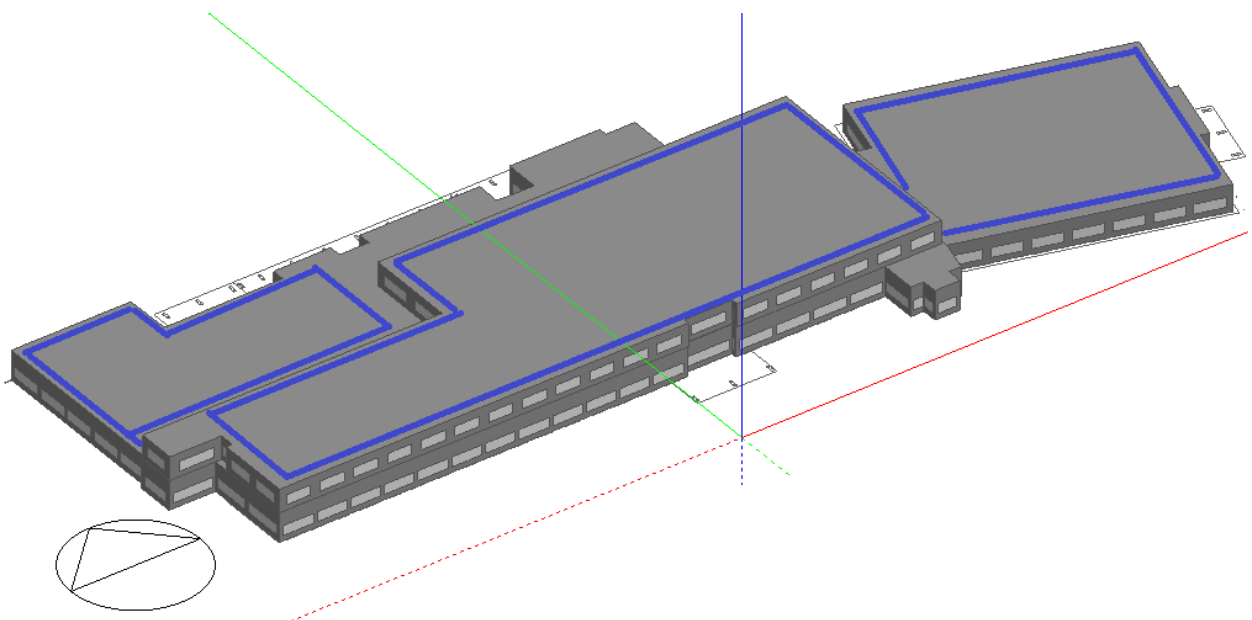

Figure 7-8. Model showing increased roof areas suitable for PV array installation

CHAPTER 8
SUMMARY AND CONCLUSION

The models analyzed in this work indicated good results after simulation analysis. However, it should be noted that the results are based on estimated inputs. Trane Trace 700 energy modelling software was used to analyze four scenarios discussed in this work, comprising the actual (existing) situation, ASHRAE 90.1-2007, ASHRAE AEDG 50%Savings, and the proposed state-of-the-art model. The existing model was calibrated and complied with FEMP 2008 and ASHRAE Guideline 14-2002. Less difference between the actual to simulated data is a good indication of the accuracy of the proposed model during operational months of the building. The available data for the Meadowbrook school energy consumption over summer was not reliable due to the ongoing construction activities. Therefore, the results generated by the software were considered for evaluating energy consumed in summer.

Financial expenditure to implement energy efficient strategies has not been discussed in this paper. Further studies can be undertaken to define an optimized balance between the higher upfront costs and obtained EUI, as well as the payback period. “Net Zero” is no more new to construction industry and schools are working as test platforms for implementing technical and financial strategies. We recommend more detailed research on integrating energy and economic policies for schools in Florida which can motivate many other schools to achieve net zero energy status.

APPENDIX A
ASHRAE'S AEDG RECOMMENDATIONS FOR CLIMATE ZONE 2

Climate Zone 2 Recommendation Table for K-12 School Buildings

	Item	Component	Recommendation	How-To Tips	✓
Envelope	Roofs	Insulation entirely above deck	R-25.0 c.i.	EN1,2,17,19,21,22	
		Attic and other	R-38.0	EN1,3,17,19,20,21	
		Metal building	R-10.0 + R-19.0 FC	EN1,4,17,19,21,22	
		Solar Reflectance Index (SRI)	78	EN1	
	Walls	Mass (HC > 7 Btu/ft²)	R-7.6 c.i.	EN5,17,19, 21	
		Steel framed	R-13.0 + R-7.5 c.i.	EN6,17,19, 21	
		Wood framed and other	R-13.0 + R-3.8 c.i.	EN7,17,19, 21	
		Metal building	R-0.0 + R-9.8 c.i.	EN8,17,19, 21	
		Below grade walls	Comply with Standard 90.1*	EN17,19, 21	
	Floors	Mass	R-10.4 c.i.	EN10,17,19, 21	
		Steel framed	R-19.0	EN11,17,19, 21	
		Wood framed and other	R-19.0	EN11,17,19, 21	
	Slabs	Unheated	Comply with Standard 90.1*	EN17,19, 21	
		Heated	R-10 for 24 in.	EN13,14,17,19,21, 22	
	Doors	Swinging	U-0.70	EN15,17	
		Nonswinging	U-0.50	EN16,17	
	Vestibules	At building entrance	Comply with Standard 90.1*	EN17	
	View Fenestration	Thermal transmittance	Nonmetal framing = U-0.45 Metal framing = U-0.64	EN24	
		Fenestration-to-floor-area ratio (FFR)	E or W orientation = 5% maximum N or S orientation = 7% maximum	EN24–25	
		Solar heat gain coefficient (SHGC)	E or W orientation = 0.25 N orientation = 0.62 S orientation = 0.50	EN24,26–29	
		Exterior sun control	S orientation only = PF-0.5	EN26	
	Daylight Fenestration	Visible transmittance (VT)	See Table 5-5 for appropriate VT value	DL1,5–6,23	
		Interior/exterior sun control (S orientation only)	S orientation = no glare during school hours	DL1,9,12,13,31	
Daylighting/Lighting	Daylighting	Classroom, resource rooms, cafeteria, gym, and multipurpose rooms	Daylight 100% of floor area for 2/3 of school hours	DL1–5,7–21, 24–30,32–41	
		Administration areas	Daylight perimeter floor area (15 ft) for 2/3 of school hours	DL1–5,8–12	
	Interior Finishes	Interior surface average reflectance for daylighted rooms	Ceilings = 80% Wall surfaces = 70%	DL14	
	Interior Lighting	Lighting power density (LPD)	Whole building = 0.70 W/ft² Gyms, multipurpose rooms = 1.0 W/ft² Classrooms, art rooms, kitchens, libraries, media centers= 0.8 W/ft² Cafeterias, lobbies = 0.7 W/ft² Offices = 0.60 W/ft² Auditoriums, restrooms = 0.5 W/ft² Corridors, mechanical rooms = 0.4 W/ft²	EL12–19	
		Light source lamp efficacy mean lumens per watt)	T8 & T5 > 2 ft = 92, T8 & T5 ≤ 2 ft = 85, All other > 50	EL4–6	
		T8 ballasts	Non-dimming = NEMA Premium Instant Start Dimming= NEMA Premium Program Start	EL4–6	
		T5/T5HO ballasts	Electronic program start		
		CFL and HID ballasts	Electronic		
		Dimming controls daylight harvesting	Dim all fixtures in daylight zones	EL8,9,11–19	
		Lighting controls	Manual ON, auto/timed OFF in all areas as possible	EL8,9,11–20	
	Exterior Lighting	Façade and landscape lighting	LPD = 0.075 W/ft² in LZ-3 & LZ-4 LPD = 0.05 W/ft² in LZ-2 Controls = auto OFF between 12am and 6am	EL23	
		Parking lots and drives	LPD = 0.1 W/ft² in LZ-3 & LZ-4 LPD = 0.06 W/ft² in LZ-2 Controls = auto reduce to 25% (12am to 6am)	EL21	
		Walkways, plaza, and special feature areas	LPD = 0.16 W/ft² in LZ-3 & LZ-4 LPD = 0.14 W/ft² in LZ-2 Controls = auto reduce to 25% (12am to 6am)	EL22	
		All other exterior lighting	LPD = Comply with Standard 90.1* Controls = auto reduce to 25% (12am to 6am)	EL25	
Plug Loads	Equipment Choices	Laptop computers	Minimum 2/3 of total computers	PL2,3	
		ENERGY STAR equipment	All computers, equipment, and appliances	PL3,5	
		Vending machines	De-lamp and specify best in class efficiency	PL3,5	
	Controls/ Programs	Computer power control	Network control with power saving modes and control off during unoccupied hours	PL2,3	
		Power outlet control	Controllable power outlets with auto OFF during unoccupied hours for classrooms, office, library/ media spaces All plug-in equipment not requiring continuous operation to use controllable outlets	PL3,4	
		Policies	Implement at least one: • District/school policy on allowed equipment • School energy teams	PL3,4	

*Note: Where the table says "Comply with Standard 90.1," the user must meet the more stringent of either the applicable version of ASHRAE/IES Standard 90.1 or the local code requirements.

Figure A-1. Recommendations by ASHRAE;s AEDG

Climate Zone 2 Recommendation Table for K-12 School Buildings (Continued)

	Item	Component	Recommendation	How-To Tips	✓
Kitchen	Kitchen Equipment	Cooking equipment	ENERGY STAR or California rebate-qualified equipment	KE1,2	
		Walk-in refrigeration equipment	6 in. insulation on low-temp walk-in equipment, Insulated floor, LED lighting, floating-head pressure controls, liquid pressure amplifier, subcooled liquid refrigerant, evaporative condenser	KE2,5	
		Exhaust hoods	Side panels, larger overhangs, rear seal at appliances, proximity hoods, VAV demand-based exhaust	KE3,6	
SWH	Service Water Heating	Gas water heater (condensing)	95% efficiency	WH1–5	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–5	
		Point-of-use heater selection	0.81 EF or 81% E_t	WH1–5	
		Electric heat-pump water heater efficiency	COP 3.0 (interior heat source)	WH1–5	
		Solar hot-water heating	30% solar hot-water fraction when LCC effective	WH7	
		Pipe insulation (d < 1.5 in./d ≥ 1.5 in.)	1/1.5 in.	WH6	
HVAC	Ground Source Heat-Pump (GSHP) System with DOAS	GSHP cooling efficiency	17.1 EER	HV1,11	
		GSHP heating efficiency	3.6 COP	HV1,11	
		GSHP compressor capacity control	Two stage or variable speed	HV1,11	
		Water-circulation pumps	VFD and NEMA Premium Efficiency	HV8	
		Cooling tower/fluid cooler	VFD on fans	HV1,8,11	
		Boiler efficiency	90% E_c	HV1,7,11	
		Maximum fan power	0.4 W/cfm	HV12	
		Exhaust air energy recovery in DOAS	A (humid) zones = 60% enthalpy reduction B (dry) zones = 60% dry-bulb temperature reduction	HV4,5	
		DOAS ventilation control	DCV with VFD	HV4,10,15	
	Fan-Coil System with DOAS	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV2,6,11	
		Water circulation pumps	VFD and NEMA Premium Efficiency	HV6,7	
		Boiler efficiency	90% E_c	HV2,7,11	
		Maximum fan power	0.4 W/cfm	HV12	
		FCU fans	Multiple speed	HV2,12	
		Economizer	Comply with Standard 90.1*	HV2,14	
		Exhaust air energy recovery in DOAS	A (humid) zones = 60% enthalpy reduction B (dry) zones = 60% dry-bulb temperature reduction	HV4, 5	
		DOAS ventilation control	DCV with VFD	HV4,10,15	
	VAV Air-Handling System with DOAS	Air-cooled chiller efficiency	10 EER; 12.75 IPLV	HV3,6,11	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3,6,11	
		Water circulation pumps	VFD and NEMA Premium Efficiency	HV6,7	
		Boiler efficiency	90% E_c	HV3,7,11	
		Maximum fan power	0.8 W/cfm	HV12	
		Economizer	Comply with Standard 90.1*	HV3,14	
		Exhaust air energy recovery in DOAS	A (humid) zones = 60% enthalpy reduction B (dry) zones = 60% dry-bulb temperature reduction	HV4,5	
		DOAS ventilation control	DCV with VFD	HV4,10,15	
	Ducts and Dampers	Outdoor air damper	Motorized damper	HV10	
		Duct seal class	Seal Class A	HV20	
		Insulation level	R-6	HV19	
M&V	M&V Benchmarking	Electrical submeters	Disaggregate submeters for lighting, HVAC, general 120V, renewables, and whole building	QA14–17	
		Benchmarking	Begin submetering early to address issues during warranty period Benchmark monthly energy use Provide training on benchmarking	QA14–17	

*Note: Where the table says "Comply with Standard 90.1," the user must meet the more stringent of either the applicable version of ASHRAE/IES Standard 90.1 or the local code requirements.

Figure A-2 Recommendations based on ASHRAE's AEDG

Table 5-2 Vertical Fenestration Descriptions

CZ	U-Factor	SHGC	VT	Glass and Coating	Gas	Spacer	Frame
1	0.50	0.26	0.40	Low-e semi-reflective	Air	Metal	Thermally improved
1	0.57	0.63	0.66	Double clear	Air	Metal	Thermal break
1–2	0.64	0.64	0.66	Double clear	Air	Metal	Thermally improved
2	0.43	0.24	0.40	Low-e semi-reflective	Air	Metal	Thermal broken
2	0.45	0.50	0.63	Low-e double	Air	Metal	Thermal broken
3	0.41	0.23	0.40	Low-e semi-reflective	Air	Insulated	Thermal broken
3	0.39	0.49	0.63	Low-e double	Argon	Insulated	Thermal broken
3	0.59	0.27	0.30	Low-e reflective	Air	Metal	No break
3	0.57	0.63	0.66	Double clear	Air	Metal	Thermal broken
4	0.37	0.35	0.59	Selective Low-e double	Argon	Insulated	Thermal broken
4	0.39	0.49	0.63	Low-e double	Argon	Insulated	Thermal broken
4–5	0.44	0.36	0.59	Selective Low-e double	Air	Metal	Thermal broken
4–5	0.43	0.50	0.63	Low-e double	Air	Insulated	Thermal broken
5	0.45	0.50	0.63	Low-e double	Air	Metal	Thermal broken
5–6	0.33	0.34	0.59	Selective Low-e double	Argon	Insulated	Thermally isolated
5–6	0.34	0.48	0.63	Low-e double	Argon	Insulated	Thermally isolated
6	0.41	0.36	0.59	Selective Low-e double	Air	Insulated	Thermal broken
6	0.43	0.50	0.63	Low-e double	Air	Insulated	Thermal broken
7–8	0.33	0.34	0.59	Selective Low-e double	Argon	Insulated	Thermally isolated
7–8	0.34	0.48	0.63	Low-e double	Argon	Insulated	Thermally isolated
8	0.24	0.40	0.54	LowE 2 Lites Triple	2 Argon	Insulated	Thermally isolated

Note: SHGC = solar heat gain coefficient; VT= visible transmittance

Figure A-3. Window glazing properties

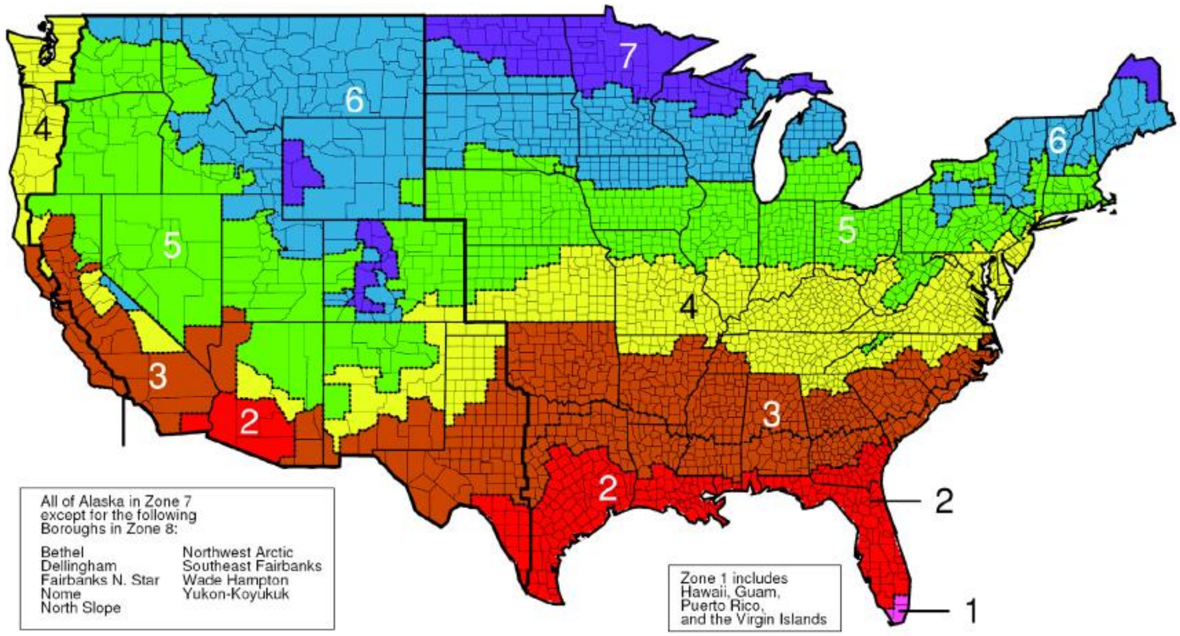

Figure A-4. Climate Zones in USA

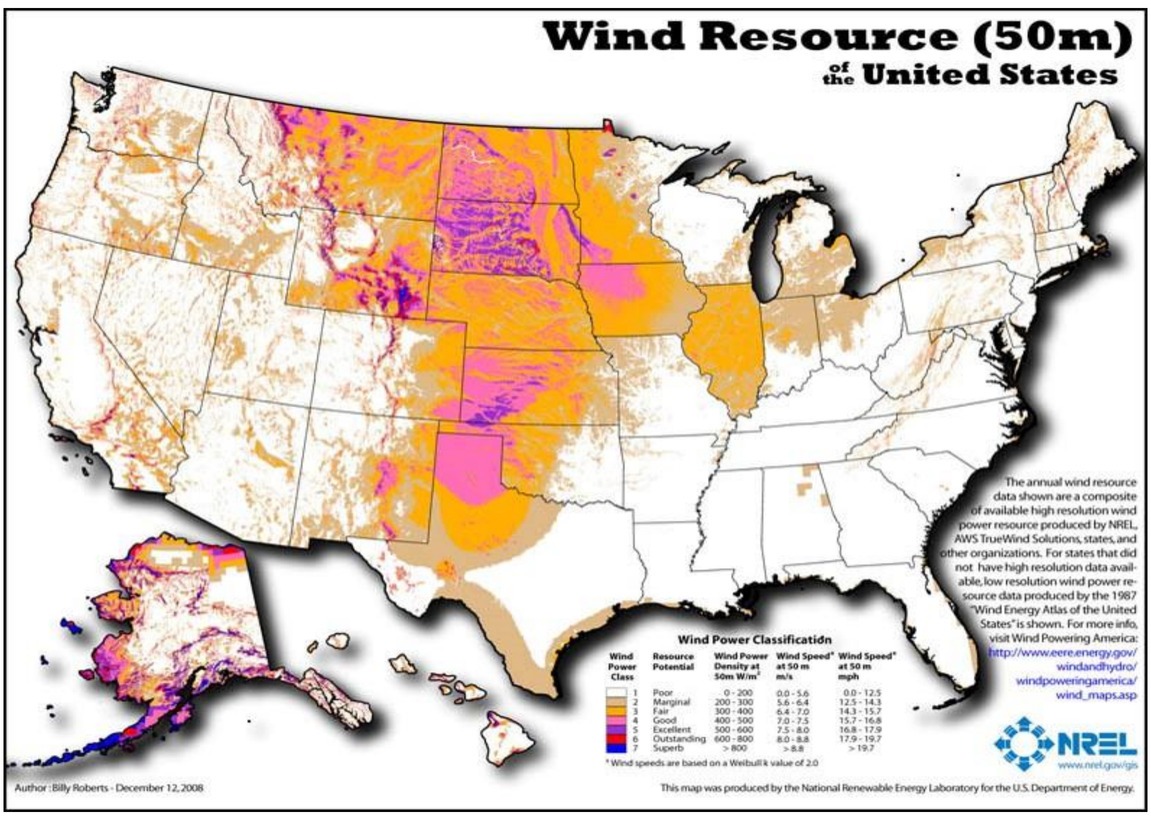

Figure A-5. Wind Energy resources in USA

APPENDIX B

NET ZERO ENERGY SCHOOLS

SCHOOL NAME	GRADES TAUGHT	PROJECT COMPLETED	LOCATION	TOTAL SF	STUDENT OCCUPANCY	KBTU/ SF/YR	TOTAL PROJECT COST	COST/SF	PROJECT FUNDING	OWNER	ARCHITECT	MEP ENGINEER	CONTRACTOR
Colonel Smith Middle School	MS	2011	AZ • Fort Huachuca	88,693 SF	350 Students	15 kBbtu/sf/yr	$21,108,934	$238/SF	Federal Funding	Fort Huachuca Accomodation School District	EMC2/ Fanning Howey	PH Mechanical Monrad Engineering Benya Lighting	Turner Construction
Evie Garrett Dennis Pre-K • 12 School	Pre-K-12	2010	CO • Denver	186,468 SF	1,278 Students	26 kBbtu/sf/yr	$36,000,000	$189/SF	$48,500,000 Public Bond	Denver Public Schools	DLR Group, Jodelle Senger	ME Group	Saunders Construction
George LeyVa Middle School Administration Building	MS	2009	CA • San Jose	9,200 SF	Administration Building	undetermined	$5,850,000	$238/SF*	Federal Funding	Evergreen School District	AEDIS Architecture and Planning	Integrated Design Associates (IDeAs) and Capital Engineering Associates, Inc. (CECI)	Urban 4 Development Corporation.
Hayes Freedom High School	HS	2010	WA • Camas	20,500 SF	153 Students (200 Students Max)	23 Kbtu/sf/yr	$3,800,000	$185/SF	School Bond	Camas School District	Mahlum Architects	KPPF Engineers	Interface Engineering
Hood River Middle School	MS	2010	OR • Hood River	7,200 SF	undetermined	27 kBtu/sf/yr	$2,300,000	$319/SF	School Bond	Hood River School District	Opsis	Interface Engineering	Kirby Nagelhout Construction
Kiowa County Pre-K • 12 School	Pre-K-12	2010	KS • Greensburg	123,045 SF	350	29 kBtu/sf/yr	$31,200,000	$254/SF	FEMA, State, Kansas Rural District, Private Donations	Unified School District 422	BNIM Architects	BGR Consulting Engineers	McCowan Gordon Construction
Lady Bird Johnson Middle School	MS	2011	TX • Irving	152,200 SF	1000	29 kBtu/sf/yr	$29,610,423	$195/SF	School Bond	Irving Independent School District	Cogan Associates	Image Engineering Group	Balfour Beauty Construction
Locust Trace AgriScience Farm (Technical High School)	HS (Technicall)	2011	KY • Lexington	47,088 SF	250	16.2 kBtu/sf/yr	$15,500,000	329/SF	undetermined	Fayette County Public Schools	Tate Hill Jacobs Architects	CMTA Engineers	Messer Construction
Marin Country Day School	K-12	2010	CA • Corte Madera	33,000 SF	540 Students	24.5 Kbtu/sf/yr	$12,800,000	$380/SF	Financial seats board decided they had funds to buy it outright as an investment strategy PV only accounts for 1.5% of construction cost.	Marin Country Day School	EHDD Architectire	Stantec	Oliver & Company
New York P.S. 62 School	ES	2015	NY • New York	68,068 SF	444 Students	34.4 kBtu/sf/yr	$55,000,000	$808/SF	undetermined	New York City Depratment of Education	Skidmore, Owings & Merrill (SOM)	AKF Group,In-Posse LLC	Skidmore, Owings & Merrill (SOM)
Prarie Hill Learning Center	MS	2005	NE • Roca	2940/ 3700	50 Students	12.5 KBtu/sf/yr	$750,000/ $325,000	$255/SF $88/SF	USDA Rural Development assisted the Prairie Hill Learning Center with a $488,000 community facility direct loan that was leveraged with $149,700 from Prairie Hills' building. These funds constructed the new net zero facility, refinanced $179,000 of existing debt incurred when Prairie Hills acquired it's existing facilities and $100,000 went towards the electric wind generation equipment.	Prairie Hill Learning Center	The Architectural Partnership	ME Group (Mechanical) Noel Engineering Electrical)	Shearer Contractors
Richardsville Elementary School	ES	2010	KY • Bowling Green	72,285 SF	600 Students	18 kBtu/sf/yr	$12,600,000	$168.22/SF	Grant received for Solar Array	Warren County Board of Education	Sherman, Cater, Barnhart, PSC	CMTA Engineering	RG Anderson
Sangre de Cristo Pre-K • 12 School	ES	2010	CO • Mosca	80,025 SF	398 Students	24 kBtu/sf/yr	$17,400,000	$217/SF	Partially funded by the Building Excellent Schools Trust (BEST), covering all but $4,000,000 of Project Cost.	Consolidated School District	Klipp + Hutton Architects	ME Group	GE Johnson Construction Co

Figure B-1. Net Zero School Projects in USA

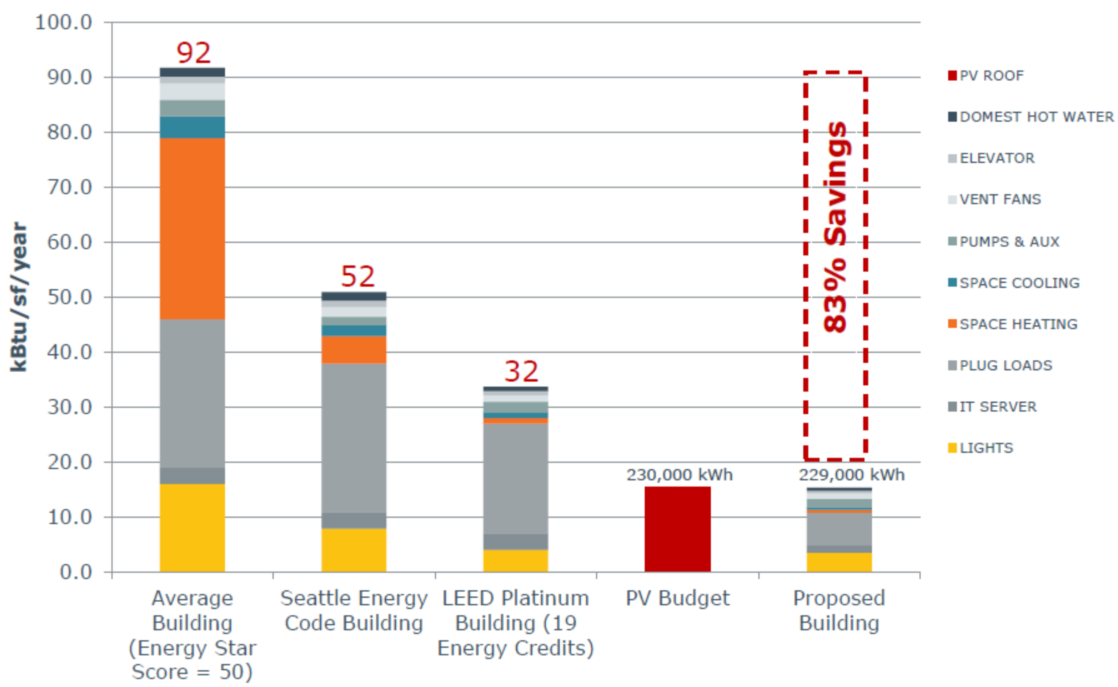

Figure B-2.Net Zero Energy: Energy use and solar impact

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Lady Bird Johnson Middle School. Courtesy of Irving Independent School District

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BIOGRAPHICAL SKETCH

Ruthwik received his Master of Science degree in civil engineering from the University of Florida in the spring of 2014. He previously achieved his Bachelor of Technology degree in civil engineering degree in 2012 from Jawaharlal Nehru Technological University, India. Even as a child, Ruthwik always had an inclination to build beautiful things. The passion to build innovative structures was always been his driving force which motivated him to choose civil engineering as his major. His interests include Net Zero Energy (NZE), Building Information Modelling (BIM) and Supply chain management. During the two years of graduation, Ruthwik has also shown keen interest in the fields of economics and finance.

After graduating from the University, he is planning to work for a company with values in the field of construction and try his luck in the field of entrepreneurship simultaneously. Finally, he hopes to spend his knowledge and energy in a right way which would make the world a better place to live.