The Age of Net Zero

Joseph Le

University of Arizona

I have adhered to University policy regarding academic honesty in completing this assignment.

Submitted to Professor Joey Iuliano, on behalf of the faculty of the School of Business and Graduate Studies in partial fulfillment of the degree requirements for the Sustainable Built Environment Degree

2015

Abstract

Captivated by the sustainable design principles and concepts, this study explores the definition of what is Net Zero and how has this concept become the new standard in today's society. By analyzing several case studies, the qualitative and quantitative data will give insight into developing the ideal performance of green and sustainable buildings in relation to a *net* zero energy focus. The idea of sustainable design began as an economic tool to reduce high energy consumption and cost in buildings and has evolved into elevating the social and environmental concerns of our natural resources.

Keywords: net-zero, zero-net energy, sustainable design

Table of Contents

List of Images

Page

List of Figures

Page

Introduction

In today's society, living more sustainably means to reduce one's footprint on the Earth's natural resources. One way to do that is to focus on reducing the energy consumption that human beings use. In doing so, the capabilities for our society to harness the natural environment and proactively implement these finite resources in the design and use of the buildings we interact with are a very attainable goal. To effectively and efficiently recycle and reuse renewable energy would allow this generation as well as future generations the opportunity to enjoy Earth's natural beauty. By analyzing several case studies of successful Net Zero building designs, we will be able to explore the benefits and cost analysis of incorporating NZB methods to future urban planning and design principles. Furthermore, through case studies and cost benefit analysis, the opportunities to explore whether advancements in technology has allowed for more inexpensive means to designing economically sustainable buildings.

Implementing net zero strategies in existing building designs is more effective than allocating funds and materials for a new building construction. The cost to benefit analysis of passive and active net zero strategies outweigh the annual cost of current inefficient building techniques. Further research can perhaps show the application of net zero energy be developed into the broader area of urban planning.

Background of the Problem

The social, economic, and environmental pillars of sustainability are the driving forces for Net Zero designs. With the advent of electricity and the revolution in technology and consumer production, humans have built up a reliance and dependence on Earths natural resources. Unfortunately, sources of energy coming from burning coal and other natural gases and materials are at a finite state. The issue of our dependency on Earths finite resources. In the U.S. alone, buildings make up about 70% of our electricity consumption. The evolution of our dependency on a natural source of energy like electricity has led us to this point where we clearly need an alternative. By taking what we currently have, such as old buildings and retrofitting them with technology, we can efficiently and effectively consume less than what is being produced. One issue at hand focuses on the cost benefits of owners and tenants spending and saving money by retrofitting old buildings with net zero technology.

Statement of the Problem

Culturally speaking, the social aspect of old towns and cities are scattered with historical buildings that require a unique approach in order to salvage what's left of the existing deteriorating conditions. Historic communities and buildings bring cultural value to the community. Without these buildings still standing, the rich culture would be lost. Retrofitting existing buildings with net zero technology would be an efficient way to

attacking the problem of reusing old buildings and at the same time, producing energy that adds more value to the building. Applying this concept further, with urban planning and development occurring faster to keep up with the growing population of people, the ability to address the issue of maximizing space, materials and resources to develop new urban sprawls by harnessing renewable energy from solar, thermal and wind power in the design. Economically speaking, technology has evolved within the past 10-15 years; constantly exploring new and innovative approaches to reusing resources at a cost effective manner would not only save money, but add value to the situation. The cost benefit analysis done in this research shows that there are several outlets in which building and designing with net zero in mind has produced renewable energy that has in turned reduced humans dependency on natural resources. By depending less on the finite natural resources, we are ultimately curtailing the effects of global warming and allowing for the security of our future generations. Last but not least, environmentally speaking, by channeling the idea of net zero into mainstream society, the ability for us to design, build and utilize living buildings allows for the resources that otherwise would be depleted, actually have time to replenish. The effects of deforestation and burning of fossil fuel are two common environmental barriers that takes years to repair. Meanwhile by optimizing passive design strategies with net zero, there is not only energy being conserved but energy recycled and returned into the environment and mitigating a slew of other environmental issues. Through reinforcing the ideals of the three pillars of

sustainability: environment, social and economic; the foundation of this research questions whether the integrity of designing and implementing net zero strategies has the ability to ultimately shape the way we can harness less dependency on natural resources. In addition, by researching and analyzing the statistical data on energy consumption of net zero buildings, determine whether this approach and design strategies can have a positive and everlasting effect on the way our society evolves towards a more sustainable community.

Purpose of the Study

Through a series of case study analysis, the qualitative and quantitative measurements of both passive and active strategies on particular buildings that have been successful in achieving net zero will demonstrate where this technology has progressed in the past ten years. By doing the case study on the DPR building in Phoenix, Arizona, the goal to understand and recognize the strategies involved in how the construction company was able to, “integrate their values and culture [through] creating a model for how to live and work in the desert… sustainably and cost effectively,” DPR Construction (2015). Ultimately, to examine the successes that DPR achieved through its passive and active strategies demonstrated how to utilize various techniques to apply to future building designs. In comparison, the Tyson Living Learning Center was another case study analysis that, “did not operate as a zero-net-energy building and was consuming more electricity than it was producing,” AASHE

(2011). By comparing the two case studies, the analysis allows a closer look at the pros and cons of what net zero strategies works and what was inefficient at producing a sustainable design.

Significance of the Study

It is ultimately important to determine the effectiveness of these case studies because by understanding the benefits and efficiencies of practical strategies, we can further advance the systematic approach to design and build better buildings. By comparing the two case studies, DPR in Phoenix and the Tyson Living Learning Center in Eureka, Missouri, the interesting statistical findings demonstrated that there is a limit to how much can be done to a building and still maintain its effectiveness to be net zero. Further assessment of the case studies illustrates that the notion of net zero isn't just a simple plug and play equation that results in positive results; ultimately, each individual scenario is a case by case challenge and requires a careful study and evaluation of various strategies that will benefit the ultimate design and build of a project.

Theoretical Perspective

According to Alexei V. Filippenko and Jay M. Pasachoff, the theory of zero energy begins by understanding that, "in the inflationary theory, matter, antimatter… consists of positive energy. This energy, however, is exactly balanced by the negative gravitational energy of everything pulling on everything else. In other words, the total

energy of the universe is zero!" (Filippenko, 2001). The two physicist infers that in the larger realm of science, the idea of zero energy is plausible in that there only needed be a tiny bit of energy that began and at all times, there is a counter balance of energy acting back to negate any positive or negative amounts of energy. In essence, this idea that energy may have come from nothing or that there has always been a virtual amount of nothing and something, which cancels each other out, suggest that the concept of a net zero energy theory to be possible. The ultimate take away from this discussion demonstrates that in terms of environmental energy, the ability to work towards reaching a zero energy balance can be achieved, it just becomes a matter of the varying strategies and applications that would allow for that. DPRs building in Phoenix is a case study that proves this theory in practice; ultimately however, the cost to benefit values from applying net zero strategies remains a long term goal and immediate gratification should not be the end goal.

Research Method

By analyzing and measuring collected data from the DPR and Tyson Research Center case studies, a quantitative research approach will provide information as to varying successful and unsuccessful strategies involved in achieving net zero energy balance. Further research on DPRs LUCID building dashboard technology allows for a closer look at how energy consumption and production changes via time of day,

weather, temperature, and particular source of energy being monitored. With Tyson Living Learning Center, the information available online is limited in information, however the numbers and statistical data that was available illustrated a discrepancy in how ineffective the net zero strategies can be. The comparison between the two case studies allows for a further understanding as to what specifically was not successful and what did work to achieve net zero energy. Referencing the New Net Zero by William Maclay and Maclay Architects to these two case studies clarified why certain strategies worked. In addition, recognizing that the location and specific settings in the surrounding environment played a factor in the process of success and failures towards achieving net zero.

Definition of Key Terms

Daylighting: a strategy in the building process in which the techniques in massing and orientation of a building allows for efficiently maximizing opportunities to bring in natural sunlight. (Maclay, Williams, 2014, p. 343)

Net Zero Building: a building with zero net energy consumption; the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site. *Also known as* ***zero net energy (ZNE)***

Pillars of Sustainability: ideal condition under which humans and nature can exist in productive harmony that permit fulfilling the social, economic, and environmental conditions of present and future generations; if any one pillar is weak then the system as a whole is unsustainable.

Scale jumping: term relating to the Living Building Challenge 2.0 which allows projects to team up and link buildings together in order to achieve the requirements as a group. * SC1

Delimitations

The broad spectrum of net zero energy strategies in buildings ranges from the theoretical to the actual building and construction methods. Some of the research topics that could be looked more in depth at can focus on understanding the broader idea of what net zero can mean. According to Maclay, “we have been looking at net zero from a narrow energy input-output model because we believe that energy concerns will be the single greatest challenge to civilizations and living systems in the twenty-first century,” (Maclay, William, 2014, pg. 27) The invaluable tool that net zero buildings emphasizes is the positive impact on the environment; however, looking at the broader idea of net zero can lead to the exploration of economic and social niches. Net-zero can provide stable energy costs and in turn away from the need for fossil fuel based energy sources.

Another direction that could be researched focuses on the sister to net-zero efficiency, being carbon-neutral. In general, carbon emission from building construction accounts for the energy and carbon gas that is produced, in essence is embodied carbon. This measurement would be different in terms of unit comparison because it is not exactly a substantial and widely recognized method of measurement.

Perhaps by exploring the potential natural sources of energy such as solar or thermal that results from applying net zero strategies could be an interesting tangent. Nonetheless, the focus of this research remains on the top of elevating the potential uses of alternative strategies that would encompass a broader range of energy efficiencies, all the way reducing cost and unnecessary waste.

Limitations of the Study

This research design will not be able to suggest a clear cut answer to what strategies will be able to work on every project. The scope of each individual project will depend on the surrounding environment as well as many other influences, therefore by pigeon hoeing certain tactics or techniques to a general format will not be plausible. Due to the scope of this research project, with the analysis focusing on two case studies, there are many other examples of net zero buildings that meet the standards using different design strategies. The most interesting application of net zero strategies would be on pre-existing buildings and structures, and to take an in depth look at some

of these other scenarios would allow more insight in whether there might be a set of systematic approaches that can be applied to a larger scale assignment and achieve the same results, if not better than the original.

Summary

The case studies being analyzed in this research project are two very specific approaches that contrast in the success and failures of implementing net zero. Most of the data collected for DPR will support the argument for more sustainable and viable approaches; in comparison, the Tyson Living Learning Center in Eureka, Missouri demonstrated their attempt at net zero and why some of the strategies did not help. Further exploration with the delimitation and of the study suggest that an in depth look at the design method and data collection will reveal invaluable understanding into the inner workings of a project.

Literature Review

William Maclay's *The New Net Zero* sets out to explore the fundamental of green buildings and its relationship with net zero energy. As a sustainable architect, Maclay sets up the foundation for builders, designers and all that are interested in this new frontier of renewable energy. With multiple awards in the field of net zero designs, Maclay has achieved high performance goals at affordable costs and makes the case for net zero design to be relevant in conversations and discussions about opportunities

for actual change. There is a comprehensive overview of information on understanding what clean and green energy is, several case studies that demonstrate and explain step by step how net zero is achieved, and projects that gear designers and builders to use strategies to incorporate into real world applications.

In this research paper, by exploring the varying strategies and solutions currently being used in today's net zero applications, the benefits and disadvantages for applying net zero would be evaluated to understand which methods were successful in achieving net-zero energy. By analyzing the qualitative data and information provided through my case study subjects, I intend to develop a solid foundation to present a next level threshold in understanding whether net zero design is feasible in everyday applications. Perhaps furthermore, be able to guide the direction of where this conversation about sustainable application can be explored on a larger and broader scale.

Sustainable Infrastructure

To understand what net-zero is and how it relates to actual sustainable design, we have to first understand the reasons why conserving energy matters. In the U.S., buildings account for 70% of our electricity consumption, indicating that a large portion of how we live and what we do is a direct result of our energy crisis. (Hootman, Thomas, 2013). With today's technology and expectations to be green, the goal of net-zero energy use in buildings carry a lot of extra weight and problems that go beyond the

surface of installing water towers or solartubes to adjust for temperature control. For instance, in an article from the *Environmental Building News*, according to Nadav Malin, "a low rise building on a low density site will have a better chance of being net-zero with onsite renewables… the investment in dollars and resources to get to net zero are significant... and might be better spent on more cost-effective energy saving options, such as a more efficient building envelop or creating a district energy system that can serve an entire campus," (Malin, Nadav, 2010).

Energy, Our Fuel and Foundation

William Maclay recognizes that the original foundation of civilization stems from energy; energy as being the fuel and source of power for our civilization. From food and consumer goods to building products and technology, everything can be seen as energy, in one form or another. Furthermore, energy can be divided into two simple categories, renewable and nonrenewable. The finite energy sources that is found on planet Earth are considered nonrenewable energy. As Maclay describes it, "energy that, once exhausted, cannot be replenished," (Maclay, William, 2014, page 1) in which such examples include fossil fuel, coal, natural gas and petroleum, and radioactive materials, are being depleted because the human population is quickly overpowering the amount of resources that are available. In comparison, renewable energy are energy sources that 'renew' through natural ideals. Thermal, solar, and hydro energy

are available and with the proper resource planning, our technology and modern world can translate what we know as net-zero into actually producing through renewable sources, energy that is consumed and kicks back more than what got consumed. Maclay points out an important issue, that many people may not understand nor overuse this idea of sustainability, nonetheless, “net-zero” refers to producing through renewable sources. In addition, the era of fossil fuel has impacted our planet and civilization, in that energy sources are dependent on humans, and vice versa. The issue that has become a part of the fabric of our society is that with the technology and innovations of the modern world, the more energy we have, the more our population grows, and as population expand the energy each one of us uses grows. The realization that we use more and more energy to produce more energy ultimately becomes an unending cycle of dependency on a finite source of energy. Within the chapter on Energy, Maclay further explains that our current world energy consumption is excessive and the ability to reduce our reliance on energy would alleviate our current issues, (reference figure 11). The essential take away from understanding energy is that it is the foundation in fueling every aspect of our Earth and that there needs to be more awareness in how we utilize the finite sources in order to sustain a future.

Defining the New Net-Zero

The International Living Future Institute states that, “a new net-zero building is proof that it is possible to live within our means,” (Maclay, William, 2014, p17) explaining that this system of sustainability is in essence a plausible approach to helping develop a better environment for the future of human civilization. According to the World Energy Report in 2014, with over 7 billion people in the world, the U.S. ranks in at only 5% of the world’s population in terms of energy consumption. Ironically however, the U.S. is also the largest consumer of energy, consuming 5 times more than the average global citizen. This suggests that as the third largest country in the world, only below China (19% of the world’s overall human population) and India (17% of the world’s overall human population), the U.S. is under the scrutiny of excessive energy waste and consumption, which has scientifically been proven to be the cause of global warming, climate control, and the energy crisis.

The premise of net-zero energy consists of generating a building’s energy performance with the expectation that the energy produced to power the building or project must inherently come from renewable sources. In today’s society, defining the new net-zero is simple: in order for a building to meet net-zero standards, all energy loads in a building are matched by renewable energy production on an annual basis. Essentially all elements of the building’s energy loads, from the heating, lighting,

cooling, equipment plug loads, pumps and fans, and hot water are considered. Interestingly enough, according to Maclay, “it is quite easy to achieve net-zero on a wide open rural property but quite challenging in a dense urban environment,” (Maclay, William, 2011, p18) explaining that there are various definitions and standards to what would be considered net-zero, however, the limitations vary in design, location, and environment layout plays a role in changing the definition of net-zero. The more accurate approach to solidifying a standard definition would be to set up a two-step process. Renewable energy options that are available on the building, the typical net-zero strategy, should be the first step. Step two would then be to investigate options to locate renewable energy on a different property. In essence, externalizing all options in addition to achieving net-zero on the property would be a sure fire method to exhaust every opportunity to salvage renewable energy as oppose to managing every project on an individual basis and analysis. By limiting net-zero to a single definition limits the broad spectrum that renewable energy truly explores. Therefore to develop a more elaborate and deliberate approach to measuring renewable energy potential requires the two step strategy to include the primary and secondary opportunities.

Research Methodology

The philosophy of this research paper aims to credit the net-zero design strategies that could be used for future sustainable designs. Answering the

fundamental question of how can we make our buildings more energy efficient and at the same time reduce our footprint on the environment. By conducting the research and analysis at the design stages, we can see understand and apply different sets of plans to determine the best options for the specific project. For instance, looking at DPRs location, Phoenix, Arizona, applying shower towers and using the natural cooling ventilation from the buildings east to west orientation would be an effective and efficient mix of passive and active implementation (Image 4). The same application at the Tyson Living Learning Center would not be very effective since Eureka, Missouri has a colder temperature environment for a good portion of the year. In this instance, researching colder climate strategies would benefit the design and effectiveness of achieving net-zero. Since the cold winter requires an emphasis on keeping warmth inside, insulating roof (at U=0.03, Walls – U=0.03) and high efficient glazing windows (at U=0.25, SHCG=0.39) alleviated the annual energy generated of 22,985 kWh to an actual 21,291 kWh. (Reference Figure 8) A decrease in energy consumption was one aspect of the Tyson Living Learning Center that minimized energy demands while maximizing efficiency. With the initial study from the design phase, the next process would be the construction phase and applying the strategies with the analysis to prove the successes of the data. These two areas of focus in this research paper has allowed a better understanding of the various applications that demonstrated how to successfully reach

net-zero. Even with the unsuccessful trials made by the Tyson LLC, there are several good lessons to take away as well.

Research Questions

Question One: Is it possible to achieve net-zero energy certification by only implementing either passive or active strategies to the design of a building or project?

Proposition One: By only implementing passive or active strategies to the design of a building or project, the ability to meet energy demands and return investment is not plausible because several design techniques would be needed to just meet standards of minimizing energy waste. Further application of active designs such as rain water harvesting, vampire switch, photo voltaic panels, among many other, are necessary to sustain energy efficiency as well as generate renewable energy that would compensate for the reuse on the building.

Question Two: Should beauty and aesthetic design be implemented as a priority into the energy efficiency strategies?

Proposition Two: The debate over whether form follows function has been a topic of conversation for centuries. Between architects and designers, the aesthetics that surround the building/project, plays a huge role in inviting the viewer into the space. Sustainable groups focus and emphasize more on achieving plans that focused on

energy conservation. Ultimately, based off the research, I realized that the architecture design process go hand in hand with the construction phase. From the publics' perspective, the aesthetics and look/feel of the site prove to be just as important as the functionality of the building in creating a welcoming and inviting atmosphere. According to *DPR Construction's Phoenix Regional Office*:

"If one found beauty in a highly-efficient building that generates 100% of its annual energy onsite… if one found beauty in a building that was contextually appropriate to its natural surroundings, city's history and name… the creative ingenuity of [DPRs] designers… have achieved beauty on all fronts," (DPR Construction Press Release, 2013).

DPR's spokesperson establishes in the DPR Construction Press release that they were able to achieve the certification along with appealing to the audience with the build and design of the form and function of the passive and active strategies.

Setting

The case studies will focus on two sites, the DPR Construction building in Phoenix, Arizona and the Tyson Living Learning building in Eureka, Missouri. At both sites, the two net-zero energy buildings were chosen based off of the criteria of successful and unsuccessful strategies, respectively. With DPR, I was able to make a physical trip to investigate the site whereas with the TLL, majority of the research was

done online. Additionally, the statistical analysis and data was conveniently found online and was helpful in designating a digital source as the frame of reference.

Case Study 1 | DPR Construction Building (Image 2)

The DPR Construction Office has the distinct honor of becoming the first net-zero energy commercial building in Arizona. Through the Living Building Challenge, a program set up by the International Living Future Institute, DPR Construction officially earned the certification as a Net-Zero Energy Building on May 17, 2013. The building also achieved LEED Platinum certification from the U.S. Green Building Council. As a forerunner in implementing sustainable strategies, along with the multitude of awards for environmental efficiency, selecting this building as my case study allowed me to analyze and research the various strategies that were successful. Furthermore, what makes this case study more applicable to this research is that DPR, a national technical builder and construction company specializing in highly complex and sustainable projects, was able to successfully renovate a 1970's abandoned retail boutique into a *living lab* for the Arizona community. With multiple passive and active strategies, DPR utilized their design and construction phase to build a highly efficient modern workplace.

In terms of designing passive energy, the concept means to work with external conditions instead of using manmade tools and machinery to adapt. Strategies that resort to natural energy as oppose to purchased energy like electricity or natural gases

reduces the reliance on finite energy, materials, water and land use. For instance, with the already existing east to west orientation of the building, passive heating and cooling uses the natural energy of the sun to maintain comfortability for the occupants as well as reduce the demand for mechanical heating and cooling. By building overhangs, the opportunity to design and capture the sun rays specifically during the winter months and avoid them during the summer months is an example of passive heating and cooling. Additionally, the orientation of the building lay out was an opportunity to create a natural ventilation system which avoided the necessity to have to install and use AC (Image 9). By understanding how energy and air moves, working with the natural forces can cut the heating and cooling energy demands in half.

In terms of active design strategies, since the entrance of the building is located on the east side, along with some of the 87 operable windows that worked in tandem with the energy monitory system, the winter and summer breeze was controlled with an energy monitoring system to open and close in stages to allow for more fine-tuned control based on the relative outdoor and indoor temperatures (Image 7). The four shower towers that acted as evaporative coolers worked together with the operable windows and solar chimney to regulate building temperatures (Image 4). There are twelve eight foot Isis ® Big Ass ® Fans that enable free air flow within the office and keep the office space cool without the need for air conditioning (Image 6). Eighty two strategically positioned Solartubes ® skylights that eliminate the need for artificial

daytime lighting. Beyond just reducing energy consumption, the Solartubes ® skylights provide variation in light spectrums throughout the day and across the season (Image 5). One of the major renewable active energy systems employed on the DPR Construction building are the 78.96 kW-DC photovoltaic panels that are installed over the structural parking canopies (Image 8). The panels are configured in two settings, staggered and arrayed as well as flat tilted array. The modules are all mounted with a 10 degree tilt in order to maximize the amount of sunlight absorbed on a daily basis. The system provided two main focuses, to provide shade to parked vehicles and to maximize the amount of Solartubes ® skylights that could be installed on the roof of the main building. One more prominent active strategy that was implemented was the "vampire shut off switch" that turned off energy from power plugs. The last person to leave the office would push the button, located conveniently at the front by the entrance, and that would disconnect all unused power sources that are ultimately sucking up wasted electricity. With the number of innovated active sustainability features, the capabilities of an efficient building showed that not only was it possible, but clearly applicable to the future of renovations.

In the grand scheme of net-zero energy efficiency, with all of the passive and active building strategies in this case study, the ultimate goal was to effectively create a net-zero energy workplace. According to figure 3, the annual energy use by fuel that DPR produced from electricity was 129.624 kWh; in relationship to the annual onsite

renewable generation from the photovoltaic system, there was a production of 142.871 kWh. This analysis suggests that the PV system alone was able to generate enough energy to cover the cost of the energy used by fuel. That specific strategy alone put DPR Construction in better position to generate and regenerate a more efficient way to not only conserve energy but create opportunities to allocate the extra energy to another area of the building. Looking further into the energy analysis on figure 3, in addition to the PV renewable energy, the solar thermal energy was around 5,670 kWh which alleviates the domestic hot water that was consumed during the same annual cycle. According to the International Living Future Institute, the DPR Construction's Phoenix Regional Office, "had a net excess generation of 6,980 kWh compared to consumption during 2012," (International Living Future Institute, 2015). The statistical analysis of these findings implicates that the design strategies involved in contributing to the net-zero goals not only were successful, but made the building net-zero positive in that the energy produced brought returned value.

Case Study 2 | Tyson Living Learning Center (Image 3)

In looking at this case study located in Eureka, Missouri, there were multiple passive and active net-zero strategies implemented that were applied to try and achieve annual zero-net-energy operation. However, based off of the original construction analysis, the original building, "did not operate as a zero-net-energy building and was

consuming more electricity than it was producing, *especially during cold winter months,*" (AASHE, 2011). The fundamental problem that made the Tyson Living Learning Center unsuccessful was not taking project cost into account and including long-term estimates of energy performance and efficiency. This case study ultimately realized that, "energy conservation is generally more cost-effective than renewable energy production, and therefore should be weighed more heavily during the design of a net-zero energy building," (AASHE, 2011). By focusing on just the design process, there can be multiple initiatives to incorporate strategies, however, without actually analyzing the potential cost and estimating the performance goal using energy analysis programs, the designers of the Tyson Living Learning Center ran into.

There were a combination of design features that ultimately led to the project not capable of achieving net-zero certification. Additionally sealing of the building envelope needed to be done; installation of storm panels to windows and doors in the winter was also necessary to improve building performance; reevaluation of the air source heat pump HVAC system showed that the performance estimates did meet code standards and therefore the electrical consumption was far higher than anticipated. There was also the problem of installing an excessive amount of photovoltaic panels that led to an increase in Kw of 17kW to 23kW, which ultimately lowered the efficiency of the buildings energy demand. Another assessment evaluated that illustrated the failed design strategy of the Tyson Living Learning Center was the, "detailed energy modeling, which

was not part of the design process, and [was] essentially unable to meeting a stringent performance goal of net-zero energy," (AASHE, 2011). Ultimately, the Living Building Challenge from the International Living Future Institute evaluated the Tyson Living Learning Center and concluded that several fixes needed to be made. In addition, both a performance modeling assessment as well as a predictive modeling analysis were required as the project makes the adjustments in order to efficiently meet the criteria's of the Living Building Challenge and be certified as a net-zero energy building. By requiring the two assessments, it ensures the maximum potential value of the overall success of the energy efficiencies of that building to be gained from the energy efficient technologies and building design aspects.

Findings

One of the most fundamental approaches to living a more sustainable life is to be proactive and conscientious of our interactions on the natural environment. We live in a world today where the human population has reached over 7.7 billion people worldwide. The demand on energy sources to sustain life has threatened the balance of our natural physical environment with a depleting marginal return on natural resources. The ultimate take away with successfully achieving net-zero sustainability has to first begin with passive strategies that include maximizing load reductions and system efficiencies. Following that initial phase, incorporating active strategy designs that would attempt to

further offset energy consumption and meet the remaining energy loads with onsite energy generation. By understanding the foundation of why there is an energy issue, we will be focusing on the U.S. energy consumption crisis and recognize the specific success and failures of net-zero strategies. Focusing on the various aspects that make a project environmentally and economically feasible only alleviates half to the table; by researching a project that met at the opposite end of the spectrum, permits a deeper understanding and appreciate for potential challenges that future generations and innovators can combat.

DPR, the Phoenix based office is the largest building in the world and is the second in the United States to achieve Net-Zero Energy Building certification from the U.S. Green Building Council (USGBC). Dave Elrod, Regional Manager of DPR Construction in Phoenix, mentions that the successes that the DPR building accomplishes not only demonstrates “our ability to walk the walk of sustainability,” but also got the ability, “to demonstrate the impact revitalization can have on an urban environment,” (DPR Construction Press Release, 2015). The forward thinking successes illustrates the applicable design principles that instigating net-zero strategies can achieve; the mix of low and high tech features used to achieve energy savings demonstrate furthermore that is possible to live and work sustainably, even in the desert environment.

In contrast, the Tyson Living Learning Center demonstrated elements of implementing strategies that ultimately fell short of achieving net-zero certification. By comparing this case study against DPR's, the data collected in figure 2 through 8 illustrates a wide range of energy conservation applications.

Results & Discussion

To be net zero or to make a building net zero does not necessarily mean it is a sustainable model. In today's society, we throw around the word sustainability when we discuss anything green energy but for the most part, we do not understand what that entails. In terms of strategy and application, sustainability requires a large range of institutions, not only is the emphasis just on the building and its performance, but the urban planning and development of the surrounding community is also important. In essence, by preaching net zero buildings, we should understand the bigger picture here is that the entire community has to be full fledge in exercising the strategies to get everything to work. In the case study of the DPR Construction building, the renovating project proved that, "it is possible to live and work sustainably, even in a desert environment," (DPR Construction Press Release)… nonetheless, the ability to incorporate an urban scale tactic would benefit the overall energy production and consumption of the ideal net-zero goal.

Conclusions, Recommendation and Implications for Theory

Throughout the research process, the one question that I was trying to answer dealt with discovering whether applying active and passive strategies would be sufficient with the future design model. By investigating the effects of each strategy, from the insulated roof and window categories to installing HVAC systems with digital monitoring computers to allocate the most effective usages. Every project that has attempted to go net-zero energy has been very successful in its own way. More importantly, on an individual basis, the attempt to utilize a more sustainable approach to conserve energy is clear, however, to ultimately accomplish the larger goal of being a more sustainable planet, it is vital that we apply the strategies of net-zero energy to a broader scale. The implications of sustainable living should be developed on a macro level where the local, regional, and even state municipalities are involved in determining the values of green sustainable development. Urban planning is a multi-faceted approach and encompasses a large circle of intertwining policies and strategies that will benefit the overall arching theme of energy conservation. According to Nadav, “It’s more useful and important to work toward net-zero communities rather than net-zero buildings. Individual high-performing buildings don’t mean so much if the neighborhood as a whole is wasteful, while if an entire community is net-zero, that’s meaningful...” (Malin, Nadav, 2010). The practice of generating a community of net-zero energy buildings will reduce the overall consumption and waste of energy, and instead, allocate

the conserved amount of energy to only the areas that require it. This can be an area of research to approach in future attempts to develop the scope of what net-zero energy can do. To sum up the idea, it is more important to understand and practically apply the functions of living a greener life style, as oppose to trying to implement practices on a small scale. For a lot of businesses and communities, the practice of going green is the direction that will one day challenge the way building and urban planning has been developing. (Refer to Figure 3 and 10). By transferring the knowledge of green strategy to a larger scale and population, there will ultimately be a reassessment of values and ideals towards a greener planet.

Appendices

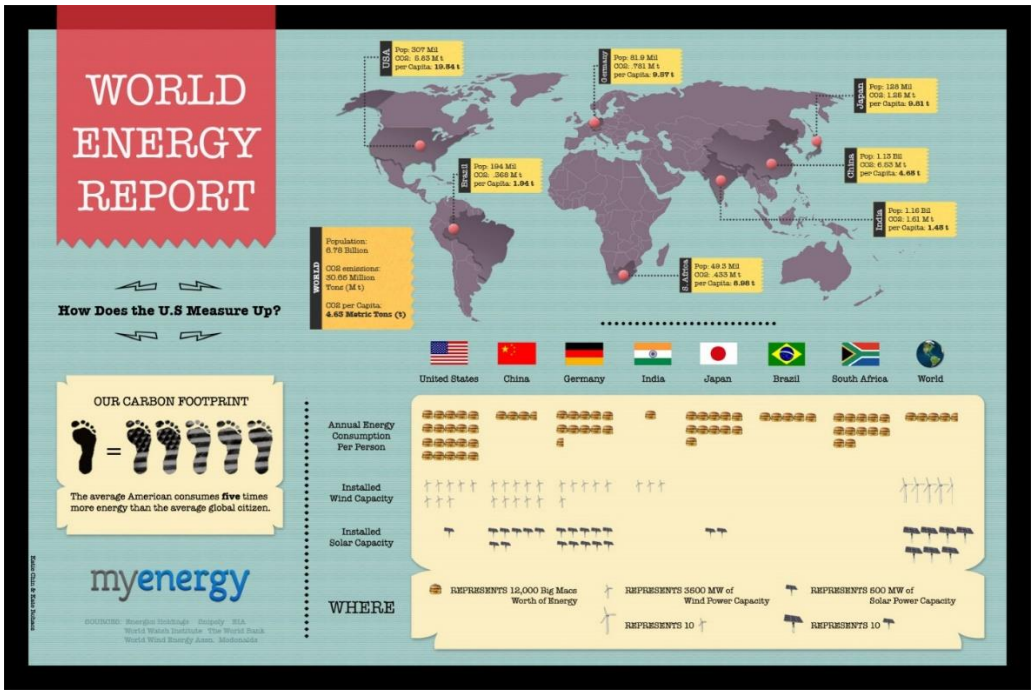

Image 1 World Energy Footprint. The U.S. alone makes up 5% of world population.

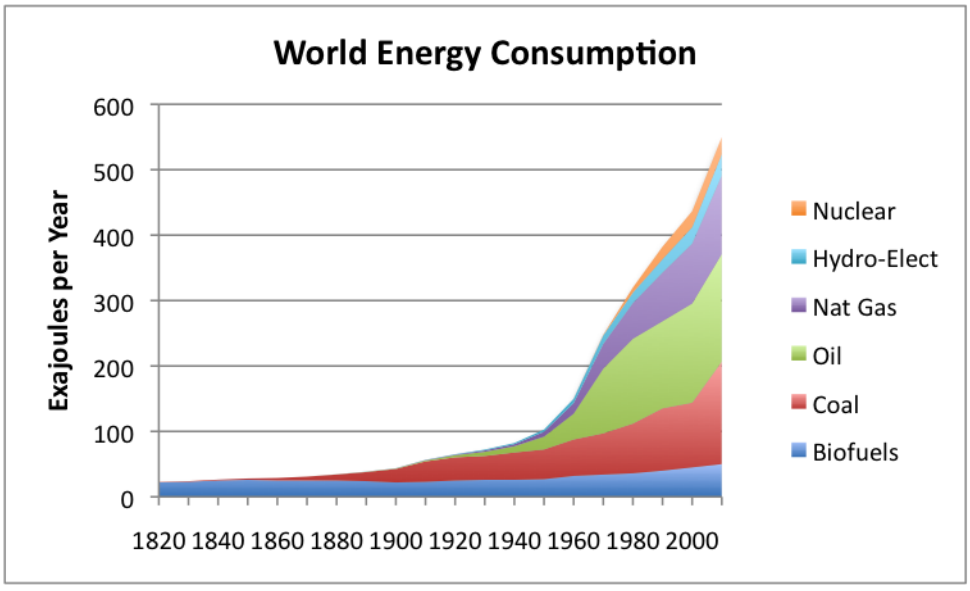

Figure 1 World Energy Consumption Chart.

ENERGY ISSUES

Energy was by far the most scrutinized aspect of the project. Each strategy was evaluated based on its cost and net contribution to the Net-Zero goals. The entire team was guided by DPR's commitment to any strategy that had a payback of 10 years or less. See narrative in the Evaluation section for individual energy related measures.

Annual Energy Use by Fuel
Electricity: 129,624 kWh
Gas: 0
Fuel Oil: 0
Biomass: 0
Other fuel: 0
Total: 129,624 kWh

Annual Energy by End Use
Heating: 14,395 kWh
Cooling: 50,893 kWh
Fans & Pumps: included above
Lighting: 20,155 kWh
Domestic Hot Water: 5,670 kWh
Plus Loads & Equipment: 39,571 kWh
Other End Use: 0

Annual On-Site Renewable Generation
PV: 142,871 kWh
Solar Thermal: 5,670 kWh
Wind: 0
Micro-Hydro: 0
Biomass Electricity: 0
Biomass Thermal: 0
Other Renewable: 0
Total: 148,541 kWh

Peak Use
Peak Electricity Demand: 15,969 kWh
Peak Natural Gas Demand: 0
Peak Cooling: 363.63 ft^2/ton
Connected Lighting Load:.96 W/sf

Data Sources and Reliability
Based on simulation? — Yes, Energy Plus
Based on utility bills? — Yes, Arizona Public Service — Jan.–Dec. 2012

Comments on data sources and reliability.
We used utility bills to identify total kWh usage for the project. Lucid monitoring data was used for all other values. This is based on actual real-time monitoring data which looks at HVAC, Lighting, DHW, and Plug Loads all in real-time.

Figure 2 Data that shows how the DPR building is managing its utilities. Macklay (2012)

Image 2 DPR Construction Regional Office, Phoenix, Arizona.

Image 3 Tyson Living Learning Center, Eureka, Missouri.

Image 4 Shower Towers that act as evaporative coolers at DPR Construction, Phoenix, Arizona.

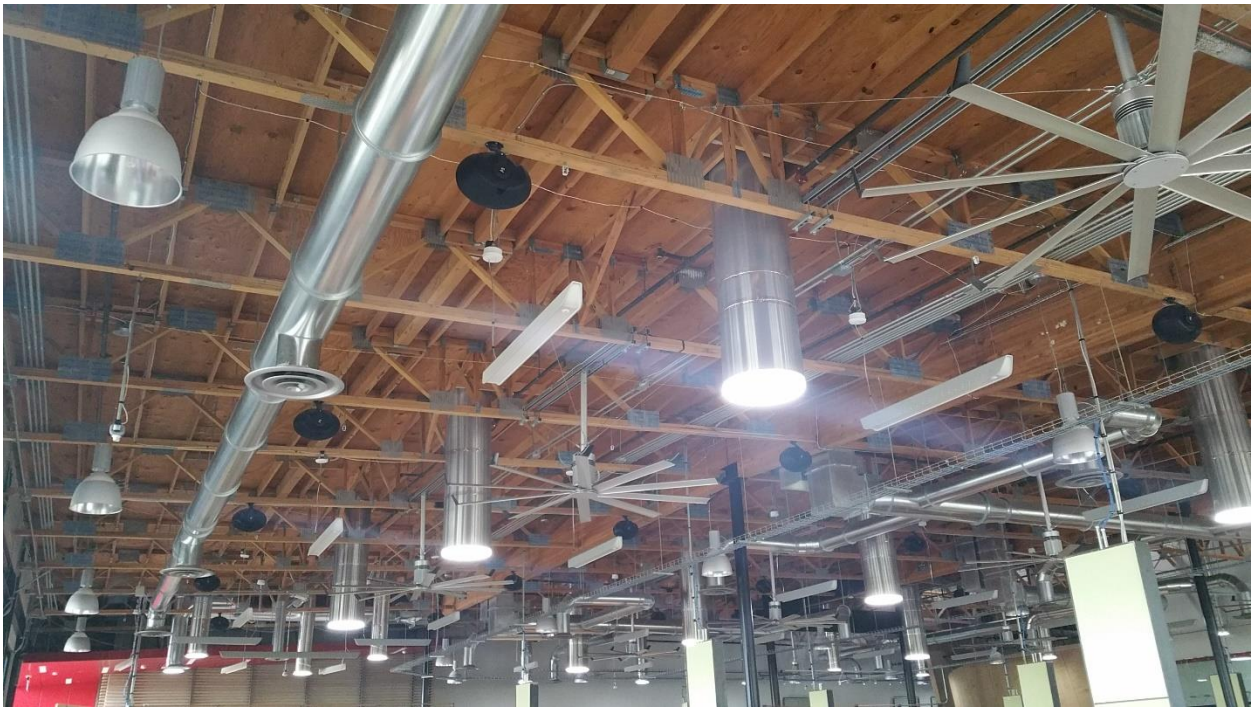

Image 5 Solartubes ® skylights that provide natural daylight into all the spaces of the DPR Construction building, Phoenix, Arizona.

Image 6 Big Ass® Fans that enable free air flow at the DPR Construction building, Phoenix, Arizona

Image 7 DPR Construction building Operable Windows that work in tandem with the energy monitoring system to open and close based on the relative indoor and outdoor temperatures.

Image 8 DPR Construction buildings Photovoltaic system installed over the structural parking canopies.

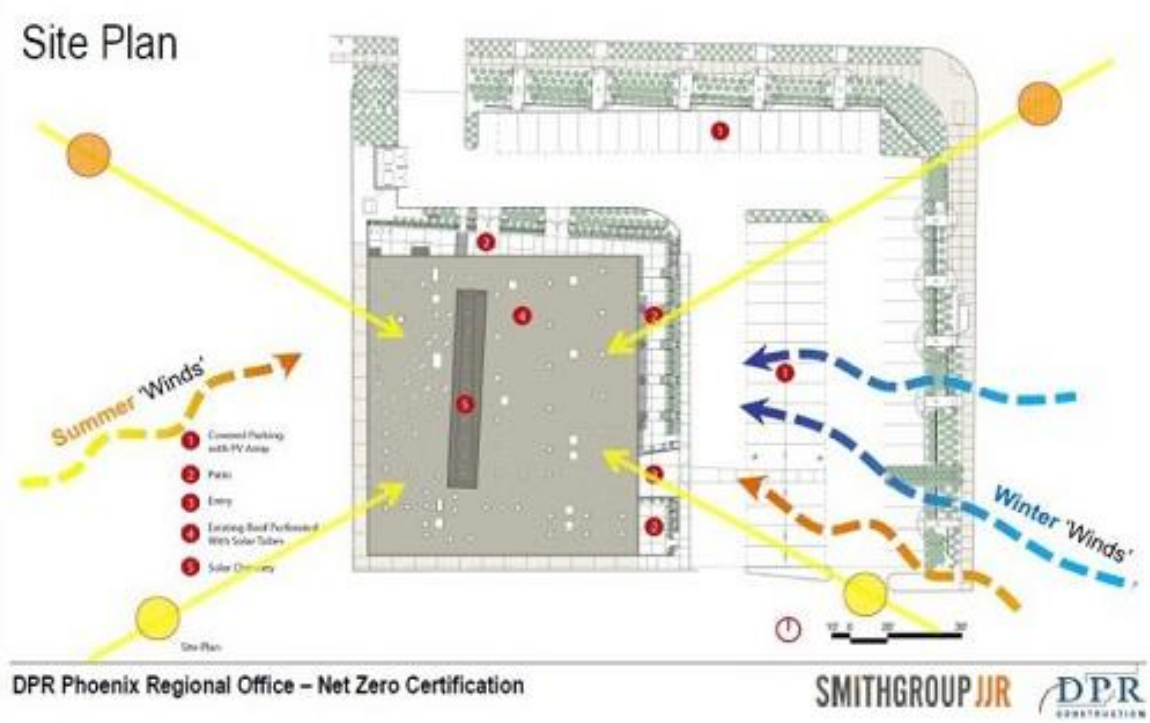

Image 9 DPR Construction building Orientation.

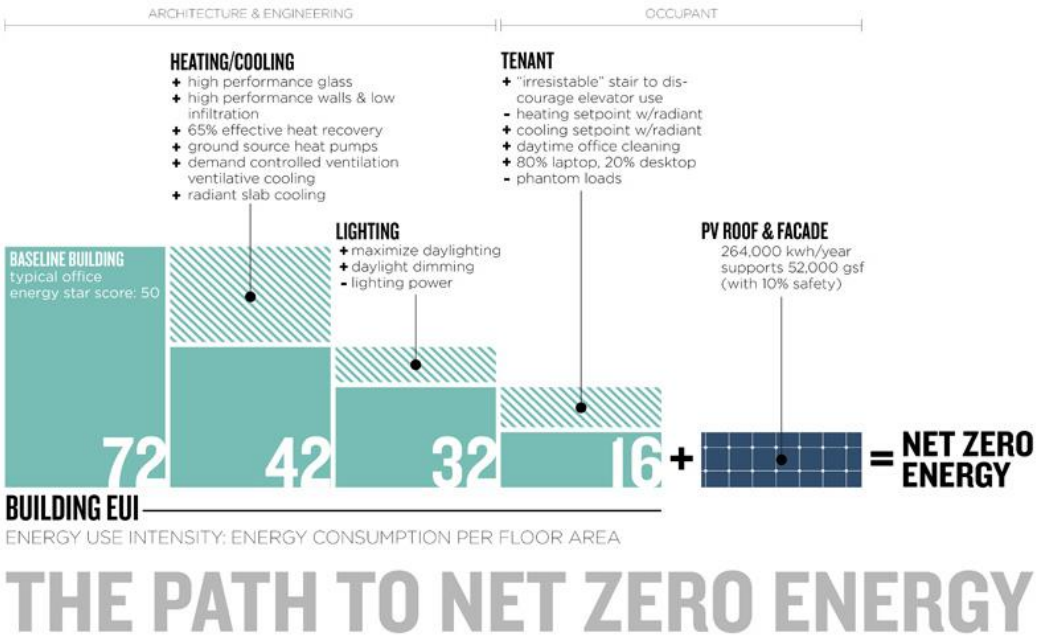

Figure 3 The functionality to achieving net zero energy requires the coexistence of both the designer, builder, and occupant.

Image 10 Vampire Switch that shuts off any electrical devices (ie. microwaves, cellphone chargers, radios, etc...) that draw energy from power plugs when there are no occupants in the building.

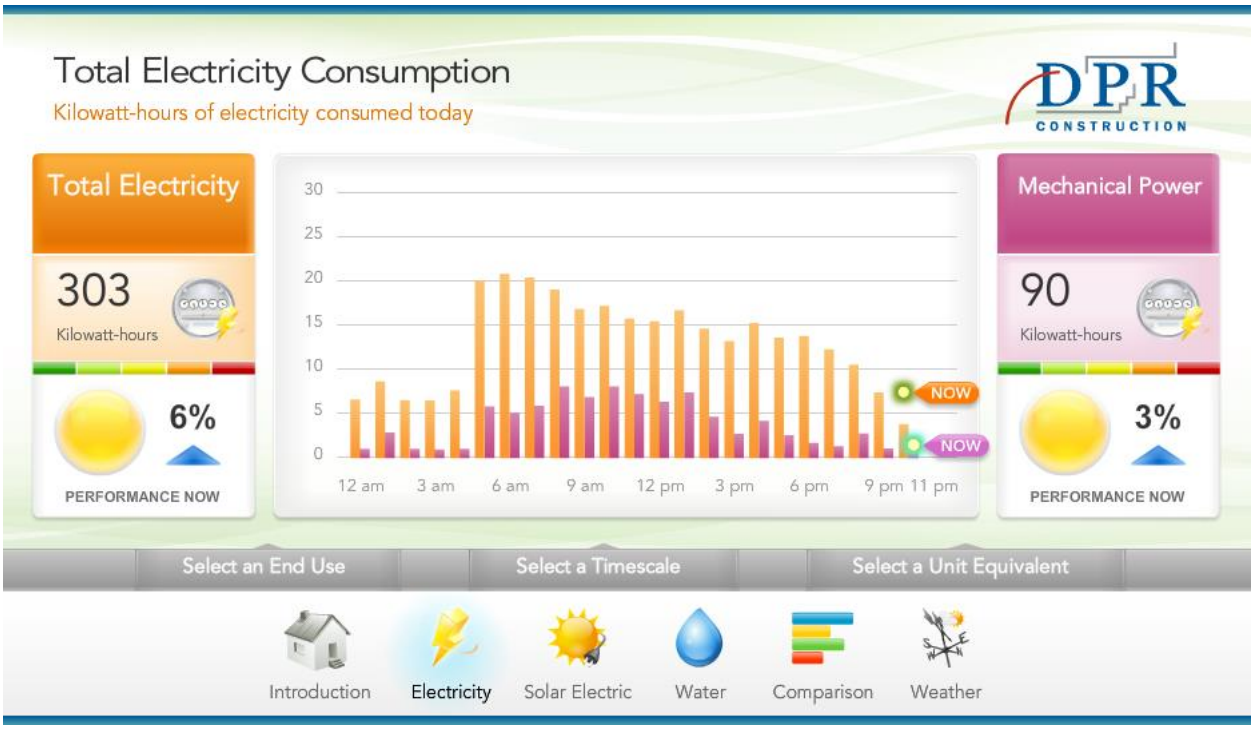

Figure 4 DPRs Total Electricity Consumption

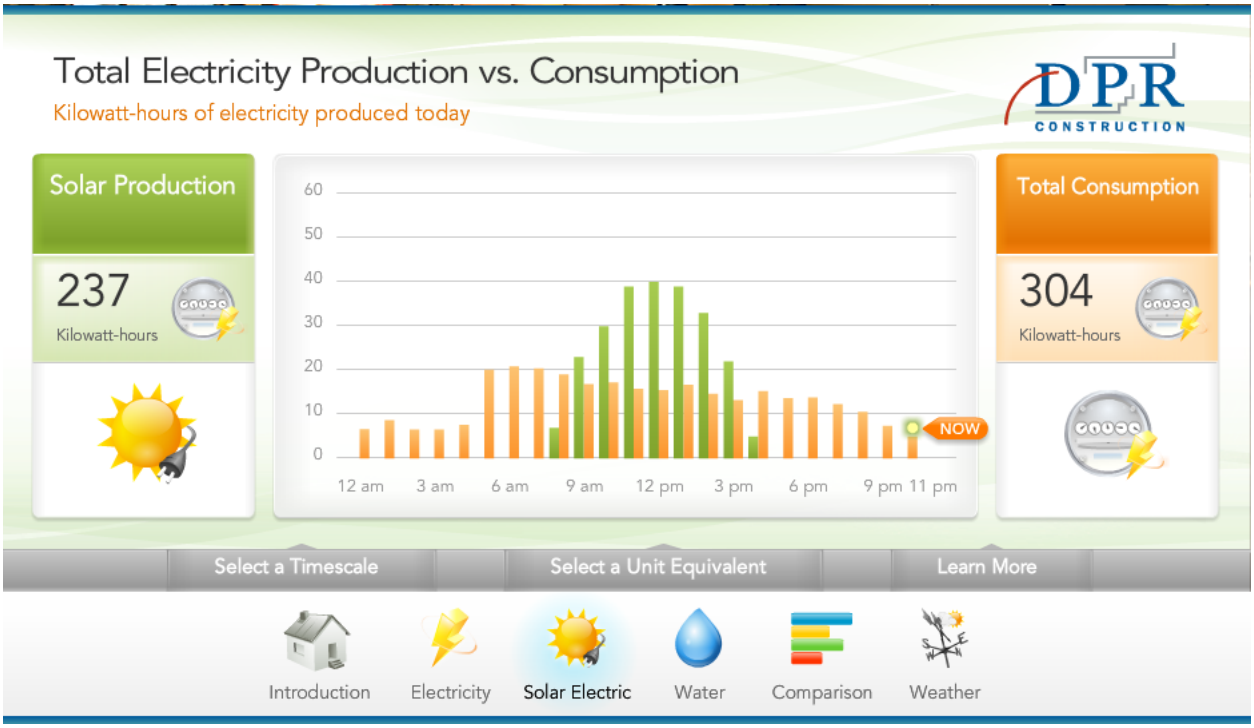

Figure 5 DPRs Total Electricity Production

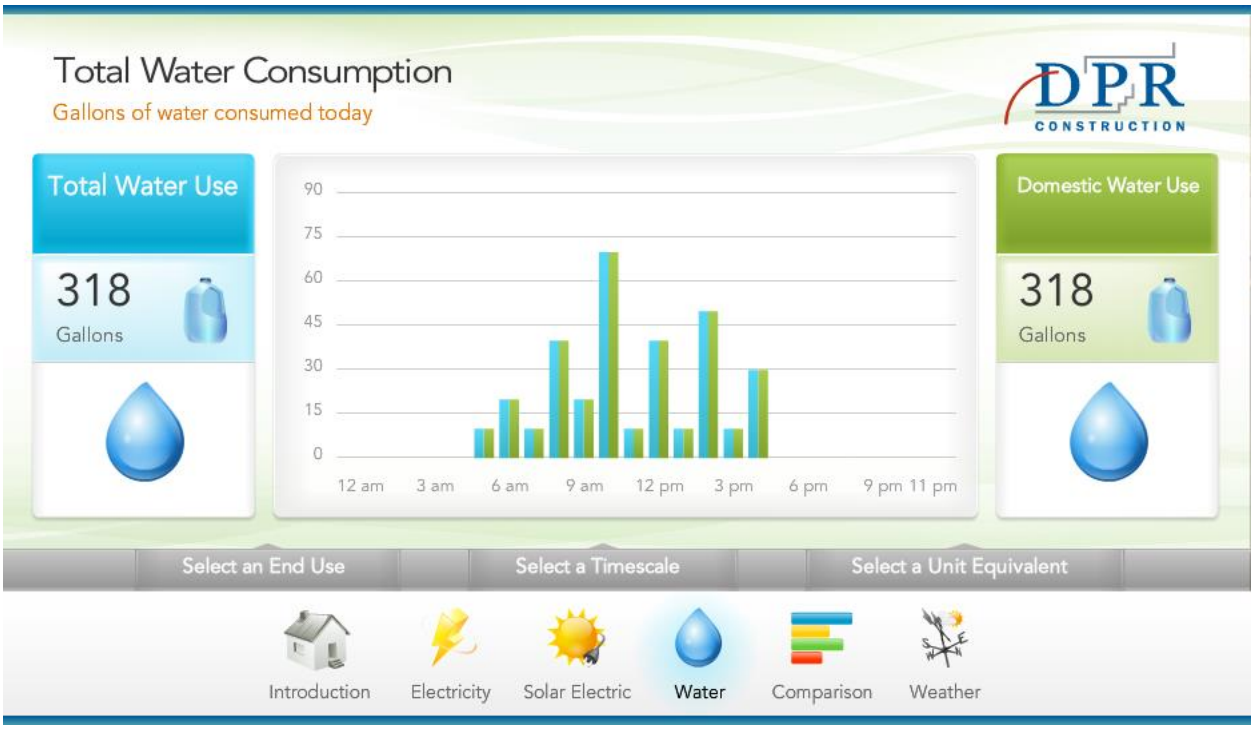

Figure 6 DPRs Total Water Consumption.

\

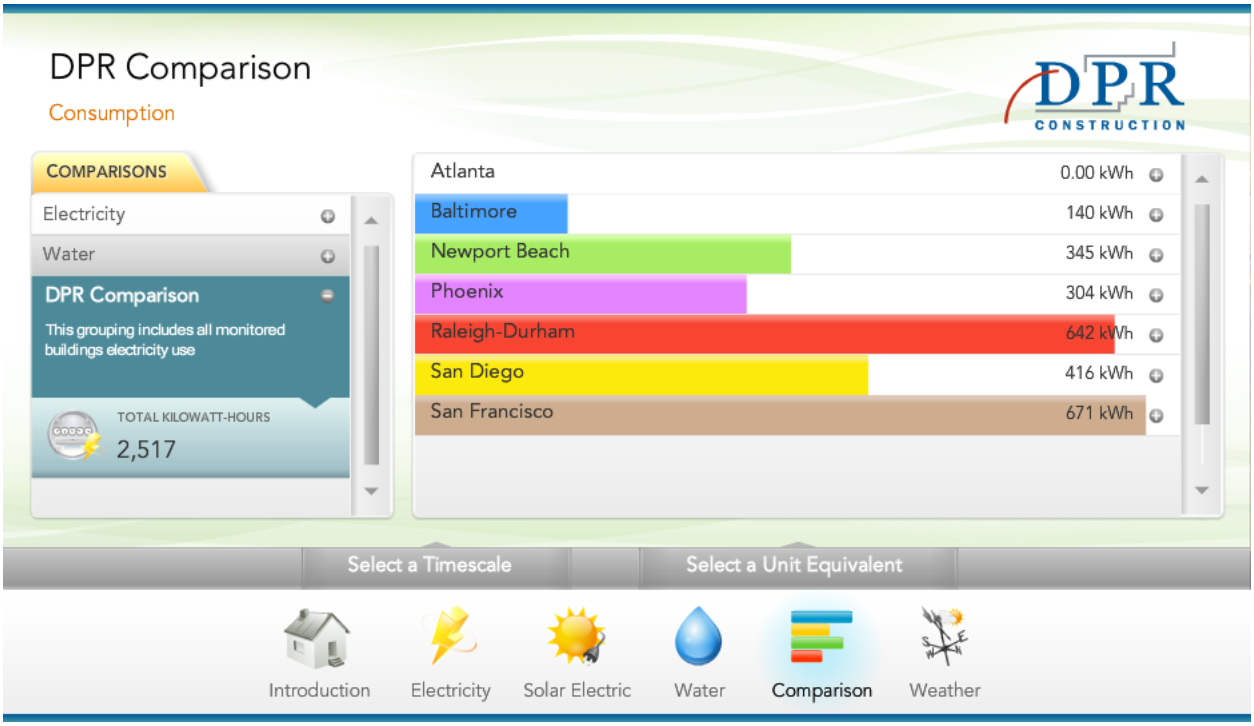

Figure 7 DPRs Consumption Comparison.

WATER

Annual Water Use: 13,000 gal
Dependent on Rainfall & Usage, Potential for 50,000+ gallons/yr of harvested rainfall.
Harvested onsite: 13,000 gal
Rainwater cistern size: 3,000 gal
Collection strategies: Rainwater capture via sloped standing seam metal roof.
Systems fed: Domestic water distribution: lavatories, sinks & hose bibs
Grey water: 13,000 gal/yr
Systems fed: Irrigation
Black water: Volume is unknown.
Systems fed: Irrigation
Estimated total water use per capita: 520 gal/yr

Design tool(s) and calculation method(s): Rainfall data sourced from NOAA Climatology and Weather Records, years 1870-2008 for St. Louis, Missouri.

Related regulatory appeals:
A barrier to the goal to use only captured rainwater for potable use, and treat and infiltrate the building's grey-water on-site was identified in the St Louis County code early on. The project team chose to meet proactively with the St Louis County Public Works Department to explore how the project goals could be achieved under the existing code restrictions. They reached an agreement to submit the project under the Alternate Compliance path. The path was ultimately successful and paves the way for future regional projects to implement the same strategies.

Additional Water Petal comments:
Lavatory & sink waste is routed to a dosing basin then to a leach field based treatment sources. Black water is naturally broken down via the composting system.

Figure 8 Tyson Living Learning Center Water Consumption and Production Statistics

ENERGY

Type + size of renewable energy system(s) used:
Evergreen Solar Roof & pole mounted photovoltaic, 23.1 kWh

Annual Energy Use
Actual: 21,291 kWh
Simulated/designed:
Energy use intensity: 33.1 kWh/sq ft
Annual electricity generated: 22,985 kWh

Design tool and calculation method:
EQuest, Trane TRACE 700

Related regulatory appeals: Ameren UE: Renewable Energy Net Metering Agreement

Additional Energy Petal comments:
The Living Learning Center required a true whole building approach to achieve net zero energy. This included minimizing energy demand while maximizing efficiency. On-site energy production was used to generate the necessary power. Through multiple design charrettes, several traditional and non-traditional energy reduction methods were agreed upon. These strategies include:

Proper building orientation	High efficiency HVAC systems
High efficiency glass	Demand control ventilation
Shading of exterior glazing	Daylighting of occupied spaces
High R-value insulation	Lighting controls
Point-of-use domestic water heating	Energy Star appliances and equipment
Utilization of natural ventilation	Owner training on efficient building operation

These strategies in conjunction with proper owner training to ensure systems are operating efficiently.

Perhaps the most formidable challenge of this Living Building Challenge is to produce a building that performs as a Net Zero Energy Building. Our design team approached this on two basic fronts. First, limit the amount of required energy the building would consume, and second, provide an on-site renewable form of energy generation capable of handling the energy needs of the building. The most detailed of this two-pronged approach was the task of limiting the building's required energy consumption. The following is a partial list of the major components of that system:

- Enhanced Building Insulation: Roof – U=0.03, Walls – U=0.03
- High Efficiency Glazing: Windows - U=0.25, SHCG=0.39
- Shading through exterior overhangs and awnings.
- Building Orientation to limit solar gain.
- Optimized ventilation: Operable Windows
- Dedicated Variable Volume OA Unit with energy recovery
- Demand Control Ventilation
- Utilization of a high efficiency variable refrigerant HVAC system. This system is anticipated to reduce the HVAC load by approximately 40% over standard Split Systems of this capacity.
- Enhanced Lighting Design: Daylighting to 100% of Occupied Spaces
- Occupancy Sensors
- Photocells for Daylight Dimming Control
- High Efficient Fluorescent Lighting
- Energy Star Rated Appliances and Equipment
- Limited or eliminated Auxiliary power loads such as automatic faucets, 24/7 computer servers, and hot water storage tanks.
- Utilized High Efficiency Point of Use Water Heaters.
- Limited energy consumption to a single utility, electricity to better control energy usage.

Through these measures the building has been estimated to consume approximately 10 KWH/SQ/YR in total electrical consumption. To compensate for this energy consumption the design team reviewed various renewable energy sources.

Wind power was considered for the project however the building is located in a valley with the nearest hilltop approximately one quarter of a mile away. In addition, wind power studies for this area were analyzed. It was determined that this was too inefficient of a source of energy. Other alternative energy and rapidly renewable sources such as geothermal, hydroelectric, and biomass boilers were evaluated and deemed inapplicable to this project.

Ultimately solar electrical power generation was selected for this project. Multiple solar options were considered including differing solar panel types as well as alternative panel locations. Ultimately the proper orientation of the building combined with the south facing sloped roof provided an ideal location for mounting the solar panels and reduced the cost by eliminating separate support for the modules. Ninety-six (96) 195 Watt photovoltaic modules have been installed on the sloped metal roof. These modules to combiner box and set of two (2) Fronius inverters. This system will feed the building and the utility grid with approximately 17 kW of peak power production. The owner has entered into an agreement with the local utility who will "buy back" excess power production the facility has.

Figure 9 Tyson Living Learning Center Energy Consumption and Production Statistics.

Net-Zero Energy Buildings and Communities: Advantages at each scale

Topic	Advantages of working with individual buildings	Advantages of working with communities
Energy load reduction	Clear definitions and boundaries make the challenge, and the steps needed to meet it, unequivocal.	Loads for systems not typically factored into the building's footprint, such as for infrastructure and transportation, are naturally included.
Solution set	Many basic measures for driving down energy use in buildings, such as envelope efficiency, airtightness, and smart controls, have to be addressed methodically and aggressively in every building.	Community design can be optimized for solar exposure and access to cooling breezes.
Renewable energy generation	Direct connection between generation and point-of-use minimizes transmission losses and connects building users to their energy source.	More cost-effective technologies are more feasible at a larger scale.
Solar access	Individual buildings may have good solar access and room onsite for renewables (although they often may not).	Design doesn't have to rely on maximizing each building's solar access, so it's less likely to encourage sprawl.
Financing	Ownership or contractual parties are clearly defined with the properties, making it easier to finance generation systems.	Larger-scale systems can pique the interest of big investors.
Cascading uses of energy	Moving energy around to share its benefits internally is relatively straightforward.	Diverse activities, generating good opportunities for sharing energy between them, are more common than in individual buildings.

Figure 10 Net Zero Energy Advantages taken from Environmental Building News by Nadav Malin

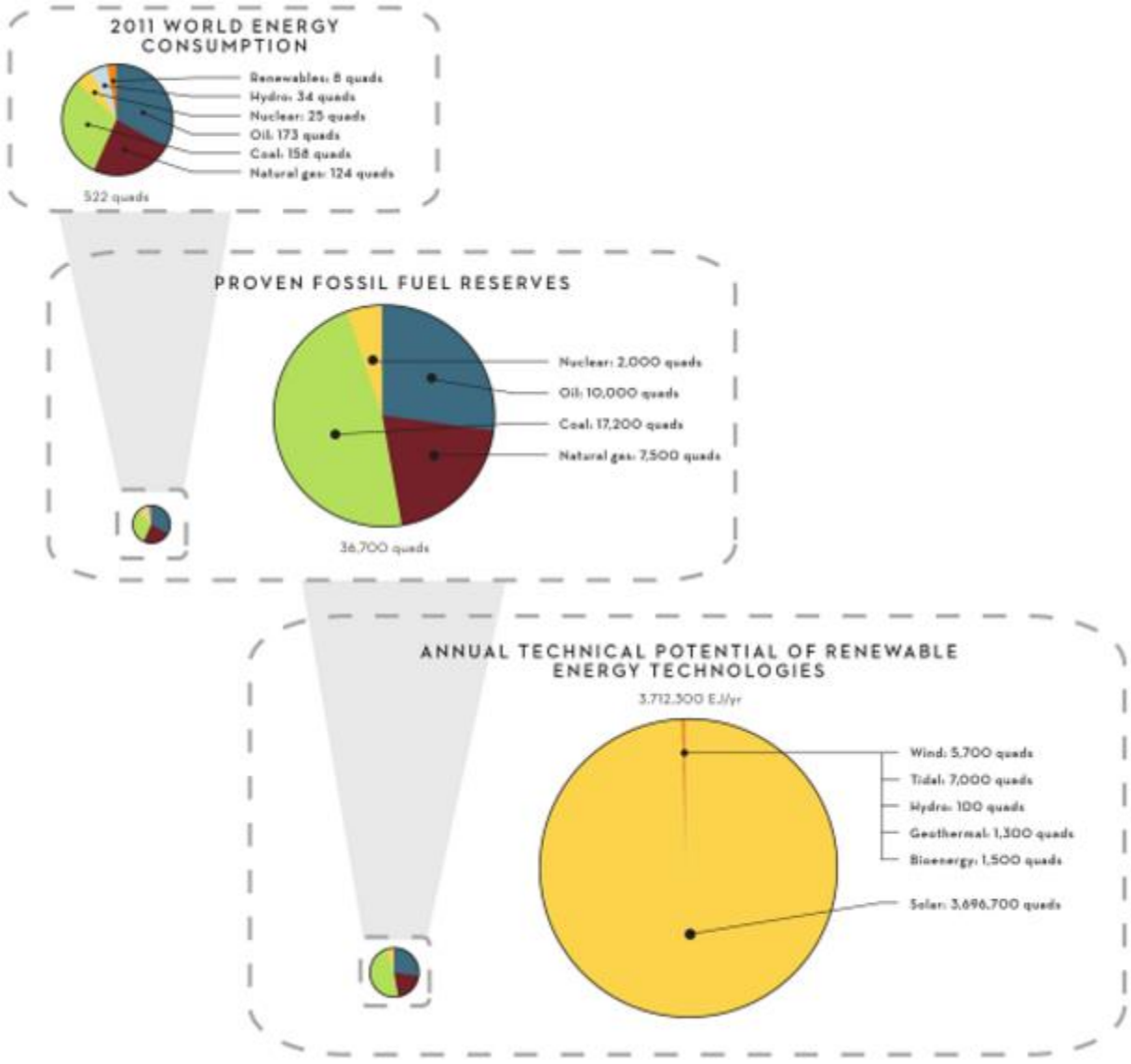

Figure 11 Current world energy consumption is small in comparison to total proven fossil fuel reserves. Renewable energy sources offer millions of times more energy annually than what we need at our current consumption rate.

References

AASHE. *Getting To Net-Zero Energy: Lessons Learned from a Living Building Challenge*. Eureka, Missouri: Biology Department: Washington University in St. Louis, Website, 11 June 2011 <http://www.aashe.org/resources/case-studies/getting-net-zero-energy-lessons-learned-living-building-challenge>

American Society of Heating, Refrigerating & Air-Conditioning Engineers. *Advanced Energy Design Guide for Small to Medium Office Buildings*. Atlanta, Georgia: American Society of Heating, Refrigerating & Air-Conditioning Engineers: ASHRAE Publishing, 2011. Print.

Brien, William. *Modeling, Design, and Optimization of Net-Zero Energy Buildings*. Berlin, Germany: Wilhelm Ernst & Sohn, 2015. Print.

Cortese, Amy. "Net Zero and Living Building Challenge Financial Study: *A cost comparison report for buildings in the District of Columbia*." District of the Environment, District's Green Building Fund Grant, 2013. Online

Crockett, Jim et al. "The Anatomy of Net Zero." *NetZero Buildings* 3.3 (2014): 1-52. Print

DPR Construction Press Release. “DPR Construction’s Phoenix Office First Net Zero Energy Commercial Building in Arizona.” DPR Construction, 2015. Online article. 17 May 2013, <http://www.dpr.com/media/press-releases/dpr-constructions-phoenix-office-first-net-zero-energy-commercial-building>

August 2015 <http://www.dpr.com/media/press-releases/dpr-constructions phoenix-office-first-netzero-energy-commercial-building>.

EarthShare. “Net-Zero Buildings.” *6 Facts About Net Zero*. EarthShare, (2015). 12 October 2015, <>

Filippenko, Alexei & Pasachoff, Jay. “A Universe from Nothing.” *The Cosmos: Astronomy in the New Millennium.* Wadsworth Group, Thomson Learning, 1st edition, 2001. Online article. < https://www.astrosociety.org/publications/a-universe-from-nothing/ >.

Hootman, Thomas. *Net Zero Energy Design: A Guide for Commercial Architecture*. Hoboken, New Jersey: John Wiley & Sons Publishing, 2013. Print.

Whole Building Design Guide. *“*Case Studies & High Performance Building

Database." National Institute of Building, National Building of Sciences, 2015. Web. 5 May 2015 <https://www.wbdg.org/references/casestudies.php>.

International Living Future Institute. Living Building Challenge 3.0. 2015. Website, <http://living-future.org/lbc/about>, <http://living-future.org/case-study/dpr-phoenix>.

Malin, Nadav. Environmental Building News. "*The Problem with Net-Zero Buildings and the Case for Net-Zero Neighborhoods*." 30 July, 2010. Online article < https://www2.buildinggreen.com/article/problem-net-zero-buildings-and-case-net-zero-neighborhoods >.

Maclay, William. *The New Net Zero*. White River Junctions, Vermont: Chelsea Green Publishing, 637 pages, 2014. Print.

U.S. Energy Information Administration. "International Energy Outlook 2014: World Petroleum and Other Liquid Fuels." Office of Integrated and International Energy Analysis, U.S. Department of Energy, Washington, DC, 62 pages, 2014

Voss, K., Musall, E., Sartori, I. and Lollini, R. (2013) Nearly Zero, Net Zero, and Plus

Energy Buildings – Theory, Terminology, Tools, and Examples, in Transition to Renewable Energy Systems (Teds D. Stolten and V. Scherer), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany. doi: 10.1002/9783527673872.ch41