DELIVERING NET ZERO ENERGY FACILITIES

Many government agencies and commercial organizations have embarked on a plan to achieve "net zero" buildings and campuses over the next decade.

We have been involved in the planning and delivery of Net Zero Buildings and Net Zero Installations across the country, which has resulted in learning some important lessons. This paper provides a summary of what we have learned.

This paper does not advocate for net zero, nor does it provide a cost benefit analysis to help you decide if net zero makes sense – either politically or economically. In addition, this paper does not provide the technical engineering aspects of achieving net zero.

What we've learned is that delivering a NZE building isn't an "engineering" problem. It is an organizational challenge that requires experienced Project Management with collaborative, structured processes and specialized expertise. The PM needs to effectively transition stakeholders, the integrated project delivery (IPD) team, and future occupants from typical thinking to a new approach and paradigm.

If you have decided to pursue a net zero strategy, here are our best thoughts on the best management approach.

What is a Net Zero Facility (or Zero Energy Building)?

Let's start by defining net zero. Net zero energy (NZE) facilities are buildings that offset the amount of energy consumed by both buildings and occupants with the amount of energy produced through renewable energy sources.

Buildings account for a significant portion of U.S. energy consumption: 39% of total energy use, 72% of electricity, 54% of natural gas and 48% of carbon dioxide emissions. Energy costs are expected to double in the next 25 years.

NZE facilities or Zero Energy Buildings (ZEB) are viewed as a potential way to reduce facility operations and maintenance (O&M) costs while also reducing energy consumption for environmental, security and financial reasons.

There are four types of Net Zero Energy Buildings (ZEBs).

It is critical to select one defition because this single metric will guide the decision-making process of the integrated project delivery team.

A successful NZE facility can be defined in four primary ways:

Net Zero Site Energy: A site ZEB produces at least as much energy as it uses in a year, when accounted for ***at the site***. (This is typically the definition used in the U. S.)

Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in a year, when accounted for ***at the source***. To calculate a building's total source energy, multiply imported and exported energy by appropriate site-to-source conversion multipliers. These ZEB buildings require more energy generation than Site ZEB.

Net Zero Energy Costs: In a Costs ZEB, the amount of money the utility pays the building owner for energy the building exports to the grid is at least equal to the amount the owner pays the utility for energy services and energy used over the year. (Typically the utility will pay less for energy generated by renewable sources, so the amount of energy generated from renewable sources is greater.)

Net Zero Energy Emissions: A net zero energy emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. More stringent variations include carbon emissions generated during construction of building and carbon emissions generated by occupants commuting to and from the building. (This is typically definition used outside of U.S.)

There are two additional definitions worth mentioning:

Net off-site zero energy use - A building may be considered a ZEB if 100% of the energy it purchases comes from renewable energy sources, even if energy is generated off site.

Off-the-grid Net Zero Energy use – A building is considered off-the-grid when it stands alone and is separated from the electrical grid. Distributed renewable energy generation and energy storage capability are required.

NREL'S Research Support Facility

Photo courtesy of NREL

Most people familiar with net zero have heard of the National Research Energy Laboratory's (NREL) Research Support Facility (RSF) located in Golden, Colorado. It is a Net Zero Facility that was completed in 2010 and is recognized as one of the nation's most energy efficient facilities.

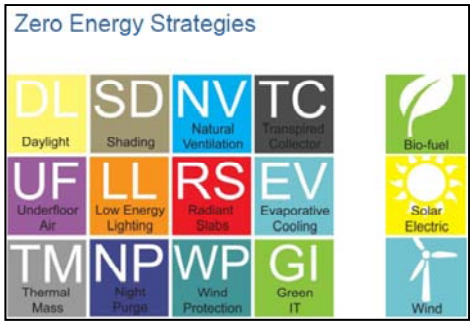
The RSF was designed for 800 staff from NREL. The RSF is a 220,000 GSF research facility constructed at a competitive price of $259/SF for a total cost of $64 million.

The construction of the RSF proved that affordable NZE facilities are possible. The photo to the right shows the unique building design with multiple narrow wing footprints.

NREL created a framework (pictured in the bottom right corner) for Zero Energy Strategies that helped the design team conceptualize the range of elements to include.

The RSF achieved energy use intensity (EUI) of 25 kBtu/ft^2 – yr. This was 23% of the 2003 Baseline of 107 kBtu/ft^2 – yr and 45% of the LEED® Baseline of 55 kBtu/ft^2 – yr.

While the RSF demonstrated that NZE could be constructed cost effectively, it did not address challenges faced by typical owners. Here are some key questions:



- RSF occupants were NREL employees with a commitment to NZE. Could typical occupants make the necessary behavioral changes required to reduce plug loads without a loss of comfort and satisfaction?
- The building is very simple with a low-grade finish and few enclosed offices, and is similar to a warehouse. Could a cost effective NZE building be delivered with a higher level of finish and more private enclosed offices for mission integrity?

- The site has four acres with plenty of space for PV, wind generation, building footprint, and parking. Could a cost effective NZE building be planned and delivered in an urban and constrained site?

Salt Lake City's NZE Public Safety Building

In early 2010, Mayor Becker of Salt Lake City gained majority vote for the funding of a $125 million new public safety building. Mayor Becker and Salt Lake City hired us as the Owner's Project Manager (OPM) with the goal to deliver the Nation's First NZE Public Safety Building in a cost effective manner. This was a formidable challenge given many constraints and unique building requirements.

The new Public Safety Building (PSB) was planned in the downtown Salt Lake City urban environment. The building would support 450 police, fire and emergency response personnel. The facility would require a large amount of open and closed office space including:

- A full Emergency Operations Center (EOC)
- A E911 center with 29 stations, each with six to eight monitors with supporting platforms and desk configurations
- The City's prime communication site for emergency communications
- The City's prime Data Center.

Seismic events are a major concern in Salt Lake City. The building would have to remain 100% operable during a major seismic event (magnitude 7.3) or other catastrophic event. Immediate re-occupancy was requested, which requires significant structural elements.

Back-up power would need to be provided "off the grid" through renewable energy sources to ensure 100% operations.

The site did not include enough land for the 425 parking stalls, so an underground parking garage was designed into the project.

Stakeholder Commitment and Alignment

NZE projects require a higher level of stakeholder alignment.

A charrette workshop was held at the start of the project to explore each NZE definition and develop challenges and opportunities for each definition. Each definition had an effect on both construction and O&M costs. Subsequent research was needed to resolve

unknowns and a NZE Resolution Document was developed to formalize the decision.

The team selected **Net Zero Energy Emissions** to achieve a zero carbon footprint or net zero carbon building.

A "NZE Resolution Document" was created to guide the future design decisions and accounting. An "Emissions Rates and Avoided Emission Rates Table" was then developed to calculate NZE Emissions and evaluate design options.

The following collaborative processes were used:

- Project Definition – Workshops to clearly define NZE goals.
- Collaborative Design Session – Charrettes for team decision making.
- Increased Communication with all Stakeholders – Public website, collaborative PMIS and an Energy Management System.
- Design Assist Contracting – OPM works with renewable energy supplier and utility company to develop PPA or direct purchase of equipment.

Early and Integrated NZE Planning (Before Design Work)

The team defined and agreed upon the following design goals during a Project Definition and Collaborative Design Session:

Waiting for the energy engineer's simulation model (which is the typical design process) doesn't work. It occurs too late in the process.

- First NZE Public Safety Building in the U.S.
- Most Energy Efficient Building in Western Mountain Region
- Ultra-Low Energy Use with 50% reduction over ASHRAE 90.1
- Energy Star Rating of 100
- Workstation/office total wattage use limited to 85 watts
- LEED Gold or Platinum without "buying" points.

Integrated design decisions were needed to start the design work. However, the development of a detailed energy model greatly limited the ability to fully identify and incorporate all the many energy saving options. Ultimately, the team developed conceptual and paramtric cost estimates with projected energy usage to make early planning decisions.

A design concept with integrated design elements was finalized that achieved an Ultra-Low Energy building with an EUI of 25 kBtu/SF/yr. The rendering to the right highlights the final design.

Rendering of Ultra Low Energy Design

These energy reduction goals were translated into building-wide systems goals. It became clear that building design elements were synergistic in their ability to reduce overall energy use.

For example, the passive daylighting approach required more glass on the exterior of the building. However, it allowed for a large reduction the interior electrical lighting system, which in turn eliminated a large amount of heat generated from the lights and reduced the size and complexity of the mechanical systems.

The team reduced energy consumption from a baseline of $1.10/SF/yr to an ultra low energy use building of less than $0.50/SF/yr, which equates to 25 kBtu/SF/yr. Savings were achieved across all major design systems including parking, elevators, hot water, HVAC equipment, and lighting.

Occupant NZE Program

The NZE goals were not achievable without an Occupant NZE Program.

To achieve EUI of 25 kBtu/SF/yr, each desk top could only consume 85 watts of energy. This allowed for 70 watts used for a laptop computer, monitor, phone and task light, plus an additional 15 watts for personal electrical equipment.

The Police and Fire personnel consume significant electricity with their personal equipment. A cultural paradigm shift was needed to help personnel make the behavioral transition from using a high amount of electrical power for personal needs, to using very little.

A comprehensive Occupant NZE Education Program was launched ***18 months prior to building occupancy*** to educate Police and Fire departments about the design of the building. The education enabled occupants to own the goal and be part of the solution.

The Police and Fire personnel quickly adopted NZE goals and internalized remediation actions.

For example, the Police posted fake "warrants" on outlawed space heaters, coffee makers, and refrigerators.

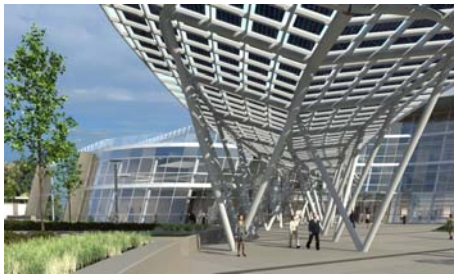
The Occupant NZE Program included the following:

- Assessment of current occupant behavior through sampling of 20% of existing work stations and offices.
- Training by leadership to occupants on unique elements of NZE building to develop a sense of pride and teamwork in achieving goals.
- Behavioral changes while in existing building helped occupants recognize that individual actions mattered.
- Web-based energy use tracking and performance reporting for feedback.
- User manuals and booklets to outline how a NZE building works with individual "do's and don'ts." The booklets will be placed on each employee's desk on first day.

Renewable Energy Program

In parallel to the Collaborative Design Sessions, a separate Renewable Energy Workshop was held to prioritize energy alternatives. This was followed by a renewable energy assessment to evaluate options.

To minimize capital outlay, several alternatives were explored. These ranged from a Power Purchase Agreement to direct purchase of the equipment.



Passive PV on walkway trellis

The selected solution used photovoltaics (PV). A total of 80,000 SF of PV arrays were required based on current PV efficiencies.

Here are specifics of the final renewable energy program:

- 20,000 SF of PV on-site on roof to handle EOC, E911, Data Center, and other critical support areas off the grid during any grid power loss event.
- 60,000 SF of PV off-site on city-owned retired landfill with net metering or another agreement with local utility.
- Additional passive PV on walkway trellis for public plug load use.
- Purchase of off-site renewable energy credits.

Performance Management and Feedback System

The real work begins after occupancy.

A performance management and feedback system is crucial to the success of a NZE building.

Maintenance crews typically work daily to keep occupants comfortable and satisfied. Ensuring that occupants are getting feedback on energy use, while prioritizing energy conservation measures for the maintenance crews is valuable for the long-term well being of the building and its systems.

An energy management system that extracts metering data and provides web-based reports and dashboards for both occupants and maintenance crews was designed for effective performance management and feedback.

Lessons Learned

Salt Lake City's NZE Public Safety Building successfully addressed the challenges faced by typical owners that were not addressed by NREL's RSF.

- Typical building occupants can make necessary behavioral changes required to reduce plug loads.
- A cost effective NZE building can be delivered with a higher level of finish and private enclosed offices for mission integrity.
- A cost effective NZE building can be planned and delivered in an urban and constrained site.

There are five critical PM capabilities to consider when delivering a cost-effective NZE Building. They are:

1. Stakeholder commitment and alignment
2. Early and integrated NZE planning (before design work)
3. Occupant NZE program
4. Renewable energy program
5. Performance management and feedback system.

1. Stakeholder Commitment and Alignment

All projects require stakeholder collaboration and communication. NZE projects require a higher level of alignment. The Owner's Project Manager (OPM) needs to be technically knowledgeable, but astute in integrated project delivery (IPD), political landscape, community relations, and how to communicate with stakeholders, occupants, and the public.

2. Early and Integrated Energy Planning

Being able to make intelligent design decisions early in the planning phase is required to save time and money.

Defining the percentage of total energy available for each engineering discipline is the best way to force integration and collaboration. This includes the integration of energy use, intensity goals and an "energy budget".

There are emerging energy planning solutions being developed to provide owners with a way to make these early decisions.

For example, the U.S. Army's Construction Engineering Research Lab (CERL) is developing a Virtual Net Zero Energy Test Bed that will enable federal agencies to identify the most cost effective way to achieve ultra low energy buildings. These applications are used in the programming phase to identify energy savings options, renewable energy options, plus the cost and schedule impact of each option.

In the future, these applications will save everyone a significant amount of money with earlier and more cost-effective decision-making.

3. Occupant NZE Program

The human factor is the most limiting to the design and operation of a NZE building. Plug loads and equipment demand a great deal of electricity. While sensors can monitor energy use, occupants play the most important role. Making occupants part of the solution to inspire new work habits, even before occupancy, works best.

4. **Renewable Energy Program**

   There are a few elements to consider when embarking on a Renewable Energy Program:

   - Utilities are critical. Understanding payment schedules and demand charges are required for the cost-benefit analysis. Also, connectivity to the grid is a major point (which side of the meter the renewable energy is placed).
   - There are many financing options. Direct purchase, power purchase agreements, and other procurement strategies are available. Utilities programs, tax credits and the location to the meter need to be considered early to meet budget needs.

   These elements take time to analyze, therefore start early and ensure the OPM team has the required expertise.

5. **Performance Management and Feedback System**

   NZE buildings are dependent on occupant behavior. Having a feedback system for both occupants and maintenance crews is critical to prioritize work and achieve NZE goals.

To Learn More

Achieving a net zero vision is a complicated and challenging endeavor.

For those owners who have decided to pursue a net zero vision, we hope this article helped you think about some critical PM capabilities. We recognize that owners are challenged with many factors in regard to the design, construction and management of their facilities.

To learn more about how to deliver cost-effective net zero energy facilities, as well as more of the technical engineering aspects, please contact a **MOCA Systems** representative.