Finding Balance in New York City:
A Roadmap to Net Zero Energy for the Natural Resources Defense Council Headquarters

THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

Fall 2012 Masters of Science in Sustainability Management Capstone Project Final Report

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NRDC
THE EARTH'S BEST DEFENSE

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1. Executive Summary

Typical high-rise office buildings rely on fossil fuels to supply energy for heat and electricity. In this regard, the headquarters of the Natural Resources Defense Council (NRDC) at 40 West 20th Street in New York City is similar to other urban commercial buildings. The NRDC's mission to promote a new way of life that does not deplete the earth's resources or spoil the natural environment has driven the non-profit organization to implement groundbreaking green building retrofits. Comprehensive efficiency measures implemented between 1988 and 2012 have elevated the energy efficiency performance of the NRDC facility to industry-leading levels and received national recognition for leadership in green design. With the "low-hanging fruit" fully leveraged, NRDC set out to achieve the next pinnacle in facility energy performance: "net zero" energy use – a next-generation designation yet to be achieved by any similar facility.

Figure 1: 40 West 20th Street

Figure 2: 40 West 20th Street (8th Floor)

"Net zero" energy buildings are an emerging class of ultra-efficient structures that achieve on-site renewable energy generation equal to total energy consumption on an annual basis. The landscape is dominated by new construction projects with ample solar power production potential, characterized by large rooftops relative to total floor area. Urban high-rises like the NRDC headquarters cannot achieve net zero energy using the strategies set forth by existing cases. The high-density energy requirements and limited solar production conditions of a typical Manhattan office building necessitated a new, innovative approach to balancing on-site energy generation with demand. NRDC envisioned a roadmap that would result in the first ever net zero energy designation for a high-rise office building retrofit in a high-density urban setting.

For this unprecedented challenge, NRDC engaged a team of Columbia University students through the Fall 2012 Capstone Seminar of the Master of Science in Sustainability Management program. The project team created a detailed implementation plan that married deep energy efficiency retrofits with innovative on-site renewable energy generation technologies. At the onset of the project, NRDC set project constraints and guidelines that guided the team's methodology. A $5 million budget and 10-year implementation timeline necessitated a full evaluation of up-front investment requirements, payback periods and ROI.

The project methodology consisted of a thorough conceptual and quantitative analysis of a field of potential energy efficiency and generation technologies. Specific evaluation criteria included: energy-benchmarked performance of each technology both individually and in concert with other technologies; appropriate sequencing of recommendations to account for current performance versus expected future performance of technologies expected to be available within ten years; and, payback period and ROI metrics appropriate to the role each technology played in the overall project. Scalability to other existing buildings was a top priority for NRDC in order to ensure the organization's achievements could serve as a model for others to follow. Accordingly, the Capstone team identified a portfolio of integrated strategies specific to the NRDC building in size and scope, but also scalable to similar building typologies, clusters, and climates. These technologies and strategies could lead NRDC to achieve net zero *site* energy, meaning that the facility will produce at least as much energy on-site as it will consume each year.


Figure 3: 40 West 20th Street (Rooftop)

To choose between competing options for energy efficiency and renewable energy generation solutions, the team created a screening framework and fully vetted each technology. Decision criteria were based on NRDC's goals and constraints, team members' experience, and new research. The team assigned decision criteria to one of three categories based on priority attributes that a given strategy or technology A) "must have," B) "should have" or C) would be "nice to have." For example, NRDC specified that no new systems can require the use of fossil fuels, regardless of efficiency. Therefore, the team classified elimination of fossil fuels as a "must have" attribute for potential solutions. On the other hand, a short payback period exemplifies a "should have" attribute, and so on.

Each recommended technology solution was grouped into one of three categories: energy efficiency (active – requiring mechanical input); energy efficiency (passive – no mechanical input required); and generation (on-site electricity generation). Each technology is discussed in detail with emphasis on its rationale for inclusion, a benchmark or identification of where it has been successfully implemented, its future development forecast, and any available financing.

To organize and consolidate the technology review research, the team created an online form and tracked key performance indicators for each technology such as: the amount of energy reduced or generated; the cost per unit of energy reduced or generated, the timeframe in which the solution should be installed, and the financing mechanisms available to deploy the solution. The results of the online form were entered into a data model designed by the team to identify the aggregate impact on the building's energy performance. In addition to the comprehensive data model, a financial model was created to calculate a comprehensive suite of financial metrics including simple payback, total cost of each recommended technology (after rebates and incentives), and cash flows for each of the recommended technologies. For illustrative purposes, the Internal Rate of Return (IRR) for each technology was also calculated, using a discount rate of 4% provided by NRDC.

The result of the energy data and financial modeling indicated that NRDC can reach net zero energy within the allotted timeframe when all individual technologies are in place and are working as a unified system. The team produced an actionable 10-year implementation plan that guides the project according to the constraints and objectives specified by NRDC. Below is a list of the recommended technologies detailed in the report and the implementation year for each:

2013: **Air Sealing**
Energy Recovery Ventilator
Variable Frequency Drivers on Blower Fans and Condenser Pumps
Advanced Lighting Controls
Smart Metering Systems (Phase 1 of 2)
Direct Current Microgrid (Phase 1 of 2)
Air Conditioning Schedule Shift

2014: **Phase Change Materials**

2015: **Exterior Insulated Panels (EIFS)**
Geo-Exchange
Biofuels in Existing Boiler (as necessary)

2017: **Direct Current Microgrid (Phase 2 of 2)**
Rooftop Concentrating Photovoltaic Solar

2018: **Smart Metering Systems (Phase 2 of 2)**
Energy-Aligned Lease to Tenants

2021: **Vertical Photovoltaic Solar Panels**

The team identified incentives, rebates, and funding strategies. Efficiency measures reduce total load by approximately 70% and the estimated costs are below the $5 million threshold. Using a financial model designed by the team, total cost over a 10-year period (including incentives, rebates, and reinvestment of energy savings from early phase technology implementation) was estimated to be as low as $2,219,472. Without the inclusion of incentives, rebates, or creative financing, the project is estimated to cost $5,836,631. If NRDC takes advantage of the financing strategies outlined in the report, the building is projected to achieve net zero site energy in 2021, two years ahead of the 10-year project deadline.

2. INTRODUCTION

2.1 NRDC ORGANIZATIONAL CONTEXT

Headquartered in New York City with offices in Washington DC, Chicago, Santa Monica, San Francisco, Montana, and Beijing, NRDC is a non-profit environmental organization with over 1.3 million members worldwide. Founded by a team of lawyers in 1970, NRDC now boasts the expertise of over 350 lawyers, policy experts, scientists, resource specialists and other environmental professionals.[1] With its mission to protect the Earth for future generations by sustaining the natural systems that support it,[2] NRDC promotes and practices the integration of sustainability principles into all aspects of its work.

NRDC's offices have been at the forefront of green building design since they began renovations on their New York Headquarters in 1988. From its initial design with Croxton Collaborative, the building at 40 West 20th Street in Manhattan was meant to be a demonstration of NRDC's environmental principles in practice. Through extensive daylighting strategies, high efficiency fixtures and equipment, thermal-paned windows, occupancy sensors, and ongoing energy assessments of the space, NRDC has already dramatically reduced their energy use compared to a typical commercial office.[3] Since then they have continued to be on the leading edge of high-efficiency, cost-effective building design, including their recent 8th floor renovation that boasts the highest LEED® Commercial Interiors score in the world to date.[4]

Maintaining this edge means continuously refining their high standards for building energy performance, and the organization envisions transforming their headquarters into *the first net zero energy retrofitted building in an urban setting* to be the next logical step in the journey of enhanced building performance leadership.

40 West 20th Street is co-owned by the New York City Public Library (Floors 1-5) and NRDC (Floors 6-12). NRDC offices occupy floors 8-12, and floors 6 and 7 are leased to two separate tenants. Significant efforts have already been made to reduce the buildings energy consumption, notably a renovation of the 8th floor, which received a LEED Platinum rating. NRDC has preexisting plans to renovate additional floors in the building and the team was asked to take this into consideration. Additional constraints outlined by NRDC were a $5 million budget over the next 10 years; no long-term technologies or strategies can rely upon fossil fuel use; and the project must consider 'Next-Generation' high-efficiency and renewable electricity generation technologies that may not at present be commercially or financially feasible. Additionally, the project components must utilize (or be eligible for) financing strategies that apply to a tax-exempt non-profit organization and recommendations must be based on successful pilot projects, research, and the existence of educational case studies. Finally, the assessment had to utilize metrics to accurately estimate the success of the project goals, before, during, and after implementation.

2.2 NET ZERO DEFINED

Primary research was conducted to select a definition of Net Zero Energy Building (NZEB) that is appropriate for this project and it was found that the definition of net zero varies widely between government and private sector agencies and organizations. For example, the United States Department of Energy (DOE) defines Zero Net Energy Buildings as "grid integrated buildings capable of generating as much energy as they consume through advanced efficiency technologies and onsite generation systems, such as solar power."[5] The definition provided in the White House's Executive Order 13514 states that a NZEB building is one that is "…designed, constructed, and operated to require a greatly reduced quantity of energy to operate, meet the balance of energy needs from sources of energy that do not produce greenhouse gases, and therefore result in no net emissions of greenhouse gases and be economically viable."[6] The DOE focuses on a balance of energy produced and consumed, while the White House emphasizes the emissions associated with the building.

At first, California's "Big Bold Energy Efficiency Strategy," which requires all new commercial construction in California to be NZEB by 2030, initially mirrored the DOE by defining NZEB as one where "the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building," but later changed this definition to "the *societal value* of energy consumed by the building over the course of a typical year is less than or equal to the *societal value* of the on-site renewable energy generated" to accommodate buildings that are unable to produce net energy needs onsite.[7] By defining net zero as the balance of on-site consumption and generation by its principle should emphasize renewable energy generation, but it leaves some ambiguity and provides loopholes for combined heat and power technology that run on natural gas or oil. Technically, the facility could consume what it produces, but it doesn't guarantee that the means of production is not emissions-free.

Massachusetts' Net Zero Energy Task Force defines a ZNEB as "one that is optimally efficient, and over the course of a year, generates energy onsite, using clean renewable resources, in a quantity equal to or greater than the total amount of energy consumed onsite."[8] Massachusetts identifies that generation must be from renewable resources, which becomes challenging because renewable energy options in Massachusetts are limited, as the solar insolation in New England is significantly less than that of California.

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) defines NZEB as "…buildings which annually use no more energy from the utility grid than is provided by on-site renewable energy sources. These buildings are designed to use 50% to 70% less energy than comparable traditional buildings. These buildings are expected to supply more energy to the grid than they consume, with the balance of remaining energy use coming from renewable sources – solar panels, wind turbines, thermal panels, renewable fuels and the like – incorporated into the building itself or located on site."[9] This definition allows for buildings to compensate for some of the intermittency issues associated with renewable energy technologies. Specifically, it is often most windy at night, but that is also the same time when energy demands are low for most buildings. But as long as a site can produce the same amount of energy as it consumes, it can technically be considered net zero.

Finally, the National Renewable Energy Laboratory's paper "Zero Energy Buildings: A Critical Look at the Definition," lists four definitions for NZEBs:

- **Net zero site energy:** produces at least as much energy as it uses in a year, when energy is accounted for at the building site
- **Net zero source energy:** produces at least as much energy as it uses in a year, when energy is accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site to source conversion multipliers.
- **Net zero energy costs:** the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Net zero energy emissions:** a building that produces at least as much emissions-free renewable energy

as it uses from emissions-producing energy sources.[10]

The following table outlines the pros and cons of the National Renewable Energy Laboratory definitions:

Definition	Pluses	Minuses	Other Issues
Site ZEB	• Easy to implement. • Verifiable through on-site measurements. • Conservative approach to achieving ZEB. • No externalities affect performance, can track success over time. • Easy for the building community to understand and communicate. • Encourages energy-efficient building designs.	• Requires more PV export to offset natural gas. • Does not consider all utility costs (can have a low load factor). • Not able to equate fuel types. • Does not account for nonenergy differences between fuel types (supply availability, pollution).	
Source ZEB	• Able to equate energy value of fuel types used at the site. • Better model for impact on national energy system. • Easier ZEB to reach.	• Does not account for nonenergy differences between fuel types (supply availability, pollution). • Source calculations too broad (do not account for regional or daily variations in electricity generation heat rates). • Source energy use accounting and fuel switching can have a larger impact than efficiency technologies. • Does not consider all energy costs (can have a low load factor).	• Need to develop site-to-source conversion factors, which require significant amounts of information to define.
Cost ZEB	• Easy to implement and measure. • Market forces result in a good balance between fuel types. • Allows for demand-responsive control. • Verifiable from utility bills.	• May not reflect impact to national grid for demand, as extra PV generation can be more valuable for reducing demand with on-site storage than exporting to the grid. • Requires net-metering agreements such that exported electricity can offset energy and nonenergy charges. • Highly volatile energy rates make for difficult tracking over time.	• Offsetting monthly service and infrastructure charges require going beyond ZEB. • Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates.
Emissions ZEB	• Better model for green power. • Accounts for nonenergy differences between fuel types (pollution, greenhouse gases). • Easier ZEB to reach.		• Need appropriate emission factors.

Table 1: NREL ZEB Definitions Summary

After evaluating the range of NZEB definitions and presenting them to NRDC, the client selected the National Renewable Energy Laboratory's definition: "Site Net Zero" approach; which views buildings at both the whole building level and the component level. This definition best suites NRDC location because it is easily measured and monitored in a co-owned facility. NRDC has established systems to track and monitor their energy consumption. Additionally, they own and operate the building HVAC systems allowing easy tracking of generation and consumption.

2.3 Project Objective

The Natural Resources Defense Council ("NRDC" or "the client") enlisted the Fall 2012 Columbia University Master's in Sustainability Management Capstone Team (hereafter referred to as "the team") to develop a net zero retrofit plan for their NYC headquarters. NRDC asked the team to create an implementation plan to retrofit their existing building to produce as much energy as it consumes by drawing upon the team's knowledge of energy management, the built environment, and the latest in green building tools and technologies. The project is the first serious attempt that the team is aware of to retrofit an existing building in a dense urban environment to be a net zero energy building (NZEB). Success in this project not only would support NRDC's core principles of protecting the environment, but also exemplifies the feasibility of undertaking similar retrofits in both urban and rural environments in similar building typologies.[11]

2.4 PROJECT SCOPE AND INITIAL CONSTRAINTS

The project scope defined by the client includes floors 6 through 12 of 40 West 20th Street. Floors 1 through 5 are owned and operated by the New York City Public Library, floors 6 and 7 are owned by NRDC, but leased to 2 tenants, and the remaining floors, 8 through 12 are occupied by NRDC's offices.[12] In January 2010, the 8th floor was renovated and received the highest LEED rating ever for a Commercial Interior under LEED-CI v.2.0.[13] NRDC plans to renovate additional floors in the building and the team was asked to take this time table into consideration as well as addressing: 1) powering the building, 2) heating/cooling loads, and 3) lighting and plug loads, while considering the embodied energy that any modifications in these areas would entail.[14] Additionally, the team had to consider that the site is listed as an historic building, which places restrictions on modifications that can be made to the building's exterior.

Multiple discussions between the project team and the client yielded the following project criteria and constraints:

- Budget: NRDC outlined a budget of $5 million to be used over 10 years, assuming a $500,000 per year outlay.
- Fossil Fuel Use: No new technologies or strategies relying upon fossil fuel use should be included in the portfolio of solutions.
- Next-Generation Technologies: The project must consider 'Next-Gen' high-efficiency and renewable electricity generation technologies in order to feasibly meet the demands for the building onsite and serve as a model for other buildings considering new technologies.
- Metrics: The assessment must utilize metrics to accurately estimate potential success of project goals, before, during, and after implementation.
- 501(c)(3) Financing: Project components must utilize (or be eligible for) financing strategies that apply to a tax-exempt non-profit organization.
- Case Studies: Recommendations must be based on successful pilot projects, research, and the existence of educational case studies.

2.5 GENERAL APPROACH TO NET ZERO

A critical first step during a NZEB construction or retrofit project is to understand the range, scope, cost and feasibility of available technologies and systems. Design decisions must include an assessment of the building's air tightness, windows, insulation, existing systems, and other building attributes.[15]

The table below prioritizes options and examples of technologies that could be implemented in a NZEB construction or retrofit project according to the National Renewable Energy Laboratory (NREL):

Number	ZEB Supply-Side Options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On-Site Supply Options		
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building
Off-Site Supply Options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other

Table 2: NZEB Renewable Energy Supply Option Hierarchy

According to Torcellini, et al., "the way the zero energy goal is defined affects the choices designers make to achieve this goal and whether they can claim success." Further, the authors also state that building energy requirements should be met by low cost, locally available, non-polluting, renewable resources for available technologies including photovoltaic, wind, hydroelectric power, and biofuels.[16] Similarly, ASHRAE states that for NZEB to become a reality, improved systems need to be integrated into construction and design; including higher efficiency equipment and systems, enhanced building automation systems and controls, consideration of indoor air quality and energy storage and performance and construction standards.[17]

3. METHODOLOGY

3.1 ANALYTICAL APPROACH

Based on the net zero definition outlined in Section 2.2, this project identified a portfolio of integrated strategies specific to the NRDC headquarters, but scalable to other buildings. The methodology for developing the recommended solutions involved both a thorough conceptual and quantitative analyses of potential technologies, including how each is expected to perform at the site, as well as in concert one with another.

Many energy efficiency and energy generation solutions are available on the market. Therefore, to arrive at a manageable set of potential solutions for this project while adhering to the initial constraints outlined by the client, the team created a framework within which each technology was vetted. This approach limited available options to those that met project objectives, that were applicable to the NRDC's building structure, and that were attainable within the client's budget and implementation timeline.

3.2 EVALUATION CRITERIA DEVELOPMENT

Preliminary brainstorm sessions outlined a set of required criteria to evaluate various technologies and strategies that the team researched. The initial criteria were grouped into three categories based on priority of attributes that a given strategy solution or technology "must have," "should have" or "would be nice to have."

"Must Have"

For a strategy or technology to be considered for the project and incorporated into all subsequent analysis, it must have met specific requirements as outlined by the client in Section 2.4. Additionally, for any technology where future capabilities were predicted, there must have been a method to quantify growth in technological efficiency. Recommended solutions also had to meet existing site limitations and meet all relevant codes as well as local restrictions based on the building's historical status. Finally, technologies included in the implementation plan had to possess a relatively acceptable payback period based on the lifespan of the equipment, although energy price fluctuations can never be predicted with certainty. As a result, no specific payback threshold was set. However, because the goal was to replace fossil fuels, payback was but a small piece of the larger puzzle. That being said, simple payback was used to choose between various alternative solutions and was calculated for every solution explored.

"Should Have"

Strategies and technologies that met the "should have" requirements were strongly preferred over those that do not, but these attributes are not unequivocally required. Specifically, these recommended solutions should be easily applied to the NRDC building, considering both tenants (employees, custodians, other building tenants) as well as facilities management teams (planners, operators, etc.). Ease of adoption also considered that ongoing operating and maintenance costs should remain low and that any recommended solution should enhance the operational efficiency of the NRDC through a lower building operational cost over time. In addition to 501(c)(3) financing strategies, solutions were sought that utilize innovative financing strategies, like performance contracting, incentives, utility rebates, etc., which will lead to better financial performance for the project as a whole. Finally, due to the aggressive nature of the project, there had to had been a quantifiable amount of energy generated or saved. It was not sufficient to propose a dramatic installation if it would only produce nominal gains in efficiency or generation (for example, as discussed below, it was determined that although wind micro-turbines are a ‘next-gen’ technology, they only generate a minimal amount of electricity in an urban setting).

“Nice to Have”

Strategies or technologies that met the following requirements were preferred over those that did not, but were not critical to the success of the project. An example of a “Nice to Have” technology would be one that is very scalable to other NRDC buildings and/or buildings in varying geographic locations, but not necessarily a clear choice for 40 West 20th Street based on the current building systems in place. Another example is that preference was given to solutions that contained a low embodied energy versus higher. The team did not conduct detailed life cycle analyses of technologies but the energy intensity of manufacturing and installation was included in discussions. At the recommendation of the NRDC, the team focused on technologies funded by capital expenditures over operation expenditures because capital expenditures do not affect the NRDC’s non-profit effectiveness rating (and do not “kick the can down the road” in terms of paying for an energy-efficiency strategy).

The brainstorm session which identified the previously discussed additional criteria to evaluate solutions resulted in the graphic on the following page:

What is Our Methodology?

Group Members: Mathew Codner, Adam Freedgood, Jenelle Hoffman, John Haugen, Jessica Esposito, Shahneeyam Reza, Rachel Cook, Scott Andrews, Marie Bazy, Logan Duran, Nazanin Amirian
Facility Advisor: Kizzy Charles-Guzman

We are identifying a portfolio of strategies specific to NRDC in order to create an actionable plan consisting of the best solutions, financing mechanisms and implementation stages required to achieve net zero site energy.

1. Project Criteria

The criteria to evaluate strategies are developed and prioritized based on the clients' goals, as identified by interviews, technical reviews, and site specific constraints.

Budget - $5m/10yr
NRDC has outlined a budget of $5 million to be used over 10 years, assuming a $500,000/yr outlay.

No Fossil Fuel Use
No long-term technologies or strategies involving fossil fuel use will be included in the portfolio of solutions.

Next-Gen Technology
The project must consider 'Next-Gen' high efficiency renewable energy generation technologies in order to feasibly meet generation demands for the building onsite.

Metrics
Utilize metrics to accurately estimate success of project goals.

501(C)3 Financing
Financing strategies that apply to a tax-exempt non-profit organization.

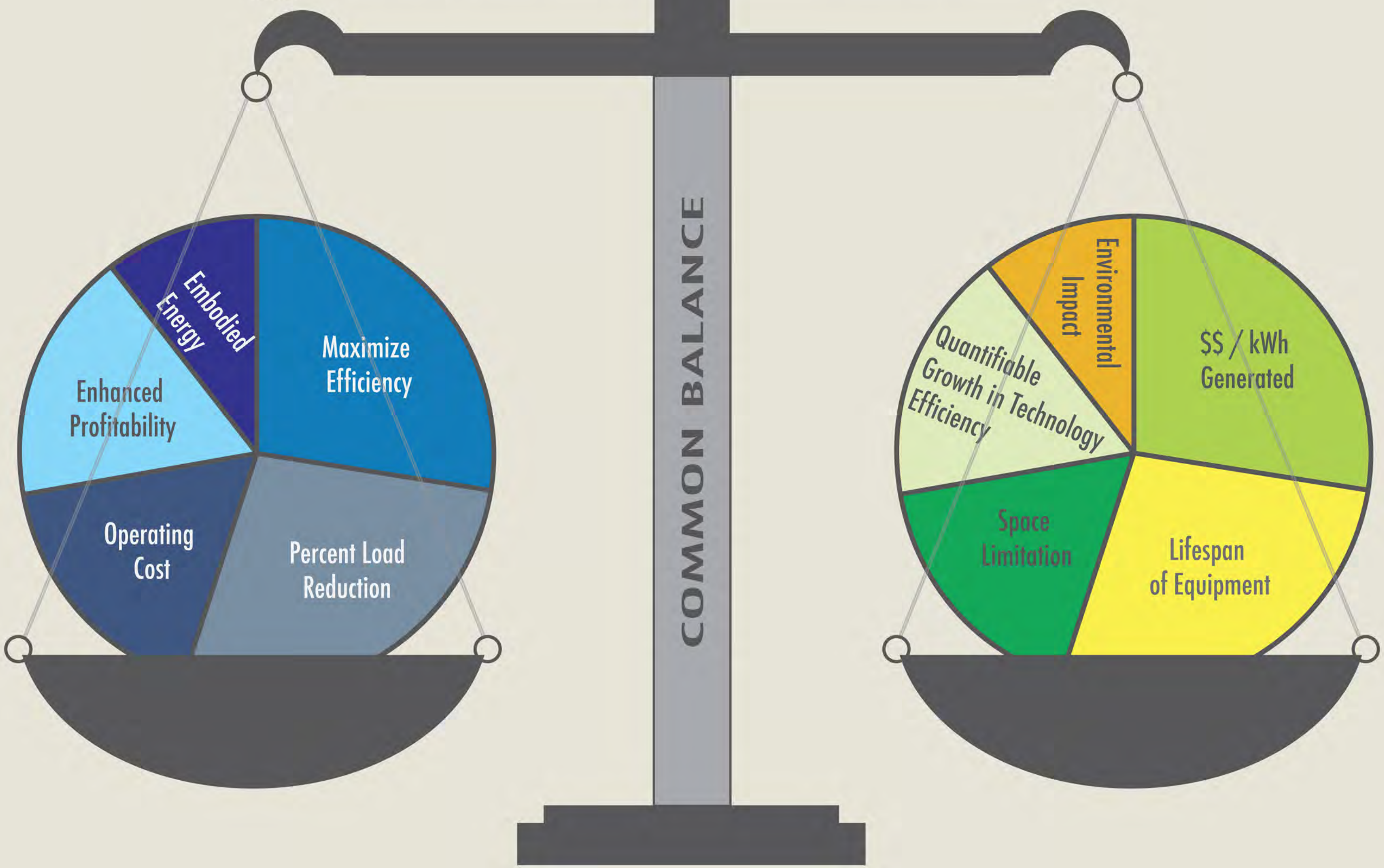
Case Study Goals
Solutions based on pilot projects, research, and educational case studies.

2. What is Efficiency?

Utilization of energy in the most cost effective manner to carry out a manufacturing process or provide a service, whereby energy waste is minimized and the overall consumption of primary energy resources is reduced.

3. What is Generation?

On-site renewable energy generation, derived from sun, wind, water, Earth's core, biomass, or plant matter. Renewable technologies are designed to capture and store this energy.



4. What is Common?

Criteria that are both common for Efficiency and Generation

Return on Investment
Metric calculation based on total finance and energy savings.

Payback Period
Length of time required to cover the cost of investment.

Next-Gen Finance
Outside funding, incentives, grants, and performance contracting.

Production & Consumption
Balance efficiency gains with onsite renewable energy.

Ease of Adoption
Feasibility of implementation, human factor, as well as installation and limited disruption.

Timing
Early phase, middle phase or late phase implementation.

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Capital Spending
NRDC favors CapEx over Operational expenditures

The visual balance helped direct the group in researching specific technology and efficiency techniques to achieve a net zero balance. The recommended implementation plan utilized efficiency to reduce energy demands in the building, while also maximizing the opportunity for on-site generation. In an effort to simplify the various possible solutions and to focus research, the team used criteria that are common to both the efficiency and generation sides of the net zero equation. The criteria that are common to both efficiency and generation are:

- Return on Investment: Whether or not the technology will cost more than it will save compared to status quo in both economic terms and energy consumption.
- Finance: Potential for outside financing, incentives, grants, performance contracting (e.g. power purchase agreements), and possible "Next-Gen" creative financing options
- Ease of Adoption: Feasibility of implementation, human factor, as well as installation and limited disruption.
- Scalability: Applicability to other NRDC offices, urban mixed-use buildings, non-profits, cities, and climates.
- Payback Period: Length of time required to cover the cost of investment.
- Production & Consumption: Balance efficiency gains with onsite renewable energy.
- Timing: When in the ten-year implementation plan the technology should be installed.
- Capital Spending: NRDC favors capital expenditures over operational expenditures.

3.3 TECHNOLOGY REVIEW

Based on an initial literature review of the documents provided by the client, the team identified specific building components, like solar generation, plug load, insulation, etc., to conduct their initial research. The above-referenced criteria formed the basis for the evaluation of over 50 individual technologies focusing on energy efficiency and energy generation technologies. The net zero scale criteria was applied to each technology to derive a comprehensive view of each potential solution. The technology review research included several key components, including reviews of case studies/pilot projects that provide proof of concept for next-generation technologies. Where available, there was a review of professional research executed by industry expert groups and governmental organizations such as the National Renewable Energy Lab (NREL), US Department of Energy (DOE), and various buildings throughout New York City. If available, the team looked for academic case studies on existing technologies that provide expected performance levels of a specific technology. Finally, the team conducted multiple interviews with industry experts – including NRDC staff – to seek guidance and professional insights on relevant technologies' feasibilities, costs, and broader concerns and implications**.**

To organize and consolidate the impact of the technology review research, the team designed an online form that each team member completed by inputting, among other things, information for each technology on:

- The estimated amount of energy reduced or produced
- The cost per unit of energy reduced or produced
- The timeframe in which the solution should be installed
- The financing mechanisms used to deploy the solution

The results of the online form were analyzed and discussed as the group. This information was entered into a data model (Appendix 9.1) designed by the team, from which the aggregate impact on the building's energy performance was calculated. A meticulous and rigorous vetting process provided the data required to determine the feasibility of retrofitting the NRDC headquarters into a net zero facility.

Finally, the team produced an actionable 10-year implementation plan that guides the project according to the constraints and objectives specified by the client.

4. Technology Analysis

4.1 Overview of Technologies

The following technology reviews are organized into three categories: energy efficiency (active), energy efficiency (passive), and electricity generation. As outlined in the graphic in Section 3.2, efficiency is the consumption of the least amount of energy possible to effectively carry out a required process or provide a specific service, whereby energy waste is minimized without sacrificing other “must have” criteria. Active energy efficiency technologies are those that put in place infrastructure or systems that use X amount of energy to produce Y amount of efficiency gains, where X is always less than Y (X<Y). They can measure, monitor, replace, or control energy use with the addition of minimal outside power or human activity.[18] This differs from *passive* techniques (e.g.: daylighting or natural ventilation) that require no outside energy inputs after the initial embodied energy of installation. Passive energy systems are used whenever possible in place of active systems, relying on existing thermal properties of a building that do not require the input of any external energy sources.[19] They can use the techniques like architectural design, natural materials, or absorptive structures of the structure as energy-saving strategies.[20]

Referring again to Section 3.2, generation is on-site renewable energy generation derived from the sun, wind, water (including tides or other movements), or, in rare cases, the Earth’s core (geothermal). Since electricity is the primary energy need for office buildings (as opposed to heat for domestic hot water of for various manufacturing processes), energy generation systems in this case were focused on the use of systems that generate clean electrical power. Energy generation systems can use renewable (solar photovoltaic panels, solar thermal collectors, wind turbines, biofuels, etc.) or non-renewable (fossil fuels) sources, and only non-fossil fuel based technologies were considered in this project (for example, distributed generation/combined heat and power using natural gas was excluded due to fossil fuel use).[21] [22]

In order to achieve net zero, it is necessary to first make a building as efficient as possible before considering (and sizing) generation needs. Therefore, passive and active energy efficiency measures were generally instituted before generation technologies were selected in this project.

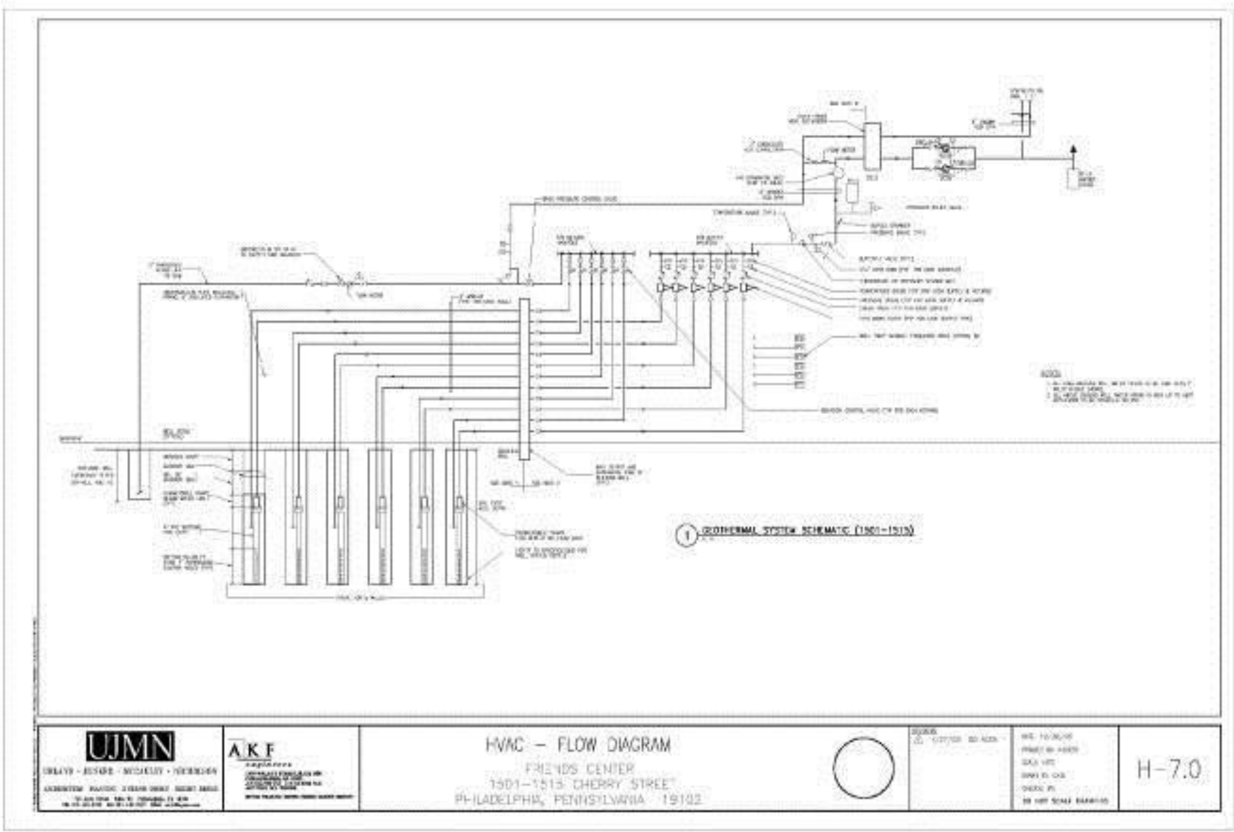


Figure 4: Schematic Drawing of Friends Center Geo-Exchange Wells and HVAC System

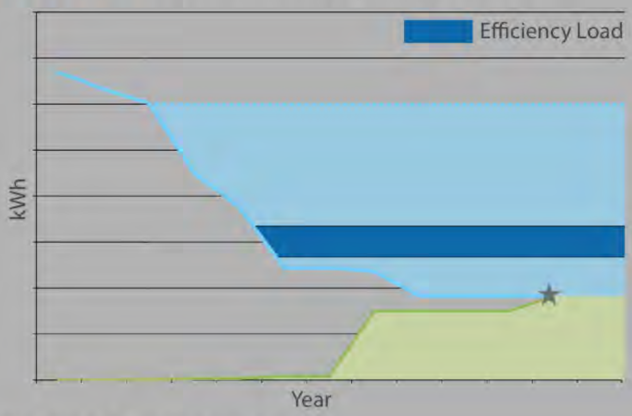
DEEP STANDING COLUMN WELL GEO-EXCHANGE

ENERGY BALANCE

191,264 kWh annual impact

2015 recommended implementation year

15.9% of total facility energy load



FINANCIAL METRICS

$1,570,000 total approx. installed cost

$9,435 incentives or rebates

NYSERDA New Construction incentive program

$493,144 cumulated savings (2013-2023)

24.9 yrs simple payback period after incentives

-19% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Percent Reduction
Total cost per kWh energy usage is reduced

Capital Spending
Capital expenditures are favored over operational expenditures

Lifespan
Must consider the lifespan of the equipment (lifespan must be greater than payback period)

Production & Consumption
Balance efficiency gains with onsite renewable energy.

Case Study Goals
Solutions based on pilot projects, research, and educational case studies.

4.2.1.

Rationale

Geo-exchange is often mistakenly referred to as geo*thermal*, which taps into high temperatures very deep within the earth (usually 5-10 miles) or, in rare cases like Yellowstone National Park, at the earth's surface. Geo-*exchange*, however, works by using the ground or groundwater's constant year-round temperature of approximately 55-65^{o}F (in NYC) as a heat source in the winter or heat sink in the summer. It transfers thermal energy to (+ΔT) or from (-ΔT) the building using a heat pump with water or refrigerant as its heat exchanger with the building's heating, ventilation, and air conditioning (HVAC) and/or domestic hot water (DHW) system. Geo-exchange can be categorized into two basic types: 1) Closed loop (ground source) systems that use the ground as the heat source/sink to circulate refrigerant in a completely closed loop; or 2) Open loop (water source) systems that use deep groundwater (1000'-1800') as the heat source/sink by pumping water to the building's heat pump from a well where closed loop coils of refrigerant are used to extract or expel heat to the water, which is then returned to either the surface of the same open well or to a separate diffusion well.[23]

NRDC's building lacks the open space needed for an effective ground-source or shallow well closed loop system, which require many wells or troughs. The team therefore recommends that NRDC consider an open loop deep standing column well (SCW) geo-exchange system to significantly augment heating and cooling needs year-round using heat pumps. According to a recent article citing Tim Weber of NextEnergy Geothermal, Inc., "The newest generation of water source heat pump heating and cooling technology for large buildings has pushed operational efficiencies into the 400 to 600 percent range. That is: for every unit of energy used to operate the equipment, the system delivers 4 to 6 units of energy in return."[24] This is, therefore, a highly efficient active system.

Using case studies as guides and by physically inspecting the site, the team has determined that it will be feasible to install at least 3 deep water source wells. These wells should be drilled under the West 20th Street sidewalk approximately 45' apart from one another, consistent with the "Friends Center" case study[25] and consultations with an experienced geo-exchange project manager.[26] A shallower diffusion well should also be considered if space permits (an engineering assessment will be required) to aid in heat diffusion back into the groundwater.

With the planned HVAC efficiency upgrades, it is estimated that 3 deep open loop wells should provide approximately 105 tons of heating and cooling capacity (35 tons each), handling approximately 95% of both the project-optimized heating and cooling loads according to the energy model produced. This equates to a projected reduction of total load by 191,294 kWh per year (237,540 kWh gross, less operating energy of 46,276 kWh per year) – 18.8% of total facility load according to the team's calculations.

Benchmark/Case Studies Used

Numerous water-source heat pump systems have proven to be effective and reliable in the past several years in dense urban environments. The three most relevant case studies include the General Theological Seminary[27] and Columbia University's Knox Hall[28] in New York City, and the Friends Center in Philadelphia.[29] All of the relevant cases utilize 1000' to 1800' wells that use semi-open loop systems and the 54,000 square foot Friends Center was able to completely eliminate their boiler and water chiller/cooling tower with just 6 deep wells and a single 675' diffusion well.[30]

Figure 5: Geo-Exchange Water Pipes and Manifold in the Friends Center's Mechanical Room, Philadelphia

Case studies and interviews consistently estimated that each well installed at the NRDC facility should yield approximately 25-40 tons of heating or cooling capacity.[31] However, experts cautioned that the technology relies upon unknown variables that cannot be quantified until the wells are drilled. Variables with the potential to affect capacity and reliability include silt blockage, gallons per minute flow rate (higher is better and requires less pump energy), and lack of adequate fissures in the bedrock to allow for thermal heat transfer.[32] Appendix 9.2 provides additional information, including several relevant case studies and backup documents that should be reviewed in detail to better understand the complexities of this technology.

Tech Development Forecast

The technology for this open loop system already exists and should be feasible for the site based on the sidewalk space available and apparent lack of subway or water tunnels directly below the site. Technologies required will include the well piping, water pumps, heat pumps, air handlers, air terminals, fan coil units, hot water coils, and digital controls (with VFD pumps) – all of which can be purchased through established manufacturers like Carrier Corporation. The team also recommends that NRDC explore the possibility of installing additional wells in case tonnage yields from 3 wells is inadequate, or if a closed loop system is deemed feasible by engineering firms inspecting the site. By using new low-clearance drilling rigs, there may be an opportunity to drill into the basement or the subterranean parking garage that is approximately 200' northeast of the building across West 20th Street (that is within proximity to utilize if lease agreements can be negotiated with the building's owner, according to a low-clearance drilling engineer interviewed for the project).[33]

Finance

Project cost and subsequent payback periods for geo-exchange systems vary significantly depending on site, scope, and fluctuating fossil fuel prices. Representatives from the NYC Department of Design & Construction (DDC) were consulted to estimate the cost of a 100-ton system for NRDC and projected total costs to be $1.4M for a "hybrid system" with 5 wells (space permitting).[34] A hybrid system design for NRDC integrates geo-exchange with the existing water-source HVAC equipment via the condenser water loop, thereby minimizing costs. In hybrid designs, the cooling tower and a source of auxiliary heating may supplement geo-exchange during times of peak demand or unexpected equipment failure. An engineering assessment and competitive bidding process will be required to determine site-specific costs and exact design specifications. For example, the project team estimates approximately $100,000 in upgrades required for existing air-cooled HVAC equipment in order to leverage geo-exchange.

The NRDC geo-exchange system is projected to have a simple payback of 24-25 years based on a total project cost of $1.57 million, however, it is likely that natural gas and other fossil fuel prices will rise and heat pump technology will become more efficient (the Future Cities Laboratory has already achieved 1300% efficiency[35]), drastically reducing this projection. Incentives and rebates are not a substantial source of cost recovery for geo-exchange, although the project may be eligible for a rebate amounting to 9% of total cost if accepted under the criteria for NYSERDA's new construction portfolio incentive.

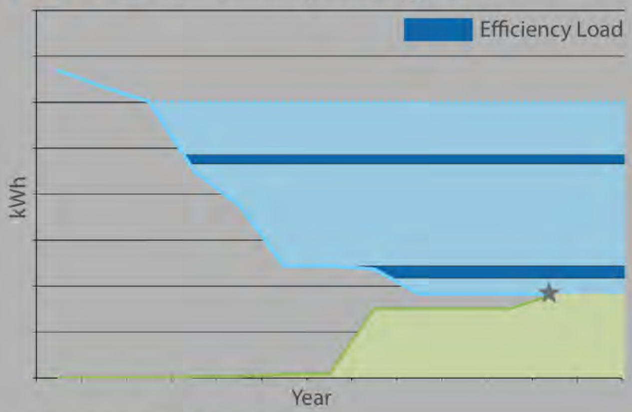
PLUG LOAD AND BEHAVIOR: SMART PLUG SYSTEM

ENERGY BALANCE

66,982 kWh annual impact

2013/2018 recommended implementation year

5.6% of total facility energy load



FINANCIAL METRICS

$54,600 total approx. installed cost

$26,533 incentives or rebates

NYSERDA New Construction incentive program

$175,202 cumulated savings (2013-2023)

1.85 yrs simple payback period after

153%/108% IRR - 10Y (Fl.8-12 / Fl.6-7)

PRIMARY METHODOLOGY CRITERIA

Environmental Impacts
Energy production with little to no local environmental impacts

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

Case Study Goals
Solutions based on pilot projects, research, and educational case studies.

Payback Period
Short payback period and high efficiency in terms of installed cost per unit of energy saved or produced.

4.2.2.

Rationale

The Data Model indicates that plug load consumes 248,080 kWh per year, or 31% of total electricity consumption. This equates to $66,814 annually according to the 2012 NRDC Energy Efficiency Report.[36] At such a high proportion of the building's electricity costs, plug load presents a substantial opportunity to reduce the building's energy load. Based on the floor-by-floor consumption figures in the Efficiency Report, floors 6 and 7 account for 42% of the electricity use for the NRDC-owned portion of the building (excluding data center) and use 1.5 to 2.2 times more energy per square foot than the NRDC office's floors.[37]

PICOwatt is a WiFi-enabled smart plug system (a form of advanced power strip) that reduces plug load by eliminating "vampire" power usage (energy consumed by devices when they are not being used).[38] According to the data model this solution should reduce electricity consumption by 66,981 kWh per year (5.6% of total facility energy load). It features advanced "on" and "off" functionality that allows users to control electronic devices and appliances remotely via a web-based monitor dashboard and real-time electricity usage readout, and should work with any plug-in device.[39] It utilizes a built-in electrical energy measurement tool in conjunction with a real-time and history display allowing the user to export energy usage history for use in reports that can be used to influence user behavior and promote user "competiveness."

Benchmark/case studies used

Plug loads account for about 25% of the total electricity consumed in office buildings.[40] The US General Services Administration (GSA) recently conducted a study to determine advanced power strips' (APS) effectiveness in plug load energy use management. Three reduction strategies were evaluated: schedule timer control, load-sensing control, and a combination of both, but none as advanced as the PICOwatt WiFi-enabled system. They found that schedule timer was most effective, with an average energy savings of 48%. The most savings was found on printers, copiers, and kitchen appliances. Payback period was less than 8 years in all applications, with kitchen appliances at only 0.7 years, printers at 1.1 years, miscellaneous devices 4.1 years, and workstations that already had power management in place 7.8 years.[41]

Tech Development Forecast

	Current Condition			Electric Savings (kWh/yr)			Payback Periods ($100/device)(yrs)		
	Total power (kW)	Electricity use (kWh/yr)	% of plug-loads end use	Schedule timer	Load-sensing	Both	Schedule timer	Load-sensing	Both
Workstation	21.3	93,465	31.7	24,153	4,112	10,437	7.8	46	18.1
Print rooms	30.9	135,342	46	67,287	43,309	30,452	1.1	5.5	6.4
Kitchen	14.7	64,386	21.9	29,618	NA	NA	0.7	NA	NA
Miscellaneous	0.3	1,314	0.4	603	690	710	4.1	39.9	17.2

Table 3: Savings for One Complex Using PICOwatt

It is likely that smart plug systems will improve over the next 10 years. One of the possible advancements will come when ConEd offers commercial smart metering. Smart metering paired with this system will improve the usefulness of this technology because they can view appliance usage directly against the time-based rates shown by smart meters.[42]

Financial

Based on the average number of workstations on each floor multiplied it by the manufacturer's per-unit price, the cost to roll out PICOwatt to the entire facility is approximately $54,600. According to the Financial Model, up to $26,553 in NYSERDA incentives may apply to NRDC floors 8 to 12 as part of the New Construction Program. After incentives, PICOwatt has a simple payback of 1.7 to 2 years. The following table shows actual savings as a result of the installation for the NRDC-occupied floors:

Device	Standby Usage Watts	Quantity	Total Watts	Standby kilowatt hours	Weekly Standby Cost	Annual Standby Cost
B & W Laser Printer	86	19	1634	176.472	$ 37.06	$ 1,927.07
PC + LCD (sleep mode)	80	200	16000	1728	$ 362.88	$ 18,869.76
Copier (sleep mode)	15	8	120	12.96	$ 2.72	$ 141.52
Water cooler	83	4	332	35.856	$ 7.53	$ 391.55
Coffee maker	50	4	200	21.6	$ 4.54	$ 235.87
			weekly	**1974.888**	**$ 414.73**	
			annual	**102694.176**		

Total annual standby cost	$ 21,565.78
Estimated annual savings	$ 21,565.78
Cost of 120 units, shipping & install	$ 39,001.80
ROI (months)	21.70
Current total annual plug load cost	$ 66,814.00
Current cost minus savings	$ 45,248.22
Reduced by	32%

*cost per kWh	$0.210	
Weekly stand by hours	108	12 hrs/night during work werk plus weekends
# of PICOwatt units	100	
cost per PICOwatt unit	$295.99	

Table 4: Cost and Savings of PICOwatt System

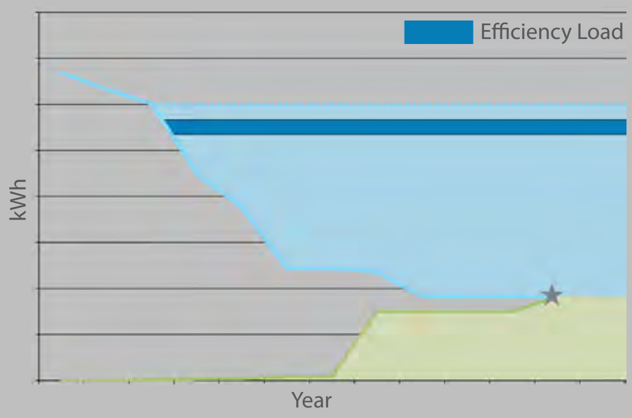
HVAC Energy Recovery Ventilator (ERV)

ENERGY BALANCE

63,420 kWh annual impact

2013 recommended implementation year

5.3% of total facility energy load



FINANCIAL METRICS

$20,000 total approx. installed cost

$0 incentives or rebates

No incentive program

$154,131 cumulated savings (2013-2023)

1.5 yrs simple payback period after incentives

214% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Efficiency
Enhance the operational efficiency of the NRDC, leading to a lower building cost over time

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Percent Reduction
Total cost per kWh energy usage is reduced

Return on Investment
Metric calculation based on total finance and energy savings.

Payback Period
Short payback period and high efficiency in terms of installed cost per unit of energy saved or produced.

4.2.3.

Rationale

Heating, ventilation and air conditioning (HVAC) loads at the NRDC facility are comprised of both electricity and fossil fuels and are the largest overall energy load category in the building. According to the Data Model, air conditioning is projected to consume 320,330 kWh of grid electricity in 2012. Heating energy amounts to 1,396 MMBtu (409,000 kWh equivalent) derived from No. 2 oil. Existing HVAC efficiency measures include the water-side economizer, variable speed fans and compressor motors, and variable airflow valves (VAVs) on some floors.[43] Despite existing efficiency measures, NRDC loses heating and cooling energy due to minimum outside air ventilation requirements for commercial buildings.

According to the Data Model, the ERV will reduce net energy consumption by 63,420 kWh annually by efficiently transferring the energy of building exhaust air to incoming fresh air. Net savings includes total heating and cooling energy savings, less the energy the ERV requires to operate. The ERV savings represents an 8.7% reduction in HVAC load and a 5.3% reduction in total load. Further, the ERV results in a reduction in peak heating and cooling system capacity requirements – a benefit that yields cost savings when modeling future cooling system retrofits including geo-exchange and/or DeVap air conditioning units discussed in Appendix 9.3.

The ERV will allow NRDC to downsize the overall cooling system without sacrificing indoor air quality or occupant comfort.[44] ERV technology benefits HVAC system efficiency in three primary ways:

1. Controlling humidity by transferring the energy from outgoing building air to the incoming fresh air with efficiency of 80% or greater[45];
2. Decreasing peak cooling capacity requirement by up to four tons per 1,000CFM of ventilation air[46], equating to substantial capital cost savings when considering geothermal and passive cooling investments; and
3. Decreasing peak heating capacity requirement by up to 50,000Btu/h per 1,000CFM.[47]

Benchmark/case studies used

Implementation of ERV technology is supported by several case studies from ASHRAE, EPA, and site-specific modeling the team performed for NRDC. In a 2012 case study analyzing excess outside air ventilation conditions in 29 large New York City buildings, ASHRAE recommends connecting return air to 100% outside air perimeter systems.[48] This approach reduces excess outside air flow and energy loss associated with multiple outdoor air exchange points. Additionally, ASHRAE recommends demand control ventilation on all floors to minimize overall outside air exchange.[49]

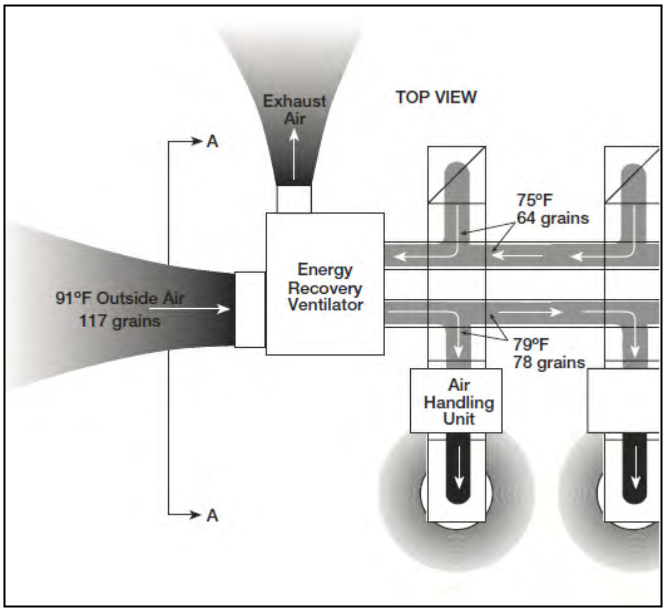


Figure 6: Plan view of a single rooftop Energy Recovery Ventilator (ERV) serving multiple air handling units located on each floor within the NRDC building

With these recommendations in mind, the team applied the EPA's EFAST modeling tool for ERV systems to estimate actual energy savings data for 40 West 20th Street. The EFAST model concluded that NRDC can achieve reductions in annual energy use and reductions in HVAC system capacity. The ERV will result in avoided heating load of 298MBH and avoided cooling load of 13.1 tons. Appendix 9.4 contains EFAST model output. Modeled energy savings amount to 235,000MBtu per year for heating and 19,000MBtu for cooling. On a kWh basis, the ERV uses approximately 10,000kWh per year for fan and motor energy. Net annual operating savings take the unit's energy use into account.

Tech Development Forecast

ERV technology has been around since the 1970s but efficiencies and operational reliability have reached a plateau in recent years. No further improvements in efficiency are expected from current designs.[50]

Finance

The EPA's "SAVES Map" shows that in New York City ERV systems have a payback of less than two years.[51] ASHRAE estimates three to six year payback for New York City buildings due to site-specific limitations and additional ventilation control systems improvements suggested in tandem with the ERV installation.[52] Through consultation with HVAC experts we obtained an estimate of $20,000 for ERV equipment that meets airflow requirements for the NRDC facility.[53] Based on this estimate, which was confirmed by the EPA EFAST software, simple payback is three to four years. Simple payback does not account for avoided system capacity, which is a much more important benefit considering other planned HVAC improvements. Decreased system capacity for both heating and cooling will lead to capital cost avoidance that the team modeled along with geo-exchange HVAC recommendations.

ERV finance would come from a mix of sources including cash up-front funding by NRDC and NYSERDA incentives. NYSERDA funding for HVAC efficiency is available, with a performance-based incentive of $0.16/kWh of verifiable annual savings (up to $2M)[54] as well as a pre-qualified incentive of $30,000 maximum per facility per year[55] (appropriate for smaller retrofits performed outside of a larger plan).

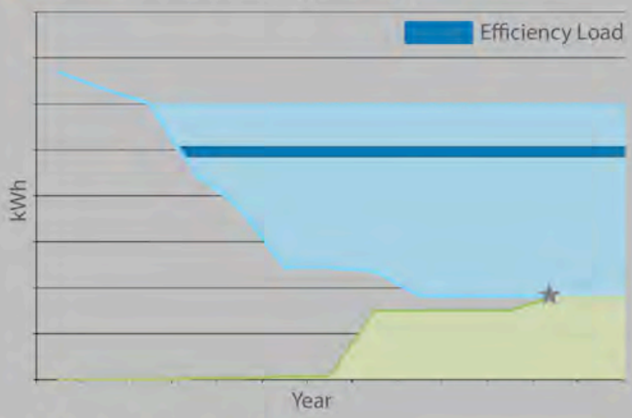
ADVANCED LIGHTING CONTROL PLATFORM

ENERGY BALANCE

51,335 kWh annual impact

2013 recommended implementation year

4.3% of total facility energy load



FINANCIAL METRICS

$713,728 total approx. installed cost

$0 incentives or rebates

No incentive program

$124,762 cumulated savings (2013-2023)

36.8 yrs simple payback period after incentives

-26% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

ROI **Return on Investment**
Metric calculation based on total finance and energy savings.

$$ kWh **Percent Reduction**
Total cost per kWh energy usage is reduced

Moore's Law **Growth in Technology**
For any technology where future capabilities are predicted, there must be a method to quantify growth in technological efficiency

4.2.4.

Rationale

To reach further energy reductions in lighting, we recommend an advanced solution that combines efficient LED light fixtures with intelligent controls. Using LED lighting with a comprehensive building performance lighting and control system can deliver 60% lighting energy savings.[56] This equates to 51,335 kWh annually (4.3% of total facility energy load).

According to the most recent Energy Audit report compiled by Code Green in 2012, the existing lighting system at NRDC contains mostly T8 and CFL lamps, with occupancy sensor controls in most areas but there are still some sections with older and less efficient lighting. According to this report, larger areas would benefit from the installation of a comprehensive lighting system to better organize, manage, and optimize lighting.[57] We recommend an integrated Building-Performance and Lighting technology system by Redwood® systems, which controls each light on an individual level. This platform can also provide detailed occupancy data to the HVAC system to control heating and cooling of a building, dynamically adjusting these systems based on real-time occupancy data. The Redwood platform uses a single dedicated system to manage and monitor sophisticated dimming, scheduling, occupancy detection, daylighting, and task-tuning strategies – all at a per-fixture level. The system consists of a high definition sensor network that uses low-voltage DC architecture instead of a traditional electrical AC wiring.[58]

Benchmark/Case studies used

According to the case studies provided by the manufacturer, the Redwood system is capable of achieving an industry best average of 75% overall reduction in lighting electrical load and 65% peak demand reduction.[59]

Among the companies that have implemented Redwood systems are Facebook, Google, SAP, and a Volkswagen research facility.[60] Redwood has formed a partnership with many of its clients to measure actual energy savings before and after each installation. Energy savings ranged from 78% for an open office and conference room application to 91% for a technology company's data center. A Connecticut-based public school district realized savings of 87% in their classrooms and hallways.[61]

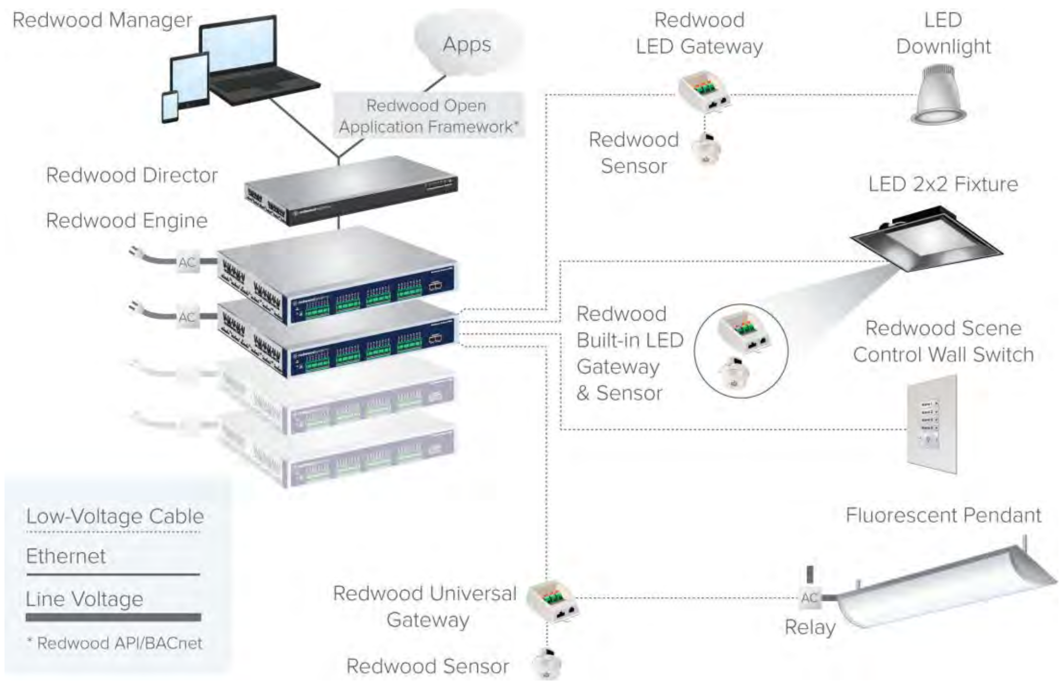


Figure 7: Components of a Redwood Building performance lighting platform

SAP, the highest-ranked software company in the Dow Jones Sustainability Index, used Redwood systems in part of their recent energy retrofit. The company had the existing fluorescent lighting replaced with LED fixtures and implemented an integrated Redwood system. The results were reduced operational costs, an improved workspace environment that spurred productivity, and realized savings of 50-75% in lighting energy costs. Additional gains were realized from analysis of detailed data results from advanced space utilization and temperature mapping techniques of an occupancy-based HVAC system.[62]

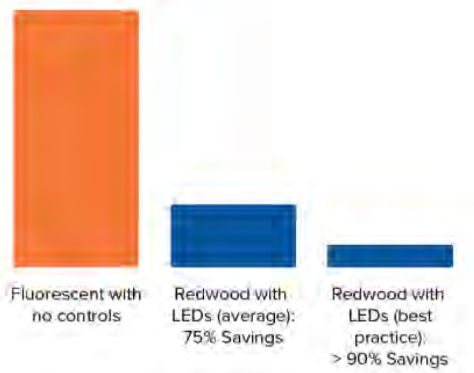


Figure 8: Energy usage comparison between fluorescent lighting and Redwood systems

Tech Development Forecast

LED lighting with a comprehensive building performance lighting and control system is yet another important step in optimizing building systems through integration – systems which in the past have had separate controlling mechanisms that often worked in opposition. In addition to lighting and HVAC systems, future lighting and building management systems (BMS) would integrate advanced operations such as alarm management and master scheduling.[63] Since more building equipment is becoming digital, the BMS of the future would evolve toward a comprehensive IT system complete with a server, a database, IP addresses and various software applications – all connected to a unified network.

Finance

There are no financing mechanisms available for a lighting management technology at this point. Similar to the cost structure of LEDs elaborated in the "Lighting Retrofit Using LEDs" section in Appendix 9.6, this cost estimation is also based on price per square foot as opposed to price per fixture. It is also based on a retrofit cost of a similar commercial space in New York City.

- Typical cost for LED lights and Redwood Engine: $4-$6 per square foot where one Redwood engine is required per either every 16 or 32 fixtures, depending on the fixture type
- Typical cost for installation - $5-$8 per square foot
    - NRDC's 7 floors = 62,063 square foot
    - Total cost = $558,567 - $ 868,882
    - The average for this range is calculated to be= $ 713,728 which is used in the data model.

Since the luminosity and foot candles for various rooms and locations will significantly differ when LEDs are in place, the fixture count will reduce (previous studies have reported a 17% drop in number of fixtures in an 18,000 square foot open office area). This cost estimation has not taken the reduction on the number of fixtures into place and therefore is just an approximation.

For more information on this technology please refer to Appendix 9.5 and Appendix 9.6.

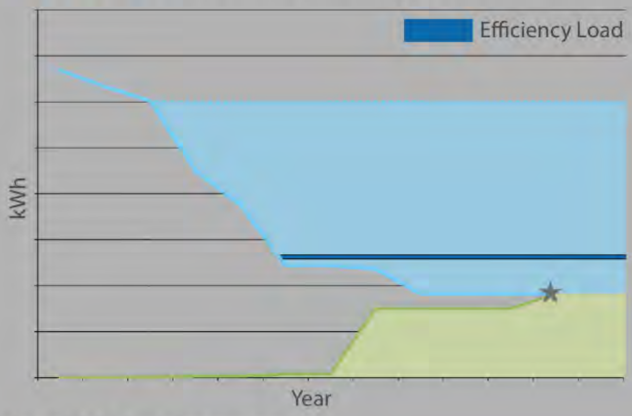
Biofuel Use in Boiler

ENERGY BALANCE

9,001 kWh annual impact

2015 recommended implementation year

0.8% of total facility energy load



FINANCIAL METRICS

$0 total approx. installed cost

$0 incentives or rebates

No incentive program

$23,208 cumulated savings (2013-2023)

Immediate simple payback period after incentives

NA IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

No Fossil Fuel Use
No long-term technologies or strategies involving fossil fuel use will be included in the portfolio of solutions.

Environmental Impacts
Energy production with little to no local environmental impacts

4.2.5.

Rationale

Until on-site power generation and/or heating technology progresses to allow for a complete shift away from combustible fuels, recycled biofuels should be used in place of conventional No. 2 heating oil or natural gas. While not ideal due to current production practices, biofuel is a renewable resource that reduces carbon dioxide, carbon monoxide, particulates, sulfur, and other emissions.

Clearly the burning of biofuel is preferred to any fossil fuel, but it remains a stopgap solution because it inherently consumes energy rather than producing it and releases GHGs into the atmosphere. Fortunately, the current boiler will not require any modifications to convert to biofuel use.[64]

Tech Development Forecast

Biofuel research and development is expected to yield more sustainable fuels that do not compete with global foodstocks, but unfortunately many proponents fear that the current natural gas boom in North America has significantly extended this technology advancement outlook.[65] In the interim, B100 biodiesel (100% biofuel) produced from local recycled cooking oil is recommended. There are a number of local companies to choose from for biodiesel, but all currently offer only B20 for delivery service. It is recommended that NRDC mobilize a campaign with other biofuel purchasers to push local providers to offer B100 for commercial delivery, starting with Metro Biofuel, whose waste oil collection is facilitated by the Doe Fund's Resource Recovery training program for homeless and recently incarcerated males.[66]

Finance

New York State offers the Claim for Clean Heating Fuel Credit which provides a $0.01 per gallon tax credit for each 1% of biofuel included in heating fuel up to 20%.[67] Prices for biofuels (including those produced from recycled sources) are dictated by daily fossil fuel and feedstock benchmark indices, so supplier prices should remain competitive with one another.

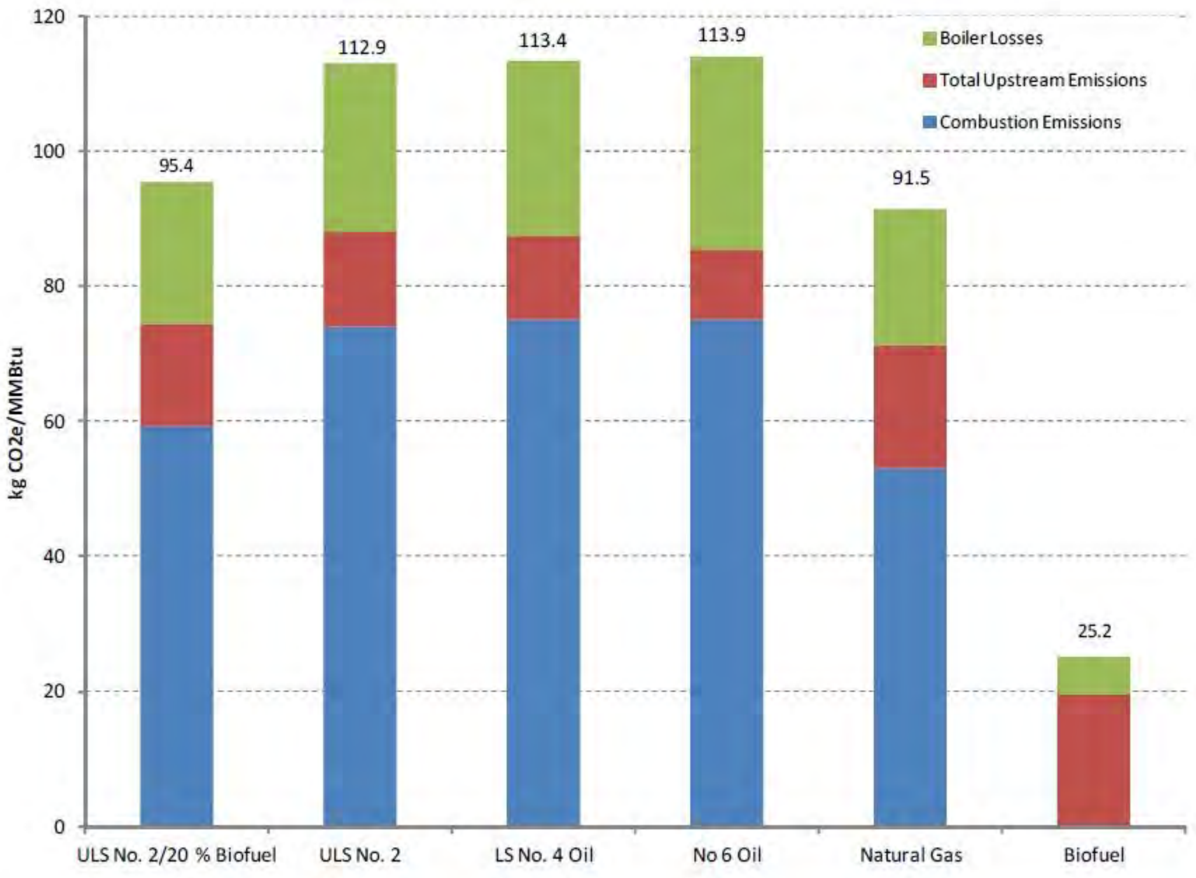


Figure 9: Life-Cycle GHG Emissions Comparison for Residential and Commercial Boilers in New York City (kg CO2e/MMBtu)

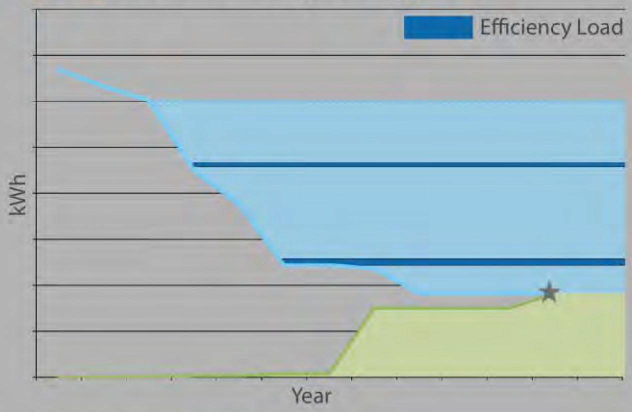
Direct Current (DC) Microgrid

ENERGY BALANCE

28,513 kWh annual impact

2013/2017 recommended implementation year

2.4% of total facility energy load



FINANCIAL METRICS

$ 148,000 total approx. installed cost

$21,671 incentives or rebates

NYSERDA New Construction incentive program

$74,824 cumulated savings (2013-2023)

17.3 yrs simple payback period after incentives

-23%/37% IRR - 10Y (Lighting & VFDs / Solar % Workspace)

PRIMARY METHODOLOGY CRITERIA

Efficiency
Enhance the operational efficiency of the NRDC, leading to a lower building cost over time

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

ROI **Return on Investment**
Metric calculation based on total finance and energy savings.

4.2.6.

Rationale

Many electronic devices and equipment used in NRDC's building require direct current (DC) input, such as electronic ballasts used in fluorescent lights, LED lighting, variable frequency drives (VFDs) used on HVAC fans and pumps, desktop computers, laptops, cell phones and other portable devices**.** Since the electricity grid distributes power to the building in Alternating Current (AC), these DC-powered devices require conversion from AC to DC. Conversion leads to energy losses caused by typically inefficient rectifiers and power supplies. According to the Lawrence Berkeley National Lab, the average conversion loss in the installed base of internal and external power supplies is 32%.[68]

In addition, NRDC's current solar PV system and the other renewable systems proposed by the project team provide DC power. Typically this necessitates an inverter that converts the native DC power to AC power in order to be used in the building's electric system, only to be converted back to DC at the individual equipment level for DC-powered devices.

Installing a DC microgrid within the building to feed certain DC power loads can minimize or eliminate these conversion losses. A DC microgrid system would involve a 380V DC bus, which would convey DC power to each floor. This would receive DC power from two sources: directly from the rooftop solar PV system, and power from the grid converted to DC by a high efficiency rectifier. Specific building loads we have targeted for this system are lighting, VFDs, and desk level plug loads that the team recommended installing the DC power distribution infrastructure in 2013, when lighting upgrades and VFD installations are proposed. LED lighting would be connected to the system through 24V DC wiring, eliminating the need for individual power supplies on each fixture and increasing lighting efficiency by 10%.

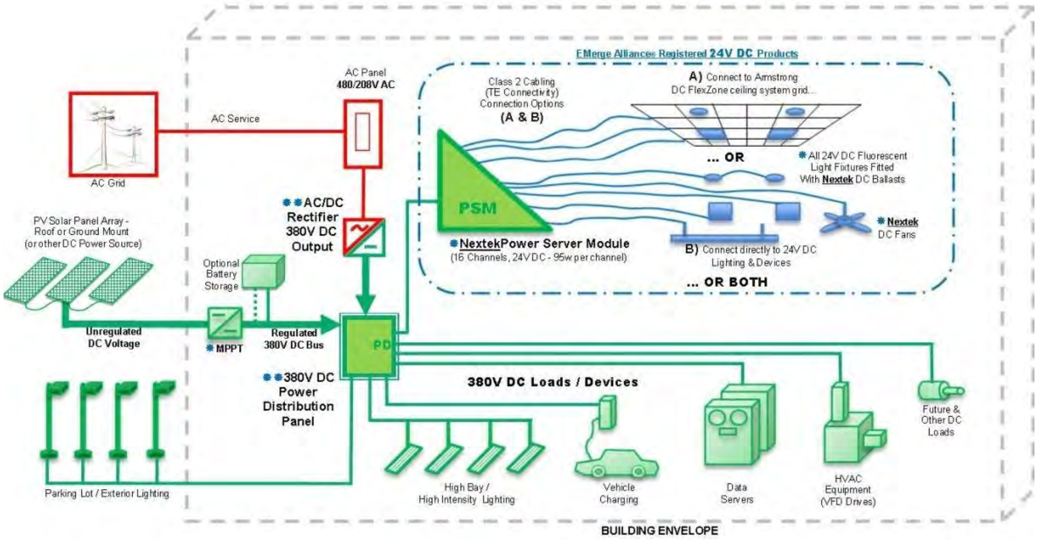


Figure 10: AC and 380VDC Input Microgrid System

Connecting the DC voltage bus of VFDs to the DC system will increase the efficiency of the drive by 10%. Feeding DC power from solar panels directly into the DC bus instead of through an inverter virtually eliminates conversion losses, resulting in a 5-10% gain in efficiency. Based on estimates from Nextek Power Systems and calculations from the Data Model, the team projects 10,393 kWh annual savings from lighting and VFDs and 18,120 kWh annual savings from solar power production and workspace areas. Total energy savings of 28,513 kWh represents 2.4% of total facility energy load. For additional information on this technology please see Appendix 9.7.

Building Load	DC Retrofit Description	Estimated Savings by Load	Total kWh saved
Solar	MPPTs instead of inverter	5-10%	3,234.9
Lighting	DC LED (vs. AC LED)	10%	3,422.3
VFDs (HVAC fans & pumps)	VFD bus terminals connected to DC	10%	6,971
Workspace	DC/USB input for desk-level equipment (laptops, phones)	15%	14,884.8
Total		**2.8%**	**28,513**

Figure 11: DC Microgrid Energy Savings by Building Load

Benchmarking/Case Studies

DC microgrids are still an emerging technology, but have been installed at varying capacity in several applications. In 2004, Nextek was contracted by William McDonough and Partners to install a DC microgrid at a distribution warehouse in Rochester, NY, which integrated a solar PV system with a DC-powered, high-efficiency lighting system. The DC microgrid included a 21-kW solar array (eliminating the need for an inverter) and T-8 lamps with DC ballasts and occupancy sensors, whose combined efficiencies resulting in savings of 20%. Power generated by the solar array not used by the lighting system is converted to AC with a high efficiency rectifier and used elsewhere in the building or sold back to the grid.[69]

In 2006, Nextek Power was commissioned to install a DC microgrid at the Town Hall of Hempstead, NY. The system linked a 40-kW solar system to the VFDs on the building's HVAC system. VFDs usually require a rectifier between the AC input and DC-voltage-regulator, and this system eliminates the need for a rectifier. Nextek estimates this setup to improve the efficiency of the drives by 10%. The town of Hempstead was awarded a NYSERDA grant of $260,000 to install the system.[70]

Nextek also managed the installation of a DC microgrid in the NextEnergy Center in Detroit, a non-profit organization that researches alternative and renewable energy technologies. Nextek reconfigured the 45,000-sq ft building to provide 380V DC power to lab and office spaces, fans, lighting systems, and wireless controls. Replacing metal halide fixtures with T-8 fixtures with DC ballasts and occupancy sensors reduced energy use by 43%. The combined savings from retrofitting with DC equipment was 67%.[71]

SAP upgraded their data center to run on DC power in 2010. The data center was retrofitted with a rectifier to convert AC grid power to DC power, which cost $128,000 and saves $24,000 a year. SAP's data center has a 5.3-year payback and reduces power consumption by 15-20%.[72]

Tech Forecast

The EMerge Alliance, a non-profit industry association, is developing Industry standards for using low voltage DC power safely in commercial buildings. DC microgrid building infrastructure and DC powered lighting systems are commercially available today. According to Nextek, VFDs can be easily adjusted to connect to a DC microgrid. A 380 VDC Data/Telecom Center standard was released by the Emerge Alliance on November 13, 2012, and DC data center products are expected to available within the next few years.[73] Nextek estimates that standards for desk level equipment will facilitate a DC-powered workspace becoming available within 5 years.

Finance

Specific rebates or incentives for DC microgrid components do not currently exist. The technology leads to overall load reduction, helping NRDC achieve DOE's Energy Efficient Commercial Building Tax Deduction (179D) of $0.30-1.80 per square foot if the building is 50% more efficient than ASHRAE 90.1-2001 (expires 31 Dec. 2013).[74] According to the Financial Model, total installed cost is estimated to be $148,000, of which $21,671 can be recovered from NYSERDA as part of the New Construction Program Incentive. After incentives, the estimated simple payback period for the lighting and VFD microgrid is 31 years. With the DC building infrastructure already installed, payback for installing the DC-powered workspace and connecting the solar PV system to the microgrid is comparatively short at just 3.6 years.

4.3 Passive Energy Efficiency Technologies

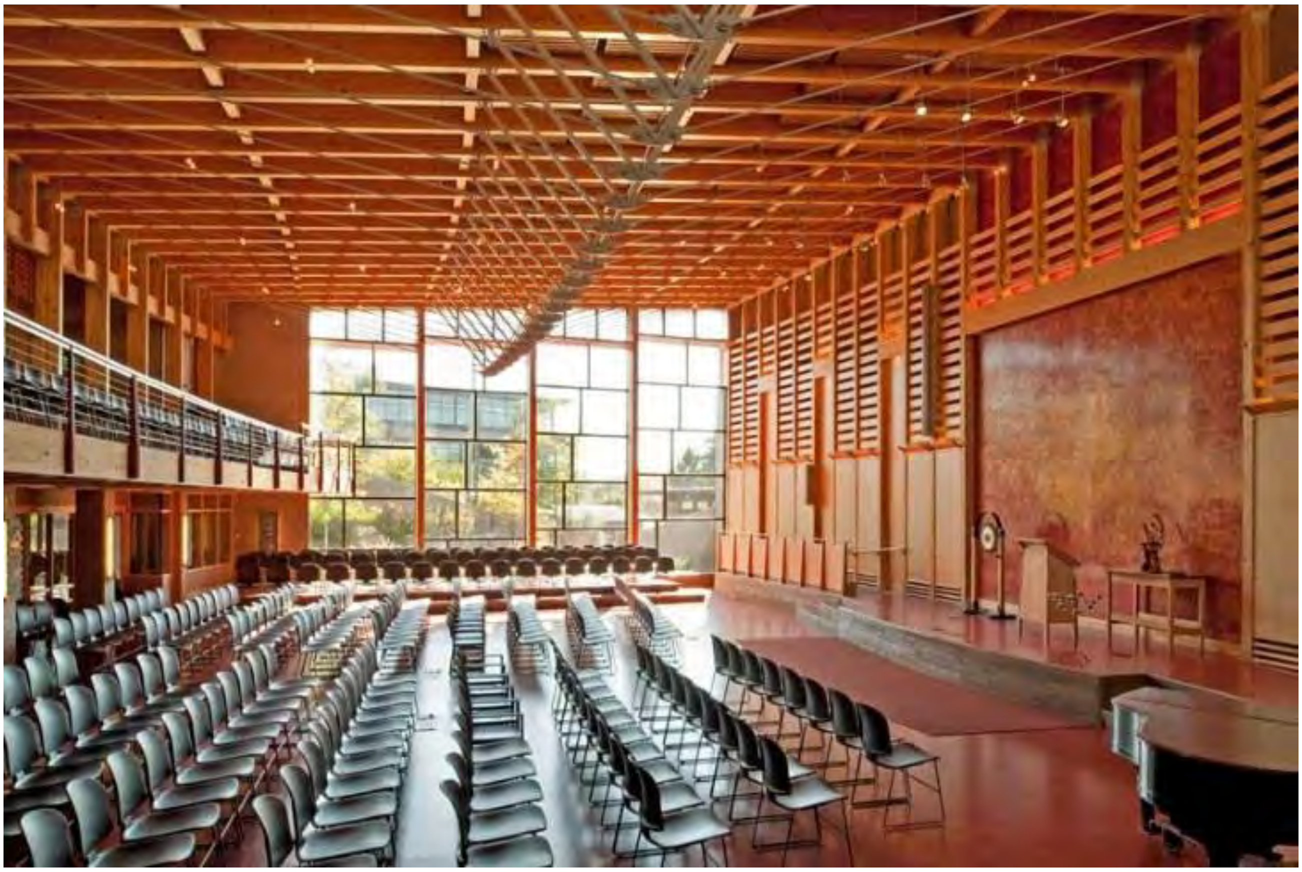


Figure 12: Example of Passive Lighting - First Unitarian Society Meeting House, Madison, WI

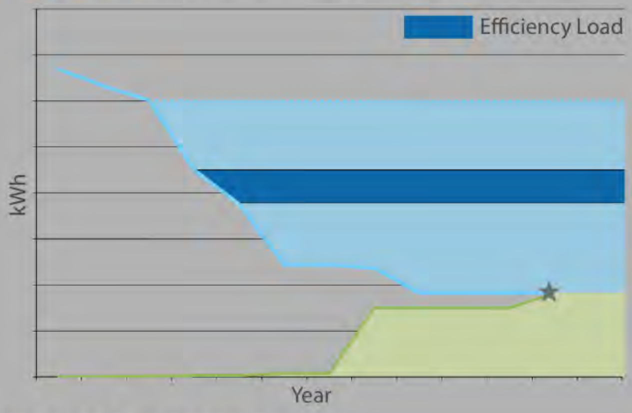
Phase Change Material (PCM)

ENERGY BALANCE

154,396 kWh annual impact

2014 recommended implementation year

12.9% of total facility energy load



FINANCIAL METRICS

$232,740 total approx. installed cost

$117,344 incentives or rebates

NYSERDA New Construction incentive program

$386,493 cumulated savings (2013-2023)

3.3 yrs simple payback period after incentives

43% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

ROI
Return on Investment
Metric calculation based on total finance and energy savings.

Payback Period
Short payback period and high efficiency in terms of installed cost per unit of energy saved or produced.

Percent Reduction
Total cost per kWh energy usage is reduced

4.3.1

Rationale

Thermal mass integration combined with passive solar design can play an important role in reducing energy use, as it stores heat during the day and releases it gradually at night. Traditional thermal mass materials include stone, adobe, and brick; however, more cutting edge products such as phase change materials (PCM) have begun to help with a building's energy efficiency regulation.[75] They store 5–14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock.[76] This type of technology can be placed in walls, floors or ceilings.[77] Phase change materials work by increasing the thermal mass of a building decreasing the time it takes for the structure of a building to warm up or cool down.[78]

These products keep offices cooler without using air conditioning by absorbing heat – leaving the rooms naturally cooler. The innovative PCM-based insulation technology is expected to enhance energy efficiency in heating and cooling buildings in moderate climates by reducing excess sensible heat in the summer and reducing heat loss in the winter.[79] At 40 West 20th Street, PCM are projected to yield annual energy savings of 154,396 kWh according to the Data Model (12.9% of total facility energy load). For more information on this technology please see Appendix 9.8.

Benchmark/case studies used

Armstrong, a British engineering company, published a case study of PCM implementation at a mid-rise masonry office building in central London. They replaced standard mineral tiles in the center of the ceiling of a meeting room that was suffering from overheating and heavily reliant on air-conditioning.[80] Occupancy, temperature, airflow and air conditioner energy use were monitored for six months.[81] When heat can be purged, the room used between 20 % and 70 % less energy compared to the untreated room. PCM can be incorporated successfully into existing buildings, but arrangements need to be put into place to purge the accumulated heat during off-hours.

Tech Development Forecast

While a large share of energy storage applications have already reached a mature stage, PCM is still in a developmental phase.[82] PCM is placed in the developmental or demonstration phase because, as EPRI concludes, "storage systems involving PCMs are still in their infancy, and will require further study to determine the compatibility of these systems with CST plants using heat transfer fluids."[83]

Figure 13: Installation of PCM in Ceiling Panels

Finance

The anticipated cost of this technology is 40% greater than the cost of standard insulation; however, the technology is expected to save 30% of the annual cost of energy for heating and cooling.[84] Costs of the technology are influenced by the application in which the technology is deployed.[85] Additionally, the system costs are influenced by the system efficiency and the frequency of use.[86] Operation and maintenance costs include buying the energy used to charge the system and variable costs, which are primarily replacement costs.[87] The installed cost of $232,740 can be partially offset by $117,344 in financial incentives from the NYSERDA New Construction Incentive program. After incentives the projected payback period is 3.3 years according to the Financial Model.

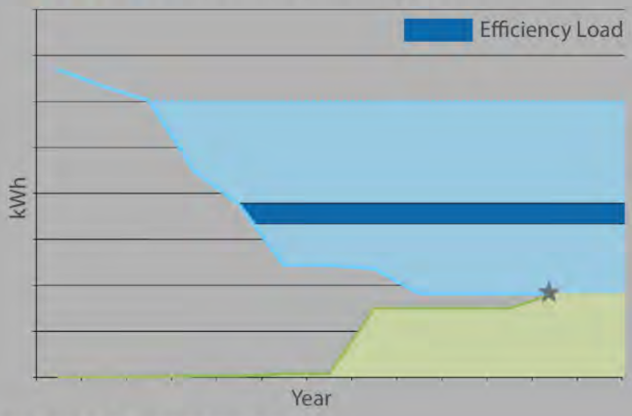
EXTERIOR INSULATED PANELS (EIFS)

ENERGY BALANCE

72,052 kWh annual impact

2015 recommended implementation year

6.0% of total facility energy load



FINANCIAL METRICS

$529,710 total approx. installed cost

$54,761 incentives or rebates

NYSERDA New Construction incentive program

$185,774 cumulated savings (2013-2023)

21.3 yrs simple payback period after incentives

43% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Efficiency
Enhance the operational efficiency of the NRDC, leading to a lower building cost over time

Return on Investment
Metric calculation based on total finance and energy savings.

Percent Reduction
Total cost per kWh energy usage is reduced

Capital Spending
Capital expenditures are favored over operational expenditures

4.3.2

Rationale

Insulation is the most effective way to improve the energy efficiency of a building.[88] Insulation of the building envelope helps keep heat in during the winter, but lets heat out during summer to improve comfort and save energy.[89] Effective insulation protects not only against the cold but against heat as well, provided that not too much heat is already present indoors.[90]

Thermal bridging is when heat is lost through the metal or wood framing studs, at any joints of a building where two dissimilar materials are connected.[91] Prevention of thermal bridges is one of the most efficient savings measures.[92]The most effective way to decrease thermal bridging in a building is by using Exterior Insulation and Finish Systems (EIFS). This type of insulations is a multi-layered exterior wall system that is used on both commercial buildings and homes.[93] EIFS provides superior energy efficiency and offer much greater design flexibility than other cladding products.[94] It is a thermal insulation system that continuously wraps the exterior of the building, and can be molded specifically to building façade design; therefore keeping the historic design approach. At 40 West 20th Street, EIFS is projected to save 75,052 kWh in total annual heating and cooling energy (6% of total facility energy load) according to the Data Model. For more information on this technology please see Appendix 9.9.

The figure below illustrates comparable nominal R-values of traditional wall systems, and an EIFS implementation.

Benchmark/case studies used

The first official Certified Passive House old masonry retrofit in NYC was completed on a 2200 SF, 120-year-old brownstone comprised of brick and beam construction with a fieldstone foundation.[95]

One of the key solutions implemented, was an exterior EIFS insulation system. The Zero Energy Design team recreated decorative molding to make the completed façade look identical to the original installation with an estimated 20 to 30% reduction of energy usage.

Tech Development Forecast

The rich appearance of EIFS bears a resemblance to stucco or stone, but the systems are far more versatile than these and other materials.[96] Not only do EIFS come in virtually limitless colors and a wide variety of textures, but they also can be fashioned into virtually any shape or design.[97]

With EIFS, skilled applicators can create all types of exterior architectural detailing[98], which is beneficial for the NRDC building, as the historic preservation committee would not approve such implementation if it were to reduce the historic appearance of the building. Implementation of an EIFS would be effective as soon as possible in the implementation timeline due to the fact that insulation reduces the sizing requirement of active energy efficiency and HVAC solutions.

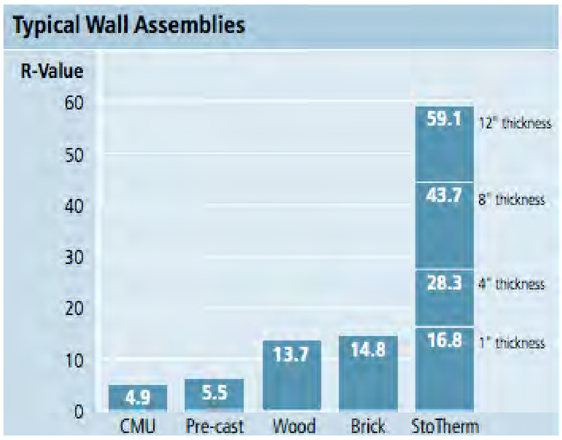


Figure 14: R-values of Typical Wall Assemblies and EIFS

Finance

The project team estimates a total installed cost of $529,710, partially offset by $54,761 from the NYSERDA New Construction Program Incentive. After incentives, simple payback is approximately 21.3 years for this technology.

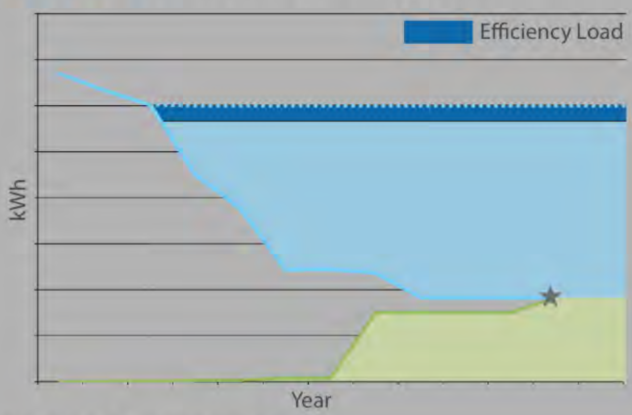
AIR SEALING

ENERGY BALANCE

57,184 kWh annual impact

2013 recommended implementation year

4.8% of total facility energy load



FINANCIAL METRICS

$25,000 total approx. installed cost

$6,862 incentives or rebates

ConEdison Rebate program

$138,976 cumulated savings (2013-2023)

1.5 yrs simple payback period after incentives

211% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Efficiency
Enhance the operational efficiency of the NRDC, leading to a lower building cost over time

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Ease of Adoption
Ease of adoption in the client building, for both tenants and facilities management

Capital Spending
Capital expenditures are favored over operational expenditures

Embodied Energy
Technology not manufactured in an energy intensive manner (i.e. low embodied energy)

4.3.3

Rationale

Air leakage is caused by three physical effects. Stack Effect airflow is the result of pressure differences between the interior and exterior air columns, generally due to temperature differences in the two columns of air.[99] Wind Effect is airflow in and out of a building due to pressure differences from wind conditions.[100] Mechanical Effect airflow is either deliberate or inadvertent pressure imbalances created by the HVAC systems.[101] All three of these physical effects can cause unintentional airflow. The airflow itself is made possible by gaps, cracks and holes in the building envelope.[102] The effect of uncontrolled air leakage in a high-rise commercial building ranges from 22-46% in energy consumption.[103] The data model assumes conservative energy savings of 10% of heating and cooling loads from air sealing, resulting in annual energy savings of 57,184 kWh.

The benefits of an air barrier retrofit:[104]

- Control flow of air in/out of building
- Reduces heat loss/gain
- Reduces dust, mold and pollutants
- Reduces noises and odors
- Reduce condensation, mold and mildew
- Improve comfort/occupant experience
- Helps control biological

Benchmark/case studies used

Air Barrier Solutions recently completed a retrofit for a building at a university in Boston where they found the equivalent of a 44.63 square foot hole in total across the building. The building was inspected visually and using smoke tracer tests in accordance with ASTM E-1186 – 02 by Air Barrier Solutions, LLC.[105] In a complex building design the connection points such as the roof wall joint, soffits and corners are usually the sources of unwanted air movement.[106]

Finance

The cost projected in the Financial Model is $25,000 before savings of $6,862 from a ConEd rebate program. After incentives, the simple payback period is 1.5 years. An Air Barrier Solutions audit would provide a more accurate cost estimate. For an in-depth look at costs, please see Appendix 9.10.

The table below shows the annual savings and simple payback of the last eight hospitals that Air Barrier Solutions have worked with.

Hole Size	Retrofit Cost	Annual Savings	Simple Payback
147.89	$145,742.00	$78,715.80	1.85
21.73	$41,924.00	$7,054.29	5.94
28.98	$33,478.00	$5,545.92	6.04
147.50	$163,897.00	$32,113.00	5.10
30.11	$44,552.00	$13,167.19	3.38
35.75	$41,260.00	$16,285.92	2.53
33.69	$89,642.00	$21,635.20	4.14
35.94	$39,907.00	$7,156.66	5.58

Table 5: Annual Savings and Simple Payback of 8 Hospitals[107]

4.4 Energy Generation

Figure15: Concentrating Photovoltaic Solar Array in Gila Bend, AZ

ELECTRICAL - ROOFTOP PLATFORMS FOR SOLAR PV

4.4.1

Rationale

The roof is a critical renewable energy asset for net zero buildings and mounting state of the art photovoltaic technologies on elevated structures on top of an existing rooftop can maximize solar energy production while overcoming challenging space constraints. NRDC operates seven stories of office space under a roof area of approximately 8,900 square feet. Mechanical equipment, skylights, planned green space, and other rooftop infrastructure inhibit expansion of solar PV arrays using conventional racking systems. In its current state, the NRDC rooftop produces a negligible amount of solar energy. Inspired by similar structures including parking lot solar canopies, solar pergolas, and solar awnings, the rooftop solar structures will more than quadruple the current amount of space available to produce rooftop solar energy.

Substantial on-site solar electricity generation is a required component of even the most basic definition of achieving net zero building energy.[108] Simulations conducted by ASHRAE suggest that the maximum height of a zero energy building ranges from two to five stories depending on location and load profile.[109] The taller a building is, the more crucial it is to maximize rooftop PV generation due to the decreasing ratio of floor area to roof area. Without rooftop platforms to maximize surface area for photovoltaics, the NRDC building would require increased investment in generation technologies that are either less efficient than rooftop solar or fall outside the ideal solution criteria on other dimensions.

Benchmark/case studies used

"The Delta" is a net zero energy building in Brooklyn, New York, that is a local example of high-density rooftop solar platform deployment. The elevated rooftop structure creates surfaces at the ideal orientation to maximize energy production in a limited space. The Delta is expected to generate 12,300 kWh of solar energy annually from a 10.2 kW-DC rated system.[110] Innovative solar panel racking, both horizontal and vertical, was a key driver of the facility's ability to meet on-site demand under space constraints similar to those faced at 40 West 20th Street.

Figure 16: The Delta building in Brooklyn, NY rooftop elevated solar racking

By extrapolating a theoretical analysis of net zero energy potential by ASHRAE, it is expected that a rooftop with the same surface area as the NRDC building should produce 150,140 kWh/yr from rooftop PV if the roof is fully leveraged.[111] A highly efficient facility exhibits energy loads 50% below ASHRAE 90.1 standards, or energy usage intensity (EUI) of 41.6 kWh/sf.[112] Assuming roof space is dedicated to solar energy production, a typical facility with highly efficient operations would reach a maximum height of five stories before load exceeds available on-site generation potential.[113]

Figure 17: Proposed locations and surface area of elevated platforms on NRDC rooftop

To determine PV generation potential from the NRDC rooftop when PV platforms are added, the team created a model based on the current solar panel technology in place at NRDC. Data from the NREL "PV Watts" system approximates solar energy production from fixed tilt crystalline solar panels. The PV Watts model and inherent assumptions are not a substitute for facility-specific energy modeling, but for purposes of estimating rooftop renewable energy production, the model is accurate to within 12%.[114] The rooftop scenarios chart indicates estimated electricity production from the current PV array and several expanded arrays that can be built using special elevated platforms like those on the Delta building. Using current crystalline panel technology, the expanded arrays would produce over 4.5 times more annual energy than the current array.

Rooftop PV Scenarios: Model of Current Array Production and Expanded Production Estimates							
Inputs:	10.764	sq ft per sq m	4.51	kWh/m^2/day (NREL PV Watts)		6917 kWh/yr (NREL PV Watts)	
Rooftop PV Scenario	Sq Ft	Proportion Available for Panels	Effective Square Footage	Irradiance (kWh/sf/yr)	Panel Efficiency	Electrical System Efficiency	Annual kWh Production (approx.)
A. Current 5.55 kW system	432	100%	432	153	15%	70%	6917
B. Expanded: Water Tower Platform	841	75%	631	153	15%	70%	10099
C. Expanded: West Bulkhead Platform	319	75%	239	153	15%	70%	3831
D. Expanded: East Bulkhead Platform	918	75%	689	153	15%	70%	11023
E. Total - All Areas	**2510**		**1991**	**153**	**15%**	**70%**	**31869**
F. ASHRAE Net Zero Theoretical	11,000	75%	8250	153	17%	70%	150140
Limitations: Model accurate to +/- 12% annual production, based on NREL model. Typical equipment and environmental assumptions used.							
Model does not account for localized shading, rooftop elevation, building shading, and other site factors							

Table 6: Rooftop PV Scenarios: Model of Current Array Production and Expanded Production Estimates (Using current technology)

Tech Development Forecast

This solution deals explicitly with the concept of constructing rooftop structures to standardize roof spaces for subsequent installation of high-output photovoltaic equipment. The following section on photovoltaic technology provides an in-depth analysis of solar generation technologies that should be installed on the rooftop structures in order to maximize energy production given this added infrastructure. The material technologies, construction methods and installers to implement this solution are readily available today.

Finance

Solar carports, pergolas and similar structures engineered for small-scale systems add approximately $1.30-$2.00 per Watt to total project costs.[115] Rooftop platforms as envisioned in the implementation diagram would cost $33,800 to $52,000 using the cost per Watt estimating approach. If higher efficiency solar technologies are used as proposed in the Concentrating PV section of this report, the cost per Watt will decrease. An average cost of $43,000 is used in the project Financial Model.

Rooftop platforms should be engineered along with the solar power generating technology that will be installed on the platforms. Therefore, financing this solution would interact with a package of project finance solutions that apply to the solar power technology. In this way, solar platforms are simply an extension of the preparatory work normally required for PV installation, which can include roof repairs and structural reinforcement.

For more information on this solution please see Appendix 9.11.

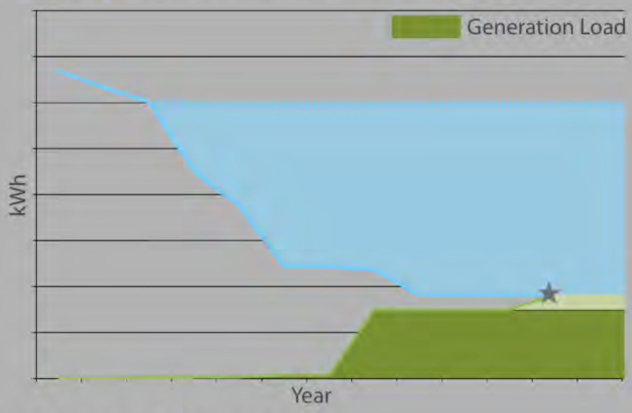
CONCENTRATING PV ROOFTOP SOLAR (CPV)

ENERGY BALANCE

288,007 kWh annual impact

2017 recommended implementation year

24.0% of total facility energy load



FINANCIAL METRICS

$2,418,124 total approx. installed cost

$150,000 incentives or rebates

NYSERDA PV incentive program

$787,806 cumulated savings (2013-2023)

23.2 yrs simple payback period after incentives

-17.5% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Production & Consumption
Balance efficiency gains with onsite renewable energy

Timing
Early phase, middle phase or late phase implementation.

Capital Spending
Capital expenditures are favored over operational expenditures

Lifespan
Must consider the lifespan of the equipment (lifespan must be greater than payback period)

4.4.2

Rationale

Next generation concentrating photovoltaic (CPV) with solar tracking technology is the high-output solar solution with the greatest likelihood of maximizing on-site generation for NRDC at a reasonable cost. This technology is currently available in pilot installations and will be widely commercially available within a three-year time horizon.[116] The main PV siting challenges for NRDC include shading, obstructions, space carve-outs for the green roof plan, and the general expense of installing and maintaining a solar power plant on a Manhattan rooftop. A solar cell with greater output per square foot than crystalline panels will maximize ROI. CPV greatly increases energy density at a similar fixed cost and will incur fewer energy losses from site characteristics than other technologies. With expected advances in rooftop CPV in the next few years, implementing this technology in Manhattan positions NRDC as a leader in on-site urban energy production.

According to the Data Model, rooftop CPV will contribute a total of 288,007 kWh per year. CPV arrays will occupy 7,142 square feet to produce the required amount of energy. The project team recommends locating 2,510 square feet on the NRDC rooftop using elevated PV platforms that do not interfere with the green roof plan. The balance of the required array area (4,632 square feet) should be constructed on an adjacent roof to avoid shading the NRDC green roof and skylights.

Benchmark/case studies used

According to an NREL report on six high-performance commercial buildings, "best practices related to maximizing PV systems' energy output are valuable for future generations of ZEBs [zero energy buildings]."[117] The process of validating CPV (Appendix 9.12) as a viable rooftop energy production solution for NRDC involved a comprehensive analysis carried out in four steps:

1) Validate the role of concentrated rooftop solar PV in achieving net zero through case analysis;
2) Determine current rooftop solar technology and production output;
3) Assess the potential for expanding rooftop solar to meet on-site energy demand by increasing available

square footage and leveraging current crystalline PV technology; and

4) Evaluate CPV technology and variants against project criteria and site conditions.

The CPV layout diagram for this report (Figure) was created using scale icons that represent strings of CPV modules. The team selected Emcore Soliant 1000 (Appendix 9.13) tracking CPV arrays for purposes of the feasibility analysis and energy modeling. The layout produces a theoretical rooftop limit of 50 strings of eight CPV modules for a capacity of 200kW-DC before the solar array infringes on the space required for the green roof plan. Each of the 50 strings of eight modules occupies a footprint of approximately 27 square feet (1,350 square feet total). The total gross surface area of the existing array location and the proposed PV platforms is 2,510 square feet. The additional 4,632 square feet of roof area required for PV production would be leased from adjacent roof owners or installed on the NRDC rooftop with aesthetic consequences.

A CPV design simulation for the 40 West 20th Street location using NREL's System Advisor Model (SAM) software concluded that CPV installed on PV platforms covering 2,510 square feet of NRDC's rooftop would produce 144,601 kWh annually (Appendix 9.14). This production value equates to 57 kWh per square foot per year compared with 15 kWh per square foot for the current crystalline panel technology. CPV delivers a substantial increase in energy density. Due to the uncertainties inherent to the modeling process and based upon a review of case studies using rooftop PV to achieve net zero energy, we determined that modeled output rarely matches actual output. The team then applied a conservative 30% reduction in modeled output yielding a final projected production value of 101,220 kWh/yr. NRDC can achieve the additional 186,787kWh of CPV production by completely covering the 40 West 20th Street rooftop, leasing neighboring roof space, or a combination of both options as discussed in Appendix 9.12, the Data Model and Financial Model.

Tech Development Forecast

While the efficiency growth for crystalline PV technologies is relatively flat, CPV is experiencing rapid growth.[118] Direct Normal Insolation (DNI) is a factor that may limit the proliferation of CPV technology in east coast locations. Today's CPV panels produce the highest energy output in high-DNI areas such as the U.S. Southwest where cloudless skies lead to high levels of direct solar energy reaching the panels. In coming years, advances in the concentrating lens technology and the underlying solar cells are likely to increase CPV cost and output advantages in lower DNI markets such as New York City.
CPV is expected to follow a decreasing price trajectory similar to crystalline panels and already produces 60% lower costs per watt due to higher efficiencies.[119] As the module price per watt drops to the $1.50 range and below in coming years, installation costs become a larger proportion of total cost. Factors such as labor, on-site handling costs, permitting and other overhead costs remain high. A complete discussion of CPV output and pricing trends according to industry sources is located in Appendix 0 Figure .

Finance

CPV system costs include $854,297 for a primary recommended system producing 101,220 kWh per year on the NRDC rooftop and $1,563,827 for an expanded system producing an additional 186,787 annual kWh from the NRDC rooftop, neighboring roofs or a combination of both. NYSERDA incentives of $1.50/W up to $75,000 are included in the Financial Model along with cash flows using debt financing with solar industry standard assumptions. Simple payback for rooftop solar is approximately 23 years using conservative assumptions. The payback period would decrease if conservative assumptions for grid energy prices and the sale of renewable energy credits (RECs) are updated in the future.

According to an NREL case analysis of six high performance buildings, "…many decisions are not made based on cost. Building owners make decisions based on values. Quite often owners will pay for features they really want in a building."[120] On-site rooftop PV at NRDC is an example of a system decision that is not motivated by cost but instead out of necessity for meeting project criteria. Levelized cost of energy (LCOE) is a secondary consideration as long as overarching project cost criteria are met. In addition, the NRDC green roof plan prioritizes environmental benefits over maximizing cost-efficient rooftop energy production.

A comprehensive financial analysis of CPV technology accounts for the overarching project criteria, constraints, and alternatives for on-site generation. High-efficiency CPV panels will maximize energy production from limited roof space at a cost comparable with current technologies on a per watt basis.121 Total cost and cash flow are modeled in SAM using best available data sources and educated assumptions. The team considered traditional project finance and power purchase agreements as well as the pros, cons, and likelihood of success given the complexity of the project and use of next generation (unproven) technology.

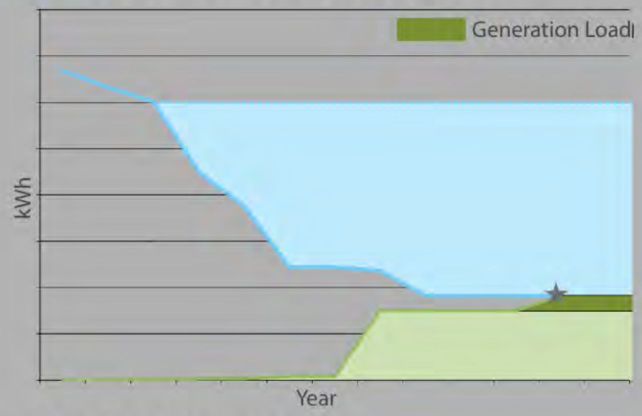
ELECTRICAL - VERTICAL PV SOLAR PANELS (VPV)

ENERGY BALANCE

64,698 kWh annual impact

2021 recommended implementation year

5.4% of total facility energy load



FINANCIAL METRICS

$94,977 total approx. installed cost

$75,000 incentives or rebates

NYSERDA PV incentive program

$199,186 cumulated savings (2013-2023)

1.1 yrs simple payback period after incentives

691% IRR - 10Y

PRIMARY METHODOLOGY CRITERIA

Scalability
Other NRDC offices, NYC mixed-use buildings, non-profits, cities/climates

Production & Consumption
Balance efficiency gains with onsite renewable energy

Timing
Early phase, middle phase or late phase implementation.

Capital Spending
Capital expenditures are favored over operational expenditures

Lifespan
Must consider the lifespan of the equipment (lifespan must be greater than payback period)

4.4.3

Rationale

An addition to the Concentrating Solar Photo Voltaic ('CPV') option is to apply traditional photovoltaic ('PV') panels to the vertical sides of the CPV support structures. This will create additional electricity generation without using additional roof space. Based on the first CPV recommendation for 2,510 square feet of panel structures above the bulkheads, we recommend vertical solar be installed on the south, east, and west sides of the water tower bulkhead, and on the south and east sides of the west bulkhead. This would create 3,489 square feet of vertical solar with these five arrays.

Benchmark/case studies used

The primary disadvantage of VPV is that it is less efficient at capturing solar energy than an optimally pitched solar array. However, in the context of Manhattan and its density, vertical solar has the major advantage of a very small footprint. At 90-degree orientation, a solar array is exposed to 45% less solar radiation than an optimally oriented solar array between 20 and 30 degrees.[122] However, by reducing the angle to approximately 80 degrees, there is only a 30% loss in solar radiation. Installing 3,489 square feet of VPV at 80-degree orientation would allow for significant auxiliary energy generation alongside the primary CPV installation, while using a negligible incremental footprint on an already-crowded rooftop.

Tech Development Forecast

Using a longitudinal survey of datasheets from existing PV panels, we projected both the future efficiency of polycrystalline PV and future price.[123] In the case of Canadian Solar, a major polycrystalline PV panel manufacturer competing in a field of several similar companies with similar products, we project that technological improvements will shift from a 185-watt, 48-cell PV panel that costs $1.10 per watt in 2011 to a 300-watt, 48-cell PV panel that costs $0.50 per watt in 2021.[124]

For the NRDC array with 432 square feet across 30 185-watt panels, we expect the annual solar generation to be 6,687 kWh based on existing generation data. If these were replaced in 2021, an additional 4,757 kWh would be produced annually—an increase of 70%. Applying that efficiency increase to 3,489 square feet of VPV using the same type of panel degraded by 30% due to the efficiency loss of the 80-degree angle, we project that the VPV arrays will generate 64,698 kWh annually.

Tower Location	Height	Width	Total Square Footage (vertical)
S side of Central water tower	35	29	1,015
W side of Central water tower	35	29	1,015
E side of Central water tower	35	29	1,015
S side of west side tower	12	25	300
E side of west side tower	12	12	144
TOTAL			**3,489**

Table 7: Locations and Dimensions of Vertical PV

Finance

The installation of 73,059 watts of solar is a relatively minor cost in the context of the larger CPV recommendation. As indicated in the Financial Model, VPV cost is estimated to be $95,977 before incentives and has a short payback period between 1.1 and 5 years.

4.5 Existing & Supplemental Measures

Code Green Sustainable Building Solutions, an energy sustainability consulting firm, issued an Energy Efficiency Report for NRDC prescribing various measures to reduce the energy load.[125] Our data model and recommendations employ these recommendations.

4.5.1 Variable Frequency Drives (VFDs) (existing)

The existing HVAC supply and return fans are "constant volume," meaning that they operate at all times at a constant rate. VFDs provide significant energy savings by controlling fan volume based on temperature and required airflow. Code Green estimates that these will reduce energy load by 62,084 kWh per year at an installed cost of $25,860 and simple payback will be 1.9 years.

4.5.2 Air Conditioner Schedule Shift (existing)

By adjusting the automatic schedule for the Air Conditioning system, building occupants would get a similar level of comfort for less energy use. Additionally, there is no additional cost required to employ this recommendation. Code Green projects that 24,128 kWh could be saved, worth $5,140.67.

4.5.3 Energy Aligned Lease (supplemental)

NRDC has leased out floors 6 and 7 to two distinct tenants: floor 6 to Jetsetter and floor 7 to Relay Graduate School of Education. These 5-year leases were under negotiation at the time this report was being written and will be signed by the end of 2012. They will be effective in January 2013.

In former lease agreements, there were no clauses regarding energy efficiency enforcement and none will be included in the new leases. Current leases require that tenants meet with NRDC twice a year to look at their energy usage and consider NRDC's suggestions to improve their performance. However, the implementation of these recommendations is not compulsory. The only energy efficiency renovations that the tenants would be obliged to complete are energy efficiency renovations that would be imposed by local laws. To fill this void, NRDC decided to bump up operating cost percentage increase per annum in the new lease agreements to account for potential energy upgrades and therefore take on the benefits of any potential capital upgrade.

Should NRDC decide to renew the existing leases or negotiate leases with new tenants when the current ones expire in 2017, we recommend introducing energy-aligned clauses into the agreements. An energy-aligned lease clause would enable NRDC to avoid the "split incentive" problem, which commonly occurs when building owners and tenants disagree on how to share the capital costs of energy efficiency retrofits and the associated energy savings benefits. The current split leaves NRDC with little incentive to undertake energy retrofits.

The energy-aligned clause would allow NRDC to pass on the capital expenses related to energy efficiency upgrades to its tenants. The capital expense pass-through would be based upon the projected savings period rather than the useful life of the equipment. This clause offers protection for the tenants against underperforming retrofits, and at the same time enables NRDC to shorten the amortization period and reap the benefits from the savings generated to repay its capital costs. The city of New York has been using such clauses in their tenancies. The State of New York is considering using them as well.

Energy savings from implementing an energy-aligned lease are included in our data model and our recommendations. By 2018, NRDC's energy loads will differ from the baseline consumption after the other recommendations are implemented. However, it is likely that the tenant loads on floors 6 & 7 will be higher than floors 8 - 12. To estimate the load reduction from an energy-aligned lease, we took the estimated average load difference per floor between floors 6 & 7 and 8-12 and applied a roughly 37,883 kWh per floor reduction for each energy-aligned lease. This results in a total energy reduction of 75,766 kWh.

4.6 Reviewed Technologies Excluded

4.6.1 Vertical Axis Wind – Appendix 9.15

This technology provides an excellent means of renewable energy. We collected wind speed data from the roof of the NRDC building using a small weather station and found that site conditions allow for satisfactory, but not ideal wind generation potential. After some review, we found that Concentrating Photovoltaics provided greater generation potential per the amount of roof space required.

4.6.2 Combined Heat and Power (CHP) – Appendix 9.16

CHP systems provide outstanding energy efficiency by generating electricity and employing the heat from this process for the building. Given that this technology uses natural gas, a fossil fuel, it was not appropriate for our final recommendation. Although this system could run on biogas, the infrastructure for this fuel mix is on the distant horizon.

4.6.3 Window Monitoring System – Natural Ventilation – Appendix 9.17

A window monitoring system would employ the use of signaling devices to encourage occupants to open their windows when it would most benefit the temperature and ventilation. This technology has potential, but was not included in the data model as quantitative case studies were not available.

4.6.4 Electricity-Generating Gym Equipment – Appendix 9.18

This technology employs generators on exercise bikes in order to provide human-powered electricity. This innovative technology would require significant floor space and occupant time and effort in order to provide a small amount of generation capacity. Given the efficiency of other generation methods, this was not employed in our data model.

4.6.5 Photo-Voltaic Insulating Glass – Appendix 9.19

This system employs photovoltaic generation capacity in the building's windows. While a promising technology, the cost of implementation is high, the technology is very new, and the potential for significant generation in an urban setting is slim. As such, we did not find a place for this in our final implementation plan.

4.6.6 Desiccant Enhanced Evaporating (DEVap) Units – Appendix 9.3

DEVap units provide cooling capacity through a thermally-activated absorption cycle, as opposed to the more traditional energy-intensive refrigeration cycle. While highly promising, this technology would require extensive new ductwork to implement and the cost was found to be high compared to the efficiency provided.

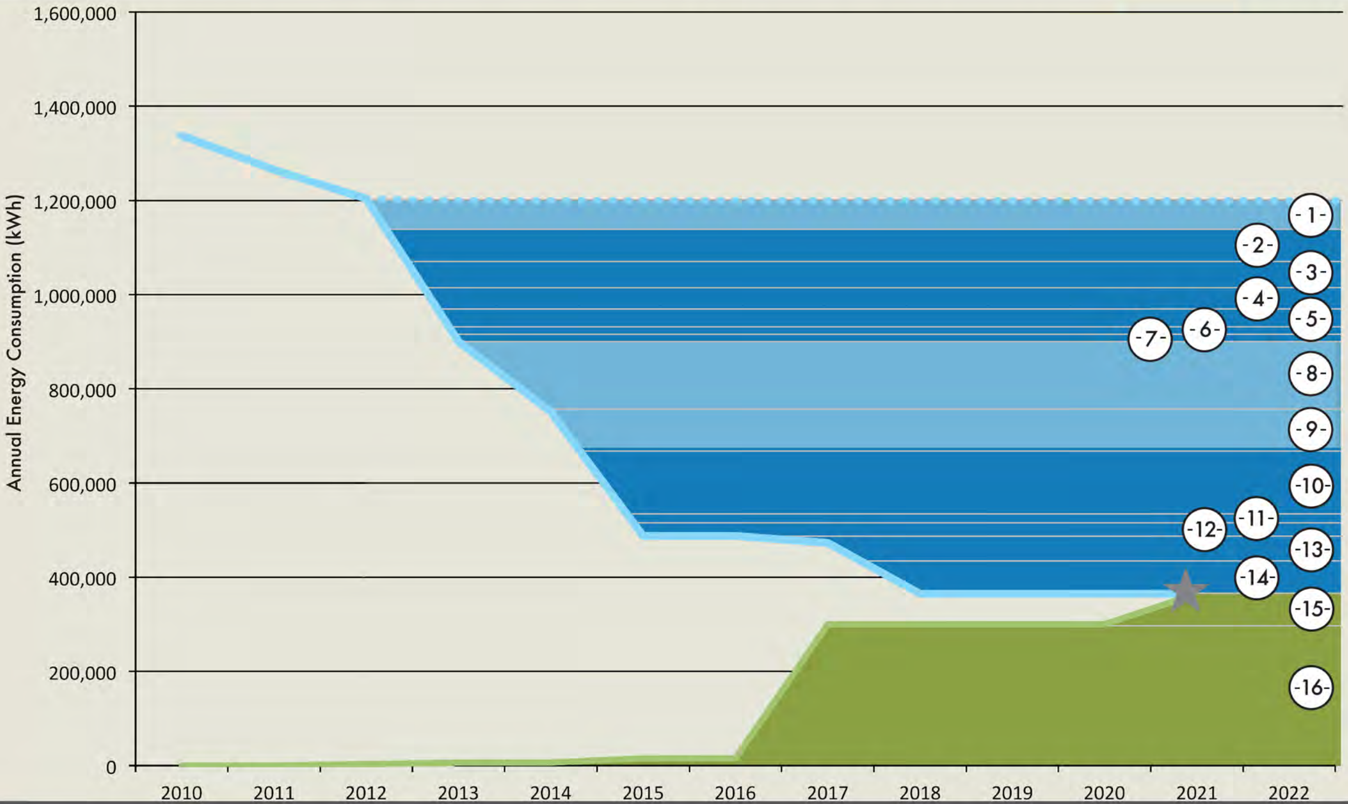
5. Recommendations and Implementation Plan

The technologies discussed in Section 4 have been evaluated against the methodology criteria, as well as a few key performance indicators, specifically; annual impact in kWh, total installed cost, suggested implementation year, total energy load, available incentives or rebates, and a calculated payback after incentives.

Technologies recommended for early phase implementation could be implemented at any year in the implementation plan. These technologies are established and not likely to evolve in any material way. Mid-phase implementation technologies are commercially developed but could be more financially feasible in a few years. Finally, technologies recommended for late-phase implementation are currently available, but the technologies will benefit from time and increased commercialization to drive down cost and improve financial viability.

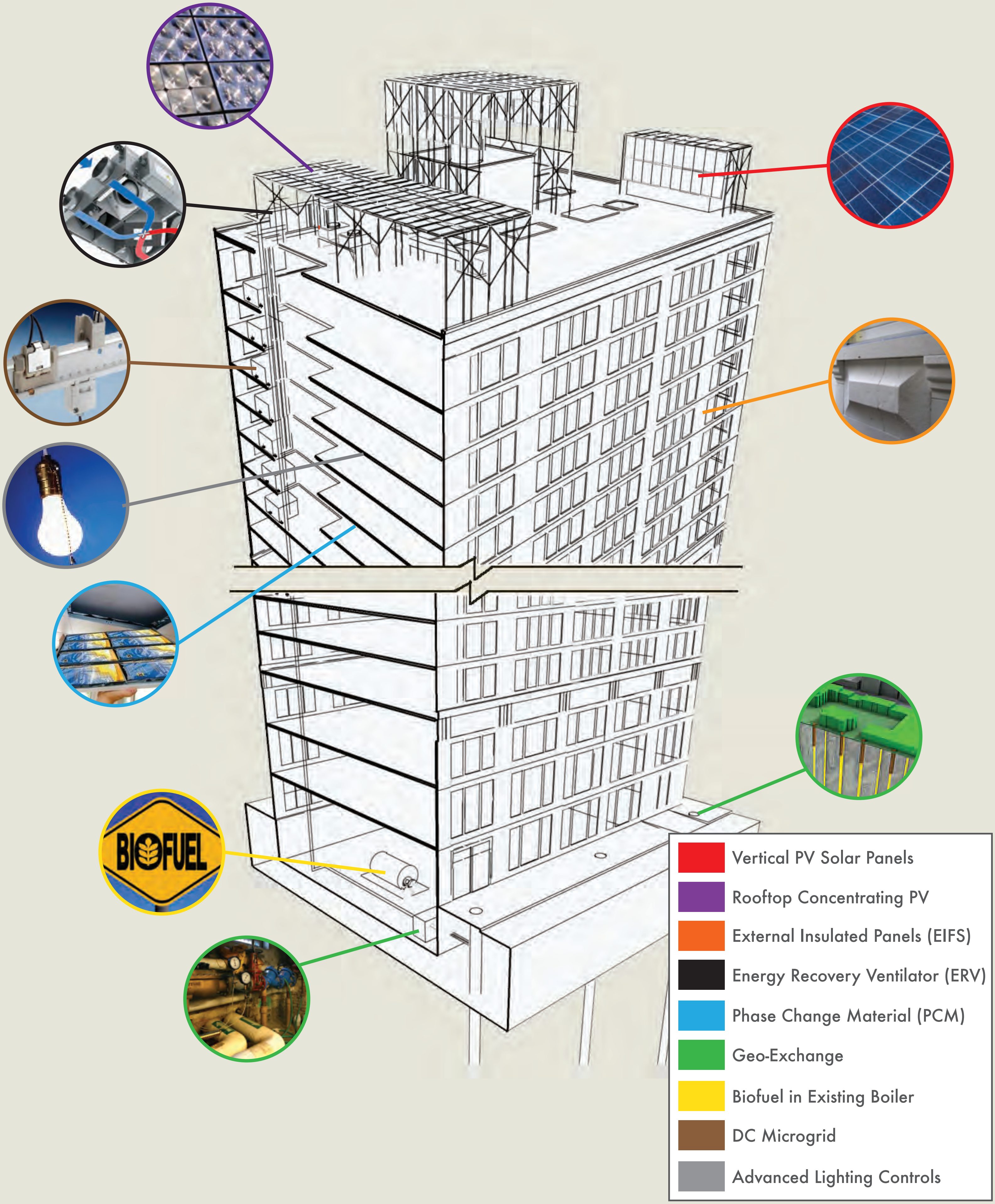
The graphic on the next page shows a compressive recommendation and implementation plan as well as providing information on timing, impact, and cost. The building sketch is a visual overview of where some of these recommendations will be implemented.

TECHNOLOGY KEY DATA MATRIX



	Air Sealing (1)	Energy Recovery Ventilator (ERV) (2)	VFDs on Blower Fans & Condensor Pump (3)	Advanced Lighting Controls (4)	Smart Metering System (Fl 8-12) (5)	Direct Current (DC) Microgrid Lighting & VFDs (6)	AC Schedule Shift (7)	Phase Change Material (PCM) (8)	Exterior Insulated Panels (EIFS) (9)	Geo-Exchange (10)	Biofuel in Existing Boiler (11)	Direct Current (DC) Microgrid Solar & Workspace (12)	Smart Metering System (Fl 6-7) (13)	Energy-Aligned Lease (14)	Vertical PV Solar Panels (VPV) (15)	Rooftop Concentrating PV (CPV) (16)
Suggested Implementation Year	2013	2013	2013	2013	2013	2013	2013	2014	2015	2015	2015	2017	2018	2018	2021	2017
kWh Annual Impact	57,184	63,420	67,108	51,335	34,912	10,393	9,479	154,396	72,052	191,264	9,001	18,120	32,070	75,766	64,698	288,007
Total Energy Load	4.8%	5.3%	5.6%	4.3%	2.9%	0.9%	0.8%	12.9%	6.0%	15.9%	0.8%	1.5%	2.7%	6.3%	5.4%	24.0%
Total Installed Cost	$25,000	$20,000	$29,750	$713,728	$39,000	$117,875	$0	$232,740	$529,710	$1,570,000	$X	$30,125	$15,600	$X	$94,977	$2,311,272
Incentives or Rebates	$6,862	$0	$9,900	$0	$26,533	$7,899	$0	$117,344	$54,761	$9,435	$0	$13,772	$0	$0	$75,000	$150,000
Payback After Incentives	1.5 yr	1.5 yr	1.75 yr	36.8 yr	1.7 yr	31 yr	Immediate	3.3 yr	21.3 yr	24.9 yr	Immediate	3.6 yr	2 yr	Immediate	23.2 yr	1.1 yr

TECHNOLOGY KEY DATA MATRIX



In 2013, the following efficiency measures are recommended to reduce energy use; building air sealing, LED lighting retrofits and a lighting controls system, a Direct Current (DC) Building Microgrid, shift AC schedule, Energy Recovery Ventilators, Variable Frequency Drives for air conditioners, and smart metering systems for floors 8-12.

It is recommended that phase change materials be installed in 2014. Phase change materials work by increasing the thermal mass of a building decreasing the time it takes for the structure of a building to warm up or cool down.[126] This technology is likely best installed as NRDC remodels floor by floor as PCMs are inserted in ceiling panels, therefore the implementation of PCMs could be delayed or required.

Three energy efficiency solutions should be installed in 2015: Exterior Insulation and Finish Systems, a Geo-Exchange heating and cooling system, and biofuels in the existing boiler as a stopgap solution for No. 2 heating oil. The switch to biofuel can be made at any time, but a gradual transition is recommended. 2015 is the recommended timing to allow for improvements in biofuel processing and delivery infrastructure as well as preparing the boiler (hoses, valves, etc.) to receive biofuel. Geo-Exchange and EIFS will require extensive permitting, so even though the recommendation is for a 2015 implementation initial work will be required to begin implementation well before 2015.

By 2017, we expect DC standards for desk level equipment to be formalized, allowing for the integration of DC power in workspaces. This would allow each workspace to connect DC-powered devices such as laptops, telephone systems, cellphones, and other portable devices directly to a DC power strip, increasing efficiency by 15%. The second phase of the DC Microgrid will be installed in 2017 in conjunction with Concentrating Photovoltaic (CPV) panels. Tracking CPV technology already exists but additional time will allow for the costs to come down as well as gains from more efficient technologies to increase. CPV increases annual yield compared with traditional crystalline solar panels at a similar fixed cost. As a result of expected advances in rooftop CPV in the next few years, implementation of this technology in Manhattan positions NRDC as a leader in urban onsite energy production. The project team outlined several implementation options in consideration of the substantial investment NRDC has made in the planned green roof coupled with the need to generate sufficient renewable energy to meet the net zero objective.

According to CodeGreen's energy audit, Floors 6 and 7 account for 42% of the total energy used by the NRDC-owned portion of the building – using 1.5 to 2.2 times more energy per square foot than the average energy use on NRDC-occupied floors. In 2017, the 5-year leases with the current subtenants will expire, and NRDC will have the opportunity to negotiate a new energy-aligned lease. In 2018, we recommend that NRDC negotiates an energy-aligned lease with the tenants on Floors 6 and 7. This would allow NRDC to pass on the capital expenses related to energy efficiency upgrades to its tenants. In concurrence with this recommendation, installing smart metering systems and converting workspaces to DC power will reduce energy use on these floors.

Finally, in 2021, a vertical solar PV system will be installed on several vertical surfaces of the roof. To eliminate conversion losses from inverting DC power produced by the PV system into AC power, micro-inverters (MPPTs) will be installed on the panels to feed this power into the 380VDC busway, increasing efficiency by 5%.

Throughout the implementation plan it is recommended that NRDC monitors, track, and adjust this implementation plan based off of actually efficiency gains and additional unforeseen advances in technology.

6. Overall Financial Analysis

6.1 Methodology, Assumptions, and Scope

We have chosen to use the simple payback period method, a metric commonly used to evaluate energy efficiency and renewable energy investments, to conduct the financial analysis of the technologies included in our recommendation.

We calculated cash flows on a technology-by-technology basis. These cash flows account for (i) the total installed cost of each technology, i.e. the equipment and installation costs involved, (ii) the financial benefits derived from the energy savings and/or additional energy generated by each technology and (iii) the technology specific rebates or incentives available as of today to help finance each technology, and where applicable, (iv) the cost of loans, and (v) the financial benefits of the sale of renewable energy credits.

NRDC has indicated that the savings generated by the implementation of both energy efficiency measures, and energy generation measures could be reinvested into the project over the ten-year period. The goal is to reach the Net Zero target, while staying within the $5 million constraint, net of incentives and rebates, as well as including reinvestment of savings.

We have analyzed each technology investment over the period required to reach simple payback. The simple payback period (including reinvestment of savings generated and technology-specific incentives) varies from approximately 1 to 30 years dependent on initial capital investment.

To calculate the financial benefits derived from energy savings and energy generation, we have used the energy impacts of each technology in the kWh equivalent detailed in the technology section and the dollar per kWh rate that NRDC currently pays to Con Edison, as listed in the latest electricity bill provided by the utility. We conservatively assume that this price per kWh will escalate by 3% per annum over the analysis period.

Internal Rate of Return (IRR) was not identified as selection criteria for the project, though to provide a more complete financial review, it was calculated for each technology based on the 4% discount rate given by NRDC.

In order to avoid paying heavy upfront costs we have introduced the use of loans for both of the photovoltaic installations. These loans will be taken on with the manufacturer for 75% of the total cost of the installation. We calculated these loans at a 6% interest rate over a term of 20 years, which is just below the lifespan of the technology. We calculated the loan with a mortgage-type amortization profile, or 'equal payment method', where the total amount of principal repayment and interest payment is equal every year.

The scope of this financial analysis model does not include financing solutions that would be applicable to the recommendation as a whole. We will present them in the creative financing opportunities subsection below. Also not included in the analysis are the operational and maintenance costs, including insurance and upkeep of each technology. Finally, we have not applied any degradation factors affecting the technologies' production capacities over the analysis period.

6.2 Cash Flow Charts

6.2.1 Cash flow analysis for each technology

See following Table for sample data.

Please see Appendix 9.20 for all technology analyses.

Advanced Lighting Controls 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2049	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10	37		
Total Installed Cost	-$713,728	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$713,728	-$713,728
Equipment Cost												$0	$0
Installation Cost												$0	$0
Rebates & Incentives	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Rebate												$0	$0
Incentives												$0	$0
Savings	$10,883	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$31,542	$396,787	$124,762
Energy impact in kWh equivalent	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	1,283,376	513,350
Cost ($)	$10,883	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$31,542	$396,787	$124,762
Total Cashflows	**-$702,844**	**$11,210**	**$11,546**	**$11,892**	**$12,249**	**$12,616**	**$12,995**	**$13,385**	**$13,786**	**$14,200**	**$31,542**	**-$316,940**	**-$588,966**
Cumulative Cashflows	*-$702,844*	*-$691,635*	*-$680,089*	*-$668,197*	*-$655,948*	*-$643,332*	*-$630,337*	*-$616,952*	*-$603,166*	*-$588,966*	*$6,448*		

Simple Payback Period after incentives	**36.8**	**years**
Simple Payback Period before incentives	**36.8**	**years**

Net Present Value 10Y	**-$586,046**
IRR 10Y	**-25.8%**
Net Present Value 25Y	**-$452,739**
IRR	**-4.0%**

6.2.2 Overall cash flow analysis

See following Table for sample data.

Please see Appendix 9.21 for all detailed analyses.

Global Portfolio of Technologies	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Cashflows (Cost net of savings) after incentives	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Advanced Lighting Controls	-$702,844	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$14,626	$15,065	$15,517	$15,982	$16,462	$16,955	$17,464	$17,988	$18,528	$19,083
Rooftop Solar Concentrated PV @ NRDC	$0	$0	$0	$0	-$755,145	$24,876	$25,623	$26,391	$27,183	$27,999	$28,839	$29,704	$30,595	$31,513	$32,458	$33,432	$34,435	$35,468	$36,532	$37,628
Rooftop Solar Concentrated PV @ NRDC or @ neighbor	$0	$0	$0	$0	-$1,444,258	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$59,897	$61,694	$63,545	$65,451	$67,414	$69,437
Rooftop Vertical PV Solar Panels (VPV)	$0	$0	$0	$0	$0	$0	$0	$0	-$2,602	$17,896	$18,433	$18,986	$19,556	$20,142	$20,747	$21,369	$22,010	$22,671	$23,351	$24,051
Smart Metering System (Floors 6-7)	$0	$0	$0	$0	$0	-$7,718	$8,118	$8,362	$8,613	$8,871	$9,137	$9,411	$9,694	$9,984	$10,284	$10,592	$10,910	$11,237	$11,575	$11,922
Smart Metering System (Floors 8-12)	-$5,065	$7,623	$7,852	$8,088	$8,330	$8,580	$8,837	$9,103	$9,376	$9,657	$9,947	$10,245	$10,552	$10,869	$11,195	$11,531	$11,877	$12,233	$12,600	$12,978
VFDs on Blower Fans	-$4,298	$13,557	$13,963	$14,382	$14,814	$15,258	$15,716	$16,187	$16,673	$17,173	$17,688	$18,219	$18,766	$19,329	$19,908	$20,506	$21,121	$21,754	$22,407	$23,079
VFDs on Condensor Pump	-$1,325	$1,097	$1,130	$1,164	$1,199	$1,235	$1,272	$1,310	$1,349	$1,390	$1,431	$1,474	$1,519	$1,564	$1,611	$1,659	$1,709	$1,760	$1,813	$1,868
Energy Recovery Ventilator (ERV)	-$6,555	$13,848	$14,264	$14,692	$15,132	$15,586	$16,054	$16,536	$17,032	$17,543	$18,069	$18,611	$19,169	$19,744	$20,337	$20,947	$21,575	$22,222	$22,889	$23,576
Air Sealing	-$6,015	$12,487	$12,861	$13,247	$13,645	$14,054	$14,475	$14,910	$15,357	$15,818	$16,292	$16,781	$17,284	$17,803	$18,337	$18,887	$19,454	$20,037	$20,639	$21,258
Phase Change Material (PCM)	$0	-$81,682	$34,725	$35,767	$36,840	$37,945	$39,084	$40,256	$41,464	$42,708	$43,989	$45,309	$46,668	$48,068	$49,510	$50,995	$52,525	$54,101	$55,724	$57,396
Exterior Insulated Panels (EIFS)	$0	$0	-$458,744	$16,691	$17,192	$17,708	$18,239	$18,786	$19,350	$19,930	$20,528	$21,144	$21,778	$22,432	$23,105	$23,798	$24,512	$25,247	$26,005	$26,785
3 Geo-Exchange Wells in Sidewalk (Geothermal) Geo-Exchange - Large Heat Pump in Basement (Geothermal) Geo-Exchange Water Pump from 1,500 Below Surface (Geothermal) Geo-Exchange Water DX Unit 6&7 (Geothermal)	$0	$0	-$1,517,548	$44,308	$45,637	$47,006	$48,416	$49,869	$51,365	$52,906	$54,493	$56,128	$57,812	$59,546	$61,332	$63,172	$65,067	$67,019	$69,030	$71,101
DC Microgrid P2 - Solar & Workspace	$0	$0	$0	$0	-$12,030	$4,453	$4,587	$4,724	$4,866	$5,012	$5,163	$5,317	$5,477	$5,641	$5,811	$5,985	$6,164	$6,349	$6,540	$6,736
Energy-aligned leases	$0	$0	$0	$0	$0	$18,620	$19,179	$19,755	$20,347	$20,958	$21,587	$22,234	$22,901	$23,588	$24,296	$25,025	$25,776	$26,549	$27,345	$28,166
AC Schedule Shift	$2,009	$2,070	$2,132	$2,196	$2,262	$2,330	$2,400	$2,472	$2,546	$2,622	$2,701	$2,782	$2,865	$2,951	$3,040	$3,131	$3,225	$3,322	$3,421	$3,524
Biofuel in Existing Boiler	$0	$0	$2,023	$2,085	$2,148	$2,212	$2,279	$2,347	$2,417	$2,490	$2,564	$2,641	$2,721	$2,802	$2,886	$2,973	$3,062	$3,154	$3,249	$3,346
Total Cashflows	**-$724,094**	**-$19,790**	**-$1,875,795**	**$164,512**	**-$2,041,986**	**$260,668**	**$284,557**	**$293,094**	**$299,285**	**$328,839**	**$338,705**	**$348,866**	**$359,332**	**$370,112**	**$381,215**	**$392,652**	**$404,431**	**$416,564**	**$429,061**	**$441,933**
Cumulative Cashflows	*-$724,094*	*-$743,885*	*-$2,619,680*	*-$2,455,168*	*-$4,497,154*	*-$4,236,486*	*-$3,951,929*	*-$3,658,835*	*-$3,359,550*	*-$3,030,711*	*-$2,692,006*	*-$2,343,140*	*-$1,983,808*	*-$1,613,697*	*-$1,232,482*	*-$839,830*	*-$435,399*	*-$18,835*	*$410,226*	*$852,159*
Simple Payback Period	**18.04**	**years**																		
$5mn budget evolution	**$4,275,906**	**$4,256,115**	**$2,380,320**	**$2,544,832**	**$502,846**	**$763,514**	**$1,048,071**	**$1,341,165**	**$1,640,450**	**$1,969,289**	**$2,307,994**	**$2,656,860**	**$3,016,192**	**$3,386,303**	**$3,767,518**	**$4,160,170**	**$4,564,601**	**$4,981,165**	**$5,410,226**	**$5,852,159**
Loan Tech 2 cashflows	$0	$0	$0	$0	$533,516	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957
Loan Tech 3 cashflows	$0	$0	$0	$0	$1,019,268	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352
Total Cashflows with loan	**-$724,094**	**-$19,790**	**-$1,875,795**	**$164,512**	**-$489,202**	**$112,359**	**$136,248**	**$144,785**	**$150,976**	**$180,530**	**$190,396**	**$200,557**	**$211,023**	**$221,803**	**$232,906**	**$244,342**	**$256,122**	**$268,255**	**$280,752**	**$293,624**
Cumulative Cashflows	*-$724,094*	*-$743,885*	*-$2,619,680*	*-$2,455,168*	*-$2,944,370*	*-$2,832,011*	*-$2,695,763*	*-$2,550,978*	*-$2,400,002*	*-$2,219,472*	*-$2,029,076*	*-$1,828,519*	*-$1,617,497*	*-$1,395,694*	*-$1,162,788*	*-$918,446*	*-$662,324*	*-$394,069*	*-$113,317*	*$180,307*
Simple Payback Period	**19.39**	**years**																		
$5mn budget evolution	**$4,275,906**	**$4,256,115**	**$2,380,320**	**$2,544,832**	**$2,055,630**	**$2,167,989**	**$2,304,237**	**$2,449,022**	**$2,599,998**	**$2,780,528**	**$2,970,924**	**$3,171,481**	**$3,382,503**	**$3,604,306**	**$3,837,212**	**$4,081,554**	**$4,337,676**	**$4,605,931**	**$4,886,683**	**$5,180,307**

Net Present Value 10Y	**-$435,326**
IRR 10Y	**-21.8%**
Net Present Value 25Y	**-$435,326**
IRR	**4.5%**
Net Present Value 25Y	**-$435,326**
IRR	**5.3%**

6.3 Current Grants & Incentives

Several state and utility funded rebates and incentives are applicable to some recommended technologies. We reviewed many programs, and determined due to various requirements that only a limited number are applicable to distinct technologies in this project.

The programs included in the financial projections are:

1. NYSERDA Existing Facilities Program
2. NYSERDA New Construction Program
3. NYSERDA PV Incentive Program
4. NYSERDA Property Tax Incentive for PV Equipment
5. Con Edison Rebate

6.3.1 New York State Energy Research and Development Authority's (NYSERDA) Programs

All of the NYSERDA incentive programs (Existing Facilities Program, New Construction Program, PV Incentive Program) used in our financial projections over the 2013-2022 period are scheduled to expire on December 31, 2015, or when the funding allocated to these programs is exhausted. We assume in our financial projections, for those technologies that will be implemented after the 2015 expiration date that these programs will be extended and available to help finance these technologies.

6.3.2 Existing Facilities Program

NYSERDA's Existing Facilities Program has two components – the "Pre-Qualified" path and the "Performance-Based" path.[127]

Among the pre-qualified incentives available for small equipment, only one applies to the technologies recommended, specifically, the Variable Frequency Drive (VFD) incentive. The incentive is calculated based upon the cumulative motor horsepower controlled by each VFD. Based on our estimates, NRDC could obtain an overall $9,900 incentive ($8,400 for the VFDs on blower fans and $1,500 for the VFDs on the condenser pump) to help finance the proposed VFDs installation.[128]

In order to qualify for the performance-based incentives, technologies must meet several criteria, which include:

- A minimum incentive of $30,000 calculated based upon the energy savings provided during the first full year of operation of the technology and the $0.16 per kWh incentive offered by NYSERDA;
- Less than 18 year payback period before receiving NYSERDA's incentive.[129]

Unfortunately, none of the technologies in our portfolio meet simultaneously both of these eligibility criteria. Therefore, NRDC cannot benefit from this specific part of the incentive.

6.3.3 New Construction Program

NYSERDA's New Construction program offers assistance for energy-efficiency measure incorporation not only in new construction, but also in substantially renovated buildings[130]. NRDC has already benefited from this program in 2012 for its previous energy efficiency retrofits in its New York headquarters. It received a $36,875 incentive from NYSERDA to help it finance initiatives including High Efficiency Lighting, Daylighting Controls, Occupancy Sensors, Demand-based Ventilation, Waterside Economizer, and Variable Speed Drive that were estimated at the time to potentially generate more than 36,797 kWh in annual energy savings, i.e a $1 per kWh incentive.[131]

We calculated the average dollar per kWh incentive that NRDC would likely receive for this particular project based upon incentives granted by NYSERDA to office buildings, universities and retail spaces over the 2010-2012 period in the State of New York.[132] Conservatively, NRDC could expect a $0.76 per kWh, which is 24% lower than what NRDC received for the previous energy efficiency project for which it received funds from NYSERDA.

We explored ways to maximize this incentive by combining different technologies from our recommendation in tentative portfolios, while staying within NYSERDA's threshold of $1.575 million per overall project and maximum incentive of 75% of incremental cost. We found that the optimal portfolio would include smart metering systems (floors 8 through 12), Phase Change Materials, External Facade Insulation System (EIFS), Geothermal DX Unit and DC Micrografts P1 & P2 as shown in the figure below.

Maximizing NYSERDA New Construction Portfolio (Max $1.575 mn): **$0.76 kWh** incentive

Split $0.76 kWh incentive per technology (Max incentive 75% of incremental cost)	Cost Portfolio Tech ($)	Energy Impact Portfolio (kWh)	Potential NYSERDA Incentive ($)	% Cost Covered (50-75%)
Advanced Lighting Controls	$713,728	51,335 kWh	$39,016	5%
Smart Metering System (Floors 6-7)	$15,600	32,070 kWh	$24,374	156%
Smart Metering System (Floors 8-12)	$39,000	34,912 kWh	$26,533	68%
Energy Recovery Ventilator (ERV)	$20,000	63,420 kWh	$48,200	241%
Phase Change Material (PCM)	$232,740	154,396 kWh	$117,344	50%
Exterior Insulated Panels (EIFS)	$529,710	72,052 kWh	$54,761	10%
Geo-Exchange (Entire System excl. Water DX Unit 6 & 7)	$1,470,000	178,850 kWh	$135,929	9%
Geo-Exchange Water DX Unit 6&7 (Geothermal)	$100,000	12,414 kWh	$9,435	9%
DC Microgrid P1 - Lighting & VFDs	$117,875	10,393 kWh	$7,899	7%
DC Microgrid P2 - Solar & Workspace	$30,125	18,120 kWh	$13,772	46%

Testing portfolios of combined technologies:	Cost Portfolio Tech ($)	Energy Impact Portfolio (kWh)	Potential NYSERDA Incentive ($)	% Cost Covered (50-75%)
Smart Metering System (Floors 8-12), Phase Change Materials, EIFS, Geo-Exchange DX Unit, DC Microgrids P1 & P2	$1,049,450	302,287 kWh	$229,744	22%
Advanced Lighting Controls, Phase Change Material, EIFS	$1,506,303	295,903 kWh	$224,892	15%
Geo-Exchange System (Entire System)	$1,570,000	191,264 kWh	$145,364	9%

Figure 18: Potential NYSERDA New Construction Program Incentives

6.3.4 Photovoltaic (PV) Incentive Program

NYSERDA offers incentives for new grid-connected solar PV system installations. The commercial site system program is capped at 50 kW.[133] The program generally covers about 25-35% of the installed cost of the system but not more than 40% of the owner out of pocket cost.[134] The current project incentive rate is $1.50 per watt or $1,500 per kW for commercial applications.[135] There is a cap to the incentive based on the system size. It may not exceed 110% of the total kWh consumption for the previous 12 months of electricity use.[136] The three PV technologies in our portfolio of recommendations are all eligible for the maximum incentive of $75,000, pending that these incentives are extended beyond 2015 or replaced by equivalent ones.

6.3.5 Property Tax Incentive for PV Equipment

PV systems installed in New York City are eligible for property tax abatement. All buildings are eligible with the exception of utility property.[137] This incentive allows for a portion of the expenditures associated with PV system installation to be deducted from the building's real property taxes.[138] Expenditures that are eligible for the incentive include: materials and labor associated with planning, designing, and installing the system.[139] PV systems that are placed into service during the time period of January 1, 2013 and December 31, 2014 are eligible for an abatement of 2.5% of eligible expenditures annually for 4 years, up to a limit of $62,500.[140]

NRDC only pays property taxes for the two floors that it rents to "for profit" tenants (floors 6 and 7). The 2009-2011 annual average property tax paid was $5,279.[141] As a result, the incentive would total $528 annually over a four-year period.

6.3.6 Con Edison Commercial & Industrial Energy Efficiency Program

Con Edison offers cash rebates and incentives for installing energy efficient electric and gas equipment and technical studies. Rebates are offered for upgrading equipment including lighting fixtures, LED exit signs, chillers, packaged heating, ventilation, and air-conditioning systems, motors, water and steam boilers.[142] Payment of up to 50% of costs, with a cap of $67,000, for an energy-efficiency technical study evaluating your energy use and recommending steps you can take to increase your gas and electric efficiency.[143] Customers with a monthly peak demand of 100 kW or less may qualify for incentives from Con Edison Small Business Energy Efficiency Program.[144]

Program Eligibility

To be eligible to participate in the Con Edison C&I Rebate Energy Efficiency Program and receive cash incentives, your business must:[145]

- Be a commercial or industrial electric or gas customer of Con Edison.
- Pay the systems benefit charge (SBC).
- Have not received an incentive from the New York State Energy Research and Development Authority (NYSERDA) or others for the same project.
- Install qualified equipment or make qualified energy efficiency upgrades at a project site located in the Con Edison service territory.

The air sealing solution included in our recommendation is eligible to this Con Edison rebate. Its amount of $0.12 per kWh up to a maximum of 70% of total project cost results in a $6,862 total rebate.[146]

6.4 Creative Financing Opportunities

6.4.1 Financing Capital Intensive Projects

We recommend that NRDC use project financing to avoid investing large amounts of cash upfront in the two concentrated solar PV rooftop installations $854,297 and $ 1,563,827, respectively, including cost of platforms. This is a common practice in the industry. Many manufacturers and/or installers offer this type of financial mechanism to their clients.

We assumed that NRDC could take out 20-year loans amounting to 75% of the total project costs at an annual interest rate of 6%. We also assumed that the loan amortization would follow an equal total payment plan i.e. the sum of the principal repayment and the interest payment is equal every year throughout the lifespan. We calculated a simplified version of the cash flows leaving out O&M costs and insurance.

NRDC can also consider taking out a loan to finance the $1,570,000 geo-exchange system. We have not included it in the model, as we do not have information on the characteristics of this type of loan, contrary to the solar, and we do not need to include a loan to remain within the $5,000,000 budget constraint.

Additionally, outlined below are several creative financing strategies for consideration. Only those that are currently available are listed below, financing strategies that were reviewed but not available at present can be found in Appendix 9.22 and should be referenced if NRDC decides to include additional technologies in the future that have not been discussed in this report.

6.4.2 Opportunity of selling Solar Renewable Energy Credits (SRECs)

New York State has a Renewable Portfolio Standard (RPS) requirement, and is part of the Region Greenhouse Gas Initiative (RGGI), which brings together states of the Northeastern United States. Yet, New York State has no SREC market as of today. Therefore, NRDC cannot sell solar renewable energy credits directly on an organized market to improve the profitability of the solar installations. NRDC could however sell renewable energy credits (RECs) on the voluntary market to utilities and/or buildings aiming to achieve a cleaner energy mix. The price of such credits would likely be lower than that on a compliance market. NRDC could register its offsets with a program certifier such as Green-e Climate to make its SRECs know from potential buyers.[147] It is possible that within the next 10 years New York may establish a mandatory SREC market similar to California.

6.4.3 Credit support from New York City Energy Efficiency Corporation (NYCEEC)

NYCEEC's aim is to assist building owners in New York City's five boroughs in making conversions to clean heat feasible through energy efficiency investments. NYCEEC assists building owners in exploring alternative financing solutions to help them complete projects.[148] In order to achieve this goal, NYCEEC works with banks and energy services companies to help them provide financing solutions that match property owners' needs. NYCEEC may also provide unsecured or partially secured loans to large building owners (over 50,000 square feet) to finance large energy retrofit projects.[149]

To be eligible buildings must meet the following criteria:[150]

- Existing buildings in all five boroughs of New York City.
- Large buildings – defined as 50,000 square feet or more – in the multifamily, affordable multifamily, commercial and institutional sectors.
- Buildings that are NOT owned and operated by state, local or federal government.

Project eligibility:[151]

- Installation of energy efficiency measures in existing buildings

- Inclusion of energy efficiency measures in building rehabs or tenant fit-outs
- Fuel conversions, under the City's Clean Heat Initiative, from #6 or #4 heating oil to ultra-low sulfur diesel or natural gas.
- Building-sited combined heat and power systems part of an energy efficiency retrofit.
- Projects designed to save at least 15% energy, as described in an ASHRAE level II audit.

6.4.4 NYSERDA On-Bill Financing

Small businesses, not-for-profits, and multifamily building owners can use the savings on their energy bills to pay for their energy efficiency upgrades.[152] In this particular case, the utility customer is the building's Condominium Association (NRDC has the majority share of the association, controls it and can make the final decision on this type of matter).

Program Eligibility: For small business, not-for-profit, and multifamily buildings, the borrower must be named on the utility account, but does not have to be the property owner. The business can qualify for On-Bill Recovery Financing if they have written authority from the property owner to make and finance the energy efficiency improvements in the property.[153]

6.4.5 Energy Savings Performance Contract (ESPC)

These contracts guarantee that improvements to a building will deliver a certain amount of water and energy savings over a fixed period of time.[154] Various organizations can be aided in paying for the costs of facility and infrastructure retrofits by using the energy and operational savings that are achieved as a result of the retrofits.[155]

There are various corporations and agencies that participate in ESPCs. Some include: ESCOs, Honeywell, Siemens, and Johnson Controls.[156] These companies have an appetite for very large projects ($20M or so) although they may look at smaller projects up to $5M.[157] They have worked with nonprofits, more on the institutional side.[158] NRDC's project might be of interest to these companies on the branding and/or communications side.[159]

6.4.6 Energy Services Agreements (ESA)

According to New York City Energy Efficiency Corporation an ESA is, "a contract that permits energy efficiency to be packaged as a service that building owners pay for through savings, and that generally requires no (or minimal) upfront cost to the owner."[160] ESAs can be used to finance a building retrofit instead of using equity or a traditional loan.[161]

6.4.7 Mortgage Debt

It is possible for NRDC to leverage their mortgage debt. Banks would most likely be comfortable with financing capital improvements with short pay-backs (i.e., 1-2 years).[162] The chances that they would consider financing investments with a longer payback are slim.[163] Other options include refinancing the existing mortgage (include investments in refinancing after discussion with mortgage provider) and taking out a second mortgage.[164]

6.4.8 Fundraising

Fundraising specifically for this project is another option, such as a capital campaign or applying for grants. Other nonprofit organizations have been able to fundraise for similar projects. Since this will be the first net zero retrofit project of this type in New York City it provides a unique opportunity for funders. The Friends Center in Philadelphia was able to fundraise $4.1M for their energy retrofit/LEED® Platinum renovation project.[165] They conducted a fundraising feasibility study for a non-green building project, which showed limited fundraising prospects. When they changed the plans to a landmark green building complex the fundraising capacity was projected to be $1.5M to $2M.[166] They were able to exceed these projections, with $1.3M alone being donated for the geothermal wells.[167]

Another nonprofit, The Aldo Leopold Legacy Center, also fundraised for their project. They conducted a multiyear $6.9M capital fundraising effort.[168] They received a $300,000 challenge grant as well as a $50,000 green building-planning grant.[169]

6.5 Overall Budget Recommendations

Taking into account the implementation timeline of the recommended technologies, as well as the incentives available and the reinvested savings, the budget spending does not go beyond the $5 million constraint over the 2013-2022 period (10-year budget period during which all investments are scheduled to be made). If a more conservative approach is taken, where NRDC reinvests savings but does not obtain the incentives and rebates described in the incentives section, the budget spending still does not exceed the $5 million threshold.

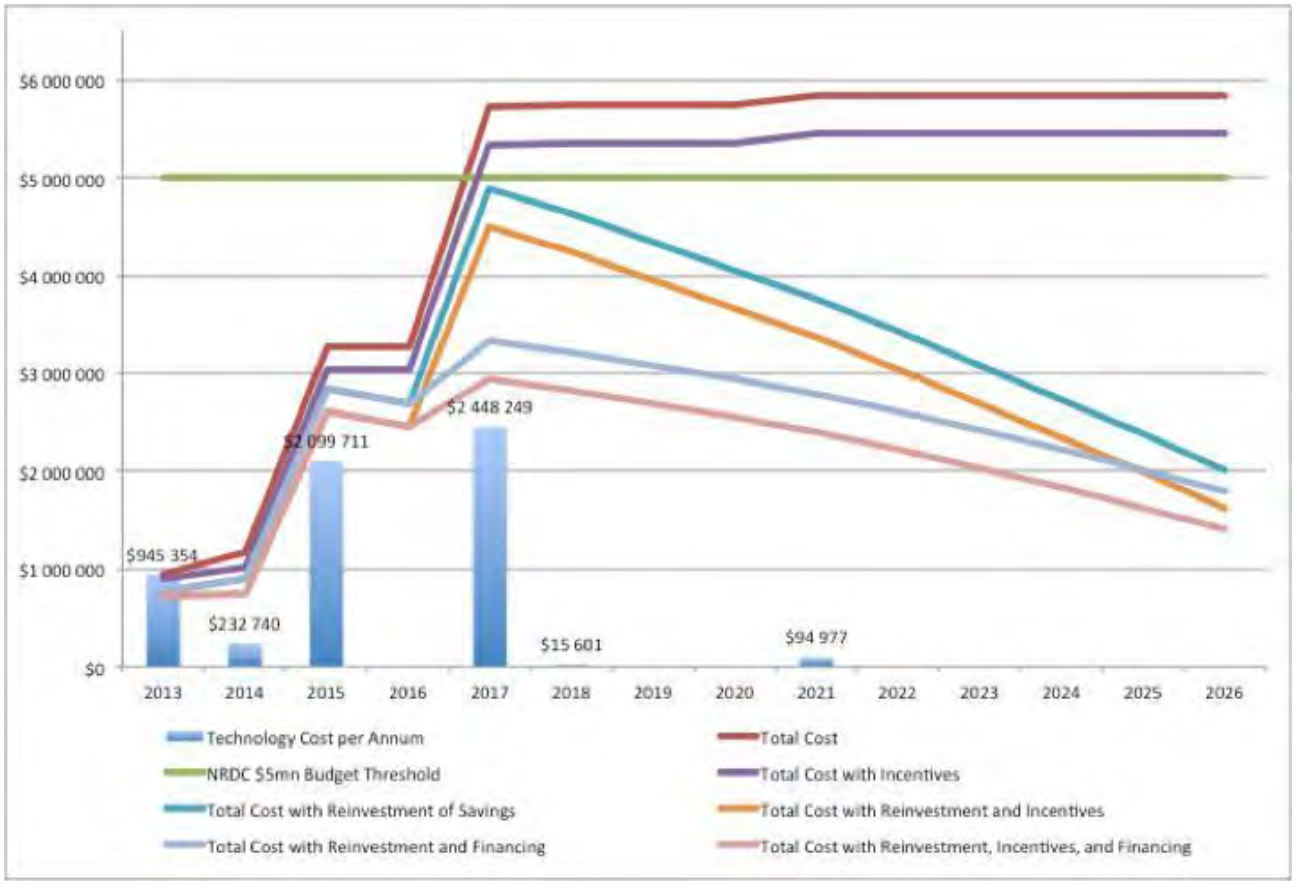


Figure 19: Project cost projection scenarios

7. CONCLUSION

The Capstone team created a roadmap to achieve net zero site energy on time and under budget for the NRDC headquarters building in New York. The team surveyed the field of highly efficient and sustainable building technologies, and extracted strategies and data from relevant case studies. A custom-made energy systems Data Model and a Financial Model helped model the long-term energy performance of the solutions portfolio and resulting return-on-investment. The report illustrates a cost-effective path to attaining a challenging and unprecedented urban net zero site energy goal.

Following the roadmap laid out herein, improvements in energy efficiency, matched with increases in generation capacity would allow NRDC to balance energy consumption with on-site generation at 375,000 kWh per year by 2021.

NRDC has achieved extensive accolades through existing efficiency initiatives, renewable energy use and sustainability principles rooted in the organization's mission to promote a sustainable future for humankind. Using a comprehensive, future-looking plan to achieve net zero will move NRDC beyond efficiency into the realm of next-generation high-performance buildings that minimize depletion of earth's resources.

Through an extensive retrofit, NRDC can achieve site net zero energy in under 10 years for a net cost of less than $5 million at the Manhattan headquarters. Targeting net zero using this plan will help further NRDC's reputation as a global pioneer in urban energy efficiency, improving on their already exemplary reputation as a leading environmental advocacy organization.

The solutions presented in this roadmap show that net zero is achievable -- not only in new construction and non-urban environments – but also in the highest density urban settings. When fully implemented, this proof of concept could serve as the catalyst for other site net zero retrofits across New York City and in similar urban environments. As such, NRDC can set an example leading to a substantial reduction of fossil energy consumption well beyond 40 West 20th Street.

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9. APPENDIX

9.1 DATA MODEL

Please see following tables for all detailed analyses.

A year-over-year output of the energy balance for the NRDC building linking historical data from 2010-2012 and future projections based on the technical recommendations in the report (page 1 of 2):

Annual Data Model - Electricity and Heating Loads 2010-2022

ENERGY BALANCE

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ALL ENERGY													
Baseline Energy Consumption - kWh	1,337,446	1,264,986	1,203,337	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204	1,199,204
Efficiency Recommendations - kWh	0	0	0	299,289	448,227	711,542	711,542	726,427	834,263	834,263	834,263	834,263	834,263
Total Consumption with Efficiency Recs - kWh	1,337,446	1,264,986	1,203,337	899,915	750,977	487,662	487,662	472,777	364,941	364,941	364,941	364,941	364,941
Production Recommendations - kWh	0	0	3,322	6,404	6,687	15,688	15,688	300,243	300,243	300,243	300,243	364,941	364,941
ENERGY BALANCE - ELECTRICITY - kWh	**-1,337,446**	**-1,264,986**	**-1,200,015**	**-893,511**	**-744,290**	**-471,974**	**-471,974**	**-172,535**	**-64,698**	**-64,698**	**-64,698**	**0**	**0**
ELECTRICITY													
Baseline Grid Electricity Consumption - kWh	960,432	876,404	794,028	794,028	794,028	794,028	794,028	794,028	794,028	794,028	794,028	794,028	794,028
Efficiency Recommendations - kWh	0	0	0	196,781	254,918	315,367	315,367	330,252	438,088	438,088	438,088	438,088	438,088
Total Consumption with Efficiency Recs - kWh	960,432	876,404	794,028	597,247	539,110	478,661	478,661	463,776	355,940	355,940	355,940	355,940	355,940
Production Recommendations - kWh	0	0	3,322	6,404	6,687	6,687	6,687	291,242	291,242	291,242	291,242	355,940	355,940
ENERGY BALANCE - ELECTRICITY - kWh	**-960,432**	**-876,404**	**-790,706**	**-590,843**	**-532,422**	**-471,974**	**-471,974**	**-172,535**	**-64,698**	**-64,698**	**-64,698**	**0**	**0**
THERMAL HEATING													
Baseline Thermal Consumption - heating mmbtu	1,286	1,326	1,396	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382
Efficiency Recommendations - heating mmbtu	0	0	0	350	660	1,352	1,352	1,352	1,352	1,352	1,352	1,352	1,352
Total Consumption with Efficiency Recs - heating mmbtu	1,286	1,326	1,396	1,033	723	31	31	31	31	31	31	31	31
Production Recommendations - heating mmbtu	0	0	0	0	0	31	31	31	31	31	31	31	31
ENERGY BALANCE - THERMAL	**-1,286**	**-1,326**	**-1,396**	**-1,033**	**-723**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

BASELINE ENERGY CONSUMPTION - Business As Usual (BAU)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
THERMAL - heating mmbtu													
Boiler Consumption - heating mmbtu	1,286	1,326	1,396	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,382
TOTAL THERMAL BASELINE - heating mmbtu	**1,286**	**1,326**	**1,396**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**	**1,382**
GRID ELECTRICITY BY FLOOR - kWh													
Baseline Floor 6	152,952	126,896	131,792	131,792	131,792	131,792	131,792	131,792	131,792	131,792	131,792	131,792	131,792
Baseline Floor 7	168,772	178,798	173,056	173,056	173,056	173,056	173,056	173,056	173,056	173,056	173,056	173,056	173,056
Baseline Floor 8	101,276	92,036	90,484	90,484	90,484	90,484	90,484	90,484	90,484	90,484	90,484	90,484	90,484
Baseline Floor 9	96,799	89,097	73,079	73,079	73,079	73,079	73,079	73,079	73,079	73,079	73,079	73,079	73,079
Baseline Floor 10	96,156	76,108	38,616	38,616	38,616	38,616	38,616	38,616	38,616	38,616	38,616	38,616	38,616
Baseline Data Center UPS	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317
Baseline Data Center AC	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004	36,004
Baseline Floor 11	107,832	91,448	71,076	71,076	71,076	71,076	71,076	71,076	71,076	71,076	71,076	71,076	71,076
Baseline Floor 12	79,324	64,700	58,604	58,604	58,604	58,604	58,604	58,604	58,604	58,604	58,604	58,604	58,604
BASELINE GRID ELECTRICITY CONSUMPTION - kWh	**960,432**	**876,404**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**
GRID ELECTRICITY BY LOAD - kWh													
Air Conditioning	N/A	N/A	302,166	302,166	302,166	302,166	302,166	302,166	302,166	302,166	302,166	302,166	302,166
Pump Usage	N/A	N/A	12,650	12,650	12,650	12,650	12,650	12,650	12,650	12,650	12,650	12,650	12,650
Cooling Tower	N/A	N/A	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514	5,514
Domestic Hot Water (DHW)	N/A	N/A	18,743	18,743	18,743	18,743	18,743	18,743	18,743	18,743	18,743	18,743	18,743
Plug Load	N/A	N/A	248,080	248,080	248,080	248,080	248,080	248,080	248,080	248,080	248,080	248,080	248,080
Lighting	N/A	N/A	85,558	85,558	85,558	85,558	85,558	85,558	85,558	85,558	85,558	85,558	85,558
Data Center UPS	N/A	N/A	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317	121,317
BASELINE GRID ELECTRICITY CONSUMPTION - kWh	**N/A**	**N/A**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**	**794,028**

A year-over-year output of the energy balance for the NRDC building linking historical data from 2010-2012 and future projections based on the technical recommendations in the report (page 2 of 2):.

ENERGY EFFICIENCY SAVINGS

GRID ELECTRICITY REDUCTION RECOMMENDATIONS													
CG ECM 5 - VFDs on AC Fan Motor	0	0	0	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084
ERVs for AC Efficiency	0	0	0	0	4,541	4,541	4,541	4,541	4,541	4,541	4,541	4,541	4,541
Air Sealing	0	0	0	23,554	23,554	23,554	23,554	23,554	23,554	23,554	23,554	23,554	23,554
Phase Change Materials - kWh	0	0	0	0	63,596	63,596	63,596	63,596	63,596	63,596	63,596	63,596	63,596
Exterior Insulation Finishing System (EIFS) - kWh	0	0	0	0	0	29,678	29,678	29,678	29,678	29,678	29,678	29,678	29,678
CG ECM 1 - AC Schedule Shift	0	0	0	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479
Advanced Lighting Controls - kWh	0	0	0	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335
CG ECM 4 - VFDs on Condenser Pump	0	0	0	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024
Smart Metering System Fl 8-12	0	0	0	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912
Smart Metering System Fl 6-7	0	0	0	0	0	0	0	0	32,070	32,070	32,070	32,070	32,070
ERV Electricity Draw	0	0	0	0	-10,000	-10,000	-10,000	-10,000	-10,000	-10,000	-10,000	-10,000	-10,000
Geothermal Cooling - kWh	0	0	0	0	0	64,633	64,633	64,633	64,633	64,633	64,633	64,633	64,633
Geothermal Well Pumps	0	0	0	0	0	-9,472	-9,472	-9,472	-9,472	-9,472	-9,472	-9,472	-9,472
Geothermal Heat Pump	0	0	0	0	0	-36,805	-36,805	-36,805	-36,805	-36,805	-36,805	-36,805	-36,805
Additional CRAC units Fls 6 & 7	0	0	0	0	0	12,414	12,414	12,414	12,414	12,414	12,414	12,414	12,414
Reduce tenant load via lease to equal NRDC floors - kWh	0	0	0	0	0	0	0	0	75,766	75,766	75,766	75,766	75,766
DC Microgrid - Lighting	0	0	0	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422
DC Microgrid - Plug load	0	0	0	0	0	0	0	14,885	14,885	14,885	14,885	14,885	14,885
DC Microgrid - Pumps	0	0	0	763	763	763	763	763	763	763	763	763	763
DC Microgrid - VFDs	0	0	0	6,208	6,208	6,208	6,208	6,208	6,208	6,208	6,208	6,208	6,208
TOTAL GRID ELECTRICITY EFFICIENCY SAVINGS - kWh	**0**	**0**	**0**	**196,781**	**254,918**	**315,367**	**315,367**	**330,252**	**438,088**	**438,088**	**438,088**	**438,088**	**438,088**
THERMAL EFFICIENCY RECOMMENDATIONS													
ERV - mmbtu	0	0	0	235	235	235	235	235	235	235	235	235	235
Air Sealing	0	0	0	115	115	115	115	115	115	115	115	115	115
Phase Change Materials - mmbtu	0	0	0	0	310	310	310	310	310	310	310	310	310
Exterior Insulation Finishing System (EIFS) - mmbtu	0	0	0	0	0	145	145	145	145	145	145	145	145
Geothermal Heating - mmbtu	0	0	0	0	0	548	548	548	548	548	548	548	548
TOTAL THERMAL EFFICIENCY SAVINGS - mmbtu	**0**	**0**	**0**	**350**	**660**	**1,352**	**1,352**	**1,352**	**1,352**	**1,352**	**1,352**	**1,352**	**1,352**

ENERGY PRODUCTION

ELECTRICITY PRODUCTION - kWh													
Existing Solar PV - kWh	0	0	3,322	6,404	6,687	6,687	6,687	0	0	0	0	0	0
Solar Concentrating PV - kWh	0	0	0	0	0	0	0	101,220	101,220	101,220	101,220	101,220	101,220
Vertical Solar around PV Structures	0	0	0	0	0	0	0	0	0	0	0	64,698	64,698
DC Microgrid - Solar	0	0	0	0	0	0	0	3,235	3,235	3,235	3,235	3,235	3,235
Solar Concentrating PV Extended - kWh	0	0	0	0	0	0	0	186,787	186,787	186,787	186,787	186,787	186,787
Total Available Production - kWh	**0**	**0**	**3,322**	**6,404**	**6,687**	**6,687**	**6,687**	**291,242**	**291,242**	**291,242**	**291,242**	**355,940**	**355,940**
THERMAL PRODUCTION - mmbtu													
Biofuels in existing boiler	0	0	0	0	0	31	31	31	31	31	31	31	31
TOTAL ENERGY PRODUCTION - mmbtu	**0**	**0**	**0**	**0**	**0**	**31**	**31**	**31**	**31**	**31**	**31**	**31**	**31**

Electricity and Heating Loads 2010-2022, summarized by month with granular data per floor. This serves as the basis for many of the other sheets and calculations (page 1 of 3):

Monthly Data Model - Electricity and Heating Loads 2010-2022

					6	7	8	9	10			11	12	Total									
ANYTHING THIS COLOR IS BASED ON A MODEL					Electricity Consumption (kWh): All (AC, Plugload, Lighting, DHW, etc.)																		
Project Phase	Month	Start Date	End Date	# of Days	Tenant Fl 6	Tenant Fl 7	NRDC Fl 8	NRDC Fl 9	NRDC Fl 10	NRDC Data Center kWh	NRDC Data Center AC kWh	NRDC Fl 11	NRDC Fl 12	Total kWh Used	Est Baseload	Total HDD	Total CDD	Estimated Fuel Used (gal)	Fuel Used (mmbtu)	Estimated Fuel Cost	Estimated kWh Cost	Total Energy Input Costs	Solar Output (existing, kWh)
Historical	Jan-2010	1/11/2010	2/11/2010	31	14,344	15,364	8,324	5,729	6,576	10,110	3,000	7,788	7,580	78,815		953	0	2698	372	$8,055	$16,675	$24,730	
Historical	Feb-2010	2/11/2010	3/12/2010	29	12,756	12,712	7,352	4,961	6,228	10,110	3,000	6,940	5,764	69,823		754	0	2284	315	$6,819	$14,773	$21,592	
Historical	Mar-2010	3/12/2010	4/12/2010	31	13,908	9,364	7,044	6,007	7,184	10,110	3,000	8,776	5,196	70,589		323	20	1110	153	$3,314	$14,935	$18,249	
Historical	Apr-2010	4/12/2010	5/10/2010	28	10,940	7,412	8,296	5,667	7,012	10,110	3,000	8,072	4,728	65,237		213	48	0	0	$0	$13,802	$13,802	
Historical	May-2010	5/10/2010	6/9/2010	30	10,524	10,484	7,956	9,115	7,976	10,110	3,000	9,252	6,120	74,537		67	151	0	0	$0	$15,770	$15,770	
Historical	Jun-2010	6/9/2010	7/9/2010	30	15,776	15,860	9,096	9,772	8,540	10,110	3,000	10,616	7,128	89,898		0	374	0	0	$0	$19,020	$19,020	
Historical	Jul-2010	7/9/2010	8/10/2010	32	19,144	18,908	9,976	11,767	10,484	10,110	3,000	11,960	8,188	103,537		0	518	0	0	$0	$21,905	$21,905	
Historical	Aug-2010	8/10/2010	9/9/2010	30	16,116	16,932	9,116	9,841	9,052	10,110	3,000	10,048	6,876	91,091		0	337	0	0	$0	$19,272	$19,272	
Historical	Sep-2010	9/9/2010	10/7/2010	28	12,156	13,352	8,028	9,042	8,148	10,110	3,000	8,972	6,120	78,928		46	91	0	0	$0	$16,699	$16,699	
Historical	Oct-2010	10/7/2010	11/5/2010	29	12,156	13,352	7,944	8,825	8,272	10,110	3,000	8,512	6,584	78,755		269	9	0	0	$0	$16,662	$16,662	
Historical	Nov-2010	11/5/2010	12/9/2010	34	8,384	16,388	8,484	8,812	8,972	10,110	3,000	9,100	7,808	81,058		678	0	1263	174	$3,771	$17,150	$20,920	
Historical	Dec-2010	12/9/2010	1/10/2011	32	6,748	18,644	9,660	7,261	7,712	10,110	3,000	7,796	7,232	78,163		1037	0	1966	271	$5,870	$16,537	$22,407	
Historical	Jan-2011	1/10/2011	2/9/2011	30	7,520	20,828	11,860	7,590	7,776	10,110	3,000	7,956	6,216	82,856		1069	0	3313	457	$9,891	$17,530	$27,421	
Historical	Feb-2011	2/9/2011	3/11/2011	30	7,860	9,964	7,808	8,730	9,604	10,110	3,000	9,128	6,508	72,712		764	0	2299	317	$6,864	$15,384	$22,248	
Historical	Mar-2011	3/11/2011	4/12/2011	32	8,044	12,356	8,520	8,560	11,676	10,110	3,000	9,280	5,804	77,350		612	1	1500	207	$4,478	$16,365	$20,843	
Historical	Apr-2011	4/12/2011	5/10/2011	28	7,940	12,028	4,356	7,999	13,524	10,110	3,000	8,700	4,204	71,861	60,425	196	12	0	0	$0	$15,204	$15,204	
Historical	May-2011	5/10/2011	6/9/2011	30	11,912	15,566	5,944	8,709	10,700	10,110	3,000	9,004	5,488	80,433	60,425	54	166	0	0	$0	$17,017	$17,017	
Historical	Jun-2011	6/9/2011	7/11/2011	32	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	60,425	0	294	0	0	$0	$18,067	$18,067	
Historical	Jul-2011	7/11/2011	8/9/2011	29	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	60,425	0	468	0	0	$0	$17,888	$17,888	
Historical	Aug-2011	8/9/2011	9/8/2011	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	60,425	0	256	0	0	$0	$15,903	$15,903	
Historical	Sep-2011	9/8/2011	10/7/2011	29	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	60,425	76	117	0	0	$0	$13,862	$13,862	
Historical	Oct-2011	10/7/2011	11/7/2011	31	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	60,425	313	17	50	7	$149	$12,336	$12,486	
Historical	Nov-2011	11/7/2011	12/9/2011	32	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	60,425	428	0	710	98	$2,120	$13,581	$15,701	
Historical	Dec-2011	12/9/2011	1/10/2012	32	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	60,425	779	0	1735	239	$5,180	$12,285	$17,465	
Historical	Jan-2012	1/10/2012	2/9/2012	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	60,425	868	0	2678	370	$7,995	$12,433	$20,429	105.18
Historical	Feb-2012	2/9/2012	3/10/2012	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	60,425	693	0	2118	292	$6,323	$12,764	$19,087	445.83
Historical	Mar-2012	3/10/2012	4/10/2012	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	60,425	343	4	1048	145	$3,129	$12,279	$15,408	53.84
Historical	Apr-2012	4/10/2012	5/10/2012	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	60,425	250	20	0	0	$0	$12,326	$12,326	0
Historical	May-2012	5/10/2012	6/9/2012	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	60,425	33	114	0	0	$0	$14,270	$14,270	22.03
Projection	Jun-2012	6/9/2012	7/10/2012	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	60,425	0	352	0	0	$0	$18,067	$18,067	690.5
Projection	Jul-2012	7/10/2012	8/10/2012	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	60,425	0	405	0	0	$0	$17,888	$17,888	717.9
Projection	Aug-2012	8/10/2012	9/9/2012	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	60,425	0	299	0	0	$0	$15,903	$15,903	695.2
Projection	Sep-2012	9/9/2012	10/9/2012	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	60,425	78	74	176	24	$525	$13,862	$14,386	591.5
Projection	Oct-2012	10/9/2012	11/8/2012	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	60,425	340	3	768	106	$2,294	$12,336	$14,630	
Projection	Nov-2012	11/8/2012	12/9/2012	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	60,425	580	0	1311	181	$3,914	$13,581	$17,495	
Projection	Dec-2012	12/9/2012	1/9/2013	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	60,425	894	0	2020	279	$6,032	$12,285	$18,317	0.0
Netzero	Jan-2013	1/9/2013	2/8/2013	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766		993	0	2245	310	$6,702	$12,433	$19,135	105.2
Netzero	Feb-2013	2/8/2013	3/10/2013	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328		771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2013	3/10/2013	4/10/2013	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038		479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2013	4/10/2013	5/10/2013	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257		233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2013	5/10/2013	6/9/2013	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447		61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2013	6/9/2013	7/10/2013	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393		3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2013	7/10/2013	8/10/2013	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550		0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2013	8/10/2013	9/9/2013	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168		0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2013	9/9/2013	10/9/2013	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517		75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2013	10/9/2013	11/8/2013	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308		334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2013	11/8/2013	12/9/2013	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190		562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2013	12/9/2013	1/9/2014	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065		921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2014	1/9/2014	2/8/2014	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766		993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2014	2/8/2014	3/10/2014	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328		771	0	1743	241	$5,203	$12,764	$17,967	445.8

Electricity and Heating Loads 2010-2022, summarized by month with granular data per floor. This serves as the basis for many of the other sheets and calculations (page 2 of 3):

Netzero	Mar-2014	3/10/2014	4/10/2014	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2014	4/10/2014	5/10/2014	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2014	5/10/2014	6/9/2014	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2014	6/9/2014	7/10/2014	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2014	7/10/2014	8/10/2014	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2014	8/10/2014	9/9/2014	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2014	9/9/2014	10/9/2014	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2014	10/9/2014	11/8/2014	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2014	11/8/2014	12/9/2014	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2014	12/9/2014	1/9/2015	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2015	1/9/2015	2/8/2015	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2015	2/8/2015	3/10/2015	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2015	3/10/2015	4/10/2015	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2015	4/10/2015	5/10/2015	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2015	5/10/2015	6/9/2015	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2015	6/9/2015	7/10/2015	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2015	7/10/2015	8/10/2015	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2015	8/10/2015	9/9/2015	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2015	9/9/2015	10/9/2015	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2015	10/9/2015	11/8/2015	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2015	11/8/2015	12/9/2015	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2015	12/9/2015	1/9/2016	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2016	1/9/2016	2/8/2016	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2016	2/8/2016	3/9/2016	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2016	3/9/2016	4/9/2016	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2016	4/9/2016	5/10/2016	31	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	241	32	544	75	$1,625	$12,326	$13,951	549.3
Netzero	May-2016	5/10/2016	6/9/2016	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	53	128	120	17	$358	$14,270	$14,628	609.7
Netzero	Jun-2016	6/9/2016	7/10/2016	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	297	6	1	$19	$18,067	$18,085	690.5
Netzero	Jul-2016	7/10/2016	8/10/2016	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	426	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2016	8/10/2016	9/9/2016	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	291	1	0	$2	$15,903	$15,905	695.2
Netzero	Sep-2016	9/9/2016	10/9/2016	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	78	74	176	24	$525	$13,862	$14,386	618.7
Netzero	Oct-2016	10/9/2016	11/8/2016	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	340	3	768	106	$2,294	$12,336	$14,630	550.7
Netzero	Nov-2016	11/8/2016	12/9/2016	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	580	0	1311	181	$3,914	$13,581	$17,495	490.1
Netzero	Dec-2016	12/9/2016	1/9/2017	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	894	0	2020	279	$6,032	$12,285	$18,317	436.2
Netzero	Jan-2017	1/9/2017	2/8/2017	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2017	2/8/2017	3/10/2017	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2017	3/10/2017	4/10/2017	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2017	4/10/2017	5/10/2017	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2017	5/10/2017	6/9/2017	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2017	6/9/2017	7/10/2017	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2017	7/10/2017	8/10/2017	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2017	8/10/2017	9/9/2017	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2017	9/9/2017	10/9/2017	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2017	10/9/2017	11/8/2017	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2017	11/8/2017	12/9/2017	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2017	12/9/2017	1/9/2018	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2018	1/9/2018	2/8/2018	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2018	2/8/2018	3/10/2018	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2018	3/10/2018	4/10/2018	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2018	4/10/2018	5/10/2018	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2018	5/10/2018	6/9/2018	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2018	6/9/2018	7/10/2018	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2018	7/10/2018	8/10/2018	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2018	8/10/2018	9/9/2018	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2018	9/9/2018	10/9/2018	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2018	10/9/2018	11/8/2018	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2018	11/8/2018	12/9/2018	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2018	12/9/2018	1/9/2019	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2019	1/9/2019	2/8/2019	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2

Electricity and Heating Loads 2010-2022, summarized by month with granular data per floor. This serves as the basis for many of the other sheets and calculations (page 3 of 3):

Netzero	Feb-2019	2/8/2019	3/10/2019	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2019	3/10/2019	4/10/2019	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2019	4/10/2019	5/10/2019	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2019	5/10/2019	6/9/2019	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2019	6/9/2019	7/10/2019	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2019	7/10/2019	8/10/2019	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2019	8/10/2019	9/9/2019	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2019	9/9/2019	10/9/2019	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2019	10/9/2019	11/8/2019	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2019	11/8/2019	12/9/2019	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2019	12/9/2019	1/9/2020	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2020	1/9/2020	2/8/2020	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2020	2/8/2020	3/9/2020	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2020	3/9/2020	4/9/2020	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2020	4/9/2020	5/9/2020	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2020	5/9/2020	6/9/2020	31	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	128	138	19	$412	$14,270	$14,682	609.7
Netzero	Jun-2020	6/9/2020	7/10/2020	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	297	6	1	$19	$18,067	$18,085	690.5
Netzero	Jul-2020	7/10/2020	8/10/2020	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	426	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2020	8/10/2020	9/9/2020	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	291	1	0	$2	$15,903	$15,905	695.2
Netzero	Sep-2020	9/9/2020	10/9/2020	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	78	74	176	24	$525	$13,862	$14,386	618.7
Netzero	Oct-2020	10/9/2020	11/8/2020	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	340	3	768	106	$2,294	$12,336	$14,630	550.7
Netzero	Nov-2020	11/8/2020	12/9/2020	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	580	0	1311	181	$3,914	$13,581	$17,495	490.1
Netzero	Dec-2020	12/9/2020	1/9/2021	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	894	0	2020	279	$6,032	$12,285	$18,317	436.2
Netzero	Jan-2021	1/9/2021	2/8/2021	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2021	2/8/2021	3/10/2021	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2021	3/10/2021	4/10/2021	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2021	4/10/2021	5/10/2021	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2021	5/10/2021	6/9/2021	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2021	6/9/2021	7/10/2021	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2021	7/10/2021	8/10/2021	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2021	8/10/2021	9/9/2021	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2021	9/9/2021	10/9/2021	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2021	10/9/2021	11/8/2021	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2021	11/8/2021	12/9/2021	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2021	12/9/2021	1/9/2022	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2
Netzero	Jan-2022	1/9/2022	2/8/2022	30	9,180	11,080	6,904	5,300	3,188	10,110	3,000	5,272	4,732	58,766	993	0	2245	310	$6,702	$12,433	$19,135	388.2
Netzero	Feb-2022	2/8/2022	3/10/2022	30	10,144	11,472	7,300	5,174	3,244	10,110	3,000	5,060	4,824	60,328	771	0	1743	241	$5,203	$12,764	$17,967	445.8
Netzero	Mar-2022	3/10/2022	4/10/2022	31	8,956	12,760	6,856	4,852	2,988	10,110	3,000	4,376	4,140	58,038	479	6	1083	149	$3,234	$12,279	$15,513	494.9
Netzero	Apr-2022	4/10/2022	5/10/2022	30	8,296	13,752	6,860	4,871	3,024	10,110	3,000	4,300	4,044	58,257	233	32	526	73	$1,571	$12,326	$13,897	549.3
Netzero	May-2022	5/10/2022	6/9/2022	30	11,596	15,936	9,016	5,373	3,344	10,110	3,000	4,688	4,384	67,447	61	123	137	19	$408	$14,270	$14,678	609.7
Netzero	Jun-2022	6/9/2022	7/10/2022	31	13,556	20,536	6,588	9,979	3,452	10,110	3,000	11,036	7,136	85,393	3	289	7	1	$22	$18,067	$18,089	690.5
Netzero	Jul-2022	7/10/2022	8/10/2022	31	14,768	23,420	6,372	7,852	3,988	10,110	3,000	8,796	6,244	84,550	0	425	0	0	$0	$17,888	$17,888	717.9
Netzero	Aug-2022	8/10/2022	9/9/2022	30	13,188	17,396	9,412	9,122	2,880	10,110	3,000	5,644	4,416	75,168	0	301	0	0	$0	$15,903	$15,903	695.2
Netzero	Sep-2022	9/9/2022	10/9/2022	30	13,548	14,572	6,228	5,179	3,188	10,110	3,000	5,544	4,148	65,517	75	77	168	23	$503	$13,862	$14,365	618.7
Netzero	Oct-2022	10/9/2022	11/8/2022	30	11,412	10,788	5,832	5,058	2,908	10,110	3,000	5,088	4,112	58,308	334	5	754	104	$2,251	$12,336	$14,588	550.7
Netzero	Nov-2022	11/8/2022	12/9/2022	31	9,576	11,184	10,012	5,600	3,336	10,110	3,000	6,000	5,372	64,190	562	0	1271	175	$3,794	$13,581	$17,375	490.1
Netzero	Dec-2022	12/9/2022	1/9/2023	31	7,572	10,160	9,104	4,719	3,076	10,110	3,000	5,272	5,052	58,065	921	0	2083	287	$6,218	$12,285	$18,503	436.2

Facts and figures included in various parts of the report, either scientific calculations or key inputs from NRDC:

Analysis Assumptions

Assumption	Metric Used	Units / Source
Heating Degree Days Calculation - Baseline Temperature	65	°F
Cooling Degree Days Calculation - Baseline Temperature	65	°F
Cost per kWh from grid	$0.212	$/kwh
Cost per Gallon Fuel (#2)	$2.986	$/gal #2
mmbtu in Gallon Fuel (#2)	0.1380	http://www.nchh.org/Portals/0/contents/Exercise_1_Benchmarking1.pdf
1 kwh to x mmbtu	0.003412	http://www.think-energy.net/energy_units.htm
1 mmbtu to x kwh	293.1	http://www.think-energy.net/energy_units.htm
kWh = 1 ton	3.517	http://www.unitconversion.org/power/kilowatts-to-tons-refrigeration-conversion.html
btu/hr = 1 ton	12000	http://www.unitconversion.org/power/kilowatts-to-tons-refrigeration-conversion.html
per ton of capacity	$140,000	Installed cost of geothermal system in NYC based on case study benchmarks
% plug load from laptops	40%	Estimate based on survey of floor plan

This is data extracted from the Energy Analysis commissioned by NRDC performed by Code Green Solutions. We used it as the baseline for load assumptions by load type, including AC usage, pump usage, cooling tower usage, domestic hot water, plug load, lighting, and data center load. We also used it to model three of their recommendations that we include in the overall Net Zero energy balance:

CODE GREEN REPORT - Electricity Usage by Load Type

(from Energy Report 9-11-12)

	Current State				Implement Code Green ECMs		
	Total Grid Energy Costs	% By Activity (non-data center)	Annual kWh by Activity		Total kWh Savings by Category	Revised Annual kWh by Activity	Revised % By Activity
AC Usage	$71,684	41.8%	302,166		86,212	215,954	39.2%
Pumping Usage	$3,407	2.0%	12,650		5,024	7,626	1.4%
Cooling Tower Usage	$1,485	0.9%	5,514		0	5,514	1.0%
DHW	$5,048	2.9%	18,743		0	18,743	3.4%
Plug Load	$66,814	39.0%	248,080		1,725	246,355	44.7%
Lighting	$23,043	13.4%	85,558		29,142	56,416	10.2%
Data Center UPS	$26,200		121,317		0	121,317	22.0%
TOTAL	**$171,481**	**100.0%**	**794,028**		**122,103**	**671,925**	**100.0%**
Cost per kWh - estimated			$0.216				

Description		**Cost**	**Rebates**	**kwh saved**	
AC - Modify activity times	CG ECM 1	$0	$0	24,128	
Lighting Upgrade	CG ECM 2	$11,442	$0	10,682	Redwood Recommendation encompasses this
Lighting - Occupancy Sensor (same as Nazanin)	CG ECM 3	$15,261	$3,400	18,460	Redwood Recommendation encompasses this
Pump Usage	CG ECM 4	$3,890	$900	5,024	
AC	CG ECM 5	$25,860	$4,350	62,084	
Plug Load	CG ECM 6	$500	$0	1,725	Too small to mention

2010 consumption of grid electricity by floor:

CLIENT INPUT - 2010 Electricity Consumption

Month	Period start reading date	Period end reading date	F6 Use (kWh)	F7 Use (kWh)	F8 Use (kWh)	F9 Use (kWh)	F10 Use (kWh)	F11 Use (kWh)	F12 Use (kWh)	Total kWh
Jan-10	01/11/10	02/11/10	14,344	15,364	8,324	5,729	6,576	7,788	7,580	65,705
Feb-10	02/11/10	03/12/10	12,756	12,712	7,352	4,961	6,228	6,940	5,764	56,713
Mar-10	03/12/10	04/12/10	13,908	9,364	7,044	6,007	7,184	8,776	5,196	57,479
Apr-10	04/12/10	05/10/10	10,940	7,412	8,296	5,667	7,012	8,072	4,728	52,127
May-10	05/10/10	06/09/10	10,524	10,484	7,956	9,115	7,976	9,252	6,120	61,427
Jun-10	06/09/10	07/09/10	15,776	15,860	9,096	9,772	8,540	10,616	7,128	76,788
Jul-10	07/09/10	08/10/10	19,144	18,908	9,976	11,767	10,484	11,960	8,188	90,427
Aug-10	08/10/10	09/09/10	16,116	16,932	9,116	9,841	9,052	10,048	6,876	77,981
Sep-10	09/09/10	10/07/10	12,156	13,352	8,028	9,042	8,148	8,972	6,120	65,818
Oct-10	10/07/10	11/05/10	12,156	13,352	7,944	8,825	8,272	8,512	6,584	65,645
Nov-10	11/05/10	12/09/10	8,384	16,388	8,484	8,812	8,972	9,100	7,808	67,948
Dec-10	12/09/10	01/10/11	6,748	18,644	9,660	7,261	7,712	7,796	7,232	65,053
Total	01/10/11		**152,952**	**168,772**	**101,276**	**96,799**	**96,156**	**107,832**	**79,324**	**803,111**

Days in mo	F6 kWh/day	F7 kWh/day	F8 kWh/day	F9 kWh/day	F10 kWh/day	F11 kWh/day	F12 kWh/day	Total kWh/day
31	463	496	269	185	212	251	245	2,120
29	440	438	254	171	215	239	199	1,956
31	449	302	227	194	232	283	168	1,854
28	391	265	296	202	250	288	169	1,862
30	351	349	265	304	266	308	204	2,048
30	526	529	303	326	285	354	238	2,560
32	598	591	312	368	328	374	256	2,826
30	537	564	304	328	302	335	229	2,599
28	434	477	287	323	291	320	219	2,351
29	419	460	274	304	285	294	227	2,264
34	247	482	250	259	264	268	230	1,998
32	211	583	302	227	241	244	226	2,033
							Average	**2,206**

2011 consumption of grid electricity by floor (page 1 of 2):

CLIENT INPUT - 2011 Calendar Year Data for Electricity Usage

Company Name: NRDC - New York

Annual Electricity Usage

Meter#	1105		Floor	8				Start of Calendar Year	End of Calendar Year
								1/1/2011	1/31/2011

Month of Usage	*Bill Period Start Date*	*Bill Period End Date*	*Electricity Usage (kWh) As listed on bill*	*# of days in billing period*	*# of days in 2011*	*KWh per day*	*Pro-rated Usage for 2011*
December 2010	12/09/10	01/10/11	9,660	33	10	292.73	2,927
January	01/10/11	02/09/11	11,860	31	31	382.58	11,860
February	02/09/11	03/11/11	7,808	31	31	251.87	7,808
March	03/11/11	04/12/11	8,520	33	33	258.18	8,520
April	04/12/11	05/10/11	4,356	29	29	150.21	4,356
May	05/10/11	06/09/11	5,944	31	31	191.74	5,944
June	06/09/11	07/11/11	6,588	33	33	199.64	6,588
July	07/11/11	08/09/11	6,372	30	30	212.40	6,372
August	08/09/11	09/08/11	9,412	31	31	303.61	9,412
September	09/08/11	10/07/11	6,228	30	30	207.60	6,228
October	10/07/11	11/07/11	5,832	32	32	182.25	5,832
November	11/07/11	12/09/11	10,012	33	33	303.39	10,012
December	12/09/11	01/10/12	9,104	33	33	275.88	9,104
January 2011							
Total			101,696	410	387	N/A	94,963

Total kWh:	**94,963**
Total MWhs:	**94.963**

Meter#	82551		Floor	9				Start of Calendar Year	End of Calendar Year

Month of Usage	*Bill Period Start Date*	*Bill Period End Date*	*Electricity Usage (kWh) As listed on bill*	*# of days in billing period*	*# of days in 2011*	*KWh per day*	*Pro-rated Usage for 2011*
December 2010	12/09/10	01/10/11	7,261	33	10	220.03	2,200
January	01/10/11	02/09/11	7,590	31	31	244.84	7,590
February	02/09/11	03/11/11	8,730	31	31	281.61	8,730
March	03/11/11	04/12/11	8,560	33	33	259.39	8,560
April	04/12/11	05/10/11	7,999	29	29	275.83	7,999
May	05/10/11	06/09/11	8,709	31	31	280.94	8,709
June	06/09/11	07/11/11	9,979	33	33	302.39	9,979
July	07/11/11	08/09/11	7,852	30	30	261.73	7,852
August	08/09/11	09/08/11	9,122	31	31	294.26	9,122
September	09/08/11	10/07/11	5,179	30	30	172.63	5,179
October	10/07/11	11/07/11	5,058	32	32	158.06	5,058
November	11/07/11	12/09/11	5,600	33	33	169.70	5,600
December	12/09/11	01/10/12	4,719	32	33	147.47	4,866
January 2011							
Total			96,358	409	387	N/A	91,445

Total kWh:	**91,445**
Total MWhs:	**91.445**

Meter#	6497		Floor	10				Start of Calendar Year	End of Calendar Year

Month of Usage	*Bill Period Start Date*	*Bill Period End Date*	*Electricity Usage (kWh) As listed on bill*	*# of days in billing period*	*# of days in 2011*	*KWh per day*	*Pro-rated Usage for 2011*
December 2010	12/09/10	01/10/11	7,712	33	10	233.70	2,337
January	01/10/11	02/09/11	7,776	31	31	250.84	7,776
February	02/09/11	03/11/11	9,604	31	31	309.81	9,604
March	03/11/11	04/12/11	11,676	33	33	353.82	11,676
April	04/12/11	05/10/11	13,524	29	29	466.34	13,524
May	05/10/11	06/09/11	10,700	31	31	345.16	10,700
June	06/09/11	07/11/11	3,452	33	33	104.61	3,452
July	07/11/11	08/09/11	3,988	30	30	132.93	3,988
August	08/09/11	09/08/11	2,880	31	31	92.90	2,880
September	09/08/11	10/07/11	3,188	30	30	106.27	3,188
October	10/07/11	11/07/11	2,908	32	32	90.88	2,908
November	11/07/11	12/09/11	3,336	33	33	101.09	3,336
December	12/09/11	01/10/12	3,076	33	33	93.21	3,076
January 2011							
Total			83,820	410	387	N/A	78,445

2011 consumption of grid electricity by floor (page 2 of 2):

Total kWh:	**78,445**
Total MWhs:	**78.445**

Start of Calendar Year | End of Calendar Year

Meter#	**762**		**Floor**	**11**			
Month of Usage	***Bill Period Start Date***	***Bill Period End Date***	***Electricity Usage (kWh) As listed on bill***	***# of days in billing period***	***# of days in 2011***	***KWh per day***	***Pro-rated Usage for 2011***
December 2010	12/09/10	01/10/11	7,796	33	10	236.24	2,362
January	01/10/11	02/09/11	7,956	31	31	256.65	7,956
February	02/09/11	03/11/11	9,128	31	31	294.45	9,128
March	03/11/11	04/12/11	9,280	33	33	281.21	9,280
April	04/12/11	05/10/11	8,700	29	29	300.00	8,700
May	05/10/11	06/09/11	9,004	31	31	290.45	9,004
June	06/09/11	07/11/11	11,036	33	33	334.42	11,036
July	07/11/11	08/09/11	8,796	30	30	293.20	8,796
August	08/09/11	09/08/11	5,644	31	31	182.06	5,644
September	09/08/11	10/07/11	5,544	30	30	184.80	5,544
October	10/07/11	11/07/11	5,088	32	32	159.00	5,088
November	11/07/11	12/09/11	6,000	33	33	181.82	6,000
December	12/09/11	01/10/12	5,272	33	33	159.76	5,272
January 2011							
Total			99,244	410	387	N/A	93,810
						Total kWh:	**93,810**
						Total MWhs:	**93.810**

Start of Calendar Year | End of Calendar Year

Meter#	**625**		**Floor**	**12**			
Month of Usage	***Bill Period Start Date***	***Bill Period End Date***	***Electricity Usage (kWh) As listed on bill***	***# of days in billing period***	***# of days in 2011***	***KWh per day***	***Pro-rated Usage for 2011***
December 2010	12/09/10	01/10/11	7,232	33	10	219.15	2,192
January	01/10/11	02/09/11	6,216	31	31	200.52	6,216
February	02/09/11	03/11/11	6,508	31	31	209.94	6,508
March	03/11/11	04/12/11	5,804	33	33	175.88	5,804
April	04/12/11	05/10/11	4,204	29	29	144.97	4,204
May	05/10/11	06/09/11	5,488	31	31	177.03	5,488
June	06/09/11	07/11/11	7,136	33	33	216.24	7,136
July	07/11/11	08/09/11	6,244	30	30	208.13	6,244
August	08/09/11	09/08/11	4,416	31	31	142.45	4,416
September	09/08/11	10/07/11	4,148	30	30	138.27	4,148
October	10/07/11	11/07/11	4,112	32	32	128.50	4,112
November	11/07/11	12/08/11	5,372	32	32	167.88	5,372
December	12/09/11	01/10/12	5,052	33	33	153.09	5,052
January 2011							
Total			71,932	409	386	N/A	66,892
						Total kWh:	**66,892**
						Total MWhs:	**66.892**

Total kWh:	**425,555**
Total MWhs:	**425.55**

	Peak Demand	Average Demand	Minimum Demand	Cost per kWh
Peak Demand - 6	54	37	23	0.219
Peak Demand - 7	65	53	39	0.215
Peak Demand - 8	43	29	23	0.225
Peak Demand - 9	34	25	19	0.21
Peak Demand - 10	46	21	9	0.205
Peak Demand - 11	38	26	15	0.214
Peak Demand - 12	17	14	11	0.193
Peak Demand (6-12)	297	205	139	
Peak Demand (8-12)	178	115	77	
Total peak Demand	246	205	170	0.213

Summary of current array data and projection for future array of 2021 vertical solar panel installation (page 1 of 2):

Solar Current array and Future Vertical PV Panels

Current Installation

Commissioning:	2/10/12
Plant power:	5.55 kWp
Modules:	Kyocera KD185GH-2P
Communication:	Sunny WebBox
Inverter:	Sunny Boy 6000US
Sensors:	Sunny Sensorbox
Cells per panel	48
Panel Dimension	1341 x 990 mm
Estimated Annual Output	6,687 kwh

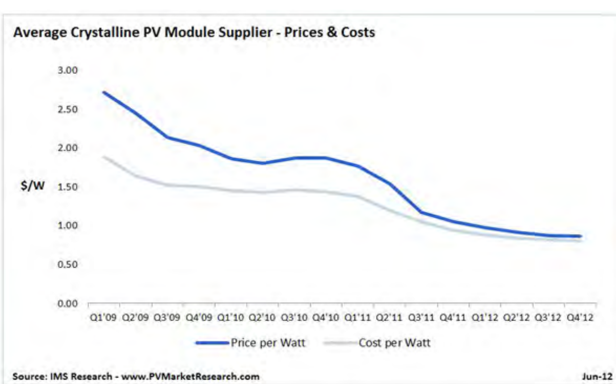
	Panels	Watts per Panel	Total Installed Watts	Annual kWh production	Production per installed kW (kWh per peak)	
Current Installation	30	185	5,550	6,687	1,205	
Replace, raise Panels	30	301.5	9,046	11,444	1,265	5% Gain from microinverters

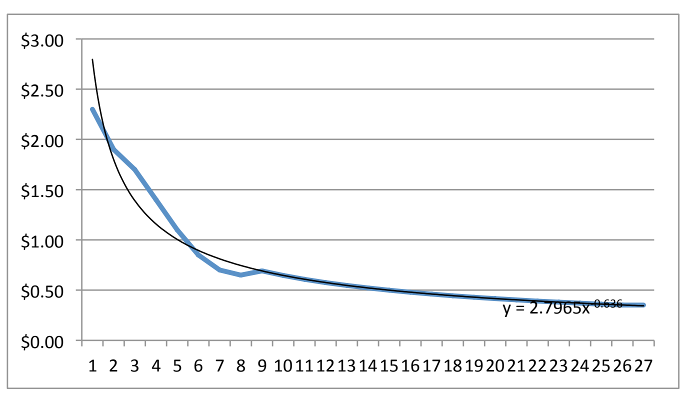
Historical YOY gain in output efficiency 4.40%

Solar Projection

Year	Half	Canadian Solar 60-cell Avg W	Annual incremental % increase		48-cell Equivalent W	Panel Price $/W
2009	H2	215		1	172	$2.30
2010	H1	220		2	176	$1.90
2010	H2	225	4.65%	3	180	$1.70
2011	H1	230	4.55%	4	184	$1.40
2011	H2	235	4.44%	5	188	$1.10
2012	H1	240	4.35%	6	192	$0.85
2012	H2	245	4.26%	7	196	$0.70
2013	H1	250	4.17%	8	200	$0.65
2013	H2	255.8		9	204.6	$0.69
2014	H1	261.0		10	208.8	$0.65
2014	H2	267.0		11	213.6	$0.61
2015	H1	272.5		12	218.0	$0.58
2015	H2	278.8		13	223.0	$0.55
2016	H1	284.5		14	227.6	$0.52
2016	H2	291.1		15	232.9	$0.50
2017	H1	297.0		16	237.6	$0.48
2017	H2	303.9		17	243.1	$0.46
2018	H1	310.1		18	248.1	$0.44
2018	H2	317.3		19	253.8	$0.43
2019	H1	323.7		20	259.0	$0.42
2019	H2	331.2		21	265.0	$0.40
2020	H1	338.0		22	270.4	$0.39
2020	H2	345.8		23	276.6	$0.38
2021	H1	352.9		24	282.3	$0.37
2021	H2	361.0		25	288.8	$0.36
2022	H1	368.4		26	294.7	$0.35
2022	H2	376.9			301.5	$0.35

equation: Cost = 2.8 * period ^ -0.634





Summary of current array data and projection for future array of 2021 vertical solar panel installation (page 2 of 2):

	sqft	kWh per annum (existing panel efficiency)	kWh per annum (future efficiency)
now	432	6,687	11444
future	2,094	32413.375	55471.61111

Vertical Solar PV - Under awnings

Tower Location	Height	Width	Total Square Footage (vertical)
S side of Central water tower	35	29	1,015
W side of Central water tower	35	29	1,015
E side of Central water tower	35	29	1,015
S side of west side tower	12	25	300
E side of west side tower	12	12	144
TOTAL			**3,489**

	Sqft	kWh output	watts installed
Existing	432	6687	5500
Future State	432	11444	9,046
	4757	0.71138	
vertical efficiency drop		70.0%	
Future State - Vertical 1	3489	64698	73059.20195

Summary of current array data and projection for future array of 2021 vertical solar panel installation (page 2 of 2):

	sqft	kWh per annum (existing panel efficiency)	kWh per annum (future efficiency)
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TOTAL			**3,489**

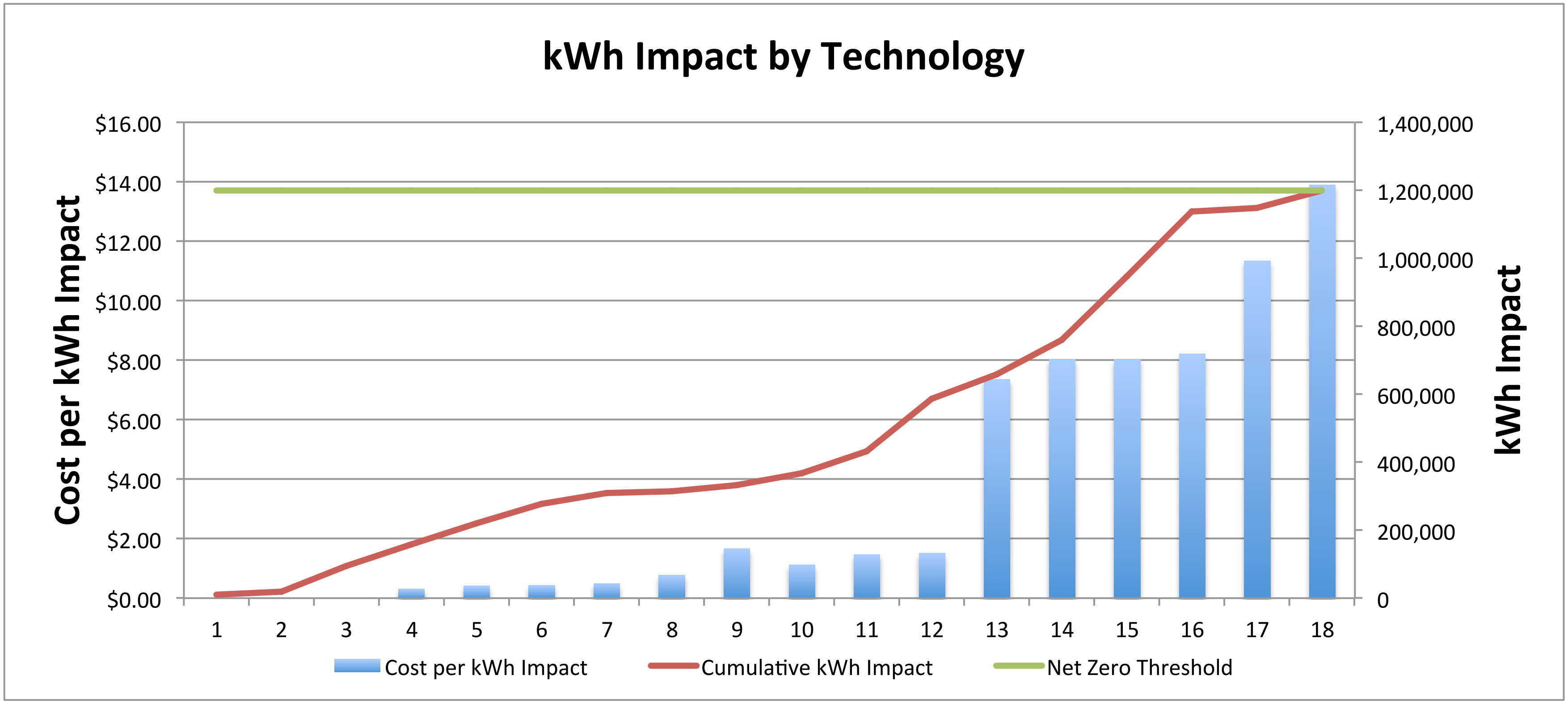
	Sqft	kWh output	watts installed
Existing	432	6687	5500
Future State	432	11444	9,046
	4757	0.71138	
vertical efficiency drop		70.0%	
Future State - Vertical 1	3489	64698	73059.20195

List of summary data by technology, with an accompanying graph of technologies sorted by cost per kWh impact (page 1 of 2):

Recommended Technologies Table

Code	Recommended Technologies	Cost per kWh Impact	Year	Annual kWh impact	Ballpark Cost	Cumulativ e kWh Impact	Annual mmbtu Impact	% of Load	Net Zero Threshold
1	Shift AC Schedule	$0.00	2013	9,479	$1	9,479		0.8%	1,199,204
2	Biofuels in existing boiler	$0.00	2015	9,001	$1	18,480	31	0.8%	1,199,204
3	Energy-aligned Lease Fl 6-7	$0.00	2018	75,766	$1	94,247		6.3%	1,199,204
4	Energy Recovery Ventilator (ERV)	$0.32	2013	63,420	$20,000	157,666	216	5.3%	1,199,204
5	VFDs on Blower fans	$0.42	2013	62,084	$25,860	219,750		5.2%	1,199,204
6	Air Sealing - Larry Harmon	$0.44	2013	57,184	$25,000	276,934	195	4.8%	1,199,204
7	Smart Power Strips Fl 6-7	$0.49	2018	32,070	$15,600	309,004		2.7%	1,199,204
8	VFDs on Condensor Pump	$0.77	2013	5,024	$3,890	314,028		0.4%	1,199,204
9	DC Microgrid P2 - Solar & Workspace	$1.66	2017	18,120	$30,125	332,148		1.5%	1,199,204
10	Smart Power Strips Fl 8-12	$1.12	2013	34,912	$39,000	367,059		2.9%	1,199,204
11	Rooftop Vertical Solar on Bulkheads	$1.47	2021	64,698	$94,977	431,758		5.4%	1,199,204
12	Phase Change Materials	$1.51	2014	154,396	$232,740	586,154	527	12.9%	1,199,204
13	External Facade Insulation System Insulation	$7.35	2015	72,052	$529,710	658,206	246	6.0%	1,199,204
14	Rooftop Solar Concentrating PV	$8.03	2017	101,220	$812,296	759,426		8.4%	1,199,204
15	Rooftop Solar Concentrating PV	$8.03	2017	186,787	$1,498,976	946,213		15.6%	1,199,204
16	Geothermal Water Pump from 1500 below surface	$8.21	2015	191,264	$1,570,000	1,137,476	653	15.9%	1,199,204
17	DC Microgrid P1 - Lighting & VFDs	$11.34	2013	10,393	$117,875	1,147,870		0.9%	1,199,204
18	Advanced Lighting Controls LED Lighting	$13.90	2013	51,335	$713,728	1,199,205		4.3%	1,199,204

List of summary data by technology, with an accompanying graph of technologies sorted by cost per kWh impact (page 2 of 2):



One-page summary of the data used for weather tracking. To reduce redundancy, we show an abridged set of data in the printed report. The full set is available in the Excel file to be delivered to NRDC:

Weather Data - 10016 (2008-2012)

Capstone Group Calculations

Source: http://www.wunderground.com/history/airport/KNYC/2012/9/22/DailyHistory.html Complete data in Excel file deliv

EST	Max Temp	Mean Temp	Min Temp	Max Dew Point	Mean Dew Point	Min Dew Point	Max Humidity	Mean Humidity	Min Humidity	Max Wind SpeedMPH	Mean Wind SpeedMPH	Max Gust SpeedMPH	Inches Precip	Cloud Cover	Events	Wind Dir Degrees	HDD	CDD	Day Sequence	Geothermal heating tons used	Geothermal cooling tons used
9/7/2008	80	74	67	66	57	53	84	63	42	15	7	23	0	0		268	0	9	251	0.0	59.0
9/8/2008	81	73	64	60	55	50	73	56	39	10	4	17	0	0		192	0	8	252	0.0	52.4
9/9/2008	75	70	65	69	64	58	93	77	61	15	5	25	0.45	5	Fog-Rain	245	0	5	253	0.0	32.8
9/10/2008	73	66	59	58	50	46	75	57	38	15	5	20	0	3		34	0	1	254	0.0	6.6
9/11/2008	72	67	61	57	54	49	73	67	60	10	5	16	0	6		63	0	2	255	0.0	13.1
9/12/2008	70	67	63	66	60	54	93	78	63	12	5	18	0.39	8	Rain	164	0	2	256	0.0	13.1
9/13/2008	81	73	65	67	65	64	100	84	67	8	2	13	0	5		60	0	8	257	0.0	52.4
9/14/2008	88	79	70	73	70	66	97	80	63	14	5	21	0	2		167	0	14	258	0.0	91.7
9/15/2008	83	74	65	70	59	51	74	57	40	18	8	29	0	1		259	0	9	259	0.0	59.0
9/16/2008	70	66	61	57	52	50	68	63	57	12	4	15	0	4		55	0	1	260	0.0	6.6
9/17/2008	74	66	57	54	51	46	80	59	38	8	2	12	0	0		117	0	1	261	0.0	6.6
9/18/2008	73	66	59	55	47	38	72	52	31	18	7	28	0	0		22	0	1	262	0.0	6.6
9/19/2008	66	59	52	47	44	39	67	56	45	17	9	24	0	1		53	6	0	263	19.4	0.0
9/20/2008	69	60	51	51	48	45	83	64	45	12	4	14	0	1		53	5	0	264	16.2	0.0
9/21/2008	80	68	56	56	52	49	83	61	39	13	2	15	0	0		353	0	3	265	0.0	19.7
9/22/2008	74	67	60	58	55	53	84	69	53	14	7	18	0	3		46	0	2	266	0.0	13.1
9/23/2008	70	62	54	54	48	42	84	64	45	15	6	21	0	1		54	3	0	267	9.7	0.0
9/24/2008	69	62	55	54	50	46	87	68	45	12	5	20	0	1		59	3	0	268	9.7	0.0
9/25/2008	64	60	55	55	50	45	94	71	54	20	10	33	0.07	5	Rain	56	5	0	269	16.2	0.0
9/26/2008	66	62	57	63	59	54	94	93	88	21	14	36	2.42	8	Rain	54	3	0	270	9.7	0.0
9/27/2008	69	66	64	67	64	62	100	94	88	13	8	16	0.01	8	Fog-Rain	57	0	1	271	0.0	6.6
9/28/2008	71	68	66	68	66	64	100	92	83	8	1		0.16	8	Rain	47	0	3	272	0.0	19.7
9/29/2008	73	67	61	64	60	54	94	78	61	10	3		0.01	6	Rain	6	0	2	273	0.0	13.1
9/30/2008	69	64	60	59	56	53	87	76	63	8	2		0	5		122	1	0	274	3.2	0.0
10/1/2008	71	64	57	61	59	52	96	76	55	12	3	18	0.3	6	Rain	256	1	0	275	3.2	0.0
10/2/2008	62	57	52	53	44	39	86	66	46	17	7	28	0	3	Rain	259	8	0	276	25.9	0.0
10/3/2008	62	57	51	45	42	40	71	60	48	17	6	24	0	3		240	8	0	277	25.9	0.0
10/4/2008	61	54	47	45	41	37	77	62	46	9	3	13	T	3	Rain	251	11	0	278	35.6	0.0
10/5/2008	62	57	52	54	52	47	93	80	67	15	4	22	0.32	6	Rain	40	8	0	279	25.9	0.0
10/6/2008	64	56	47	54	42	38	86	66	46	14	5	18	0	3		38	9	0	280	29.1	0.0
10/7/2008	63	54	44	41	36	31	83	57	30	10	3	15	0	0		284	11	0	281	35.6	0.0
10/8/2008	64	56	47	51	44	39	77	60	43	13	4	21	0.01	1		238	9	0	282	29.1	0.0
10/9/2008	75	67	58	59	57	54	93	71	49	14	6	22	0.04	5	Rain	240	0	2	283	0.0	13.1
10/10/2008	72	65	58	54	42	33	72	49	25	9	3	14	0	0		279	0	0	284	0.0	0.0
10/11/2008	69	61	52	51	44	39	80	57	33	14	3	18	0	0		65	4	0	285	12.9	0.0
10/12/2008	70	62	53	52	48	42	90	64	37	9	3	14	0	0		132	3	0	286	9.7	0.0
10/13/2008	74	66	58	55	53	50	78	64	49	12	4	16	0	0		245	0	1	287	0.0	6.6
10/14/2008	68	63	58	60	56	52	87	78	68	12	4	15	0	4		154	2	0	288	6.5	0.0
10/15/2008	70	64	57	58	49	43	78	59	39	9	2	14	0	0		350	1	0	289	3.2	0.0
10/16/2008	75	65	55	62	55	39	93	72	51	13	5	18	T	4		292	0	0	290	0.0	0.0
10/17/2008	60	55	50	41	37	32	71	57	43	17	7	23	0	1		22	10	0	291	32.3	0.0
10/18/2008	58	51	43	36	31	26	58	48	38	18	9	23	0	1		43	14	0	292	45.3	0.0
10/19/2008	55	49	42	31	28	25	57	46	35	17	8	25	0	0		36	16	0	293	51.7	0.0

A display of our calculations for the Geothermal and HVAC system, based on several factors including:

1) Envelope improvements - EIFS, Air sealing, Phase change materials
2) Geothermal heating and cooling energy
3) Existing systems that will be retained

COOLING LOAD - Geothermal & HVAC Calculations

	Metric
Installed tons	190
Max one-day CDD	29
Tons needed per CDD	6.55
Recommended Geothermal System tons	105
Max CDD where Geothermal = all cooling	16.00

Floor	AC installed tons	AC installed BTU
12	25	300,000
11	25	300,000
10	25	300,000
9	25	300,000
8	30	360,000
7a	30	360,000
6a	30	360,000

	Historical weather for 10016 (NOAA)			
Metric Description	**Number of Annual Days where CDD > 16**	**Number of Annual Days where 0 < CDD <= 16**	**Number of Annual Days where CDD = 0**	**TOTAL**
Annual Days (last 4 yrs)	17.5	112.75	235	365.25
Cumulative CDD on those days	337.00	919.25		1256.25
Avg CDD on those days	19.3	8.2		3.4
Daily CDD above 16	3.3	0.0		
% Cooling - Current system	16.9%	0.0%		
% cooling - Geothermal	83.1%	100.0%		
Total CDD handled by Geothermal	280	919.25		1199.25
Total CDD handled by Current System				57.00
% Total Cooling handled by Geothermal				**95%**

Current Cooling Systems in NRDC Building

Floor	System Type 1	System Type 2	System Type 3	Annual Draw
Roof	AC 10-1	Condenser		5,008
Roof	AC 10-2	Condenser		5,008
Roof	AC 10-3	Condenser		5,008
Roof	AC 10-4	Condenser		5,008
12	MER 12	Water-Source	Loop	33,679
11	MER 11	Water-Source	Loop	27,595
10	MER 10	Water-Source	Loop	27,595
10	Server Room	CRAC	floor	36,004
9	MER 9	Water-Source	Loop	27,595
8	MER 8	Water-Source	Loop	37,991
7	MER 7	Air Cooled	floor	22,382
7	MER 7	Air Cooled	floor	22,382
6	MER 6	Air Cooled	floor	22,382
6	MER 6	Air Cooled	floor	22,382

	Percent Improvement	kWh reduction	Tonnage Reduction	Resulting kWh	Resulting tonnage
			190	302,166	
VFDs		62,084	0	240,082	190
ERVs		4541	13	235,541	177
Air sealing	10%	23,554	18	211,987	159
Phase change	30%	63,596	48	148,391	112
Stotherm	20%	29,678	22	118,713	89
Metering - Code Green	8%	9,479	0	109,233	89
Geothermal				64,633	

A display of our calculations for the Geothermal and HVAC system, based on several factors including:
1) Envelope improvements - EIFS, Air sealing, Phase change materials
2) Geothermal heating and cooling energy
3) Existing systems that will be retained

HEATING LOAD - Geothermal & HVAC Calculations

Gallons of oil consumed in 2011	10,856
Oil mmbtu required for heating in 2011	1,498
btu from the oil in 2011, 100% efficiency	1,498,128,000
Heating Efficiency of boiler system	80%
btus used for heating in 2011	1,198,502,400
number of total HDD in 2011	4,291
btu required per HDD	279,306
Heating Efficiency of geothermal system	90%
Geothermal btu used for heating per HDD	310,340
hours of boiler activity per day	8
Geothermal btu hrs used for heating per HDD	38,793
tons of geothermal used for heating per HDD	3.23
Installed tonnage of Geothermal system	105
Max HDD where Geothermal = all heating	32.00

	Historical weather for 10016 (NOAA)			
Metric Description	**Number of Annual Days where HDD > 32**	**0 < Number of Annual Days where HDD <= 32**	**Number of Annual Days where HDD = 0**	**TOTAL**
Annual Days (last 4 yrs)	36.5	192.25	136.5	365.25
Total HDD	1403.25	3026.75		4430.0
Avg HDD	38.4	15.7		12.1
HDD above 32	6.4	0.0		
% Heating - Current system	16.8%	0.0%		
% Heating - Geothermal	83.2%	100.0%		
Total HDD handled by Geothermal	1168	3026.75		4194.75
Total HDD handled by Current System				235.25
% Total Heating handled by Geothermal				**95%**

kW per well	14.7
kW per ton	0.42
heating tons	14321
cooling tons	8231
pump usage from well	**9472**

kw per installed ton	2.57
annual tons needed	14321
kWh for heat pump	**36805**

		mmbtu Reduction	mmbtu consumption
			1,382
			1,382
ERVs		235	1147
Air Sealing	10%	115	1033
Phase Change	30%	310	723
StoTherm insulation	20%	145	578

Heating oil consumed from October 2009 through April 2012:

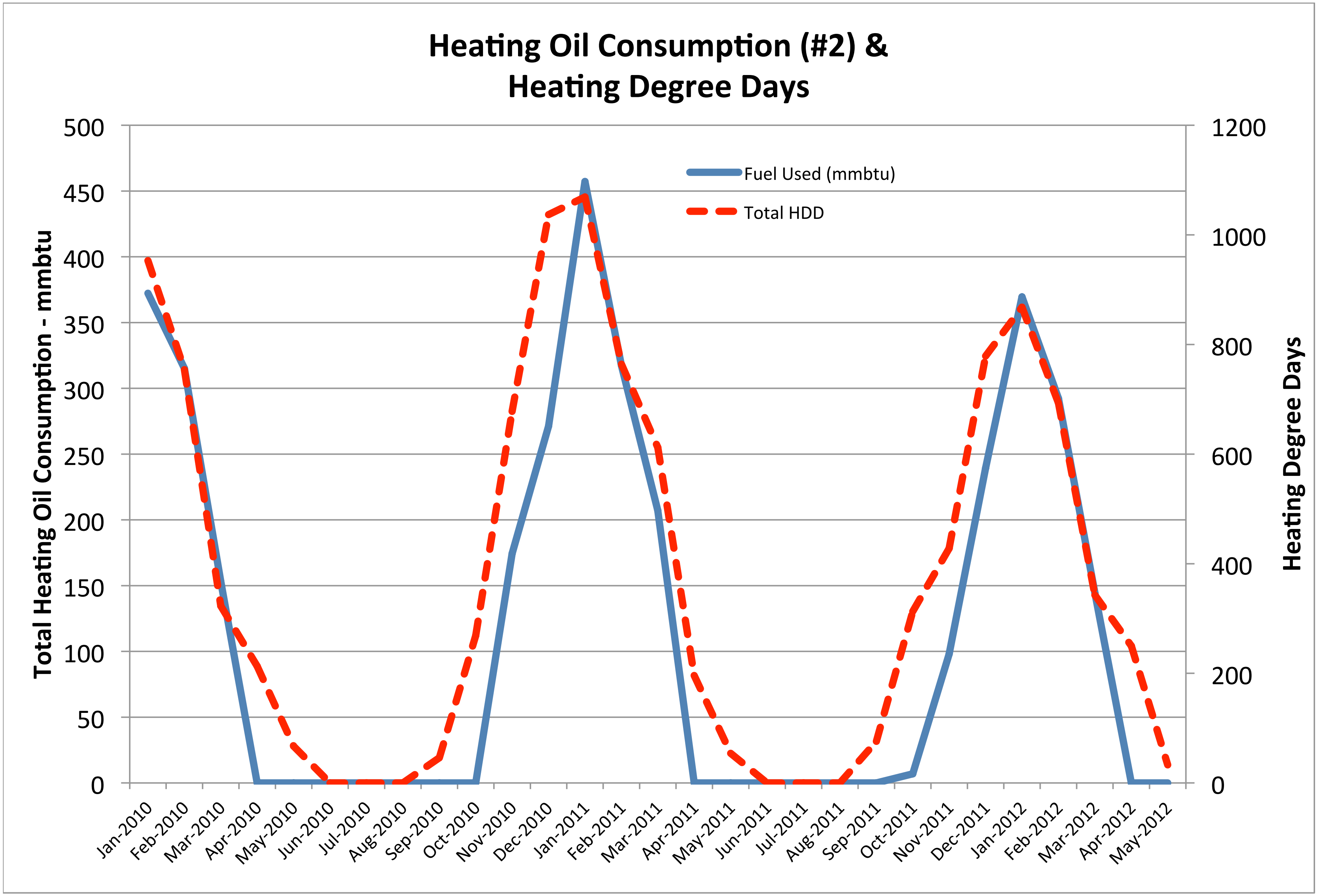
Client Input - Heating oil 2009-2012

Company Name:	NRDC - New York
Office Location:	40 West 20th Street, New York, NY 10011

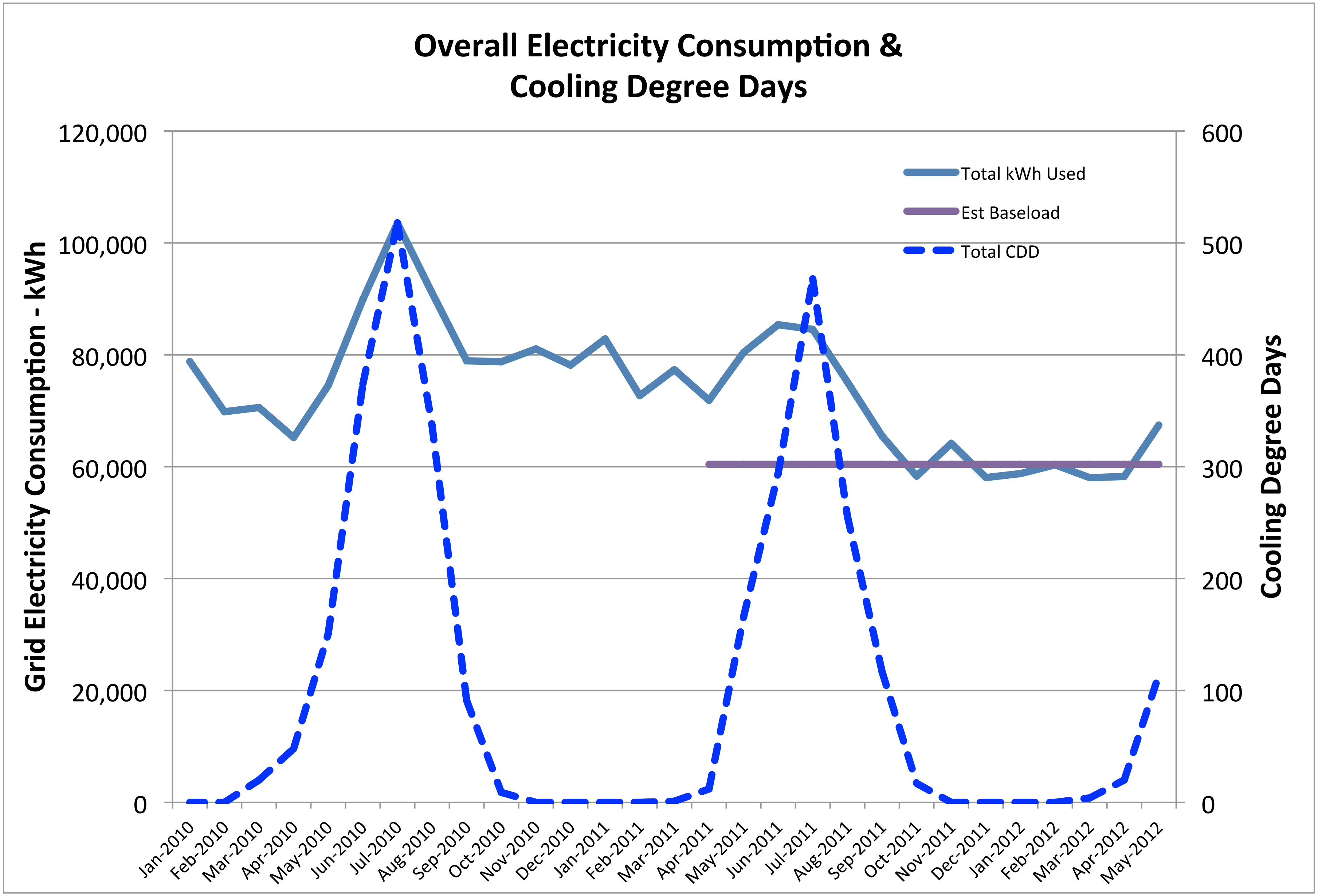
Annual Fuel Usage

	Gals Used	HDD	Gals/HDD
10/1/09	107	310	0.34516129
11/1/09	678	407	1.665847666
12/1/09	2324	893	2.602463606
1/1/10	2698	1000	2.698
2/1/10	2284	885	2.58079096
3/1/10	1110	512	2.16796875
4/1/10	0	230	0
5/1/10	0	0	0
6/1/10	0	0	0
7/1/10	0	0	0
8/1/10	0	0	0
9/1/10	0	0	0
10/1/10	0	218	0
11/1/10	1263	504	2.505952381
12/1/10	1966	992	1.981854839
1/1/11	3313	1086	3.050644567
2/1/11	2299	804	2.859452736
3/1/11	1500	695	2.158273381
4/1/11	0	326	0
5/1/11	0	94	0
6/1/11	0	2	0
7/1/11	0	0	0
8/1/11	0	0	0
9/1/11	0	22	0
10/1/11	50	255	0.196078431
11/1/11	710	385	1.844155844
12/1/11	1735	665	2.609022556
1/1/12	2678	924	2.898268398
2/1/12	2118	693	3.056277056
3/1/12	1048	428	2.448598131
4/1/12	**27881**	**12330**	**2.261232766**

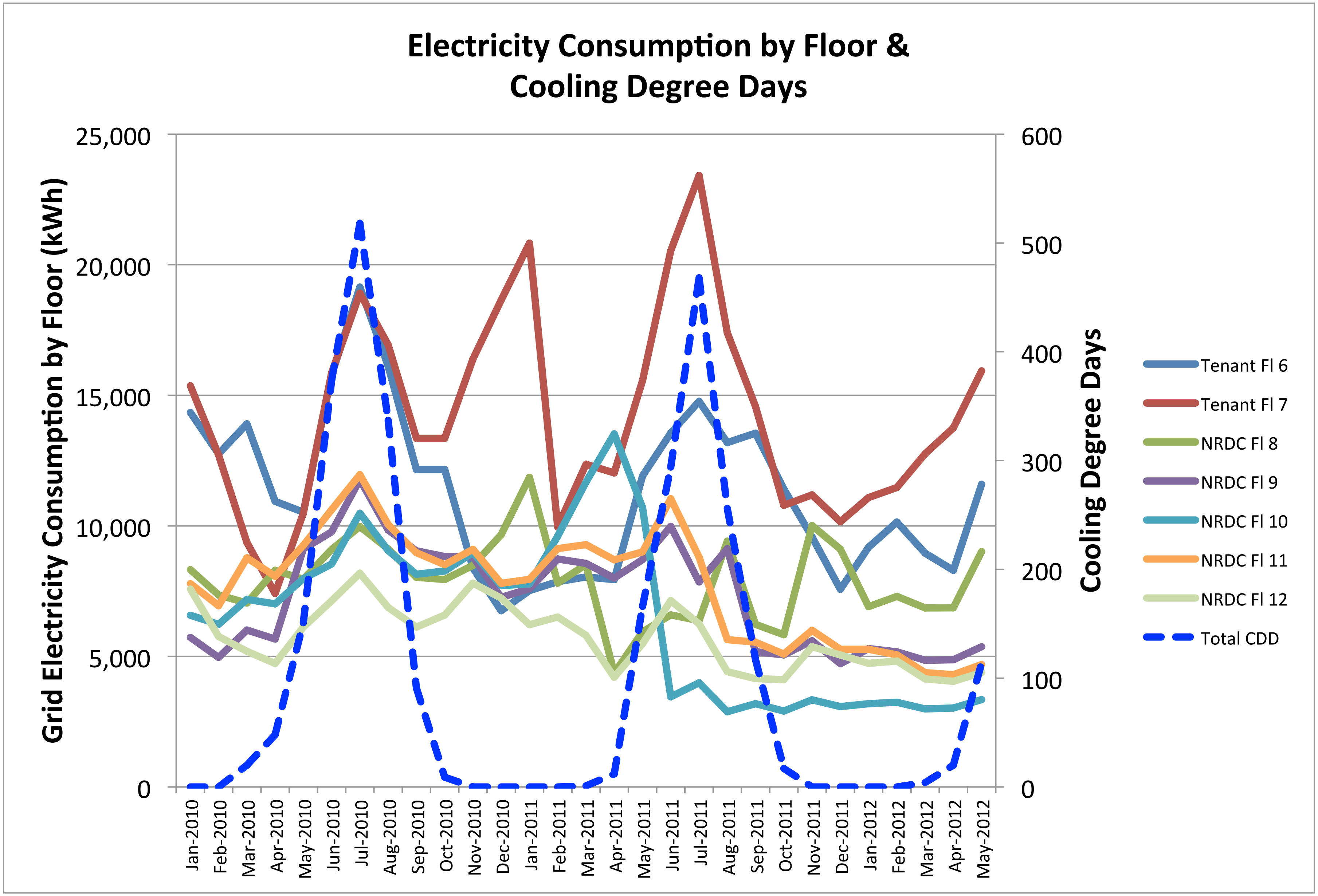
A historical view of the heating oil consumed as it relates to the number of Heating Degree Days (HDD) per month. This shows there is a strong correlation between HDD and oil consumption:



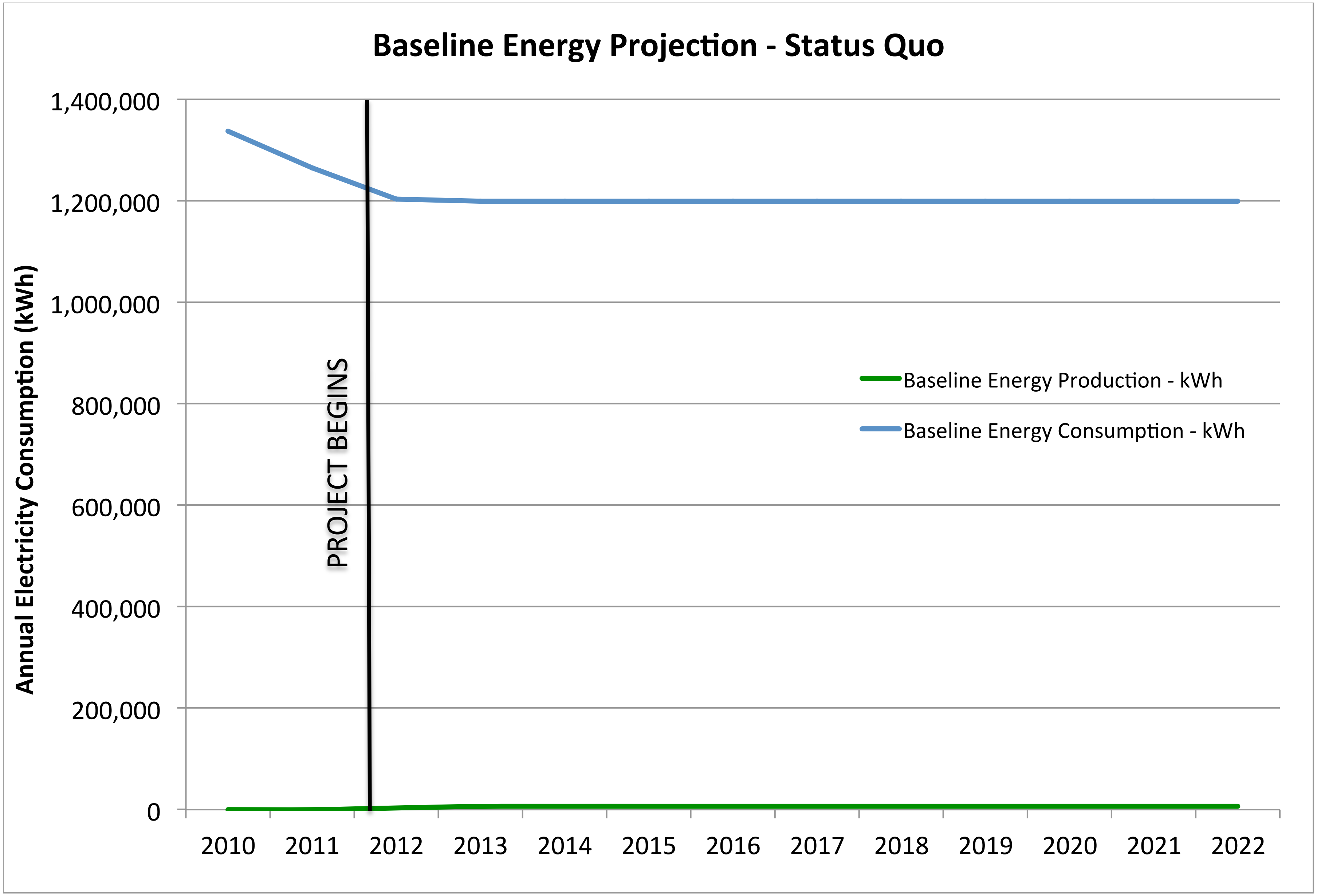
A historical view of the electricity consumed as it relates to the number of Cooling Degree Days (CDD) per month. Generally, there is a spike in the summer when CDD are highest, and the non-AC baseload is represented by the cooler months in 2012:



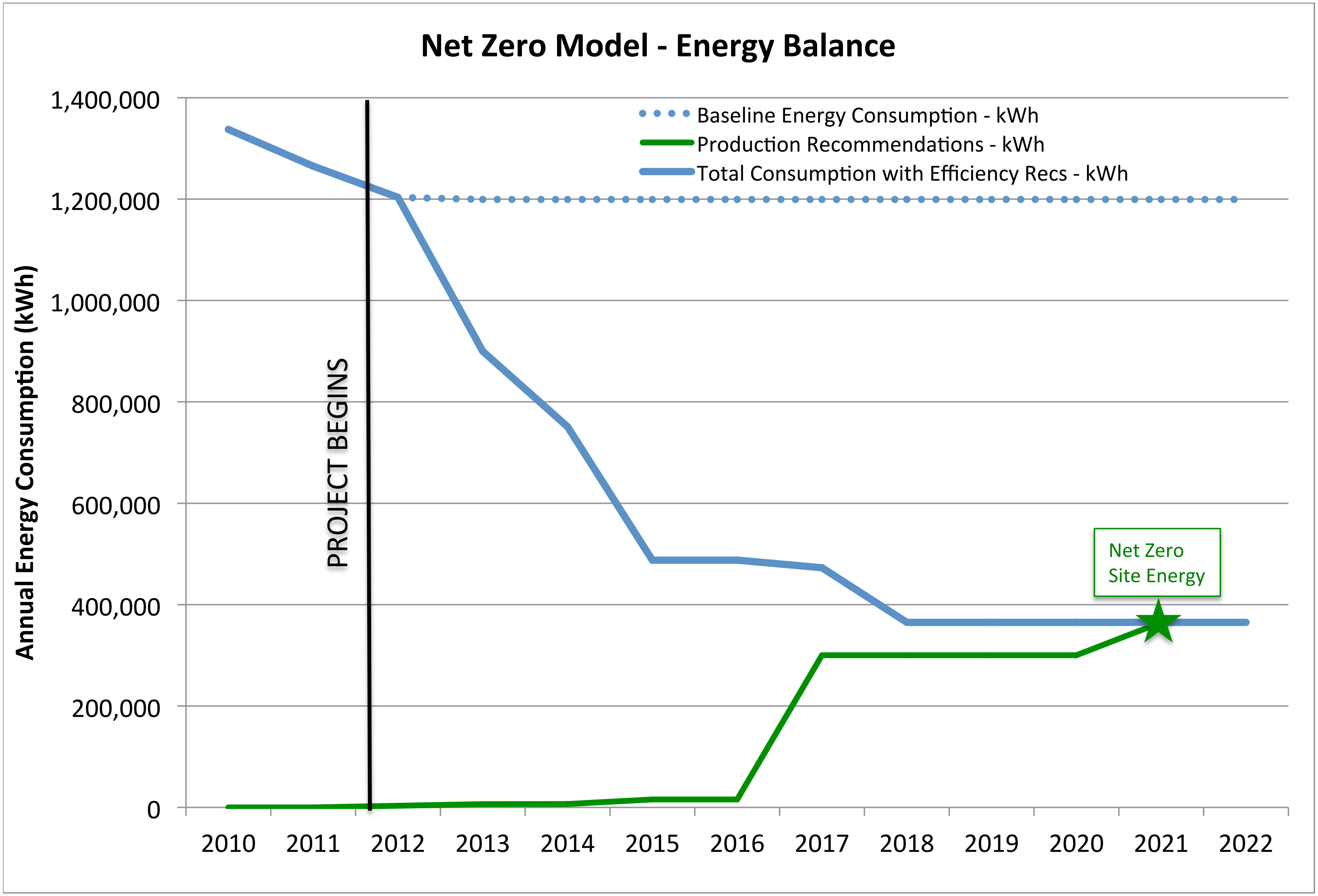
A historical view of the electricity consumed per floor as it relates to the number of Cooling Degree Days (CDD) per month. While the overall chart shows a consistent spike in electricity consumption during summer months, this chart per floor shows that it is not a consistent trend across all floors. In Summer 2010 there was a small spike in July, but in 2011 this was observed in some floors and not in others. This suggests uneven cooling load draw, which is an efficiency opportunity through metering and insulation improvements:



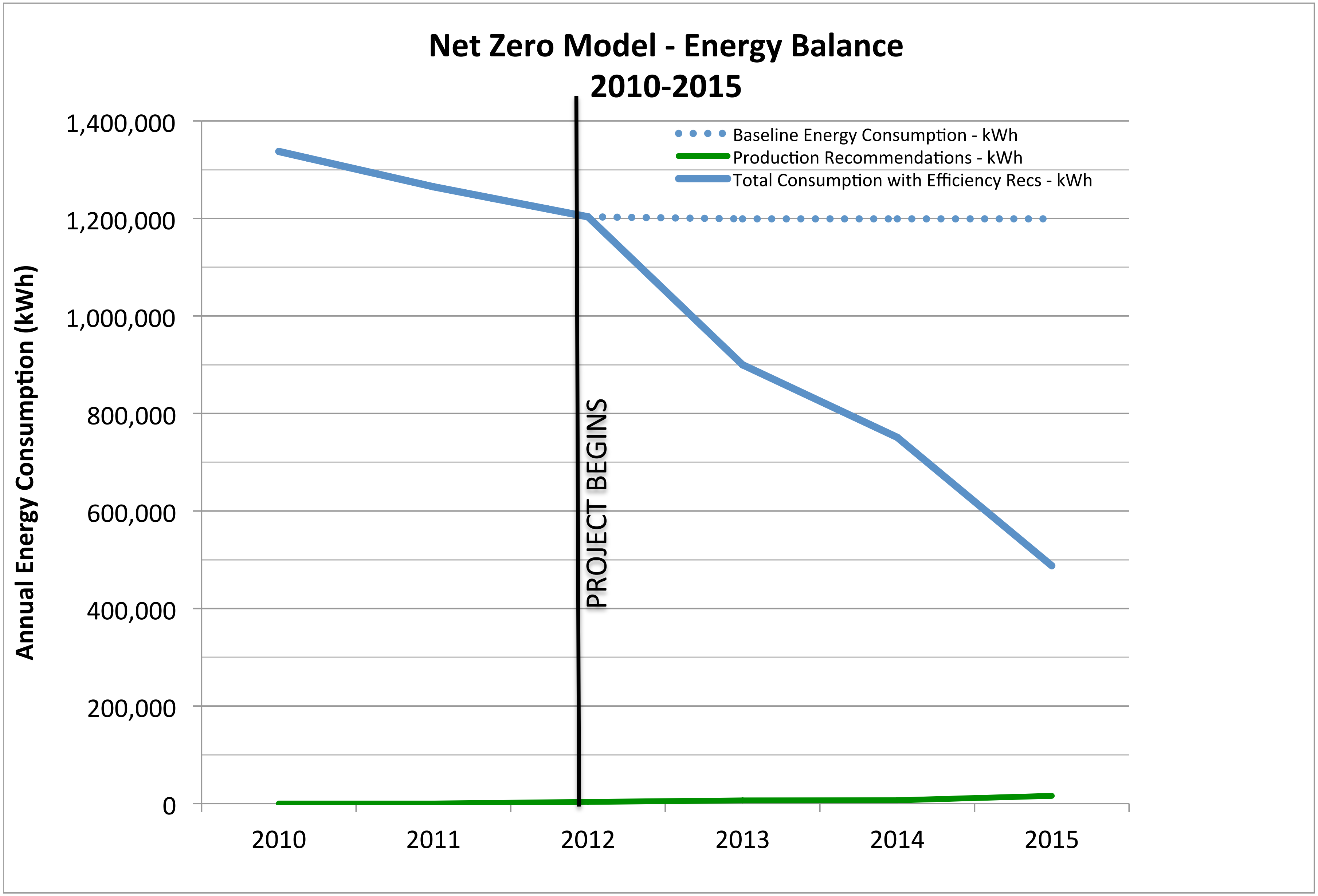
The energy projection based on the most recent 12 months of data, projected through 2022. This is the "no action" scenario, which is unlikely to occur but best represents the energy balance as it is today and serves as the basis for our recommendations:



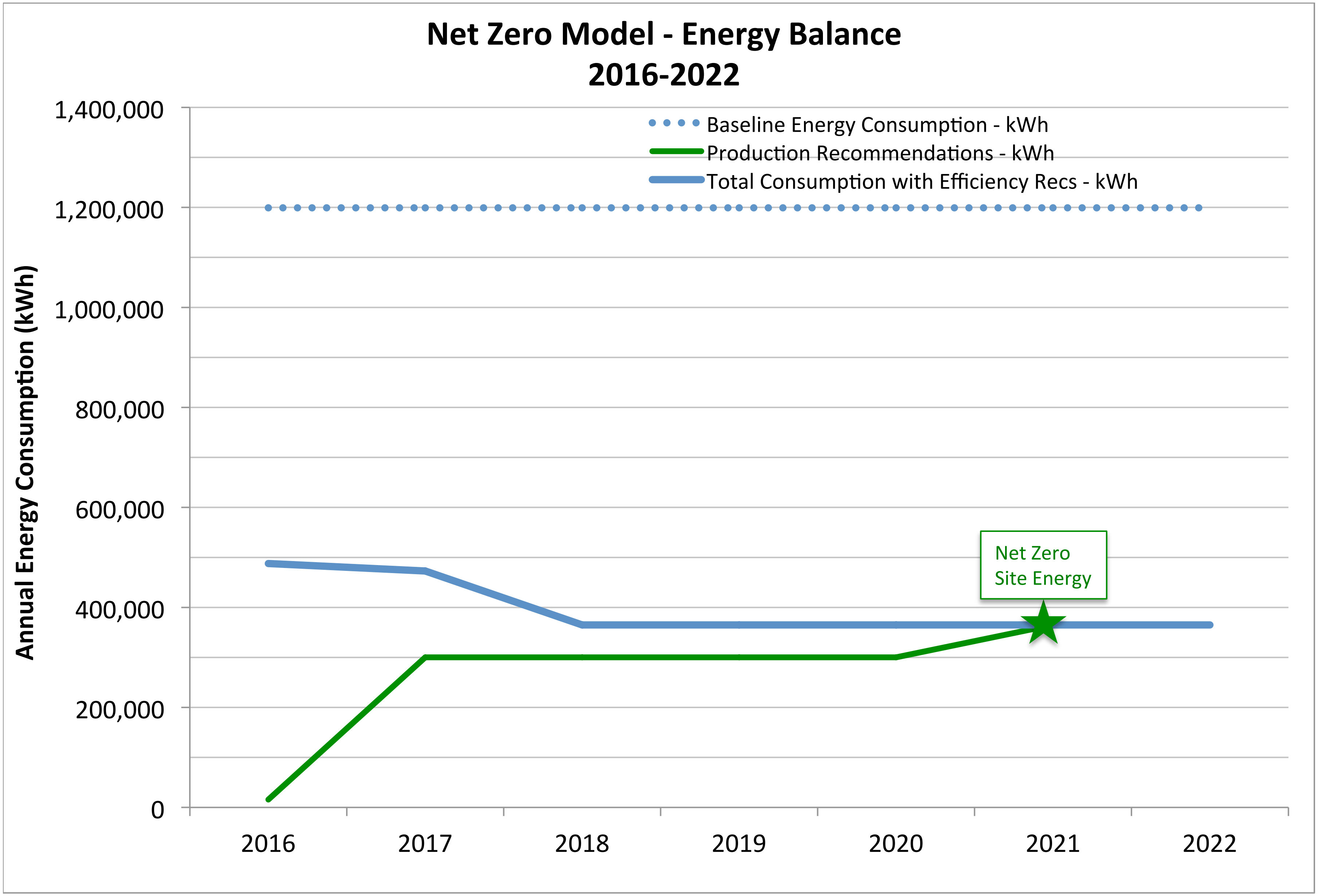
The energy balance after all efficiency and generation recommendations, showing Net Zero Site Energy status in 2021 (page 1 of 3):



The energy balance after all efficiency and generation recommendations, showing Net Zero Site Energy status in 2021 (page 2 of 3):



The energy balance after all efficiency and generation recommendations, showing Net Zero Site Energy status in 2021 (page 3 of 3):



9.2 DEEP STANDING COLUMN WELL GEO-EXCHANGE (GEOTHERMAL)

Introduction

Due in part to the waning US recession and North American natural gas boom, it may still be decades before wind and photovoltaic electricity generation capabilities progress significantly.[170] Tall buildings with small rooftop areas to place solar panels or wind turbines (i.e.: buildings with floor area ratios (FARs) similar to 40 West 20th Street) must therefore continue to rely upon off-site fuels to generate enough power to effectively heat and cool their interiors. Since transforming a sufficient amount of sunlight into electricity will therefore likely be infeasible for the NRDC headquarters in the near-term, accessing the sun's thermal energy in the winter (or expelling it efficiently during the summer) via ground- or water-source heat pumps is an augmentation strategy the project team chose to explore.[171] The EPA lauds geo-exchange as "a highly efficient renewable energy technology… for space heating and cooling, and hot water."[172] Overall energy reductions can be as high as 22% or more for similar sized buildings in an urban setting[173], reducing the 40% of America's total power consumption that is used for heating and cooling our buildings.[174]

Geo-exchange is often mistakenly referred to as geo*thermal*, which taps into high temperatures very deep within the earth (usually 5-10 miles) or, in rare cases like Yellowstone National Park, at the earth's surface. Geo-exchange, however, works by using the ground or groundwater's constant year-round temperature of approximately 55-65°F as a heat source in the winter or heat sink in the summer. It transfers thermal energy to (+ΔT) or from (-ΔT) the building using a heat pump with water or refrigerant as its heat exchanger with the building's HVAC and/or DHW system. Geo-exchange can be categorized into two basic types: 1) Closed loop (ground source) systems that use the ground as the heat source/sink to circulate refrigerant in a completely closed loop; or 2) Open loop (water source) systems that use deep groundwater (1000'-1800') as the heat source/sink by pumping water to the building's heat pump where closed loop coils of refrigerant are used to extract or expel heat to the water, which is then returned to either the surface of the same open well or to a separate diffusion well.[175]

NRDC's building lacks the open space needed for an effective ground-source or shallow well closed loop system. The team therefore recommends that NRDC consider an open deep standing column well (SCW) geo-exchange system to significantly augment heating and cooling needs year-round. According to a recent article citing Tim Weber of NextEnergy Geothermal, Inc., "The newest generation of water source heat pump heating and cooling technology for large buildings has pushed operational efficiencies into the 400 to 600 percent range. That is: for every unit of energy used to operate the equipment, the system delivers 4 to 6 units of energy in return."[176] Whereas shallow ground source wells only produce 2-3 tons of heating/cooling exchange per well, deep water source wells can produce 35 tons or more of exchange capacity per well with the potential to eliminate the need for additional heating or cooling completely in an urban environment.[177]

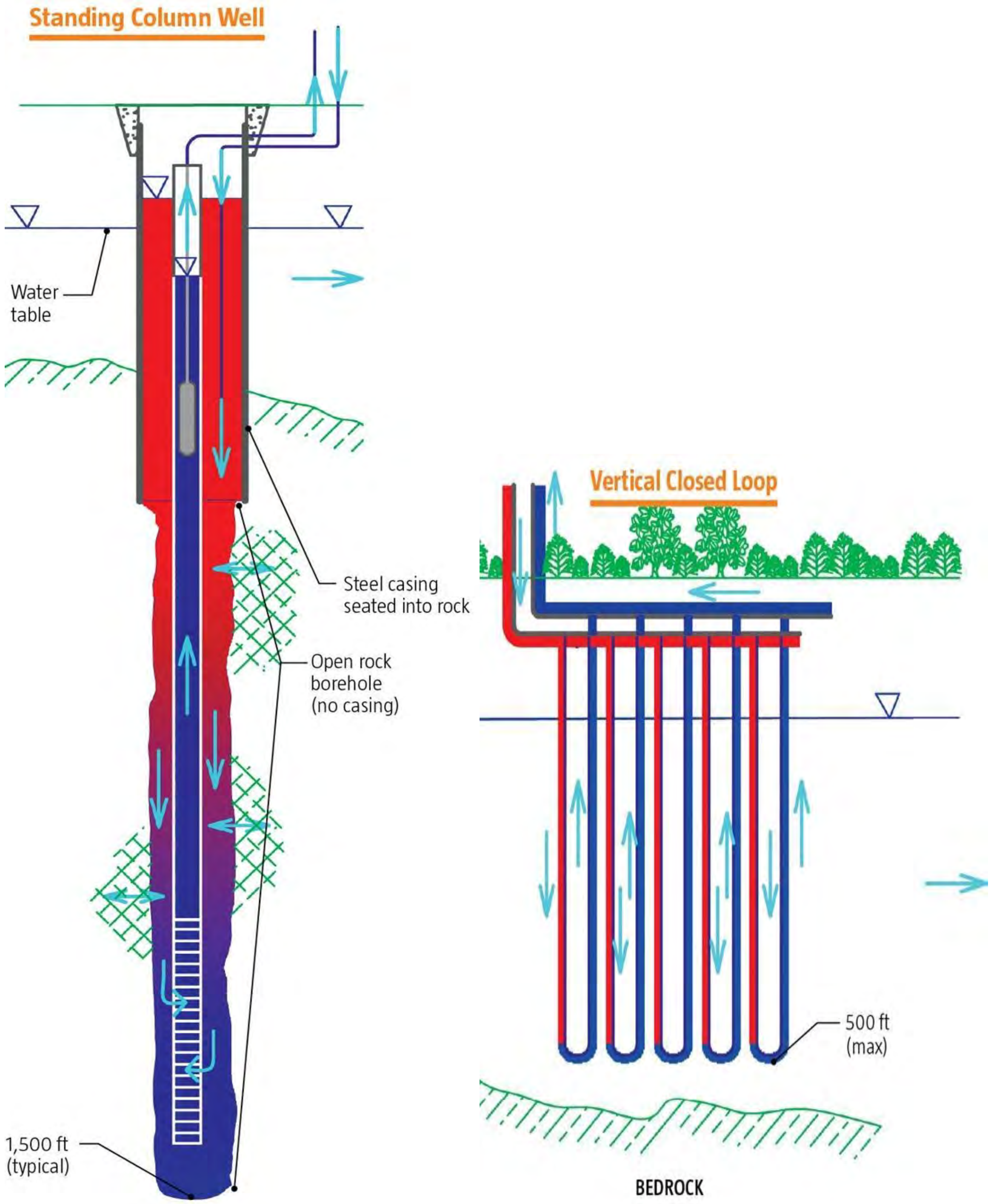


Figure 20: Diagrams of Open Loop (Standing Column Well) and Closed Loop Geo-Exchange System

Using case studies as a guide and by physically inspecting the site, the team has determined that it will be feasible to install at least 3 deep water source wells. These wells should be drilled under the West 20th Street sidewalk approximately 45’ apart from one another, consistent with the “Friends Center” case study[178] and a consultation with an experienced geo-exchange project manager.[179] A shallower diffusion well should also be considered if space permits (based on an engineering assessment) to aid in heat diffusion back into the earth's crust.

Water-to-water heat pumps like the four 30-ton Carrier 50PSW units we recommend for NRDC have a non-chlorine based refrigerant output range of 20-110^{o}F (i.e.: cooled to as low as 20^{o} during hot summer months or as high as 110^{o} when heating is needed) and are Energy Star certified.[180]

According to the team's Data Model, the proposed 105 ton geo-exchange system is projected to reduce total load by 191,294 kWh per year (237,540 kWh gross, less operating energy of 46,276 kWh per year). This savings amounts to 18.8% of total facility load according to the team's calculations. Currently the NRDC building is heated exclusively by its 200-horsepower steam boiler that burns approximately 11,000-12,000 gallons of oil per year and is cooled by a combination of water- and air-source AC units with a maximum capacity of 190 tons.[181] With the planned HVAC efficiency upgrades, it is estimated that 3 deep open loop wells should provide approximately 105 tons of heating and cooling capacity (35 tons each), handling approximately 95% of both the project-optimized heating and cooling loads according to our energy model.

Benchmark/Case Studies Used

Numerous water-source heat pump systems have proven to be effective and reliable in the past several years in dense urban environments. The three most relevant case studies include the General Theological Seminary[182] and Columbia University's Knox Hall[183] in New York City, and the Friends Center in Philadelphia.[184] All of the relevant cases utilize 1000' to 1800' wells that use semi-open loop systems and the 54,000 square foot Friends Center was able to completely eliminate their boiler and water chiller/cooling tower with just 6 deep wells and a single 675' diffusion well.[185]

Case studies and interviews consistently estimated that each well installed at the NRDC facility should yield approximately 25-40 tons of heating or cooling capacity.[186] However, experts cautioned that the technology relies upon unknown variables that cannot be quantified until the wells are drilled. Variables with the potential to affect capacity and reliability include silt blockage, gallons per minute flow rate (higher is better and requires less pump energy), and lack of adequate fissures in the bedrock to allow for thermal heat transfer.[187] Documents included below provide additional information, including several relevant case studies and backup documents that should be reviewed in detail to better understand the complexities of this technology.

Figure 21: Geo-Exchange Water Input and Return Pipes in the Basement of Chelsea General Theological Seminary

Tech Development Forecast

The technology for this open loop system already exists and should be feasible for the site based on the sidewalk space available and apparent lack of subway or water tunnels directly below the site. Technologies required will include the well piping, water pumps, heat pumps, air handlers, air terminals, fan coil units, hot water coils, and digital controls (with VFD pumps) – all of which can be purchased through established manufacturers like Carrier Corporation (see below).

Unfortunately, it is virtually impossible to predict precise open loop well tonnage at this time for several reasons. First, the presence horizontal fissures in the bedrock will allow for greater diffusion of water, increasing rock exposure for radiant heat transfer before it percolates down to the water table to be pumped back to the heat pump. Second, flow rate (measured in gallons per minute) can vary well to well and will determine the horsepower requirements for the pump in each well (lower flow equates to less tonnage and increased electricity required to pump water).[188] Third, unexpected silt can cause filter blockage and reduced flow. Last, if diffusion wells are unavailable and return water is overheating source water (reducing ΔT), diverting return water to the sewer system is sometimes necessary.[189] This is undesirable both because it depletes groundwater and because the NYC Department of Environmental Protection may assess wastewater charges.[190]

For the reasons above, the team recommends that NRDC also explore the possibility of installing additional wells in case tonnage yields from 3 wells is inadequate, or if a closed loop system is deemed feasible by engineering firms inspecting the site. By using new low-clearance drilling rigs, Fēnix Energy (Vancouver, BC) believes that several wells may be feasible in the basement, but will need to inspect the site to confirm.[191] [192] In addition, there is a subterranean parking garage with closed loop system potential approximately 200' northeast of the building across West 20th Street that is within proximity to utilize if lease agreements can be negotiated with the building's owner and NYC DOT to lay pipes under the street and sidewalks.[193] However, the project team is hesitant to strongly recommend pursuing this option because it is not a scalable solution for many buildings in dense urban environments.

Finance

Project cost and subsequent payback periods for geo-exchange systems vary significantly depending on site, scope, and fluctuating fossil fuel prices. The NRDC geo-exchange system is projected to have a simple payback of 24-25 years based on a total project cost of $1.57 million , however, it is likely that natural gas and other fossil fuel prices will rise and heat pump technology will become more efficient (the Future Cities Laboratory has already achieved 1300% efficiency), drastically reducing this projection. Incentives and rebates are not a substantial source of cost recovery for geo-exchange, although the project may be eligible for a rebate amounting to 9% of total cost if accepted under the criteria for NYSERDA's new construction portfolio incentive.

At the Friends Center installation, drilling costs ran significantly over budget, totaling $2.3M, with only one final bid received for the project.[194] New HVAC equipment to replace the existing boiler and chiller totaled $2M.[195] The non-profit organization was able to fundraise $4.1M for the energy retrofit and LEED® Platinum renovation project.[196]

Representatives from the NYC Department of Design & Construction (DDC) were consulted to estimate the cost of a 100 ton system for NRDC and projected total costs to be $1.4M for a "hybrid system" with 5 wells.[197] A hybrid system design for NRDC integrates geo-exchange with the existing water-source HVAC equipment via the condenser water loop, thereby minimizing costs. In hybrid designs, the cooling tower and a source of auxiliary heating may supplement geo-exchange during times of peak demand or unexpected equipment failure. An engineering assessment and competitive bidding process will be required to determine site-specific costs and exact design specifications. For example, the project team estimates approximately $100,000 in upgrades required for existing air-cooled HVAC equipment in order to leverage geo-exchange.

An additional financial consideration is that all NYC streets, sidewalks, and the ground beneath them are the property of the NYC Department of Transportation (DOT). Building owners wishing to dig or drill into streets or sidewalks are required to lease underground space per cubic foot, but this fee can be waived through a Revocable Consent Agreement with the NYC DOT. Following the Chelsea General Theological Seminary's successful model, it is recommended that NRDC solicit a letter of support from the NYC Historic Landmarks Commission since 40 West 20th Street is a landmarked building.[198] According to the Seminary's project manager, Yetsuh Frank, it is likely that the City would grant the waiver to a non-profit organization like NRDC.[199]

Finally, it should be noted for the purposes of this project that geo-exchange installation would constitute an up-front capital project with required maintenance that is often minimal and can be handled by the current facilities managers.[200] For more information and to receive bids for many of the services discussed above, we recommend contacting the following individuals:

- Adrian Ryan, B.Sc Eng, LEED AP
  Co-founder, Senior Vice President of Engineering, Fēnix Energy
  Suite 1290 – 1500 West Georgia

Vancouver BC Canada V6G 2Z6
Phone: 604-684-7241 ext. 307
Email: aryan@fenixenergy.com

- John Rhyner, PG, LEED AP
  Senior Project Manager, P.W. Grosser Consulting
  630 Johnson Avenue, Suite 7
  Bohemia, NY 11716
  Phone: 631-589-6353
  Email: johnr@pwgrosser.com
- Yetsuh Frank
  Programs & Communications Consultant, Green Light New York, Inc.
  315 Bleecker Street, Suite 343
  New York, NY 10014
  Phone: 917-769-7538
  Email: yfrank@greenlightny.org

9.2.1 Tax-related incentives not captured by NRDC

Several of the financial incentives that apply to geo-exchange are realized through tax deductions that NRDC will not be able to monetize due to tax-exempt status. Tax benefits are relevant to other New York City buildings considering geo-exchange as a viable efficiency solution. In addition to NYSERDA and ConEd incentives discussed in the Financial Mode, there is also a Federal Business Energy Investment Tax Credit (H.R. 1424, Section 48a), which credits 10% of the total cost of the system, including installation (must be by 31 Dec. 2016), plus classifies equipment as 5-year depreciable property ("tax savings equal to 33.25% of the energy property spending within the first 5 years").[201] In addition, NRDC can apply for the 179D DOE Energy Efficient Commercial Building Tax Deduction (if it is not already doing so), which deducts $0.30-1.80 per square foot if the building is 50% more efficient than ASHRAE 90.1-2001 as evidenced by an approved modeling system (expires 31 Dec. 2013).[202]

9.2.2 Friends Center Case Study – Philadelphia, PA

Numerous water-source heat pump systems have proven to be effective and reliable in the past several years in dense urban environments, including, most relevantly, the General Theological Seminary in New York City (Chelsea) and the Friends Center in Philadelphia. Both of these buildings utilize 1000-1500' deep SCWs that use semi-open loop systems. Below are additional details on the Friends Center case study. However, it must be noted that case studies for geo-exchange systems should only be used as very rough benchmarks because there are hundreds of independent and interdependent variables (including drilling problems, gallons per minute from wells, water temperature, silt blockage, variable pump efficiency, etc.) that cannot be controlled or planned for until all of the pieces of the puzzle have been put in place.

Friends Center, Philadelphia, PA (2008)[203 204 205 206]

- Square feet: 54,000
- Building use: Mixed – office, conference, daycare, congregation meetings (300 employees + 75 children)
- System type: Open-loop deep standing column wells
- Number of wells: 6 deep wells + 1 diffusion well
- Depth: 1000-1500' + diffusion well = 675'

- Flow rate: 105gpm per well
- Key lessons learned: Eliminated boiler and water chiller/cooling tower completely using water to water heat pumps that serve simultaneously as boilers and chillers depending on need and location in building
- Drilling capital cost: $2.3M (including soft costs); estimate 9-year payback period with the grants/incentives they received or 16-18 years without
- HVAC/equipment capital cost: $2M (replaced virtually everything sans partial duct system) ; pumps require replacement every 5 years (1 per well @ $7000 each including labor); steel casings in wells should last 100 years+ and PVC piping is indefinite
- Operating cost: Unknown
- Energy use: Installation of wells required 60,000 gallons of diesel fuel (<5 recovery period with boiler savings); daily kW use of associate HVAC equipment is unknown
- Energy supplied: 38 tons (133.6 kW) per well; 228 tons (801.8 kW) total; thermal heat testing (post-install) found that they have a potential heat transfer of 392 Btu/hr/ft
- Unexpected problems encountered: Only one bid received for drilling (Stothoff Co.) – job was expected to take 7 weeks but took 8 months (however, noise during drilling was considered tolerable by building users); silt clogged one well temporarily; supplying heat/cooling to building during system replacement was challenge (*therefore probably best to replace during shoulder months*); permitting took longer than expected
- HVAC notes: "[I]ndividual water-to-air geothermal heat pumps were used to provide efficient space comfort. In the two newer buildings, water-to-water heat pumps replaced the existing chiller and city steam system. The existing air handler was improved with a variable speed drive, which increases efficiency and extends equipment life, while the air system was upgraded to variable air volume, again an efficiency improvement. Finally, fan coil units were deployed in perimeter spaces to offset heating loads." (*fan coil units replaced radiators for heating*)
- Additional notes: Shallow (200-400') closed-loop wells were considered but it would have required 60-90 wells (2-3 tons each) to achieve same exchange capacity. Claim to have eliminated 326 tons of GHGEs per year.
- Companies/firms contracted: Carrier Corporation (pumps and HVAC equipment); The McGee Company (drilling); AKF Engineers (drilling); Wm. Stothoff Company (drilling)

AIRSIDE / APPLIED / CONTROLS / SERVICE / SPECIAL SOLUTION / TOTAL SYSTEM / UNITARY

Case Study – Friends Center

EDUCATION / HEALTH CARE / LODGING / MANUFACTURING / OFFICE BUILDING / RETAIL / SPECIAL

Sustainable Comfort, Small Footprint

Deep wells plus Carrier geothermal heat pumps and controls enabled The Religious Society of Friends to retrofit their historic center-city facility for a sustainable future using 100 percent renewable energy for heating and cooling.

Responsible Comfort and LEED® Platinum Certification at Historic Friends Center

Project Objectives

The Friends Center is a campus of three buildings in central Philadelphia, owned and operated by The Religious Society of Friends, commonly known as the Quakers. The complex includes the historic Race Street Meetinghouse. Faced with the need to renovate the heating and cooling plant, the Friends decided to take this opportunity to eliminate their reliance on fossil fuels and secure the future comfort of worshippers, office inhabitants, and the children and staff of the onsite daycare center using 100 percent renewable energy. Environmental integrity, responsible use of resources and the goal of carbon neutrality were driving forces in the Friends' decision-making process. In addition, their design solution had to take into account the campus's location in center-city Philadelphia.

Solution

The centerpiece of the $12.5 million Friends Center renovation is a Carrier geothermal exchange system designed to eliminate the property's reliance on fossil fuels for heating and cooling. Using deep wells installed directly below the Friends Center campus, the new system — which includes Carrier geothermal heat pumps, air handlers, air terminals, fan coil units, hot water coils and digital controls — enabled the Friends to use geothermal technology despite their metropolitan location, in which the extensive surface water-loop of a typical geothermal system would have been impossible. In addition, the i-Vu® open protocol web-based building automation system was specified, enabling Friends Center staff to monitor and control every aspect of the geothermal system as well as other building functions. This forward-looking solution helped the Center attain a Leadership in Energy and Environmental Design (LEED)® Platinum certification.

UNITARY / APPLIED / CONTROLS / SERVICE / SPECIAL SOLUTION / TOTAL SYSTEM / UNITARY

turn to the experts

Case Study – Friends Center

EDUCATION / HEALTH CARE / LODGING / MANUFACTURING / OFFICE BUILDING / RETAIL / SPECIAL

"I was very impressed with the operation of the Carrier water-to-water heat pumps and with their ability to operate as both a chiller and a boiler."

Jonathan Salemo, Project Manager, Elliot-Lewis

Project Synopsis

The Friends Center campus, located just two blocks from City Hall in historic downtown Philadelphia, includes three buildings: the Race Street Meetinghouse, a national historic landmark built in 1856, and two modern facilities that house office and conference space. The 54,000 square foot facility is home to nineteen non-profit organizations and a day care center, and is used by about 300 employees and 75 children each day, plus the congregation of the Central Philadelphia Monthly Meeting.

The Religious Society of Friends felt that the Center required renovation before it could be used to serve the next generation responsibly. In particular, the Friends felt a need to eliminate the Center's dependence on nonrenewable resources and cut greenhouse gas emissions to zero, while still providing a comfortable place for workers and worshippers alike. In addition, the historic integrity of the Race Street Meetinghouse had to be preserved. And finally the Friends hoped to complete the project according to such high standards that it would receive a LEED® Platinum registration.

Geothermal technology was identified as the key to the Friends Center's sustainable future. Robert Diemer of AFK Group, the award-winning firm that created the engineering design, said, "A traditional geothermal system would have required a well field larger than possible within the dense Philadelphia environment, so deep wells were used instead." The six deep wells drilled for the Center are the first in Pennsylvania, each six inches in diameter and more than 1,500 feet deep. Water from the wells is used to supply the geothermal heat pumps, which provide heating and air conditioning for the Center. Carrier geothermal equipment was chosen to transform the latent energy of the well water into comfort for the inhabitants of the Center.

Jonathan Salemo, Project Manager for Elliott-Lewis, the renovation's LEED-experienced contracting firm, selected the equipment for the Center. "We chose Carrier because they provided heat pumps and controls that met our requirements in terms of efficiency, capacity, features and cost. I was very impressed with the operation of the Carrier water-to-water heat pumps and with their ability to operate as both a chiller and a boiler, allowing the system to provide simultaneous heating and cooling." This ability enables Friends Center staff to manage the comfort of the highly diverse areas of the facility using one integrated system that draws solely on renewable energy.

In order to avoid wastefully replacing equipment that was still in good working order, the new system was integrated into some existing components. Dan DeSantis, Senior Sales Engineer for Carrier, said, "Mixed use facilities provide unique design challenges." In the Race Street Meetinghouse facility, which could not use ductwork due to its National Register status, individual water-to-air geothermal heat pumps were used to provide efficient space comfort. In the two newer buildings, water-to-water heat pumps replaced the existing chiller and city steam system. The existing air handler was improved with a variable speed drive, which increases efficiency and extends equipment life, while the air system was upgraded to variable air volume, again an efficiency improvement. Finally, fan coil units were deployed in perimeter spaces to offset heating loads.

Robert Pry, Senior Controls Engineer for Carrier, said, "One of the most significant challenges of the controls design at Friends Center was the integration of water, air and ancillary systems. The equipment was connected via the open protocol i-Vu® system, which allows staff to observe and control the operation of the heating, ventilation, air conditioning (HVAC) and rainwater collection systems."

In the end, the careful process of renovating Friends Center paid off. The Center eliminated its fossil fuel emissions of 326 tons per year, is now positioned for a sustainable future in their center-city location, and was rewarded with a LEED Platinum certification, indicating that the Friends have obtained their goal of responsible comfort and good stewardship of resources.

Project Summary

Location: Philadelphia, PA

Project Type: Retrofit of major mechanical systems

Building Size: 54,000 square feet

Building Usage: Mixed: Office, conference, daycare, worship

Objectives: To be fossil fuel free and carbon neutral

Main Decision Drivers: Using geothermal heat pumps to eliminate chiller and boiler

Project Cost: $12.5 Million ($2 million in HVAC)

Project Date: 2008

Equipment: Carrier water-to-water geothermal heat pumps, water-to-air geothermal heat pumps, fan powered mixing boxes, single duct VAV boxes, fan coils, and one air handler

Controls: i-Vu® open protocol control system used to integrate Carrier equipment, existing HVAC equipment, VFD (variable frequency drive) pumps, water valves, and radiant panels.

For more information, contact your nearest Carrier Representative, call 1.800.CARRIER or visit our web site at **www.carrier.com**

9.3 NREL DESICCANT EVAPORATIVE AIR CONDITIONING (DEVAP)

Introduction

Air conditioning at the NRDC building consumes 320,000 kWh kWh annually and represents approximately 45% of the entire electricity load. Traditional air conditioners use a lot of electricity to run the refrigeration cycle, but DEVap replaces that refrigeration cycle with an absorption cycle that is thermally activated.[207] Desiccants are an example of a thermally activated technology (TAT) that relies on heat instead of electricity.[208] It can be powered by natural gas or solar thermal energy and uses very little electricity.[209]

Rationale

Currently, the NRDC building consumes 320,000 kWh of electricity for air conditioning according to the Data Model. The U.S. Department of Energy reports DEVAP uses up to "90 percent less electricity and up to 80 percent less total energy than traditional air conditioning," with an estimated payback of 3 years.[210] By replacing the four air cooled air conditioners on floors 6 and 7 with four DEVap units, NRDC will reduce electric loads by approximately 80,575 kWh a year. (Note, this kWh calculation does not take into account any prior building energy efficiency gains). It is also a scalable solution that can be used in their other offices and for the CMI buildings. However, note that if NRDC chooses to install a geothermal system this will likely not be a compatible technology, but if it chooses to utilize DG/CHP, DEVap will be complimentary because waste heat can be harnessed.

Other advantages to the DEVap unit include:

- DEVap controls humidity more effectively to improve the comfort of people in buildings.[211]
- DEVap uses salt solutions rather than refrigerants, and therefore avoiding the use of harmful *chlorofluorocarbons* (CFCs) or *hydrochlorofluorocarbons* (HCFCs).[212]
- The DEVap unit is scalable to other buildings and projects in New York City, the United States, and globally.
- The net packaging of a DEVap unit is smaller than a traditional DX AC unit.[213]
- The lifespan of a DEVap unit is estimated to be 15 years.[214]

Potential disadvantages/risks

Most technological risk from DEVap stems from its evaporative aspect. Evaporative devices eject heat from the building to the atmosphere in the same device that cools the building air.[215] This means a second set of exhaust air ductwork must be routed to and from the DEVap A/C and the outside, and constitutes the greatest implementation risk for retrofits.[216]

Benchmark/case studies used

In a desiccant-enhanced evaporative, or DEVap, air conditioner, a polymer membrane coated with both a teflon-like substance that repels liquid water and a desiccant divides the air flowing through the system into two streams.[217] The membrane has pores about 1 micrometer to 3 micrometers in diameter; these are large enough for water vapor to pass through but too small for the desiccant to sneak across.[218] The desiccant draws moisture from the airstream, leaving dry but warm air. Indirect evaporative cooling takes place in a secondary chamber, chilling the other half of the divided airstream.[219] As the air in the second chamber grows cooler and wetter it cools the dividing membrane, which in turn cools the first airstream, and out of the machine comes cool, dry air.[220] Unlike most heating, ventilation, and air-conditioning systems, DEVap uses no environmentally harmful fluids, hydrofluorocarbons, or chlorofluorocarbons; instead, it uses water and concentrated salt water.[221] DEVap does not require a large outdoor condenser, but instead uses a much smaller desiccant regenerator that can be placed inside or outside, and can be integrated with solar and waste heat.[222]

NREL researchers are leaders in using thermally active technologies to condition air. They have extensive analytical and modeling expertise in TATs and evaporative technologies, which work well together to cool buildings.[223] They have also created best-in-class test facilities that helped them develop DEVap and enable them to assist private companies in bringing their products to market.[224]

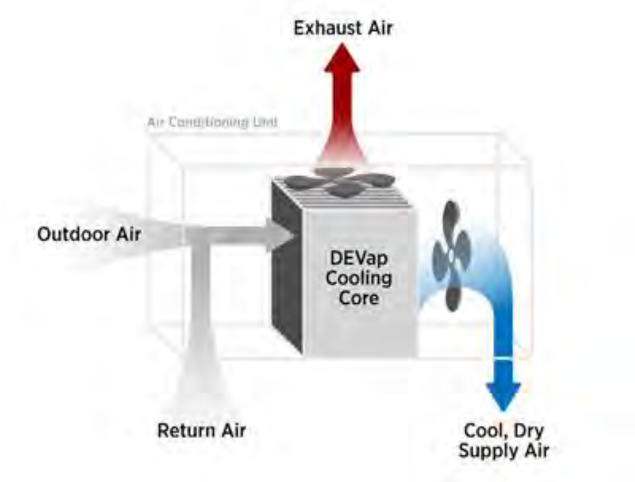


Figure 22: DEvap Unit

In 2011, an NREL study performed an economic analysis of a ten ton DEVac unit in Houston using natural gas as the energy input at a price of $1.10/therm.[225] The yearly natural gas cost was $874 and therefore this unit consumed approximately 795 therms.[226] With four DEVap units installed, 3200 therms will be provided from solar thermal panels at the NRDC facility. The result of the study performed in Houston is shown in the table below.

Simulation	DX	DEVap	Units	Difference (%)
Total Cooling	14,819	14,695	ton h	-1%
Sensible cooling	9,933	9,937	ton h	0%
Latent Cooling	4,866	4,768	on h	-2%
Cooling electric energy	15,750	1,579	kWh	-90%
Total electric energy	27,166	1,747	kWh	-94%
Cooling thermal energy	0	24,391	kWh	
Cooling source energy	53,550	32,791	kWh	-39%
Total source energy	92,366	33,365	kWh	-64%
Cooling electric energy (specific)	1.06	0.11	kWh/ton	-90%
Source Cooling COP	0.97	1.58		-62%
Peak electric	10.26	2.18	kW	-79%
Total site water evaporation	0	30511	gal	
Total site water evaporation	0.00	2.08	gal/ton h	
Total off-site water use (1 gal/kWh)	27,166	1,747	gal	-94%
Total off-site water use (1 gal/kWh)	1.83	0.12	gal/ton h	-94%

Table 8: Results Summary for Houston[227]

Tech Development Forecast

NREL plans to hand off the design to industry for commercialization by 2015.[228]

Finance

Currently, a 10-ton DEVap A/C RTU unit including installation is projected to cost $20,461.[229] Four of these units will cost $81,844. NREL is working to increase the efficiency and reduce the cost per unit before it is commercially released in 2015, but this reduction in cost is not currently quantifiable. The table below outlines the kWh savings from the four DEVap units.

Current consumption of AC units (annual)	302,166 kWh
Number of AC units and condensers	17
Number of AC units to be replaced by DEVap	4
Estimated consumption of 4 AC units (annual)	89,528 kWh
Estimated consumption of 4 DEVap units (annual)	89,528kWh
Reduced electric load from 4 DEVap units (annual)	80,575 kWh

Table 9: kWh savings estimate

9.4 HVAC – Energy Recovery Ventilator (ERV)

How Energy Recovery Ventilator (ERV) technology improves upon existing HVAC efficiency measures

An ERV would drive further efficiency from the existing HVAC efficiency measures already in place. Existing measures include the use of a water-side economizer, variable speed fans and compressor motors, and variable airflow valves (VAVs) on some floors.[230]

Energy efficiency contribution from the current NRDC water-side economizer

At NRDC there is no chiller or chilled water pump in the loop. Instead, condenser water is piped directly to Direct Exchange (DX) air conditioning units on each floor. NRDC operates a water-side economizer mode for its air conditioning system whereby the condenser water loop is used to take advantage of free cooling from the rooftop cooling tower on days when outdoor temperature and humidity levels are optimal.[231] According to the New York City Energy Conservation Code, "the water-side economizer system uses condenser water directly to meet cooling loads and does not introduce air-side contaminants or excessively dry winter outside air, as air economizers may do."[232] Economizers must be able to handle all of the expected air conditioning load when "outdoor air temperatures are 50°F (10°C) dry bulb and 45°F (7°C) wet bulb and below."[233] While operating, economizer mode can save 70% or more of typical cooling costs.[234] In New York City, a properly functioning economizer is only part of the total HVAC efficiency solution.

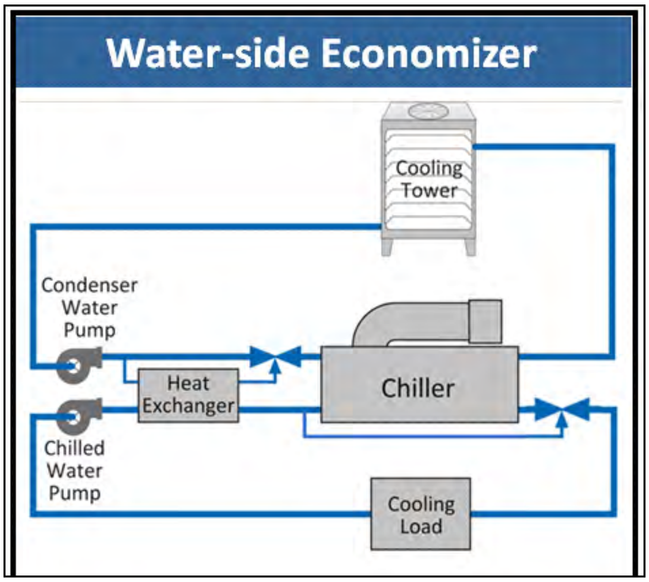


Figure 23: Typical water-side economizer diagram

There are two main factors that limit the effectiveness of the economizer. First, economizers are rendered ineffective when combined humidity and temperature conditions in New York City exceed design limits. Figure 24 below – a map designed around the 24/7 load profile for data centers— indicates that New York City receives approximately 4,500 "free cooling" hours per year, using a 24 hour per day load basis[235]. For a commercial building like NRDC, the number of effective free cooling hours is reduced due to higher daytime temperature and humidity levels during business hours.

The outside air ventilation requirement presents the second challenge to the overall impact of the economizer as an HVAC load reduction system. Despite maximizing free cooling hours, NRDC must still bring in a large amount of outside air to meet code requirements. As NRDC aspires to reach net zero site energy, all major energy losses must be addressed.

Estimating ERV energy savings required calculating NRDC building outside air flow requirements

Energy losses due to outside air ventilation requirements can be substantial, especially in cooling months when the humidity of outdoor air requires electrical energy for dehumidification. Until recently, the New York City Building Code required base ventilation of 20 cubic feet per minute (CFM), per occupant for office spaces.[236] To address sick building syndrome and indoor air quality concerns, the Code represented a three to fourfold increase in required outdoor air compared with previous standards.[237]

The NRDC building presently uses a combination of constant flow and variable airflow systems that are responsible for maintaining required outside air ventilation rates.[238] With the exception of during shoulder months fresh outdoor air coming into the building requires active heating or cooling using electrical or fossil fuel energy before the fresh air can be introduced into the building. Because ventilation rates are based in part upon the number of occupants, the team estimated the total ventilation requirement of NRDC's floors by multiplying the approximate number of typical occupants (350) [239] by the code required ventilation rate (20 CFM) [240]. NRDC's theoretical ventilation rate is 7,000 CFM. Advanced sensors on the 8th and 9th floors read CO2 levels, allowing NRDC to reduce ventilation rates to spaces that are not being used. While this reduces fan energy and may reduce heating and cooling load, the total amount of ventilation required by code will be fairly constant in the 7,000 CFM range due to total occupancy levels, present lack of VAV systems and advanced sensors on floors 6, 7, 10, 11 and 12, and other design factors that require an engineering analysis.

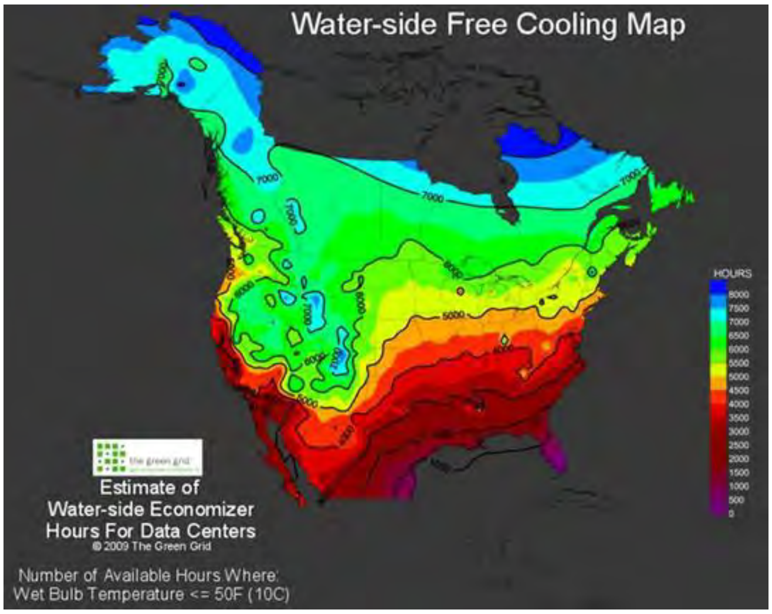


Figure 24: Water-side economizers provide approximately 4000-4500 hours per year of free cooling in the New York City climate zone

The New York City Building Code has recently been updated to follow ASHRAE 62.1 ventilation standards for offices – yielding a slight reduction in ventilation requirements for the NRDC facility compared with the prior standard.[241] Outside air ventilation requirements are now calculated according to the formula "5 CFM per person, plus 0.06 CFM per square foot." [242] Because NRDC may be considering an increase in occupant density, the project team maintained the previous code-required ventilation rate of 7,000 CFM as a conservative approach to approximating the size and cost of the ERV system.

ERV systems result in reduction in heating and cooling system capacity requirements

There is a strong case for ERV implementation at NRDC in addition to planned efficiency and passive HVAC techniques. "Buildings that were built with energy efficiency in mind may have the least excess capacity and therefore may have the greatest difficulty in raising outdoor air flow rates to meet current ASHRAE standards."[243] The ERV will allow NRDC to downsize the overall cooling system without sacrificing indoor air quality or occupant comfort. In the absence of an ERV system, the EPA cautions that "downsizing as an energy conservation strategy ought to be judiciously applied, taking into account the increased capacity needed to accommodate outdoor air flow rates consistent with indoor air quality."[244]

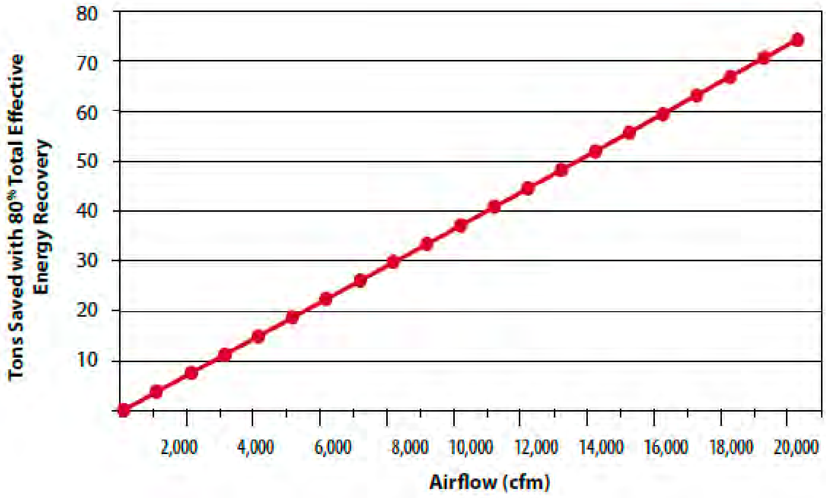


Figure 25: Cooling system capacity reduction potential with ERV

Energy savings for NRDC will be realized through immediate operational heating and cooling energy savings as well as reduction in required system capacity. Figure 25 estimates NRDC will save 20-25% of required system tons. Based on a total of 190 tons installed cooling capacity, this equates to up to 47 tons reduction in system size. Because NRDC already employs several HVAC efficiency mechanisms, this figure is likely to overstate ERV benefits. It was necessary to use a modeling tool to assess more realistic energy and system capacity reductions resulting from ERV installation.

Applying the Environmental Protection Agency (EPA) "EFAST" model to estimate ERV efficiency gains for NRDC

The Environmental Protection Agency (EPA) EFAST software is a site-specific modeling program designed to support the business case for ERV installation in facilities with outside air ventilation requirements similar to NRDC. The model takes into account site-specific inputs including NRDC's use of an economizer for free cooling at appropriate times in New York City, total number of occupants, and the approximate facility layout. Originally designed for schools, the EFAST tool is also appropriate for offices due to the similar ventilation requirements of classrooms and office buildings. EFAST applies conservative ERV unit efficiencies of 67% for winter heating energy recovery and 65% for summer cooling energy recovery.[245] An approximate high-end code-required ventilation rate of 7,000 CFM was used. EFAST accesses New York City weather data and calculates heating degree and cooling degree days, subtracting days when conditions allow the economizer to provide free cooling. For simplicity, we modeled the entire building as a single zone rather than breaking out the loads of each individual floor. The rationale for this decision is that a single ERV unit will serve the building by supplying conditioned outdoor air to the air intakes on each floor. The system operates at a variable rate based on total airflow requirement.

The EFAST model concluded that NRDC can realize annual net operating savings of $4,925 from an initial capital investment of $14,275. A more significant benefit is 298 MBH of avoided heating capacity and 13.1 tons of avoided cooling capacity. Limitations of the model include optimistic cost estimates of $2.26 per CFM for the ERV equipment. Costs are likely to be higher in New York City and may be higher at the NRDC site depending on the amount of labor and materials required to tie the ERV to existing sources of outside air. Some manufacturer's documentation placed ERV costs as high as $3.60 per CFM. The model may not include costs of site-specific design work required to link the outside air inputs of several air handling units to one rooftop ERV. The project team obtained an estimate of $20,000 from a New York City HVAC engineering firm which is applied in the Financial Model. [246]

Figure 26: Payback period for ERV systems by climate zone

Finance

The EPA "SAVES Map" shows zero to two-year simple payback time for ERV systems with total energy recovery in New York City[247]. The ASHRAE estimate of three to six years for New York City buildings may be appropriate due to the site-specific considerations and additional ventilation control systems improvements that are suggested in tandem with the ERV installation[248]. The result of the EFAST model produced simple payback of just under three years.

Consistent with the overall project approach, we applied conservative energy savings calculations to the energy balance model and high-side costs to the financial model and implementation plan in order to project the most realistic scenario for NRDC given the observed spread in cost and energy savings data across sources.

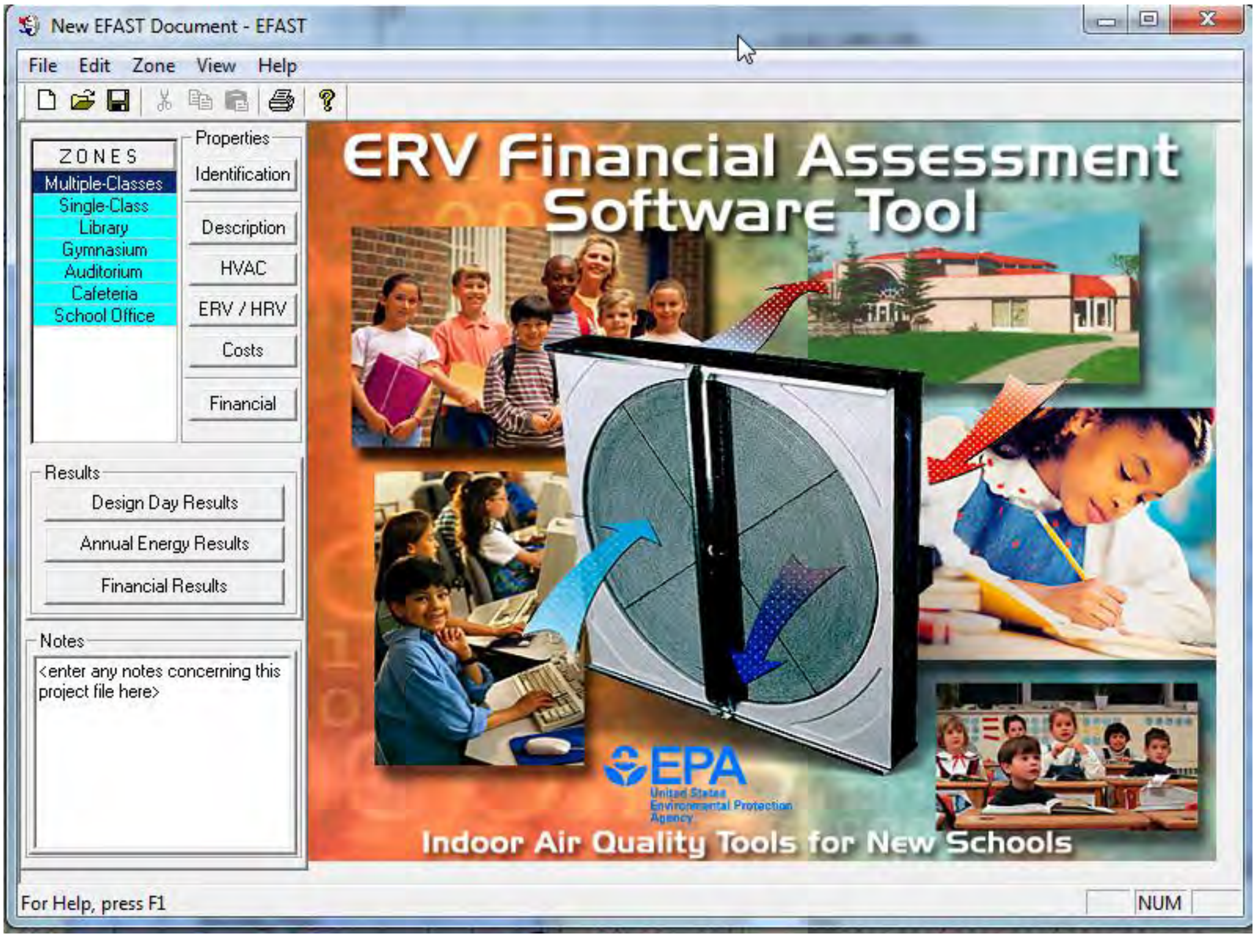


Figure 27: Results of EFAST Model for ERV Energy Savings – NRDC Site-Specific

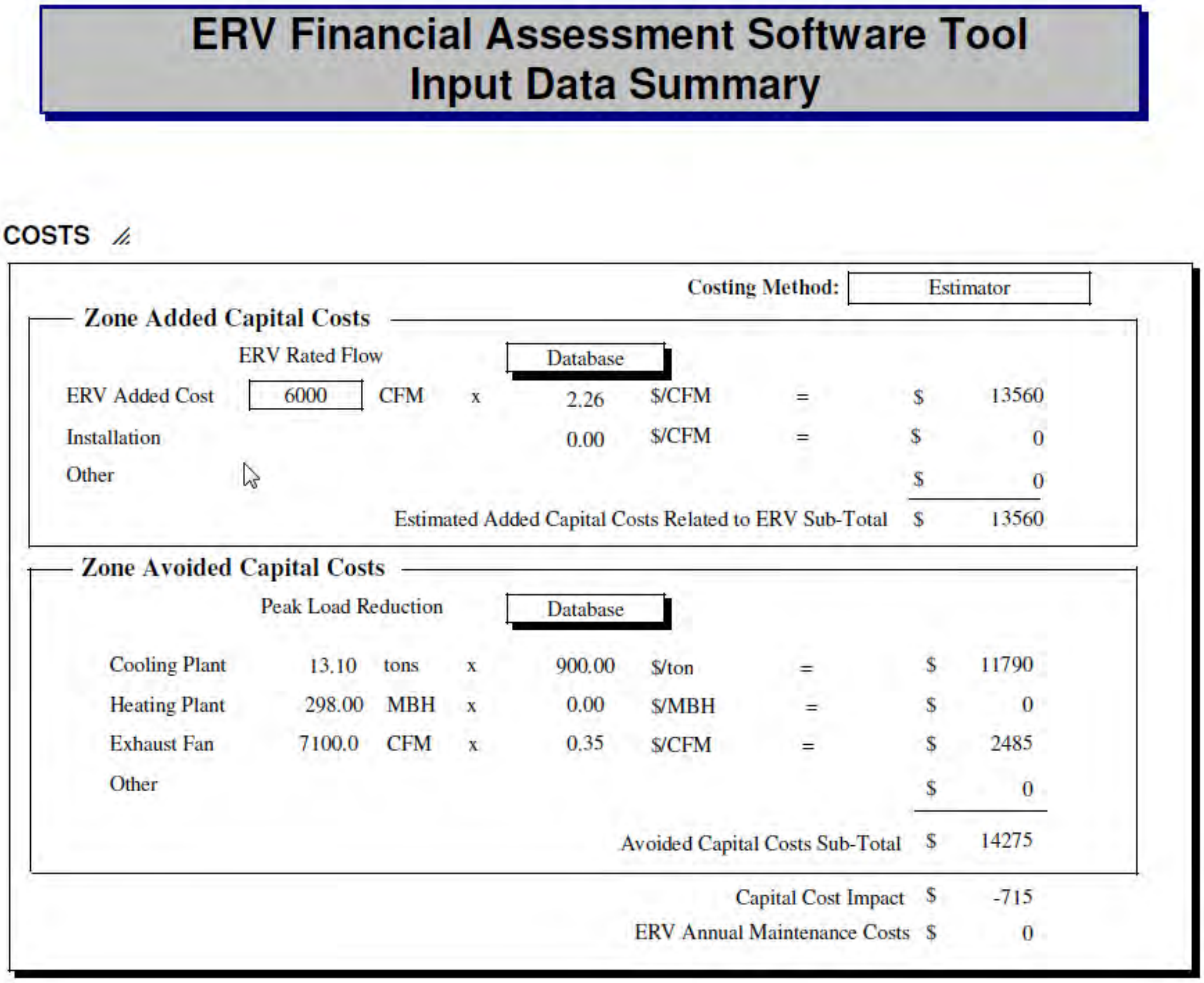


Figure 28: ERV Financial Assessment Software Tool Results

RESULTS OF ANALYSIS

Project Identification

School	NRDC HQ		School Board	
Zone Name	Multiple-Classes	Zone# 1	City, State	New York, NY
Weather File Location	New York City, NY elev. 23 ft		Outdoor Air Ventilation	7100 CFM

Design-Day Conditions & Results

Winter/Heating

Outdoor Air:	Entering ERV	Leaving ERV
Dry Bulb Temperature	15°F	54°F
Humidity Ratio	6 grain/lb	24 grain/lb
Sensible Effectiveness	69%	
Latent Effectiveness	63%	
Total Effectiveness	67%	

Avoided Heating Load: 298 MBH

Summer/Cooling

Outdoor Air:	Entering ERV	Leaving ERV
Dry Bulb Temperature	88°F	80°F
Humidity Ratio	98 grain/lb	79 grain/lb
Sensible Effectiveness	68%	
Latent Effectiveness	63%	
Total Effectiveness	65%	

Avoided Cooling Load: 13.1 tons

Annual Energy Results

	Load Savings per zone		Cost Savings per zone	
Heating Energy	234,633	MBTU/year	6,643	$/year
Cooling Energy	19,452	MBTU/year	413	$/year
	Load Increase per zone		**Added Costs per zone**	
Preheat Energy	N/A	MBTU/year	N/A	$/year
ERV/HRV Added Fan Energy	10,013	kWh	2,131	$/year
Annual Cost Savings			4,925	$/year

Financial Results

Costing Method: Estimator	1 Zone	x 1 similar zones	Total
Added Capital Costs Related to ERV/HRV	$ 13,560		$ 13,560
Avoided Capital Costs	$ 14,275		$ 14,275
Capital Costs Impact	$ -715		$ -715
Annual Energy Cost Savings	$ 4,925		$ 4,925
ERV Annual Maintenance Costs	$ 0		$ 0
Annual Operating Savings	$ 4,925		$ 4,925

Simple Payback: Immediate **Life Cycle Savings (per zone):** $ 81,698 N/A

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9.5 ADVANCED LIGHTING CONTROLS AND BUILDING PERFORMANCE PLATFORM

Rationale

The Redwood integrated building-performance and lighting system is capable of controlling lighting in addition to heating and cooling systems of a building. It offers one of the most advanced and efficient lighting platforms available in the market today. The system is capable of operations such as advanced dimming, scheduling, occupancy detection, daylighting and task- tuning strategies – all at a per fixture level. The system can be setup to communicate detailed occupancy data to an HVAC system to be dynamically adjusted based on real-time occupancy data.

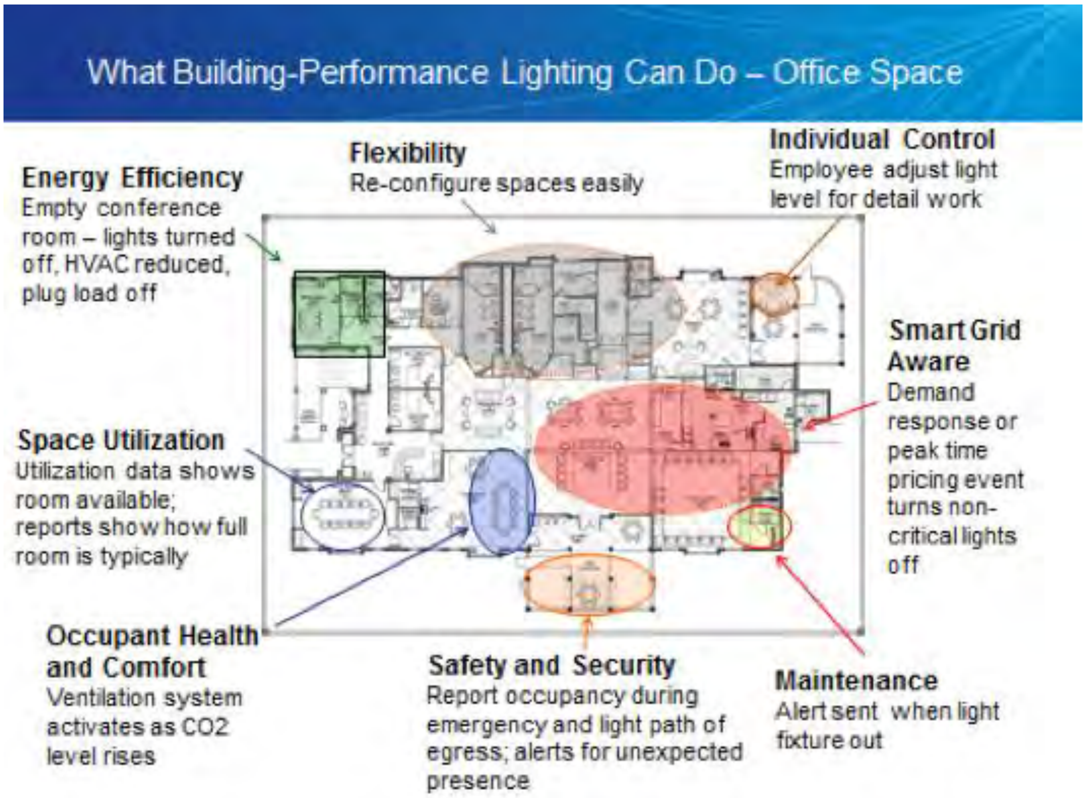


Figure 29: A snapshot of a building performance system's capabilities

Typically a lighting control system technology involves three separate systems for power, control, and measurement, however this technology enables a single dedicated system to power and control lighting at the individual fixture level where the most accurate data on occupancy to measure and maximize space utilization are easily accessible building managers.[249]

A typical Redwood lighting system shown below contains the following components: a director, engines, sensors, gateways and adapters, wall switches, compatible fixtures, electrical wiring to connect to the engines, low voltage cabling and a low-voltage DC architecture.[250] The high definition sensor network uses the state of the art networking technology and low-voltage DC architecture to achieve significant reduction in planning, installation and commissioning costs.

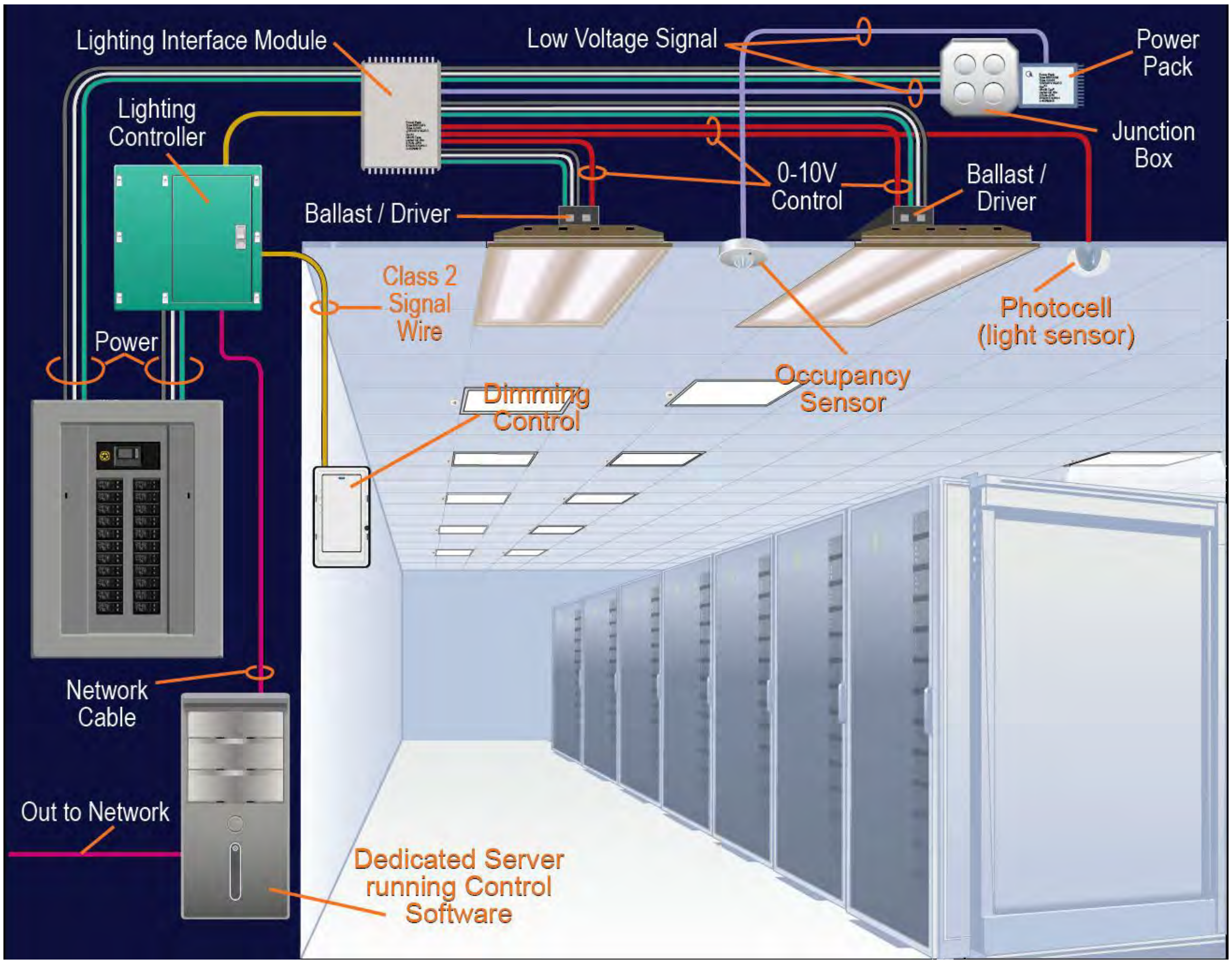


Figure 30: Diagram of a wired overly control system (*Redwood systems*)

The overlaying capability of this technology enables easy retrofitting on top of the existing AC lighting power infrastructure and offers increased efficiency as well as lower installation costs for a building retrofit.[251]

The following list provides some of the benefits of this system:

- Redwood Systems provides 64,000 different levels of dimming and optimal light level for each individual fixture within a given space.[252]
- It utilizes lights at 85% of maximum output resulting in 30% energy savings.[253]
- Per-fixture daylighting harvesting capability trims another 30% savings due to tailored occupancy sensors and individual lighting controls
- Follow-me-lighting in the hallways and open spaces reduces lighting levels, brightening as people walk through and dimming after they pass through
- Allows intelligent control customized to building occupant behavior

These features have resulted on an average 75% overall reduction in lighting load and 65% peak demand reduction, resulting in cost and energy savings. The system also helps a building gain LEED credits.

Benchmark/case studies used

Among companies that have implemented Redwood systems system are Facebook, Google, SAP, and Volkswagen research facilities.[254] These companies have recorded energy savings ranging from 78% to 91%. Their applications vary from open office spaces and conference rooms to data centers and classrooms and hallways.

SAP implemented Redwood systems in early 2012. To maximize its energy efficiency and workspace productivity, the company replaced fluorescent lighting with LED fixtures and implemented an integrated Redwood system. The retrofit resulted in 50-75% in lighting energy savings, as well as HVAC energy savings through occupancy-based HVAC with Trane ™ VAV system.[255]

Lighting programming controls can operate according to specific schedules to maximize natural daylighting, allowing superior flexibility in light levels. Smooth dimming has helped SAP preserve and extend LED fixture lifespan by reducing their operating temperatures. In addition, the web-based reports has provided insight on the buildings occupants energy consumption habits and has enabled the facility management team to better understand lighting and temperature energy consumption for tweaking the system to more aggressive control settings.

Tech Development Forecast

The advantages offered by LED lighting combined with advancements in lighting management technology solutions are increasingly helping commercial buildings meet their energy efficiency goals. Currently building operations are offered through individual and disconnected management systems. Seamless integration of all these procedures into one comprehensive network has been proved to be quite challenging. The building management industry is at its infancy with mostly the early adopters to reap the derived long-term benefits from tweaking a buildings energy consumption habits. Market studies outlining the benefits of LEDs, in terms of their long lifespan, mercury-free disposal, and increased productivity from enhanced ambient lighting has just begun. To thrust the market forward for increased commercial adaptation of these technologies further innovation in incentives and creative financial solutions are required. LEDs are becoming even more efficient and less costly – reaching up to 100,000 hours where ultimately the LED choice will become more cost effective than traditional technologies.[256]. As costs and efficiencies for both lighting devices and integrated systems improve, more forward- thinking decision makers will make the leap to more comprehensive building management systems.

9.6 LIGHTING RETROFIT USING LIGHT EMITTING DIODES (LEDS)

Rationale

Lighting typically contributes to 40% of a commercial building's energy use.[257] Retrofitting a lighting system is a relatively simple solution for cutting down energy consumption while minimizing capital expenses. NRDC's previous renovations have incorporated natural and advanced daylighting techniques to make the most out of solar energy as well as updating more than hundreds of lights to efficient T8 and T5 fluorescent tubes and Compact Fluorescent Lighting (CFLs). According to the data model this retrofit has had a great impact on overall energy consumption where lighting (annual 85,558 kwh) now comprises about 10.77% of the entire load and lighting power density has improved to 40.7% better than ASHRAE Standard 90.1-2004.[258]

To achieve additional lighting energy savings at NRDC a thorough examination of existing and next generation technologies was performed. Cutting edge lighting advancements utilizing semiconductor materials have enabled integration of Light Emitting Diodes (LEDs) into residential and commercial spaces.[259] LEDs are part of a fast growing technology called Solid-State lighting which utilizes carbon- based compounds that glow or illuminate in the presence of an electrical current.[260] But as advancements in manufacturing segments and demand for various LED applications have increased, LEDs with lower prices have become more mainstream. Considering their extended lifetime and the quality of light they produce, LED bulbs have become more cost-effective than CFLs.[261] The following chart compares the Luminous Efficacy of different types of light bulbs throughout the years. Luminous Efficacy in an indicator of energy efficiency of the light or amount of light produced for each watt of electricity, and is measured in Lumens per watt.

Unlike CFLs, LEDs have low embodied energy, do not contain mercury and there is no risk of breakage associated with them.

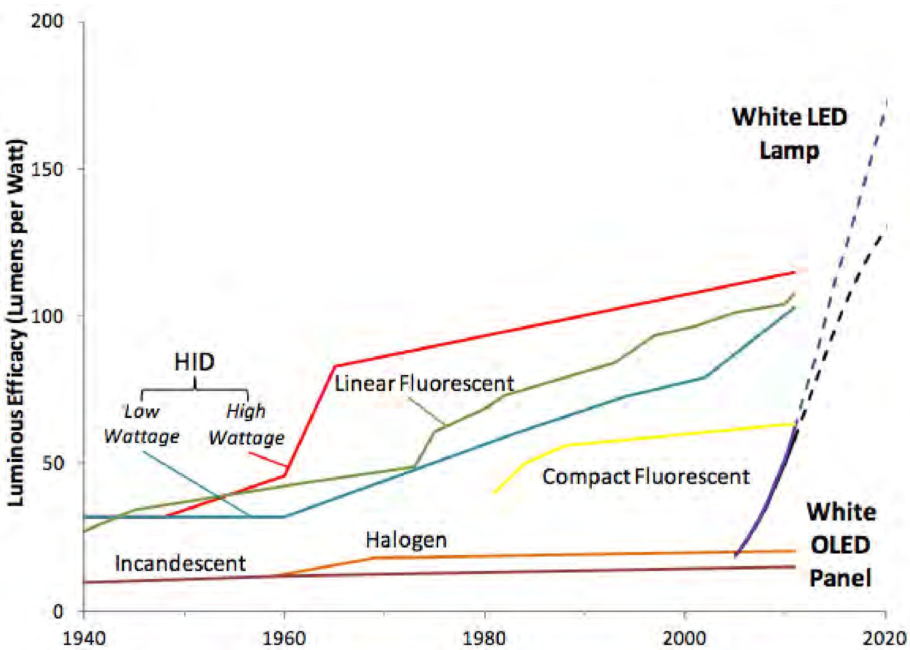


Figure 31: Historical and predicted efficacy of light sources according to Navigant Consulting, Inc.

To date, LEDs are solely used to illuminate exit signs on Floors 8 and 9 at NRDC.[262] To take advantage of LEDs constant light output and long life (at least four to five times the lifetime of fluorescent systems as indicated by the table) and their improved efficiencies and greater cost savings, our recommendation is to retrofit all lighting fixtures with LEDs. The following table provides a comparison of some of the key differences between

LEDs and CFLs.

	Light Emitting Diodes (LED)	Compact Fluorescent Lighting (CFL)
Life span	50,000 hours plus	10,000 hours
Energy Savings	300- 500 kwh	700 kwh

Table 10: LED and CFL Comparison Chart [263]

An added benefit for using LEDs at NRDC is the efficiency gains from reduction in cooling load of the building. Lighting systems in general create energy when electrical current is passed through them; in CFLS 80% of this energy is released as heat.[264] Since most commercial environments have drop ceilings, the heat generated by the static nature of the fluorescent lamps[265] is radiated down into the occupied space. This reaction results in increased cooling load for the building. LED fixtures create less heat by nature and keep the heat within the commercial space as opposed to releasing it into the occupied space. Therefore, less cooling energy is required to cool the place when LED lights are used.

Due to improved and more efficient microchip technology and economies of scale in manufacturing applications, LED prices have fallen 24% in two years and are projected to decrease even further.[266] Currently LED prices are still 20 – 30% more than fluorescents systems. However, taking into account the dimming capabilities, as well as savings from reduced maintenance and cooling costs, added values from tax effects in depreciation, and various incentives from utilities, the payback period for LED systems are projected to be in the range of 6 months to 3 years.

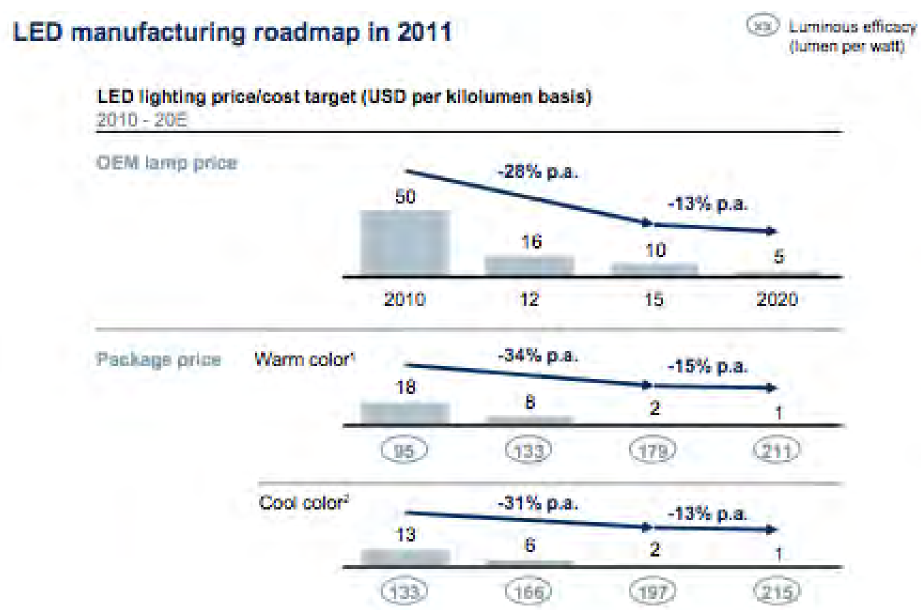


Figure 32: LED price and efficacy trends from the US Department of Energy

Benchmark/Case Studies

In a lab study performed by Redwood systems, a lighting company which offers comprehensive lighting and HVAC management systems, LED troffers were compared against their 1'x4' linear 2 lamp T8 fluorescent counterparts. To match a commercial space, a 180' x 100' sized room with 10' ceiling was chosen. Independent lab testing results indicated that the LED luminaries were able to save 30% more energy while using 17% fewer fixtures.

Luminaire	Power (W)	Number of fixtures	Average Lluminance	Max:Min	Lighting Power Density
1 1’x4’ linear 2-lamp T8 fluorescent troffer	58	216	37	2.1:1	0.7
LED 2 ‘ X2’	51	180	35	1.8:1	0.5

Table 11: Lighting performance comparison of linear fluorescent and LED luminaries[267]

These results translate to cost savings for both fixture installations as well as lighting maintenance. The study also indicated that with fluorescents, dimming affected the efficiency and lifespan of the light where dimming below 20% resulted in no energy savings at all. Dimming LEDs by 30% reduced power usage by 50% where in dimming fluorescents by 30% reduced power only by 20%.[268] The LED lighting also offered more uniform lighting throughout the space. Another major difference was the impact of dimming on a light’s lifetime. Switching fluorescents on or off from a dimmed state shortened their lifetime, whereas dimming LEDs in fact extended their lifetime.

Tech Development Forecast

If the industry predictions are true, the growth of LED lighting within the commercial spaces will be exponential in the next 5 years. The first wave of LED products were exploited by early adopters and Fortune 500 companies when they payback was within 5-10 years.[269] The reduction in costs, improvements in semiconductor performance, functionality and quality is rapidly increasing the value of this technology for decision makers in the field of energy efficiency and is broadening its acceptance in the commercial market space. With short paybacks of less than five years, rebates, and vendor competition, LEDs luminary choices and ease of use have already made them a popular choice for lighting retrofits in energy efficient buildings.[270] The convergence of building automation to monitor a commercial space’s energy consumption will also push this industry to innovate more efficient chip and driver technologies.

Finance

At this time there are no known incentives for this retrofit however some utilities might offer rebates for lighting retrofits using LEDs in the future. For a more comprehensive look, refer to the financial section of this document.

As for the approximate cost of LEDs plus their installation, Redwood systems has provided an estimation based on a similar retrofit at a commercial space in NYC. This cost estimation is based on per square foot as opposed to a cost per fixture.

- Typical cost for LED lights: $4-$6 per square foot
- Typical cost for installation: $4-$5 per square foot
- Total cost: $8-$11 per square foot
- NRDC-owned 7 floors = 62,063 square feet
- Total LED cost plus installation = $ 469,504 – $682,693

Currently there are a total of 910 fixtures at NRDC’s 7 floors. This cost estimation has not taken the luminosity or foot-candles for various rooms and locations into consideration so once the price per fixture is determined, the fixture count as well as the cost and installation will be significantly reduced.

9.7 Direct Current (DC) Building Microgrid

AC vs. DC Power in Buildings

Many electronic devices used in commercial buildings need direct current (DC) input –including lighting (electronic ballast fluorescent lights and LED lighting), desktop computers, laptops, cellphones and other portable devices, HVAC actuators, and variable frequency drives (VFDs) on HVAC fans and pumps**.** These devices are becoming an increasing portion of the building load, representing as much as half of the electric load in today's buildings[271]. NRDC uses DC-powered devices for lighting, computers, and server room equipment.

Power from today's electric grid is distributed as Alternating Current (AC) power, and DC-powered devices require conversion of AC power into DC, which typically involves inefficient rectifiers. Renewable energy systems, such as NRDC's rooftop solar PV system (and other potential onsite renewable generations systems we will consider) produce DC power. This requires an inverter to convert the native DC power to AC power in order to be used in the building's electric system, only to be converted back to DC at the individual equipment level for DC-powered devices. Both AC-DC and DC-AC-DC conversions result in significant energy losses. According to Lawrence Berkeley National Lab, the average conversion losses for internal and external power supplies used in AC systems are 32%.[272]

DC Microgrids

A DC microgrid within a building can minimize or eliminate these conversion losses by centralizing AC-DC power conversions and feeding onsite DC power directly to DC power equipment. DC microgrids can be used for a portion of a building, for an entire building, or for several buildings as a campus grid.

A DC building microgrid system uses a high-efficiency rectifier to convert grid-supplied AC power to a DC building grid, and distributes the power directly to DC equipment connected to the grid. According to a Yale study, a bulk high-efficiency rectifier used to convert AC power in a DC microgrid system can reduce AC conversion losses to 10%. Additionally, onsite solar PV systems, wind turbines, and other DC generation systems can feed directly to this grid instead of converting to AC power, eliminating conversion losses altogether. DC microgrids also produce less heat inside the building envelope become of their enhanced efficiency, resulting in reduced cooling costs, particularly when used in data centers.

Integrating a DC Microgrid in NRDC's Building

The team worked with representatives from Nextek Power Systems to map out how a DC microgrid can be integrated at NRDC. Nextek is a manufacturer of DC microgrid components and they position themselves as the "leader in emerging DC energy technologies." They are also heavily involved with developing standards for the DC industry with the EMerge Alliance.

The DC microgrid system recommended for NRDC is a hybrid system that uses both grid AC power and onsite DC power generation. The most feasible DC grid opportunities we have identified for NRDC are lighting, VFDs on HVAC pumps and fans, and desk-level equipment. According to Nextek, installing a 380V DC microgrid can improve the efficiency of NRDC's lighting and VFDs by 10%, and desk-level equipment by 15%. Based on estimates from Nextek Power Systems and calculations from the Data Model, the team projects total energy savings of 28,513 kWh, representing 2.4% of total facility energy load.

DC Building Distribution System (Install in 2013)

A DC power distribution system would include:

- High Efficiency AC/DC Rectifier
- DC Power Distribution Panel (PDP)

- Power Server Module (PSM)
- 24V DC load cables
- Maximum Power Point Trackers (MPPTs) on Solar Panels

A high efficiency AC/DC rectifier will be installed in the building's basement, in proximity to the AC power supply to the building. Emerson Network Power produces modular rectifiers (15kW) that can be sized to the DC building load. We recommend a 90kW rectifier based on these loads. The rectifier is connected to a 380VDC bus that will provide DC power to each floor. A DC PDP on each floor, similar to an AC panel board, will intake power from the DC bus and distribute it throughout the floor to PSMs (4 per floor). The PSMs will convert the incoming 380VDC power to 24VDC power, and distribute to DC fixtures through Class 2 24V load cables. This system is depicted in the one line diagram below. The DC building infrastructure will cost $117,875, according to estimates given by Nextek. When solar panels on the roof are replaced in 2017 with Concentrated PV, the panels will be connected to microinverters (MPPTs) that will feed DC power into the 380VDC bus instead of using an inverter to tie panels into the AC building system. According to Nextek, this can increase efficiency of solar panel power output by 5-10%.

DC LED Lighting (Implement in 2013)

NRDC's current fluorescent lighting will be upgraded to LED lighting in 2013. As part of this upgrade, we recommend integrating this lighting system into a DC building grid. AC-powered LEDs require a power source on each fixtures; instead LED fixtures would be connected directly to the DC microgrid, eliminating the need for this. Nextek estimates that using DC power instead of AC powered LED fixtures can improve LED lighting efficiency by 10%. This will result in 3422.3 kWh of additional savings to lighting load annually.

Variable Frequency Drives (Implement in 2013)

While a VFD takes in 60 Hz AC power and outputs variable Hz AC power, in between this the VFD typically contains a rectifier that converts AC power to DC to power and control the motors. This DC bus on VFDs can instead be connected to the DC microgrid to eliminate conversion losses, with an estimated 10% efficiency gain.[273] We have estimated these savings to be 6,971 kWh annually. There is no cost for this retrofit.

DC-Powered Workspace (2017-2018)

By 2017, experts at Nextek and the Emerge Alliance expect DC standards for desk level equipment to be formalized, allowing for the integration of DC power in workspaces. This would allow each workspace to connect DC-powered devices such as laptops, telephone systems, cellphones, and other portable devices directly to a DC power strip, increasing efficiency of the equipment by 15%, according to Nextek. We have estimated this savings to be 14,884.8 kWh annually (assuming laptops to be 40% of the plug loads on each floor). Nextek estimates this installation cost to be $125 per workspace.

Not Included in Data Model: Server Room

There is also potential to use DC power for server room equipment. Given the recent upgrades and investments in the server room in 2010, and the lack of available cost data for specific UL-listed DC power sources currently available for server equipment, we did not include this in our model. Nextek estimates potential savings at 15%.

DC Microgrid Case Studies

DC microgrids are still an emerging technology, but have been installed at varying capacity in several applications. In 2004, Nextek was contracted by William McDonough and Partners to install a DC microgrid at a distribution warehouse in Rochester, NY, which integrated a solar PV system with a DC-powered, high-efficiency lighting system. The DC microgrid included a 21-kW solar array (eliminating the need for an inverter) and T-8 lamps with DC ballasts and occupancy sensors, whose combined efficiencies resulting in savings of 20%. Power generated by the solar array not used by the lighting system is converted to AC with a high efficiency rectifier and used elsewhere in the building or sold back to the grid.[274]

In 2006, Nextek Power was commissioned to install a DC microgrid at the Town Hall of Hempstead, NY. The system linked a 40-kW solar system to the VFDs on the building's HVAC system. VFDs usually require a rectifier between the AC input and DC-voltage-regulator, and this system eliminates the need for a rectifier. Nextek estimates this setup to improve the efficiency of the drives by 10%. The town of Hempstead was awarded a NYSERDA grant of $260,000 to install the system.[275]

Nextek also managed the installation of a DC microgrid in the NextEnergy Center in Detroit, a non-profit organization that researches alternative and renewable energy technologies. Nextek reconfigured the 45,000-sq ft building to provide 380V DC power to lab and office spaces, fans, lighting systems, and wireless controls. Replacing metal halide fixtures with T-8 fixtures with DC ballasts and occupancy sensors reduced energy use by 43%. The combined savings from retrofitting with DC equipment was 67%.[276]

SAP upgraded their data center to run on DC power in 2010. The data center was retrofitted with a rectifier to convert AC grid power to DC power, which cost $128,000 and saves $24,000 a year.[277] Facebook, JPMorgan, Bank of America, Sprint, and Boeing have all built DC data centers as well. Nextek, who is currently piloting a DC data center in Detroit, estimates that DC powered data centers are 15% more efficient.

DC microgrid systems can also serve multiple buildings. In March 2012, Xiamen University in China installed a DC microgrid serving three campus buildings. A 150-kW solar PV array powers LED lighting systems, HVAC systems, computer servers, and EV chargers.[278]

Tech Development Forecast

The EMerge Alliance is a non-profit, membership-based industry association that includes over 50 building product manufacturers, architecture firms, governmental agencies and trade groups. The Alliance was founded in 2008 to develop DC power distribution standards for using low voltage DC safely in commercial buildings. Emerge has already developed the Occupied Space standards for using 24-V DC power in commercial interior spaces, such as lighting. DC microgrid building infrastructure and DC powered lighting systems are commercially available today.[279] According to Nextek, VFDs can be easily adjusted to connect to a DC microgrid. A 380 VDC Data/Telecom Center standard was released by the Emerge Alliance on November 13, 2012,[280] and DC data center products are expected to available within the next few years. The Alliance is also working on standards for Outdoor power (lighting, signage, and EV charging stations), and Building Services (HVAC, motor loads, and industrial applications). According to the Yale study, "existing plug-in devices pose a transitional challenge for DC microgrids because until these products are replaced by ones using a standard voltage, not all can be plugged in without a DC to DC converter."[281] However, Nextek is confident that developing standards for desk-level equipment will facilitate a DC-powered workspace becoming available within 5 years. For additional information regarding the potential installation of a DC microgrid system, we recommend contacting the following Nextek representative:

- Doug Hamborsky, Director of Design Services, Nextek Power Systems, Inc. Doug.hamborsky@nextekpower.com, (313) 887-1321 ext. 137

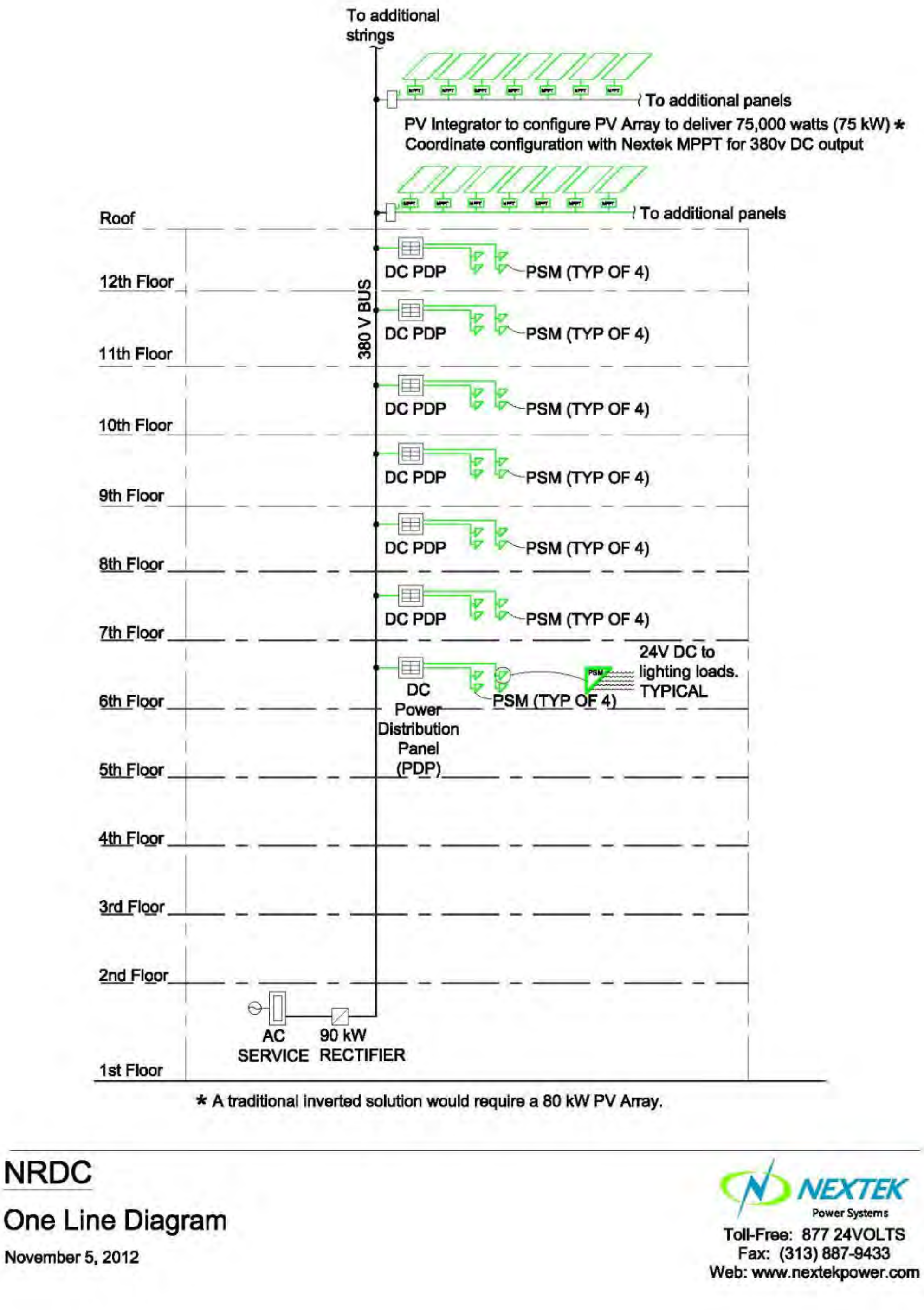


Figure 33: NRDC 24vDC lighting One Light Diagram, produced by Nextek November 5, 2012.

9.8 PHASE CHANGE MATERIAL (PCM)

Technical explanation

PCMs are ''latent'' heat storage materials.[282] They use chemical bonds to store and release the heat.[283] Latent heat thermal storage has proved to be an effective way for solar energy utilization and industrial waste heat recovery due to its high storage density and small temperature variation from storage to retrieval.[284] In a latent heat storage system, energy is stored during melting and recovered during freezing of the PCMs.[285]

Figure 34: Installation of PCM in Ceiling Panels

The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid.[286] This is called a change in state or phase.[287] PCMs, having melting temperatures between 68°F and 89°F, are used and recommended for thermal storage in conjunction with both passive storage and active solar storage for heating and cooling in buildings.[288]

This thermal-storage system has the following advantages over conventional building thermal-storage systems that use concrete floor slabs.[289]

1. More efficient thermal storage is expected, since high-density cool air pools on the PCM ceiling board that forms the floor of the ceiling space.[290]
2. All of the ceiling board can be used for thermal storage, since the cool air can flow through the ceiling chamber without being interrupted by beams.[291]
3. Since the surface temperature of the ceiling board is kept at the PCM melting point for an extended period, the indoor thermal environment, including the radiant field, can be improved.[292]

The innovative PCM-based insulation technology is expected to enhance energy efficiency in heating and cooling buildings in moderate climates by reducing excess sensible heat in the summer and reducing heat loss in the winter.[293] The anticipated cost of this technology is 40% greater than the cost of standard insulation; however, the technology is expected to save 30% of the annual cost of energy for heating and cooling.[294]

Benchmark/case studies used

Armstrong, a British engineering company, published a case study of PCM implementation at a mid-rise masonry office building in central London. They replaced standard mineral tiles in the center of the ceiling of a meeting room that was suffering from overheating and heavily reliant on air-conditioning.[295] They placed PCM tiles in 25% of the room, which are reversible and can be wholly recycled at the end of their life.[296] These PCM materials had a melting point of 73ºF, providing a total heat storage capacity of 136.2 Wh/m².[297] They covered 60% of the ceiling in the basement room that had an air circulation rate of 13l/s m² managed by a split HVAC system incorporating a ventilation fan.[298] Occupancy, temperature, airflow and air conditioner energy use were monitored for six months.[299]

Results:

- When heat can be purged, the room used between 20% and 70% less energy compared to the untreated room.
- PCM can be incorporated successfully into existing buildings, but arrangements need to be put into place to purge the accumulated heat during off-hours.

  The below image identifies the layout of a typical office floor. The purple spaces in plan illustrate the PCM layout within the space. Only 30-50% of existing ceiling needs to be replaced with PCM ceiling panels.

Tech Development Forecast

Figure 35: PCM Effect During the Day

Figure 36: PCM Reaction At Night

Figure 37 below shows that storage applications in general will become more valuable and important when renewable energy penetration climbs.[300] As can be seen in the figure, the Strategic Energy Analysis and Applications Center of the National Renewable Energy Laboratory of the U.S., currently deems energy storage a valuable technology but is not considered necessary with the current U.S. electricity grid.[301] However, the future situation of a low-carbon economy will demand high levels of energy storage applications.[302]

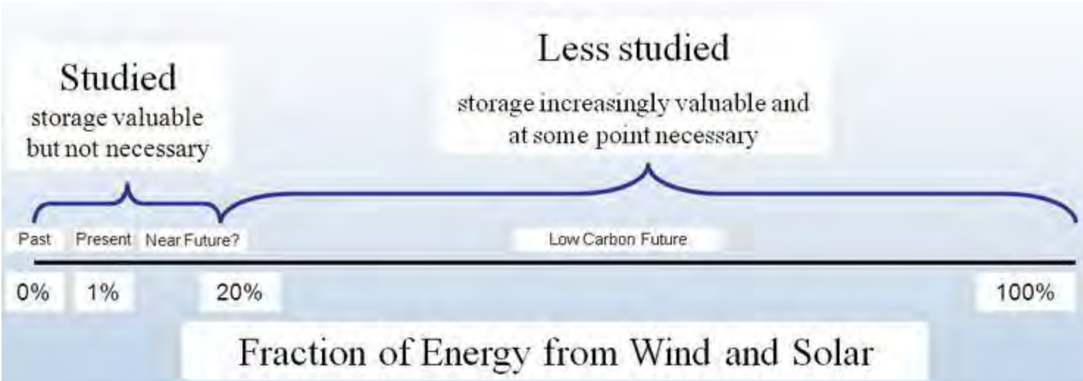


Figure 2: Importance Energy Storage Technologies

While quite a large share of energy storage applications has already reached a mature stage, PCM is still in a developmental phase.[303] PCM is placed in the developmental or demonstration phase because, as EPRI concludes that "storage systems involving PCMs are still in their infancy, and will require further study to determine the compatibility of these systems with CST plants using heat transfer fluids".[304]

Finance

There are a number of factors that influence the cost of the PCM technology. Storage tends to be an application-specific resource and therefore the costs (and benefits) can vary greatly.[305] One of the complications in developing detailed cost estimates of PCM technologies and methods, and with storage applications in general, is that the costs of a given technology are greatly influenced by the particular application in which that technology is deployed.[306]

For storage applications in general the total installed cost varies on two dimensions: power (which is the amount of electricity, heat or cold which can be discharged at one time) and energy (the amount of hours that the application can discharge continuously).[307] These two dimensions greatly influence system size and therefore installed cost.[308] In addition, the system costs are influenced by the system efficiency and the frequency of use.[309] System efficiency is determined by measuring the number of useable kWh that can be discharged compared to the amount charged.[310]

Operating and maintenance cost (O&M) is the other main financial aspect to a storage system.[311] O&M cost includes the cost of buying the energy used to charge the system (when it is an active system; passive system used natural temperature fluctuations), fixed costs that do not depend on how much or often the system is used, and variable costs which is mostly replacement costs.[312]

Clean Development Mechanism market status top:
Application of PCMs in buildings leads to more energy efficient buildings since there is a reduced need for heating and cooling activities.[313] This reduces GHG emissions and is an option under the Clean Development Mechanism (CDM).[314] This methodology considers energy efficiency measures for a single building, such as a commercial, institutional or residential building, or group of similar buildings, such as a school district or university.[315]

9.9 EXTERIOR INSULATED PANELS (EIFS)

Rationale

A Passive House combines high-level comfort with very low energy consumption.[316] Passive components like thermal windows, insulation and heat recovery are the key elements.[317] On the outside, Passive Houses are no different from conventional buildings, because the term "Passive House" describes a standard and not a specific construction method.[318] Passive House has many beneficial insulation implementations, which are important to leverage and use for our retrofit as well.

Insulation is the most effective way to improve the energy efficiency of a building.[319] Insulation of the building envelope helps keep heat in during the winter, but lets heat out during summer to improve comfort and save energy.[320] Thicker insulation layers may cost a bit more (in order to build suitable walls, for example), but the price for additional materials is usually quite low, and installation costs do not increase significantly.[321]

The improved thermal insulation reduces heat losses and leads to higher indoor surface temperatures in the winter and lower temperatures in the summer.[322] They hardly differ from the ambient temperature, providing for a pleasantly warm, uniform indoor climate without any cold corners or risk of condensation.[323] The good insulation protects not only against the cold but against heat as well, provided that not too much heat is already present indoors.[324]

Prevention of thermal bridges is one of the most efficient savings measures.[325] Building envelopes consist not only of standard construction elements like walls, roof and ceilings, but also include edges, corners, connections and penetrations.[326] The heat loss at these points is generally higher (thermal bridges).[327] Observing some simple rules helps to reduce losses caused by such thermal bridges.[328]

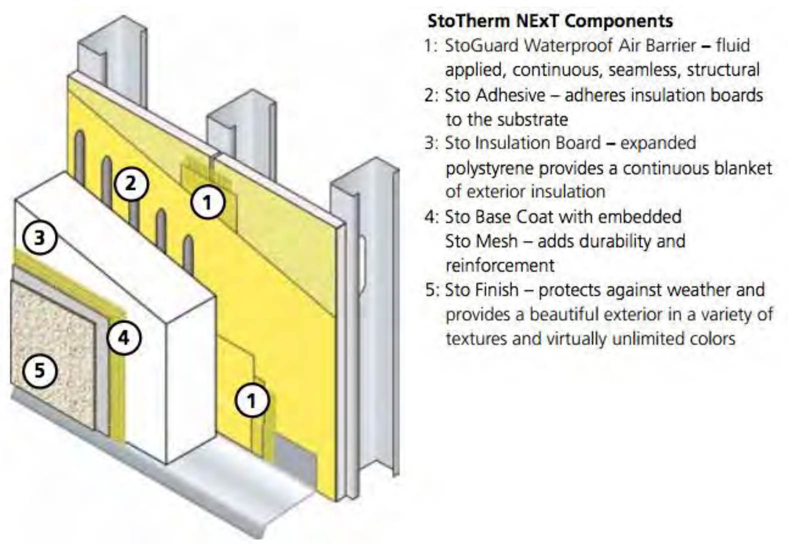


Figure 38: StoTherm Components

The most effective way to decrease thermal bridging in a building is by using Exterior Insulation and Finish Systems (EIFS). This type of insulations is a multi-layered exterior wall system that is used on both commercial buildings and homes.[329] They provide superior energy efficiency and offer much greater design flexibility than other cladding products.[330] Today, EIFS account for nearly 30% of the U.S. commercial exterior wall market.[331]

It is a thermal insulation system that continuously wraps the exterior of the building, and can be molded specifically to building façade design; therefore keeping the historic design approach.

EIFS typically consist of the following components:
Boards with thicknesses of 1 to 12 inches can provide insulating R-Values of up to 59, more than 4 times that of non-insulated claddings such as brick.[332] Plus, by placing the insulation layer on the exterior of the

building, heat loss caused by thermal bridging through the metal or wood framing studs is minimized.[333] This heat loss, called thermal bridging, can significantly reduce the effective R-value of traditional, between-the-studs insulation.[334]

The following figure illustrates comparable nominal R-values of traditional wall systems, and an EIFS implementation.

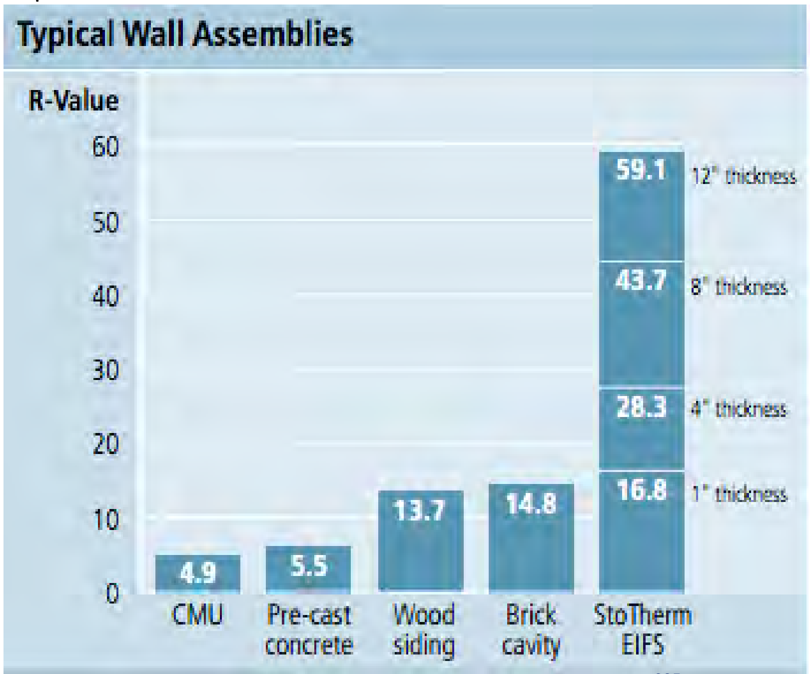


Figure 39: R-values of Typical Wall Assemblies vs. StoTherm[335]

Junction of roof and exterior wall at the intersection of an EIFS shows that the layers are connected continuously. Therefore, the thermal bridge coefficient becomes negative, as shown in the thermographic image below:[336]

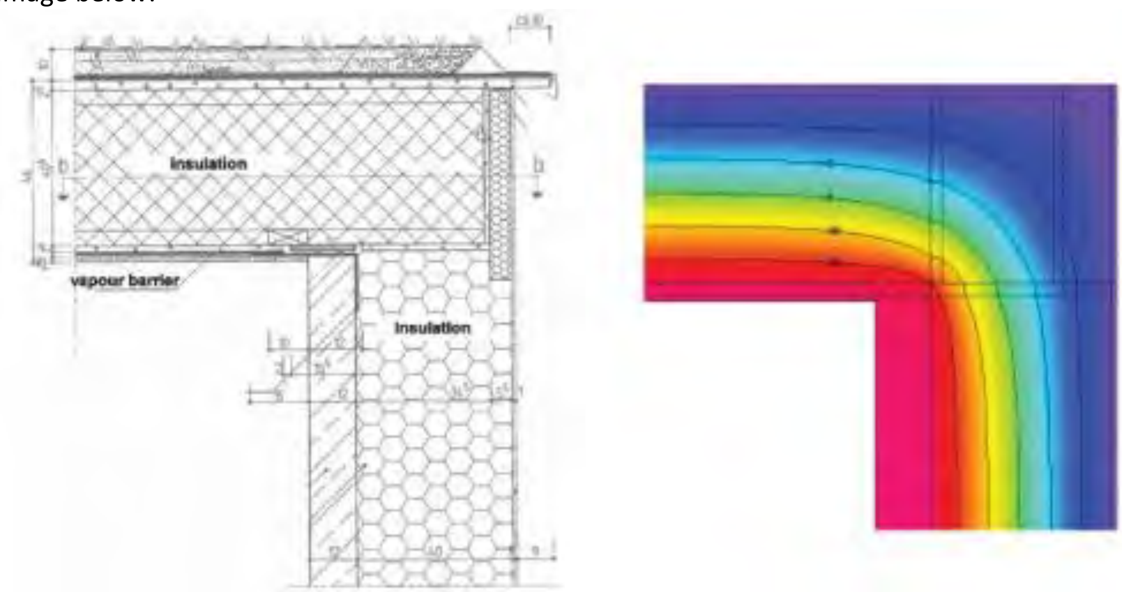


Figure 40: Thermographic Image Showing Reduction of Thermal Bridging with EIFS

Benchmark/case studies used

In Brooklyn, the first official Certified Passive House old masonry retrofit in NYC was completed. The 120-year-old brownstone building was comprised of brick and beam construction with a fieldstone foundation.[337] The townhome included 2200SF on 2 levels and a full basement.[338]

One of the key solutions implemented, was an exterior EIFS insulation system. The Zero Energy Design team recreated decorative molding to make the completed façade look identical to the original installation; however much more energy efficient. See image below for construction installation. Above ground walls of R33 are EIFS with 3" of EPS foam plus a stucco finish on the exterior and 4" waterblown closed cell sprayfoam on the interior.[339] It is estimated a 20 to 30% reduction of energy usage will occur, provides an R-value of 4 for each inch of foam.

Figure 41: Brooklyn Passive House Installing EIFS

In fact, EIFS can reduce air infiltration by as much as 55% compared to standard brick or wood construction.[340] And since walls are one of the greatest areas of heat and air conditioning loss, improvement in the wall insulation can be very meaningful in terms of energy conservation.[341]

Tech Development Forecast

The rich appearance of EIFS bears a resemblance to stucco or stone, but the systems are far more versatile than these and other materials.[342] Not only do EIFS come in virtually limitless colors and a wide variety of textures, but they also can be fashioned into virtually any shape or design.[343]

With EIFS, skilled applicators can create all sorts of exterior architectural detailing that would often be cost prohibitive using conventional construction — cornices, arches, columns, keystones, cornerstones, special moldings and decorative accents are but a few examples.[344] This is beneficial for the NRDC building, as historic preservation committee would not approve such implementation if it were to reduce the original historic appearance of the building.

Most of this detailing is computer-generated.[345] The designs are precision-cut out of insulation board, attached to the substrate or wall, then covered with the EIFS base coat, mesh and finish coat.[346] More efficient installation and computer detailing strategies may be developed in the future; however, the efficiencies are there now and implementation of an EIFS would be effective as soon as possible.

9.10 AIR SEALING (IMPROVING PASSIVE EFFICIENCY)

Air leakage is outside air that enters a building uncontrollably through cracks and openings. Larry Harmon, CEO and founder of Air Barrier Solutions, will use his company's innovative strategies and technologies to provide an audit at no cost for the NRDC building to determine the efficiency gains from air sealing the building envelope.

Rationale

The effect of uncontrolled air leakage in a high-rise commercial building ranges from 22-46% in energy consumption.[347] Air Barrier solutions will perform a formal audit of the NRDC building at no cost to determine the amount of reduction in energy consumption that can be attained by controlling air leakage in the building. For the time being, a conservative 10% in energy reductions will be assumed for the buildings heating and cooling needs. This will reduce electric loads by 26,615 kWh.

The benefits of an air barrier retrofit: [348]

- Controls movement of air into an out of the building
- Reduces heat loss/gain
- Reduces dust, mold and pollutants in the building
- Reduces noises and odors
- Reduces condensation, mold and mildew
- Improves comfort and occupant experiences
- Helps control biologicals

Benchmark/case studies used

Air leakage can either be conditioned air from inside the building or unconditioned outside air. Air leakage is caused by three physical effects. Stack Effect airflow is the result of pressure differences between the interior and exterior air columns, generally due to temperature differences in the two columns of air.[349] Wind Effect is airflow in and out of a building due to pressure differences from wind conditions.[350] Mechanical Effect airflow is due to either deliberate or inadvertent pressure imbalances created by the HVAC systems.[351] All three of these physical effects can cause unintentional airflow. The airflow itself is made possible by gaps, cracks and holes in the building envelope.[352]

Air Barrier Solutions recently did a retrofit for a building at a university in Boston where they found the equivalent of a 44.63 square foot hole in total across the building. The building was inspected visually and using smoke tracer tests in accordance with ASTM E-1186 – 02 by Air Barrier Solutions, LLC.[353] A smoke puffer was used to identify the location and severity of air leakage paths.[354] Areas inspected include: roof-wall joints, elevation changes, soffit areas, roofs, walls, windows, doors and other penetrations.[355]

At the same time, during the ASHRAE testing, infrared scanning was performed in accordance with ASTM standards using the building pressure differentials with the orifice fans.[356] These tests validated the locations identified by the smoke tracer testing.

In a complex building design the connection points such as the roof wall joint, soffits and corners are usually the sources of unwanted air movement.[357] A commissioning process would integrate the design, material selection, construction process/sequencing, and project management to ensure tight connections at these critical junctures.[358]

Finance

Currently, using conservative estimates, the cost is predicted to be $25,000 with a payback of 9.39 years. A more accurate cost estimate will be developed once Air Barrier Solutions has completed its audit.

The table below shows the annual savings and simple payback of the last eight hospitals that Air Barrier Solutions have worked with.

Hole Size	Retrofit Cost	Annual Savings	Simple Payback
147.89	$145,742.00	$78,715.80	1.85
21.73	$41,924.00	$7,054.29	5.94
28.98	$33,478.00	$5,545.92	6.04
147.50	$163,897.00	$32,113.00	5.10
30.11	$44,552.00	$13,167.19	3.38
35.75	$41,260.00	$16,285.92	2.53
33.69	$89,642.00	$21,635.20	4.14
35.94	$39,907.00	$7,156.66	5.58

Table 12: Annual Energy Savings and Simple Payback for 8 Hospitals [359]

9.11 ELECTRICAL - ROOFTOP SOLAR PHOTOVOLTAIC PLATFORMS FOR EXPANDED GENERATION CAPACITY

Importance of maximizing rooftop generation to achieve net zero energy

To determine the role the NRDC rooftop plays in achieving net zero site energy it was necessary to examine case studies that have successfully modeled various roof surface areas and solar technologies in relation to building load ratios determined by the number of stories. According to simulations conducted by members of the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), the maximum height of a zero energy building ranges from two to five stories depending on location and the load profile of the building[360]. Feasibility of achieving net zero energy is inversely related to the number of floors in a building due to the decrease in the ratio of available roof space to total energy loads.

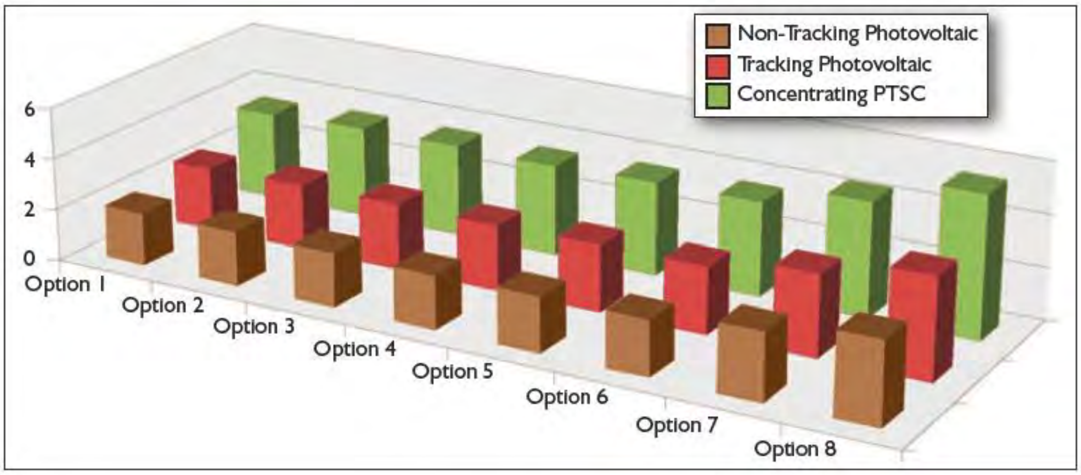


Figure 42: Effective number of floors to match roof mounted renewable energy production

Theoretical net zero building solar energy production

To illustrate the limitation that building height has on building's ability to achieve net zero site energy, ASHRAE experts modeled a reference case using various building types in a region with very high solar energy potential. This model provides a best-case scenario for buildings with several different efficiency and shape profiles. A highly efficient facility ("Option 8" in the figure above) exhibits energy loads 50% below ASHRAE 90.1 standards, or energy usage intensity (EUI) of 41.6 kWh/sf.[361] Assuming roof space is dedicated to solar energy production, this typical facility with highly efficient operations would reach a maximum height of five stories before load exceeds available on-site generation potential[362].

The model indicates maximum floor heights based on typical ratios of roof area to building height, three different solar energy technologies, and other assumptions that provide insight for the NRDC facility. From the results of the reference case for "Option 8" the team inferred the following conclusions:

- Due to competing uses of the rooftop, NRDC will fall short of the 75% roof area utilization rate applied in the model. The number of floors of energy usage that can be offset by rooftop solar production will be lower for NRDC than for the reference case.

- Non-tracking crystalline photovoltaic panels (the type presently installed at NRDC) are not likely to enable net zero energy for buildings greater than one or two stories; tracking and concentrating technologies roughly double the number of stories supported by a given rooftop surface area but still fall short of NRDC energy demand.
- Concentrating parabolic trough solar collector (CPTSC) technology enables the greatest number of net zero floors; however, the model assumes deployment of this technology over 66% of total roof area and requires high levels of direct solar energy. These assumptions are not feasible for the NRDC project due to site conditions.

Challenges of the NRDC rooftop inhibiting traditional photovoltaic energy production

The unique condition of the NRDC rooftop requires an innovative approach to maximizing solar energy generation. The proposed green roof will provided critical environmental benefits including storm water management, natural habitat, and increased insulation value.[363] With more than 6,000 square feet of surface plantings, drainage features and deciduous trees planned, the green roof also drastically limits rooftop space available for expansion of photovoltaic generation.[364] Additionally, rooftop structures such as the water tower penthouse, cooling tower and mechanical equipment reduce solar production. A physical inspection of the facility by the project team showed that rooftop structures shade the current photovoltaic array and inhibit installation of additional capacity using traditional rooftop racking.

Proposed solar platform sizes and locations

Figure 43: Proposed locations and surface area of elevated platforms on NRDC rooftop

The blue areas represent elevated structures capable of supporting photovoltaic equipment. The structures will rise 15 to 35 feet above the current rooftop surface. At this height, the structures would minimize shading effects that reduce energy production while clearing most obstructions. Measurement are approximate and were captured digitally using reference measurements provided by the NRDC Green Roof plan produced by Croxton Collaborative Architects, PC.[365]

Projection of additional generation capacity enabled by elevated rooftop PV platforms

Rooftop PV Scenarios: Model of Current Array Production and Expanded Production Estimates							
Inputs:	10.764	sq ft per sq m	4.51	kWh/m^2/day (NREL PV Watts)		6917 kWh/yr (NREL PV Watts)	
Rooftop PV Scenario	**Sq Ft**	**Proportion Available for Panels**	**Effective Square Footage**	**Irradiance (kWh/sf/yr)**	**Panel Efficiency**	**Electrical System Efficiency**	**Annual kWh Production (approx.)**
A. Current 5.55 kW system	432	100%	432	153	15%	70%	6917
B. Expanded: Water Tower Platform	841	75%	631	153	15%	70%	10099
C. Expanded: West Bulkhead Platform	319	75%	239	153	15%	70%	3831
D. Expanded: East Bulkhead Platform	918	75%	689	153	15%	70%	11023
E. Total - All Areas	**2510**		**1991**	**153**	**15%**	**70%**	**31869**
F. ASHRAE Net Zero Theoretical	11,000	75%	8250	153	17%	70%	150140
Limitations: Model accurate to +/- 12% annual production, based on NREL model. Typical equipment and environmental assumptions used.							
Model does not account for localized shading, rooftop elevation, building shading, and other site factors							

Figure 44: Rooftop PV Scenarios: Model of Current Array Production and Expanded Production Estimates (Using Current Technology)

Data from the NREL "PV Watts" system approximates solar energy production from fixed tilt crystalline solar panels installed at a south-facing location in New York City. The PV Watts model and inherent assumptions are not a substitute for facility-specific energy modeling; however, for purposes of estimating rooftop renewable energy production, the model is accurate to within 12% .[366] Explanation of scenarios in Figure 44:

A. The current rooftop photovoltaic array at NRDC consists of 30 crystalline panels covering an area of approximately 432 square feet. The nameplate capacity of the system is 5.55 kW, yielding a projected annual output of 6,917 kWh/yr according to PV Watts. This number may differ from actual observed output used in the net zero energy Data Model, as it does not account for actual site conditions.
B. Creating an elevated solar platform above the footprint of the water towers and mechanical penthouse would yield an additional 841 square feet of available surface area, assuming modest overhangs that would not excessively shade the green roof or skylights. Solar energy output scales linearly to this additional proposed structure, yielding annual output of 10,099 kWh. We assume that only 75% of the built area of platforms is available to install solar panels. When determining the solar potential for a net zero building, a solar equipment coverage ratio of 75% is used by ASHRAE analysts[367]. Reducing the platform area by a fixed ratio accounts for maintenance access and the fact that solar panels may not precisely conform to the exact platform dimensions.
C. The west side of the roof houses a large stairway bulkhead and mechanical room. This concrete outcropping has skylights on top and other surface irregularities that presently prevent solar panel mounting. A PV platform over this structure would homogenize the surface, gaining an additional 319 square feet of PV production surface.
D. On the east side of the rooftop, another stairwell bulkhead is situated adjacent to various condensers and mechanical equipment. The bulkhead and its surrounds will support a large platform totaling 918 square feet.
E. Construction of all platforms and maintaining the existing array yields 2,510 gross square feet available for solar panel mounting. An estimated 1,991 square feet will be available after accounting for space losses. Scaling up the existing crystalline PV technology to the expanded roof area yields new annual production potential of 31,869 kWh.
F. The ASHRAE discussion of net zero energy potential would classify the NRDC building as a facility with 150,140 kWh/yr rooftop production potential at the New York City location. This figure is included as a point of comparison to the ASHRAE reference cases based upon 11,000 gross square feet, 75% utilization rate, 17% efficient solar panels and other assumptions captured in the model.

The purpose of including this benchmark is to illustrate the level of rooftop energy production that NRDC must approach in order to theoretically offset the demand from just five of its seven floors.

Figure 45: Elevated photovoltaic racking structure for 540kW system

A combination of groundbreaking energy efficiency, reduction in occupant loads and innovative renewable energy technologies will help close the apparent gap in production capacity.

Case studies that inspired the PV platform solution

The U.S. Department of Energy (DOE) maintains a catalogue of successful elevated photovoltaic solar mounting systems that enable renewable energy production in dual-use environments such as parking lots. These systems maximize available real estate while providing valuable secondary functions such as shading from the elements, safety lighting and electric vehicle charging.

PV Watts — AC Energy & Cost Savings — Cautions for Interpreting the Results

(Type comments here to appear on printout; maximum 1 row of 90 characters.)

Station Identification

Cell ID:	0269370
State:	New York
Latitude:	40.8 ° N
Longitude:	73.7 ° W

PV System Specifications

DC Rating:	5.55 kW
DC to AC Derate Factor:	0.800
AC Rating:	4.44 kW
Array Type:	Fixed Tilt
Array Tilt:	40.8 °
Array Azimuth:	180.0 °

Energy Specifications

Cost of Electricity:	21.3 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.08	439	93.51
2	3.92	502	106.93
3	4.95	674	143.56
4	5.03	640	136.32
5	5.35	689	146.76
6	5.57	675	143.77
7	5.21	637	135.68
8	5.16	637	135.68
9	5.04	618	131.63
10	4.43	583	124.18
11	3.19	416	88.61
12	2.90	406	86.48
Year	4.49	6916	1473.11

Output Hourly Performance Data

(Gridded data is monthly, hourly output not available.)

Output Results as Text

Saving Text from a Browser

Run PVWATTS v.2 for another location

Run PVWATTS v.1

Figure 46: NREL PV Watts model of current NRDC solar array annual energy production

Cautions for interpreting PV Watts estimated production results

The following section is taken from the NREL PV Watts website and provides guidance for applying solar modeling data:

"Weather variability

The monthly and yearly energy production are modeled using the PV system parameters you selected and weather data that are typical or representative of long-term averages. For reference, or comparison with local information, the solar radiation values modeled for the PV array are included in the performance results.

Because weather patterns vary from year-to-year, the values in the tables are better indicators of long-term performance than of performance for a specific month or year. PV performance is largely proportional to the amount of solar radiation received, which may vary from the long-term average by ± 30% for monthly values and ±10% for yearly values. How the solar radiation might vary for your location may be evaluated by examining the tables in the Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors(*http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/*).

For these variations and the uncertainties associated with the weather data and the model used to model the PV performance, future months and years may be encountered where the actual PV performance is less than or greater than the values shown in the table. The variations may be as much as 40% for individual months and up to 20% for individual years. Compared to long-term performance over many years, the values in the table are accurate to within 10% to 12%.

System design and operating conditions

If the default overall DC to AC derate factor is used, the energy values in the table will overestimate the actual energy production if nearby buildings, objects, or other PV modules and array structure shade the PV modules; if tracking mechanisms for one- and two-axis tracking systems do not keep the PV arrays at the optimum orientation with respect to the sun's position; if soiling or snow cover related losses exceed 5%; or if the system performance has degraded from new. (PV performance typically degrades 1% per year.) If any of these situations exist, an overall DC to AC derate factor should be used with PVWATTS that was calculated using system specific component derate factors for *shading*, *sun-tracking*, *soiling*, and *age*.

Module choice

The PV system size is derived from the nameplate DC power rating. The energy production values in the table are estimated using coefficients relevant to crystalline silicon PV systems, assuming common silicon module designs. Adjusting these coefficients for specific silicon products and/or for thin-film products may result in results varying by as much as ~10%. If the user's goal is to differentiate performance of specific products, a module-specific calculation must be used.

Net-metering policy and/or customer use habits

The cost savings are determined as the product of the number of kilowatt hours (kWh) and the cost of electricity per kWh. These cost savings occur if the owner uses all the electricity produced by the PV system, or if the owner has a net-metering agreement with the utility. With net-metering, the utility bills the owner for the net electricity consumed. When electricity flows from the utility to the owner, the meter spins forward. When electricity flows from the PV system to the utility, the meter spins backwards.

If net-metering isn't available and the PV system sends surplus electricity to the utility grid, the utility generally buys the electricity from the owner at a lower price than the owner pays the utility for electricity. In this case, the cost savings shown in the table should be reduced.

Besides the cost savings shown in the table, other benefits of PV systems include greater energy independence and a reduction in fossil fuel usage and air pollution. For commercial customers, additional cost savings may come from reducing demand charges. Homeowners can often include the cost of the PV system in their home mortgage as a way of accommodating the PV system's initial cost.
To accelerate the use of PV systems, many state and local governments offer financial incentives and programs. Go to http://www.nrel.gov/stateandlocal for more information." [368]

Financial Case Study: Victor Valley College

Outline of Key Metrics

Project Size	1 MW-AC
Technology: SolFocus SF-1100S	122 8.4 kW arrays
Energy Cost	$4.663 million
Annual kWh Energy Produced (Year 1)	2,421,900 kWh
Degradation Factor	0.85%*
Electricity Generated Over 25 Years	54,755,952 kWh
Avoided Electricity Purchases	($12,043,473)
Renewable Energy Credits (RECs)	($547,560)
CSI Performance-Based Incentive	($3,809,722)
Option R Tariff Savings	($3,762,041)
Total Savings Over 25 Years	($20,162,796)
M&O Costs (Years 1-10)	($409,920)
Total Savings Less Expenses	($19,752,876)
Net Savings at 5% Utility Escalation	($15,090,036)
Estimated Levelized Cost of Energy (LCOE)	8.5 ¢/kWh
LCOE with Performance-Based Incentives	1.5 ¢/kWh
Payback Period	5 Years

- 2.5 million kWh/year; 30% of college's electricity demand
- Project cost of $4.7M
- Estimated LCOE without incentives: 8.5 ¢/kWh
- Payback period 5 years

* Energy production was calculated using this conservative rate. In reality, degradation is expected to be significantly lower.

8

Figure 3 -- Financial case study for a CPV system

The Victor Valley College case study, above, establishes key financial metrics for a large-scale CPV project. While this project exceeds the proposed size of the NRDC system, the project's payback period of five years and LCOE of $0.085 per kWh demonstrate that a non-profit organization can leverage CPV technology at a reasonable overall cost of energy.

9.12 Concentrating Photovoltaic (CPV) Rooftop Solar Energy

The process of modeling Concentrating PV (CPV) potential energy output

The process of validating CPV as a viable rooftop energy production solution for NRDC involved a comprehensive analysis carried out in four steps:

1) Validate the role of concentrated rooftop solar PV in achieving net zero through case analysis
2) Determine current rooftop solar technology and production output
3) Assess the potential for expanding rooftop solar to meet on-site energy demand by increasing available square footage and leveraging current crystalline PV technology
4) Evaluate CPV technology and variants against project criteria and site conditions

The role of concentrated rooftop solar PV in achieving net zero

According to an NREL report on six high performance commercial buildings "for the ZEB [zero energy building] goal to become a reality, energy production through PV systems on the roofs of buildings will have to produce more energy than the building uses. Future ZEBs will not only require efficient energy use, they will need to maximize energy production. Therefore, lessons learned and best practices related to maximizing PV systems energy output are valuable for future generations of ZEBs."[369]

The feasibility for a building to produce as much energy as it consumes is largely a function of the ratio of rooftop generating capacity to total floor area.[370] With seven floors of demand to meet using limited rooftop surface area, the role of CPV energy production is to generate energy per square foot in excess of current net zero energy building benchmarks. Relative to other net zero building cases with similar efficiency and floor plate square footage, the baseline rooftop energy production expectation for NRDC is a minimum of 150,000 kWh if the entire roof area could be used.[371] In order to approach this theoretical value, NRDC will need to both expand the rooftop PV surface area and install the highest density technology available.

Current rooftop solar technology and output

The crystalline solar panels presently in use at NRDC are reliable and inexpensive but are subject to the same production shortfalls that NREL observed in their analysis of several high performance buildings; "PV systems are affected by operational performance degradations include snow, inverter faults, shading, and parasitic standby losses."[372] The current siting on the south side of the roof is ideal with the exception of morning shading effects caused by close proximity to a large rooftop mechanical penthouse.

An analysis of year-to-date production output provided by NRDC shows the present 5.5 kW PV array is expected to produce 6,687 kWh per year. The 30 panels making up the 432 square foot fixed-tilt array individually produce peak energy of 185W. Therefore, the power density of the current array is roughly 15.5 kWh per square foot per year. The panels installed on the NRDC rooftop are already outdated from a peak power output perspective. Canadian Solar, a major Chinese solar supplier, produces "model CS6P-255M" mono-crystalline panels with 250W per panel peak output and 16% efficiency.[373]

The next step in the analysis requires modeling the energy production of present crystalline technology in an expanded system size. The model will indicate if NRDC can achieve greater solar energy contributions toward the generation component of the net zero goal.

Expanding current crystalline solar technology to a larger surface area

Section 4.4 recommends rooftop PV platforms that maximize the surface area available to install photovoltaic panels. Based on the new available square footage yielded by the PV platforms recommendation, the team developed a simplified energy production model to extrapolate the production of the current PV array. The purpose of this analysis is to determine if NRDC should simply scale-up currently available technology or explore a higher-density emerging PV technology. When available square footage is increased from the current value of 432 sf to 2,510 gross square feet (1,991 effective square feet after subtracting for estimates of unusable area) total generation potential increases to 31,869 kWh per year.

Annual solar panel efficiency increases would further increase maximum generation potential along a curve of annual output increases. For example, assuming a 2015 installation date for expanded PV, today's maximized crystalline PV generation of 31,869 kWh would increase to approximately 37,000 kWh per year as a result of two consecutive years of 13% annual efficiency improvements (Figure).

Whether NRDC installs expanded PV capacity in the near term or at a later date (to capture efficiency improvements) maintaining the current 430 square foot array as the sole source of solar energy production is simply not an option. The nominal amount of annual energy production and negligible contribution toward meeting total demand are the largest drivers. Similarly, expanding installation of crystalline panels toward a theoretical production limit of 37,000 kWh per year represents a negligible percentage of the facility's current and projected energy load.

CPV implementation (specs, layout, production model)

Concentrating Photovoltaic generation is an emerging technology that is fast outpacing efficiency rates of traditional crystalline PV cells. There are three principle differences between traditional PV and CPV that are most relevant to net zero energy applications:

1. Solar cell type – traditional PV uses a large solar collection surface that generates energy across the surface area of the panel at an efficiency rate between 10% (thin-film) and 17% (high-efficiency mono-crystalline).[374] CPV cells are much smaller but capture energy from a broader solar energy spectrum.
2. Concentration ratio – Unlike traditional crystalline PV, CPV introduces an optical component which can consist of Fresnel lenses, glass spheres, or other optics that concentrate and focus solar energy onto a point.[375] At the focal point, a small high-output solar cell converts solar into electricity. [376]
3. Solar tracking – while all solar panels are more effective at generating electricity when pointed directly into the sun, CPV panels typically include a single or dual axis tracking mechanism to ensure optimal alignment with direct solar energy as the sun moves across the sky throughout the day. Tracking produces an increase in net energy output and produces more power at times of the day when traditional solar output drops off substantially.[377] This advantage of CPV can help NRDC offset peak demand charges. According to NREL, traditional PV arrays typically do not contribute to peak demand reductions due to the fact that most buildings peak in the mid to late afternoon whereas rooftop PV peaks at noon.[378]

The data sheet in Appendix 9.13 details the CPV technology modeled for installation at NRDC. Emcore's Soliant 1000 is one of over a dozen CPV brands but is one of the few CPV panels actually in production for installations as early as 2012.[379] Unlike traditional PV panels which are assembled into a large array one at a time, there are eight individual modules on a 12.5 foot long Soliant 1000 CPV string.[380] Each module is consists of eight triple-junction high-efficiency solar cells with a 504W peak power rating (471W max, measured at "performance test conditions").[381] Each set of eight modules is affixed to an integrated two-axis tracking mechanism that follows the movement of the sun to within 1/10 of one degree accuracy.[382]

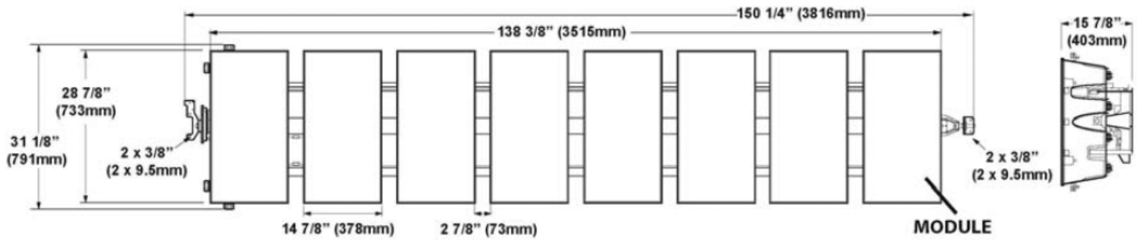


Figure 48: Soliant 1000 eight module CPV string dimensions

The compact footprint of the Soliant 1000 array is ideal for a rooftop location due to wind performance up to 130 mph.[383] A single string of eight modules "requires 60 percent fewer panels, produces 60 percent more watts per string, and 60 percent fewer DC strings" than conventional PV.[384]

A key benefit of the Soliant 1000 system is the ability to produce higher instantaneous wattage and greater total kWh peak energy than crystalline or thin film PV. This advantage will have a positive effect on NRDC summer demand by corresponding with times of peak cooling load. The chart below shows the Soliant 1000 power output curve compared with traditional PV.

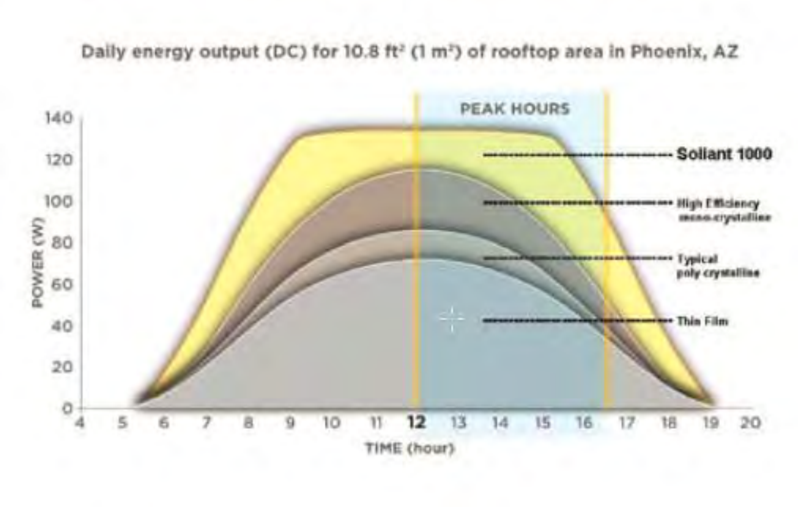


Figure 49: Soliant 1000 power output curve compared with other PV technologies

Approach to modeling CPV production for NRDC

Rooftop CPV systems are presently being pilot tested at a select number of locations including the U.S. Naval Air Warfare Center (NAWS) China Lake, California. At NAWS, the Department of Defense expects a levelized cost of energy around $0.15/kWh from a 50kW array that will be completed in 2013.[385] Although specific system output for existing facilities is not currently available, NREL provides a tool that can estimate system production for any location in the U.S. using the manufacturer specifications of the CPV technology.

NREL System Advisor Model (SAM) is a free software tool for solar industry professionals, researchers and academics. SAM performs advanced site-specific energy production and financial modeling for a variety of current and prospective solar technologies.[386] Before modeling CPV generation for NRDC, the first step is to validate that SAM will produce a relevant energy production projection given all of the unique site conditions on the 40 West 20th Street rooftop. Many factors affect generation potential but are not feasible to quantify precisely within the scope of this project. Examples of factors that affect energy output include shading, building elevation, exact orientation, wind, snow cover, soot, and bird soiling.

Since NRDC has a crystalline PV array that is currently producing energy, it is logical to first model the production of the current panels to compare the projection in SAM to actual observations. Upon entering all of the known system parameters for the current PV array, SAM produced an annual output of 6,031 kWh per year for the current 5.5kW array. This value is approximately 15% below earlier estimates.

Preparing to model CPV by first modeling the current NRDC array		
Modeling Method	**Annual kWh Production**	**Explanation**
Observed	6,687	Extrapolated current year-to-date production as measured by solar array metering system
Theoretical (NREL PV Watts)	6,917	NREL PV Watts tool based on solar energy and common system assumptions
System Advisor Model (NREL SAM)	6,031	Inputs into SAM included nameplate capacity of current PV system, building location, tilt angle and building orientation

Table 13: Methods of modeling the current NRDC PV array for purposes of calibrating estimates of CPV production

The difference in observed and modeled production is low enough to trust the SAM tool to model CPV. A difference in output may not be entirely attributable to modeling error. Since we do not have a full year of actual PV production observations for the NRDC building, the SAM estimate may be more accurate than estimating by observing current generation. The SAM tool incorporates seasonal weather and solar energy data whereas the observed production values for a partial year may not scale perfectly to an entire year of energy production. Additionally, SAM produced the lowest output of the three methods which meets the conservative budgeting methodology of the project.

After confirming that SAM produces reasonable solar energy estimates for the NRDC site, the second step involves modeling the exact specifications of the Emcore Soliant 1000 CPV technology to determine maximum production from the expanded NRDC rooftop surface area.

Results of rooftop CPV production model

Overlaying scale icons of Soliant 1000 CPV arrays produces a rooftop layout indicating the approximate number of panel strings that will fit on the PV platforms. Per the Soliant 1000 spec sheet, arrays are assumed to be densely packed. According to a review of documentation for the NRDC green roof load assessment, the distributed roof load of five pounds per square foot should remain well within limits of the roof capacity.

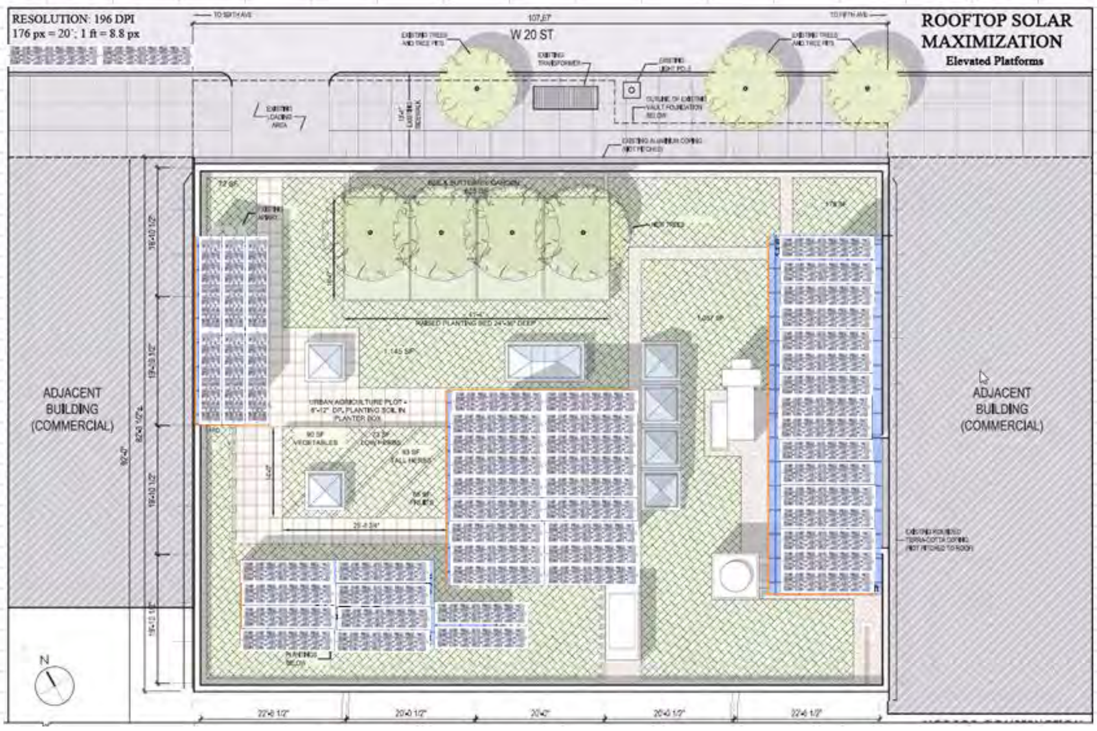


Figure 50: Visual layout of rooftop CPV panels mounted on PV structures

The layout produces a theoretical rooftop limit of 50 strings of eight CPV modules for a total nameplate capacity of 200kW DC (188kW max under production test conditions). At 198 pounds per string, the total roof load is 9,900 pounds not including the PV platforms and standard PV racking required to elevate the panels to unobstructed positions as shown.[387] The feasibility of this layout can be validated by comparing total square footage to actual square footage occupied by the equipment.

Each of the 50 strings of eight modules occupies a footprint of approximately 27 square feet (1,350 square feet total). The total gross surface area of the existing array location and the proposed PV platforms is 2,510 square feet. The disparity in gross square footage and installed square footage is justified by the need to leave spacing between the strings. Additionally, imperfect sizing of the PV strings relative to the available footprint of some of the spaces requires a buffer to account for wasted space.

The SAM model concludes that CPV would produce 144,000 kWh annually. In order to effectively model CPV generation in the overall NRDC energy balance model, it is necessary to determine the most realistic range of actual production levels that will account for uncertainties in the model. For example, the SAM generation result represents 57 kWh per square foot per year compared with 15 kWh per square foot for the current crystalline array. This may not be realistic.

Rooftop PV Technology Comparison		
Power production summary statistics: annual output per square foot of rooptop surface area		
Technology	**Production kWh/yr/sf***	**Watts per panel (peak)**
Current fixed crystalline panels	15	185-250
Proposed CPV with tracking	57	500
** estimates calculated based on gross area: 432 sf current array; 2,510 sf proposed PV platforms + current array for CPV.*		

Table 14: Energy yields per square foot, per year for crystalline vs. CPV technology

A leading CPV industry group claims that system modeling performed in SAM for CPV installations is "generally found to be accurate within a few percent."[388] To the contrary, NREL cautions that nearly every PV system overstates performance at the design stage. In almost all cases, shading and other site factors cause actual performance to fall 2% to 44% below modeled output.[389] The following site-specific CPV generation factors could not be modeled with a high degree of certainty due to the timeframe and scope of this project analysis. Each will require further study consistent with a full-scale CPV engineering analysis to determine actual production with a higher degree of certainty.

- Shading of CPV panels by other buildings, rooftop structures such as adjacent water towers
- Obstruction of CPV panels caused by the inherent characteristics of the rooftop location e.g. max panel tilt not lining up with early morning or late afternoon solar energy due to building elevation
- Optimal spacing between rows of CPV strings to maximize production without units shading each other
- Wattage consumed by the tracking mechanism over the course of a year of operation
- Soot, soiling and miscellaneous factors that were not quantifiable in SAM at the time of the analysis

In consideration of these factors, annual CPV output is likely to fall in a range of 101,220 kWh and 144,601 kWh. The high end of the range represents modeled output using standard production assumptions while the low end represents a 30% potential reduction. For analysis purposes, the team adopted the lower end of the range to minimize the risk of overstating energy production.

Further PV expansion options to meet on-site energy demand

Maximizing energy production using CPV on elevated rooftop platforms totaling 2,500 square feet will still fall short of meeting 100% of the facility's annual on-site energy demand. NRDC should consider solutions that increase energy output to the levels required to achieve net zero energy:

1. Install PV platforms and CPV panels over the entire rooftop surface
2. Lease neighboring roof space and install CPV or crystalline panels.

NRDC should select high-density CPV for any expansion of on-site capacity. Depending on the availability and cost of leasing neighboring roof space, conventional crystalline panels may remain a consideration. The table below summarizes the cost, energy output and roof coverage area associated with various scenarios the team explored in order to arrive at the final recommendation captured in the energy Data Model.

Expansion of PV recommendation to meet on-site energy demand										
Linearly scaling recommendation to increase annual solar production using additional roof space on or off site										
On-Site Scenarios	**PV Technology**	**Total Sq Ft**	**Usable Sq Ft**	**Nameplate Capacity (kW)**	**Annual Production (kWh)**	**Platform Cost**	**PV System Cost/W**	**PV System Total Cost**	**Grand Total Cost**	**Grand Total Cost/W**
On-site										
1. NRDC preexisting array	Crystalline (2011)	432	432	5.55	6,917	$ -	-	-	-	
2. Recommended platform layout	CPV (2016)	2,510	1,983	200	101,220	$ 42,000	$4.05	$810,000	$852,000	$4.26
3. Platforms over entire rooftop	CPV (2016)	8,857	6,643	670	339,094	$ 148,207	$4.05	$2,713,558	$2,861,765	$4.27
4. Platforms over entire rooftop	Crystalline (2016)	8,857	6,643	111	122,317	$ 148,207	$4.05	$449,327	$597,534	$5.39
Off-Site Scenarios	**PV Technology**	**Total Sq Ft**	**Usable Sq Ft**	**Nameplate Capacity (kW)**	**Annual Production (kWh)**	**25 yr roof lease**	**PV System Cost/W**	**PV System Total Cost**	**Grand Total Cost**	
5. Lease 1,000 sq ft off-site	CPV (2016)	1,000	750	76	38,285	$ 300,000	$4.05	$306,369.46	$ 606,369	$8.02
6. Lease 1,000 sq ft off-site	Crystalline (2016)	1,000	750	16	20,295	$ 300,000	$4.05	$65,949.61	$ 365,950	$22.47
Assumptions:										
-constant cost of $4.05/W used for all PV technologies (based on CPV estimate; therefore, understates crystalline cost)										
-cost/W includes panels, inverter, racking (based on NREL System Advisor model and best available data for CPV Cost/W)										
-linearly scales annual production estimates generated by NREL System Advisor and PV Watts to increased installation sizes										
-linearly scales cost of constructing PV platforms on NRDC roof using mid-range construction cost estimate										
-CPV or crystalline panels would be flush mounted on leased rooftop at fixed tilt (like current NRDC array)										
-75% utilization rate for rooftop area consistent with ASHRAE assumptions in similar modeling exercises (allows for access/spacing)										
-likelihood of PPA based on project complexity, use of proven / unproven technology and project scale										
-future crystalline PV installation estimated to be 30% more efficient than existing crystalline technology (higher energy density)										
-25-year roof lease cost based on $1/sf/mo. Needs validation; selected because typical manhattan commercial rents can be higher by a factor of 10.										

Table 15: Expansion of PV recommendation to meet on-site energy demand

Explanation of scenarios in Table 15**Error! Reference source not found.** – Expansion of PV recommendation:

1. The existing PV array occupies 432 square feet and generates 6,917 kWh/yr from crystalline panel technology
2. The final recommendation of this report is to expand available square footage for on-site PV generation using elevated platforms that do not interfere with the green roof, skylights or mechanicals. This recommendation would increase production to 101,220 kWh per year.
3. To maximize on-site generation (regardless of aesthetic impact) the PV platforms could be expanded to cover the entire roof area. Using CPV technology, this option would generate 339,000 kWh/yr from 6,643 usable square feet of solar arrays. The cost would be $2.8 million using CPV. This option generates energy in excess of NRDC's requirements for achieving net zero. The Data Model subsequently showed that CPV covering 4,632 square feet of usable roof space would balance total energy production and consumption.
4. Applying crystalline technology to platforms over the entire roof area would yield annual production of 122,317 kWh at a cost of $597,534. The cost per watt increases substantially due to the platform construction cost and low energy density.
5. Metrics are established for solar output resulting from leasing 1,000 square feet of off-site roof space. Using CPV technology, every 1,000 square feet of leased space would yield 38,285 kWh annually at a total lifetime cost of $606,369. Half of the total cost is the lease (estimated to be $1 per square foot per month over the life of the project). It is likely a roof lease could be negotiated in another fashion; however, using a placeholder value is logical for this exercise in order to show the impact on total project cost and subsequent impact on levelized cost of energy (LCOE).
6. Leasing 1,000 square feet of off-site roof space and installing crystalline panel technology would yield 20,295 kWh per year at a total installed cost of $365,950 including the lifetime cost of the roof

lease. This option results in a grand total cost per watt of $22.47 which would certainly result in an unreasonable levelized cost of energy.

This scenario tool provides NRDC with scalable estimates of rooftop PV production using two technologies. The next step would be to determine the feasibility of covering the NRDC rooftop with CPV panels and/or negotiating roof leases for adjacent real estate. The project team was asked not to approach neighbors on behalf of NRDC and could not produce an actual solar roof lease case study in New York City to use as a comparison; therefore, a placeholder value of $1 per square foot per month was used in financial projections pertaining to leased roof space.

Summary of conclusions for NRDC rooftop PV

The Data Model indicates NRDC has a total solar PV requirement of 352,705kWh annually. 101,220kWh can be supplied by rooftop CPV panels installed on elevated platforms that do not interfere with the planned green roof. An additional 64,698kWh can be provided by vertical solar panels as detailed in section 4.3.1. The remaining 186,787kWh could be produced from a 4,632 square foot CPV installation covering the balance of the NRDC rooftop or, ideally, a neighboring roof accessed through a negotiated lease.

CPV installation

Figure 51: Rooftop CPV installation

Figure 52: Tracking CPV rooftop racking system

Figure 4: Emcore Soliant 1000x high-density rooftop CPV

Tech Development Forecast

Figure, below, shows the spectrum of available photovoltaic generation technologies and evolution of efficiency over time. While the efficiency growth for crystalline PV technologies is relatively flat, CPV is experiencing rapid growth.

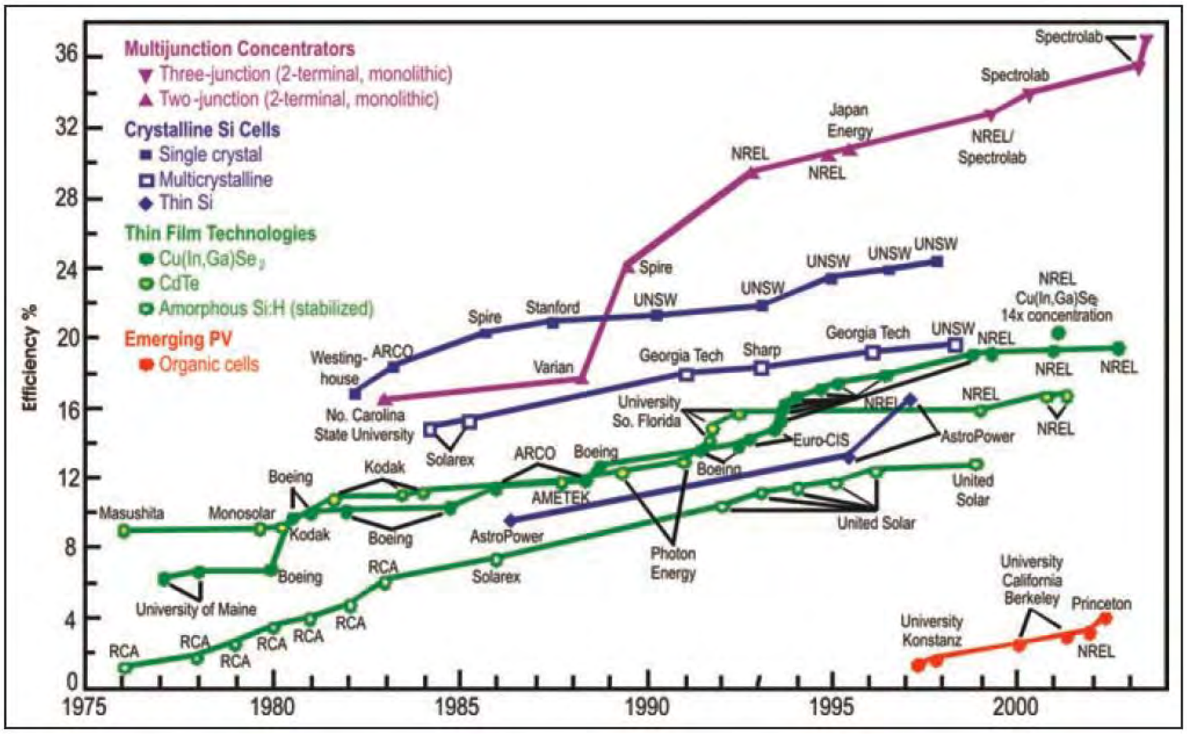


Figure 54: Photovoltaic cell efficiencies improvement 1975 through 2003

The CPV Consortium and Solar Power International are two industry authorities tracking the development in CPV technology. The mission of The Consortium is "supporting the development and optimizing the long-term success of CPV as a mainstream source of renewable energy."[390]

Company Name/Web Link	Location	Comment
Arima	Taipei, Taiwan	Reported achieving >40% cells.
Azur Space (RWE)	Heilbronn, Germany	Reported 36% efficiency; custom designs available.
CESI	Milano, Italy	Datasheet reports efficiency >30%.
Compound Solar Technology	Hsinchu Science Park, Taiwan	Website shows I-V curve with 33.4% efficiency
Cyrium	Ottawa, Canada	Datasheet describes typical > 39% cells
Emcore	Albuquerque, NM, USA	Datasheet describes typical 39% cells and receivers at ~500 X.
Epistar	Hsinchu, Taiwan	Multijunction cells in development
IQE	Cardiff, Wales, UK	Has demonstrated state-of-the-art efficiencies
JDSU	Milpitas, CA, USA	Advertises multijunction concentrator cells on website
Microlink Devices	Niles, IL, USA	Multijunction cells removed from substrate in development
Quantasol	Kingston upon Thames, Surrey, UK	Multijunction cells with quantum wells
RFMD	Greensboro, NC, USA	Multijunction cells in development
Sharp	Japan	Has demonstrated high efficiencies; has not indicated plans for external commercialization.
Solar Junction	San Jose, CA, USA	"Approaching 40%"
Spectrolab (Boeing)	Sylmar, CA, USA	Datasheet describes minimum average 36% cells and cell assemblies at 50 W/cm². Will ship 35 MW in 2009, and plan to ship 100 MW in 2010 (@500X).
Spire	Boston, MA, USA	Announced achievement of 42.3% efficiency.
VPEC	Ping-jen city, Taiwan	Multijunction cells in development

Figure 55:Companies developing high-efficiency CPV solar cells

Finance

A comprehensive financial analysis of CPV technology takes into account the overarching project criteria, constraints, and alternatives for on-site generation. Unlike utility-scale CPV project cases and other commercial rooftop solar installations, the reality of aiming for net zero energy in a multistory New York City office building requires the facility to maximize generation from any and all viable resources. Levelized cost of energy (LCOE), the gold standard of solar power cost benchmarking, emerges as a secondary consideration as long as overarching project cost criteria are met.

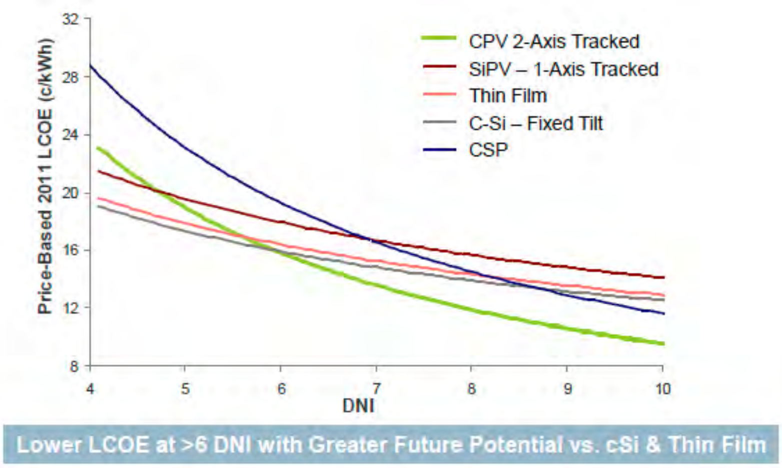


Figure 56: Levelized cost of energy (LCOE) for CPV compared with other PV technologies, by Direct Normal Insolation (DNI)

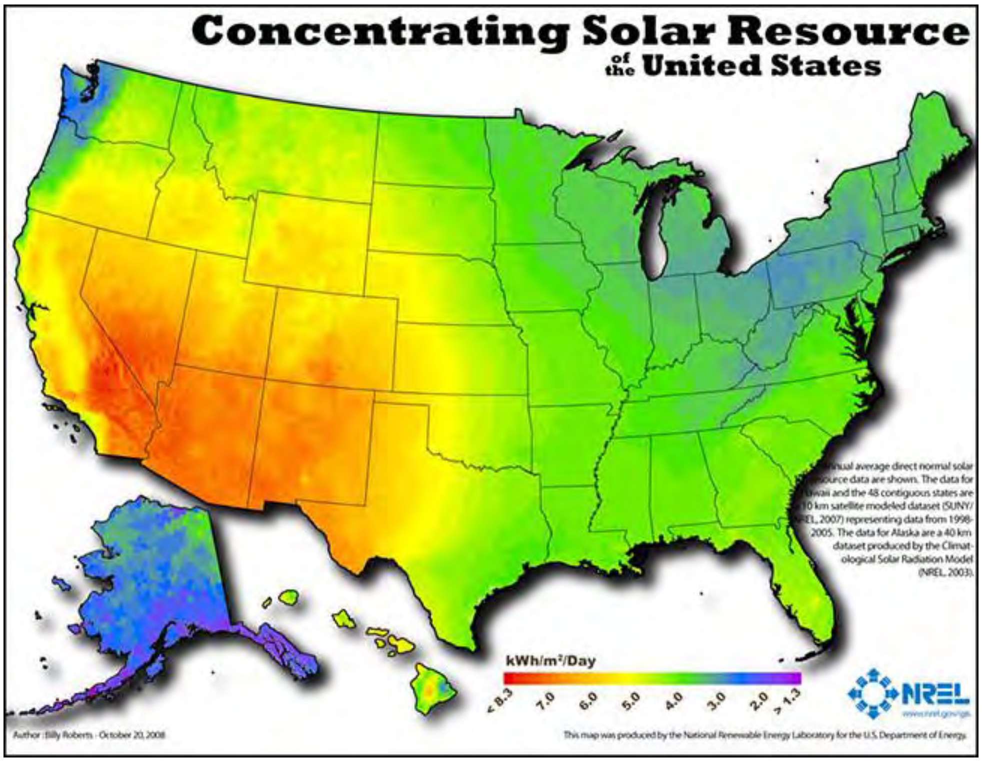


Figure 57U.S. Direct Normal Insolation (DNI) map for assessing CPV cost potential

According to the figures above, CPV in the New York region may have a slightly higher LCOE than conventional solar technologies. Because this project prioritizes total energy generation, the difference in LCOE is a low priority consideration.

NREL confirms that a similar logic has been applied to other high-performance building endeavors. A case analysis of six high performance buildings concluded that "many decisions are not made based on cost. Building owners make decisions based on values. Quite often owners will pay for features they really want in a building."[391] On-site rooftop PV at NRDC is an example of a system decision that is not motivated by cost but instead out of necessity for meeting project criteria.

The NRDC green roof plan prioritizes environmental benefits over cost-efficient rooftop energy production. The allocation of roof space to the green roof necessitates an innovative PV platform system with a price tag of up to $45,000. High-efficiency CPV panels will maximize energy production from the remaining space at a cost comparable with current technologies on a per watt basis.[392]

Input costs, financial incentives, and projected revenue from net metered energy production are readily available. Total cost and cash flow are modeled in SAM using best available data sources and, in some cases, ballpark assumptions for factors such as installation cost. The output from the financial model is included in the Implementation Plan.

In general, costs per Watt for crystalline panels have been steadily decreasing while efficiencies edge upward (Figure). CPV is expected to follow a similar price trajectory and is already showing lower costs per watt due to higher efficiencies.[393] As the module price per watt drops to the $1.50 range and below in coming years, installation costs rise in the financial hierarchy as major considerations. Labor, on-site handling costs, permitting and other overhead expenses are not subject to the "Moore's Law" and global competitiveness forces that have driven down solar technology prices in recent years.

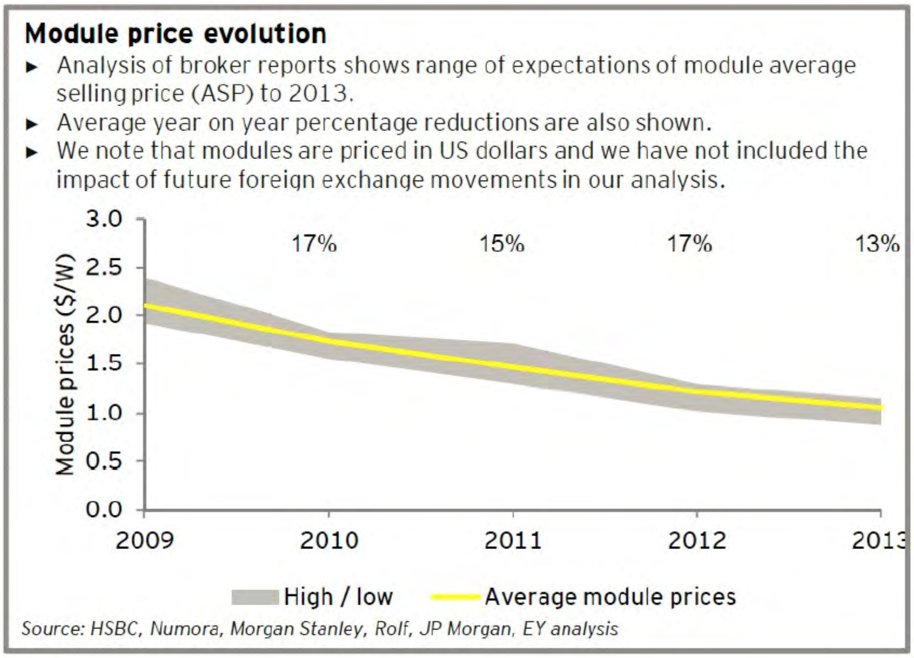


Figure 58: Decrease in average prices of solar modules 2009-2013

9.13 EMCORE SOLIANT 1000 CONCENTRATING PHOTOVOLTAIC (CPV) SPEC SHEETS[394]

EMCORE Soliant 1000

Commercial Rooftop Concentrator Photovoltaic (CPV) System

DATASHEET | APRIL 2012 SOLAR POWER

With the EMCORE Soliant 1000 you get:

- **More energy output.** You can nearly double your rooftop's energy production* with the Soliant 1000's high-efficiency solar cells, dual axis TipTilt Tracking™, and superior temperature coefficient.
- **Lowest cost of energy.** Because the Soliant 1000 gives you much more energy output, you get the lowest cost of energy on the market.
- **Low installation cost.** Save even more money with 60% fewer panels, 60% more watts per string, and 60% fewer DC strings.**
- **Maintenance-free tracking components.** Get 25+ years life with EMCORE's smart, reliable, robust design.
- **Low wind profile.** Save construction costs with the Soliant 1000's low wind profile design offering reduced lift and drag.

* Compared to conventional thin film PV.
** Compared to conventional PV.

Lowest Cost of Energy
Highest Energy Output Per Area
Most Reliable Peak-Hour Performance

The EMCORE Soliant 1000 delivers smart energy

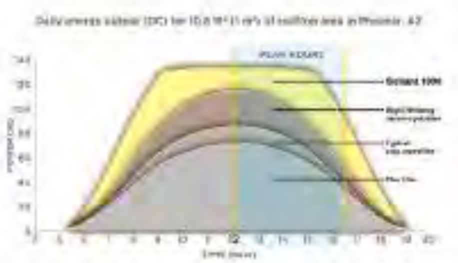
EMCORE's Soliant 1000 delivers the most powerful, reliable and cost-effective solar solution for commercial rooftops with high-energy demands and limited space. Critical peak-hour energy output stays strong with EMCORE's patent-pending TipTilt Tracking™ dual-axis technology. The Soliant 1000 gives you unsurpassed energy output, long-term reliability and the lowest cost of energy.

TipTilt Tracking™ precision gives you the lowest cost of energy and the highest energy output per area.

Take control of your energy costs

EMCORE's reliable, field-proven materials and components are efficient, compact and lightweight. Installed less than 2 feet tall, the Soliant 1000 generates more than 500 watts peak with EMCORE's proprietary high-powered receiver and Fresnel lens. And EMCORE's TipTilt Tracking™ system tracks the sun's movement throughout the day within 1/10 of one-degree precision.

EMCORE's reliable peak-hour performance is unsurpassed. The Soliant 1000 continues to generate power during crucial afternoon peak hours while other systems lose power.



Soliant 1000 38" (97 cm) East to West Spacing. Others 10° tilt, South facing.

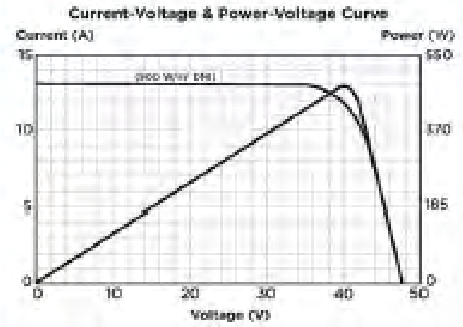
EMCORE Soliant 1000

Specifications

DATASHEET | APRIL 2012 **SOLAR POWER**

ELECTRICAL DATA - TRACKING PANEL

P_{max} STC	504	W	(900 W/m² DNI)
P_{max} PTC	471	W	
V_{oc}	47.7	V	
I_{sc}	13.2	A	
V_{pmax}	39.8	V	
I_{pmax}	11.8	A	
Max V IEC, UL	1000, 600	V	
Series Fuse Rating	25	A	
NOCT	61	°C	(800w/m², 20°C, AM 1.5, WS = 1 m/s)
Temp. coeff. Power	-0.2	%/°C	
Temp. coeff I_{sc}	5	mA/°C	
Temp. coeff. V_{oc}	-9.2	mV/°C	module
Module Efficiency	25.3	%	(900 W/m² DNI)

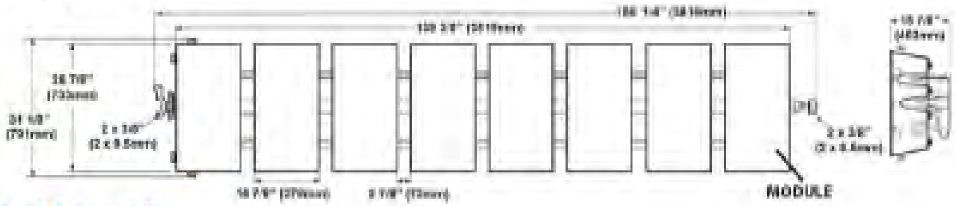


Measured at performance test conditions (PTC). Irradiance of 900 W/m² DNI, Ambient Temp. 20°C, 4 m/s wind speed.

MECHANICAL DATA

Cell Type	Triple-junction high-efficiency solar cells on Ge substrate
Panel Construction	Lens (silicone), composite housing, aluminum heat sink
Integrated Tracker	Coated steel and 304SS construction, TipTilt Tracking™ closed loop tracking, fits most PV mounting systems
Output Cables	80 inch (2m) length with locking connectors
Grounding	Integrated to mount, or optional factory-installed lug
Roof Load	5 lbs/ft² (0.0024 kg/cm²) high density array, 2 lb/ft² (0.0009 kg/cm²) low density array
Max Load	50 lbs/ft² (2394 Pa)
Wind Performance	130 mph (208 km/h) non-penetrating or penetrating
Operating and Storage Temp.	15°F to130°F (-9°C to 54°C)
Cells Per Module	8
Modules Per Panel	8
Cells Per Panel Assembly	64
Concentration Ratio	1000x
Weight	198 lbs (90 kg)
Dimension	(see diagram)
Area*	27.7 ft² (2.6 m²)

*Includes internal tracking components.

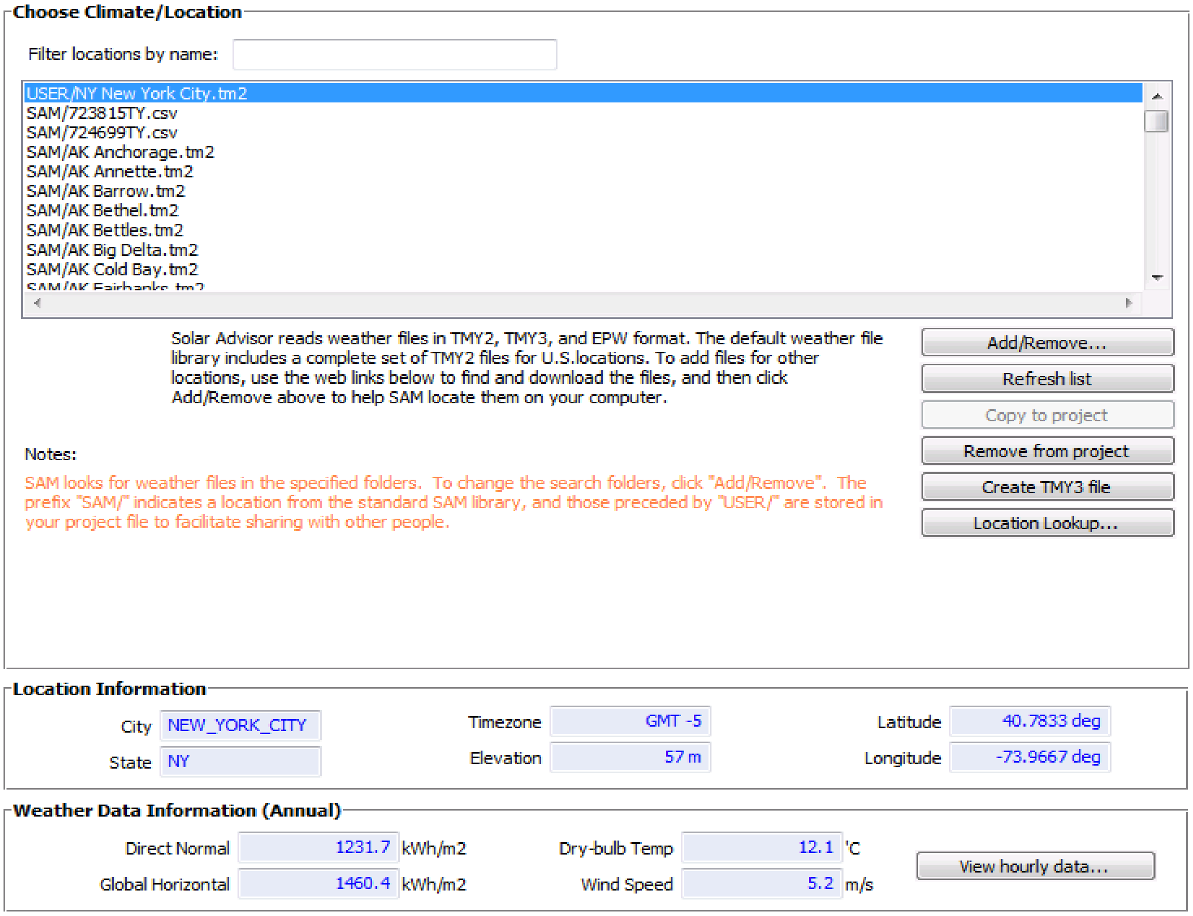


Tracking Panel Assembly

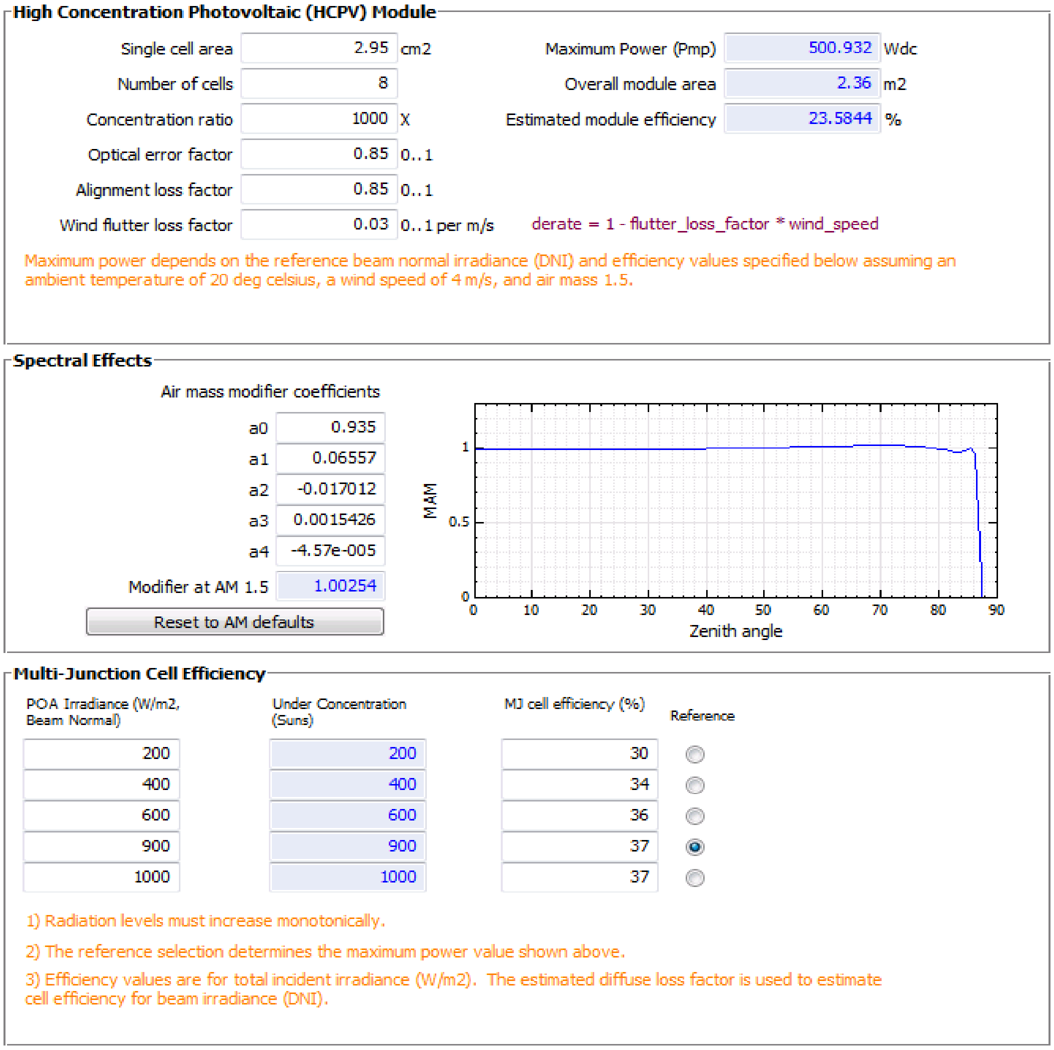
CERTIFICATIONS	Pending
WARRANTY	25-year limited power warranty, 5-year limited product warranty
CAUTION	Read safety and installation instructions before using this product

9.14 NREL System Advisor Model (SAM) Generation Estimate for Concentrating Photovoltaic (CPV) with Tracking

Step 1: Importing New York City weather and solar energy data into SAM



Step 2: Mapping manufacturer specifications to SAM CPV cell performance inputs



Step 3: Entering overall system sizing based on graphic layout of rooptop panels on elevated PV support structures

Array Configuration

Number of trackers	50	
Modules on each tracker	8	
Single tracker nameplate capacity	4.00745	kWdc
System nameplate capacity	200.373	kWdc
Number of inverters	1	
Inverter AC capacity	333	kWac

Tracker

General tracking error	0.98		0..1
Single tracker power during operation	25		W
	min (deg)	max (deg)	
Tracker elevation angle limits (deg)	35	85	
Tracker azimuth angle limits (deg)	60	310	

Note: It is assumed that no diffuse is captured by the HCPV module, and so the system output beyond when a tracker limit is reached is zero. Also, in the southern hemisphere, the tracker azimuth limit angles are interpreted to include the 0 (360) degree arc of the circle. Example, min=300 max=60 for a 120 degree range

Soiling and Derates

Monthly soiling factors	Edit values...	
DC wiring loss factor	0.97	0..1
DC module mismatch loss factor	0.98	0..1
Diodes and connections loss factor	0.99	0..1
AC wiring loss factor	0.99	0..1
Estimated overall system conversion efficiency	19.8764	%

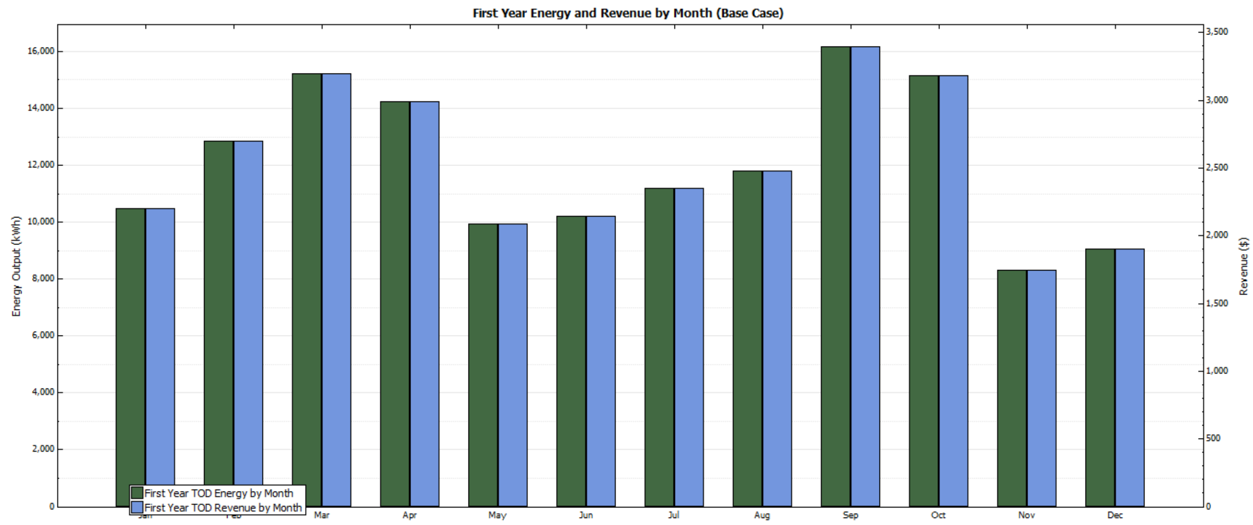
Stowing

Max allowed wind speed before stowing	11	m/s

Land Area

Packing factor	1	
Total land area	0.233262	acres

Step 4: SAM produces detailed energy output data



9.15 ELECTRICAL - VERTICAL AXIS WIND TURBINE (UGE 4K)

Rationale

A survey of the NRDC building's wind potential found it to be satisfactory with a mean wind speed on the roof of 10.1 mph / 4.5 meters per second. Vertical Axis Wind Turbines are ideal for small-scale wind production. These turbines are typically small enough to be used in residential and commercial applications. Due to their unique shape, they can take advantage of shifting winds, updrafts and downdrafts without adjusting for direction.[395] New York City's new Zone Green Code Amendments allow these devices on building roofs, as of April 30, 2012.[396]

Figure 59: UGE 4k Conceptual Photo

The Urban Green Energy 4k turbine, installed by Pfister Energy,[397] is extremely quiet, producing less than 38 decibels (about the volume of a conversational tone) at high speed,[398] and at the measured wind speeds will produce 2900 kWh per year.

Benchmark/case studies used

Urban Green Energy and the National Renewable Energy Laboratory have conducted extensive studies and established wind modeling projections and software.

UGE vertical axis turbines are used around the globe, in Manhattan, the UGE Eddy turbine is used at the Town School, and in Toledo, Ohio, the University of Toledo installed a 4k turbine on a rooftop at their Scott Park Campus in July 2011. The school's average wind speed is only 4m/s, slightly slower than NRDC's average 4.5 m/s.[399]

Tech Development Forecast

Wind power advances are most significant with regard to size and scale. Given the constraints of the roof, we do not anticipate significant development of vertical axis wind in the near term.

Finance

In March 2013, NYSERDA is expected to provide a small-wind incentive of $3.50 per kWh of expected Annual Energy Output (AEO) if the AEO is less than 100,000 kWh. Given our AEO of 2,900 kWh, this project could qualify for $10,150 of the total project cost of $31,000 per turbine.[400] One logistical consideration of installation is transporting the 15 foot blades to the roof. This may be possible in the freight elevator or other conveyance. If not, an external lift may be necessary.[401]

9.16 Distributed Generation/Combined Heat and Power (DG/CHP)

NOTE: DG/CHP SHOULD ONLY BE CONSIDERED IF GEO-EXCHANGE, CONCENTRATED PV, AND OTHER MEASURES ARE NOT IMPLEMENTED TO ALLOW FOR REMOVAL OF BOILER AND SUBSTANTIAL GENERATION INCREASES

Rationale

Distributed Generation (DG) / Combined Heat and Power (CHP), also known as cogeneration (cogen), is an on-site power generation system that produces electricity and utilizes the thermal energy created by the generation process as a heating or cooling source. DG/CHP systems are more energy efficient than separate electricity and heat generation methods and can result in significant energy consumption and GHGE reductions. Some common types of CHP systems are reciprocating engines (diesel/biodiesel or gasoline), micro turbines (natural gas or biogas), photovoltaic solar (PV), wind turbines, and fuel cells. By generating electricity on-site and utilizing the "waste" heat for heating and/or cooling, CHP systems can achieve up to 85% efficiency, as opposed to conventional power plants that are only about 30% efficient due to significant losses from unutilized waste heat and through transmission.[402] These systems can be implemented on scales ranging from less than 100 kW to over 100 MW [403], so we could conceivably generate all of the electricity for the building with a CHP unit.

The 2012 estimated total thermal and electrical energy consumption at 40 West 20th Street is 1,203,337 kWh in 2012 according to the Data Model. The DG/CHP system could completely replace the boiler for space heating and domestic hot water, as well as supply both electricity and heat to the HVAC system (including potential DEVap air conditioning units). Although the system is much more efficient than consuming power from the grid, it still requires fuel combustion.

Tech Development Forecast

Current non-fossil fuel availabilities in NYC would dictate that a reciprocating engine compatible with B100 (100% biodiesel) would be the only viable option for NRDC at this time. It is likely that sustainable biogas production in the New York City region is a long-term scenario (perhaps 30 years+ due to low natural gas prices).[404]

The third-party also seeks out and retains any subsidies or tax credits that the project is eligible for. The project developer then converts the project's total cost stream into a per kilowatt-hour price, which the building owner agrees to pay for the duration of the contract period (or as otherwise described in a contract). Although individual contracts can vary significantly, the period usually tends to be about 8 years and the per-kilowatt price paid by the user is usually around 15% less than they would be paying to the local utility on a daily basis (the third-party assumes that they can recoup their investment and save in excess of 15%, which is where they make their profit). Unfortunately, low natural gas prices may complicate this payment structure if biofuels are to be used.

ConEd estimated in 2005 that an Internal Combustion Engine CHP system has:

- Capital Cost ($/kW) of $1,420
- Fixed O&M Cost ($/kW-yr) of $3.30
- Variable O&M Cost ($/MWh) of $17.50

Since the NRDC wants to employ technologies that are considered capital expenditures rather than operational costs, the power purchase agreement model may not be ideal. Therefore, a joint-ownership model, which combines private ownership and a PPA agreement through the creation of a joint debt-and equity-financed LLC formed between the third-party and site owner. The third party installs, operates, and maintains the CHP system at the site while allowing the site owners to benefit from the energy savings in proportion to the amount of equity they invest. This model would provide greater savings to the site owner than a normal power purchase agreement because they also earn a portion of the third-party's profits.

Finance

It would usually be advised to enter into a power purchase agreement (PPA) model, where a third-party installs, owns, and operates the CHP system at the site and sells electricity and heat to the building owner over an extended period of time. Under this agreement, all up-front and ongoing maintenance/operation costs are absorbed by the third-party, removing financial, technical, and liability risk from the building owner.

ConEd had incentives for DG/CHP owners of "$275/kW installed, up to 65% of the eligible project costs."[405] Also, because the CHP's absorption chillers and existing cooling towers will enable the building to permanently reduce their peak demand for energy in the summer, the owner would also be eligible for an additional reduction of $425/kW called a Permanent Demand Reduction. There was also an ICAP ISO incentive of $20,000 for five years, and a NOx reduction credit, estimated to be between $50,000 and $75,000. Between these additional incentives, a third party could make up a significant difference in the cost for the CHP unit under a Shared Savings Plan.

The technology is available today but fuels for the cogeneration unit have the potential to improve significantly in the coming years. However, due to recent natural gas production increases, alternative fuel (particularly biofuel) R&D is expected to slow (per Greg Hale interview). However, the technology should be considered regardless because it has the highest efficiency available at this time.
A third party can be used to install and manage this equipment seamlessly, but in NYC in particular, there are obstacles related to local regulations and policies for interconnection issues. When a CHP system is linked to the grid, it is said to be "interconnected" – or operating "in parallel" to the grid, as opposed to systems that operate completely independently of the grid (IEA's International CHP/DHC Collaborative, 2008).

Currently, the most efficient cogeneration systems are powered by natural gas. These turbine systems could be easily converted to biogas, but biogas is currently unavailable in NYC. If a biodiesel-fired reciprocating engine DG/CHP system is installed, biogas will not be compatible.

The vast majority of cogeneration facilities in NYS utilize natural gas at this time (http://chp.nyserda.org/facilities/index.cfm), but we should recommend a biodiesel CHP unit to avoid having to use natural gas until biogas is available. Biodiesel will be more expensive than natural gas, but is still a very efficient system and biodiesel is already available and has potential for better availability and sustainability.

There are also site vs. source considerations to be discussed with the client because this technology could conceivably take the building off the grid, thereby making it a source net zero electricity user, leaving the only off-site energy consumed as the fuel (biodiesel) burned in the DG/CHP generator.

9.17 WINDOW MONITORING SYSTEM – NATURAL VENTILATION

Rationale

Past research (ASHRAE RP-884) demonstrated that occupants of naturally ventilated buildings are comfortable in a wider range of temperatures than occupants of buildings with centrally controlled HVAC systems.[406] Natural ventilation has the potential to reduce first costs and operating costs for some commercial buildings while maintaining ventilation rates consistent with acceptable indoor air quality.[407] These natural ventilation systems may reduce both first and operating costs compared to mechanical ventilation systems while maintaining ventilation rates that are consistent with acceptable indoor air quality.[408] Also, some studies have indicated that occupants reported fewer symptoms in buildings with natural ventilation compared to buildings with mechanical ventilation.[409] If natural ventilation can improve indoor environmental conditions, such improvements can also potentially increase occupant productivity by reducing absenteeism, reducing health care costs, and improving worker productivity.[410]

Because of these potential benefits, natural ventilation is being increasingly proposed as a means of saving energy and improving indoor air quality within commercial buildings, particularly in the "green buildings" community.[411] These proposals are often made without any engineering analysis to support the claimed advantages, e.g., without calculating expected ventilation rates or air distribution patterns.[412]

When thinking about naturally ventilated buildings, probably the most important architectural issue is the window.[413] Windows can be used for ventilative cooling of the building structure and, more importantly for this paper, the attainment of thermal comfort by moving air through the building.[414] Designs for low-energy office buildings increasingly incorporate operable windows for the benefits of personal control, environmental quality, and architectural value.[415] However, integrating operable windows with mechanical systems to achieve their full benefits is an unresolved energy challenge.[416] If operable windows are left up to the control of the occupants, designers run the risk of putting unpredictable or unnecessary loads on the HVAC system, causing air pressure balancing issues, or causing unreliable or unwanted air change rates.[417] However, if windows are automated for natural ventilation, the building design loses the comfort benefits, amenity, appeal and robustness of manually-controlled windows.[418]

Signaling systems that inform occupants about when to open and close their windows (such as red/green lights or lighted signs) have become a popular, low-cost solution that strikes a balance between manual control and building intelligence.[419] But there has been little feedback about whether and how occupants respond to them.[420]

Benchmark/case studies used

Little research has been done to characterize how these systems operate in practice, and whether they influence how occupants use their windows.[421] The Center for the Built Environment, or CBE, took a broad look at window signaling systems in existing buildings in the U.S.[422] Through interviews, site visits and occupant survey, they investigated 16 projects across the country to better understand a) why signaling controls were implemented in the project; b) how "open windows" mode was defined; and c) the extent to which the signals play a role in window use behaviors.[423]

Two of the buildings had comparable location and weather attributes to New York City; New Haven, CT and Annapolis, MD. These buildings switch completely from a mechanical cooling mode to a fully passive mode by shutting down the central air handler within an acceptable outdoor temperature range.[424] Because mechanical air supply is discontinued based on outdoor temperature only, occupant behavior does not impact the building's operating status, but it may result in uncomfortable indoor conditions if a sufficient number of people do not actually open the windows, or if solar gain in the building is higher than expected.[425] Building form, upper-level automated openings and thermal mass are all used to minimize this impact.[426]

In the New Haven building, three of the four air handlers serve the office spaces with windows, and the central fans shut off during natural ventilation mode, reducing overall power consumption from 30 kW to 8 kW.[427] Natural ventilation mode falls between 55 and 75 F outside air temperature, depending on humidity and wind speed criteria, and these conditions are all monitored by a dedicated weather station.[428] The building spends most of its operating hours in natural ventilation/"green light" mode during the swing seasons (April, May, September, October).[429]

The quantitative benefits of natural ventilation cannot be analyzed consistently, therefore it is difficult to determine what type of energy savings this type of mechanism could have on a building. However, we do know that when applicable, natural ventilation can offset cooling energy consumption and the associated energy costs and carbon dioxide emissions thought to be related to global climate changes.[430] Data from the United Kingdom has found direct comparisons of naturally ventilated and air-conditioned offices, naturally ventilated buildings offset from 14 kWh/m2 to 41 kWh/m2 of cooling energy annually, for good practice standard office buildings to typical prestige office buildings respectively, saving from approximately $0.12 per square foot to $3.60 a square foot annually in energy costs.[431] These savings account for approximately 10% of total energy costs in a climate where outdoor air temperatures seldom exceed thermal comfort limits in the summer and thus, one well-suited for ventilative cooling of office buildings.[432]

Of course, cooling through natural ventilation may be accomplished by either natural means or mechanical means (e.g., using so-called economizer cycle operation).[433] When resorting to mechanical means to cool buildings, however, fans will consume a significant amount of the energy.[434] While a directly comparable number is not readily available for the U.S., there is a growing awareness that fans consume a large portion of the energy used to cool buildings.[435] When compared to all-air mechanical cooling systems, naturally ventilated buildings in the U.K. offset from 20 kWh/m2 to 60 kWh/m2 of fan energy consumption annually for cooling purposes, saving approximately $0.16 per square foot to $0.48 a square foot annually in energy costs.[436]

These statistics from the U.K. establish the potential that natural ventilation offers when climatic and operational conditions prove particularly suitable.[437] Roughly, natural ventilation may be expected to provide cooling energy savings on the order of 10 % and fan power savings (i.e., for all-air systems) on the order of 15 % of annual energy consumption when climatic and operational conditions are suitable.[438]

Tech Development Forecast

The success of window signaling systems are completely dependent on human interaction. CBE studies found that the number of people who reliably respond to either the close or open signals, typically does not exceed 50%.[439] Historically, window behavior has been modeled with very limited evidence from the field. Assumptions about behavior are made based on generic occupancy patterns or outdoor conditions, usually outdoor temperature.[440] Models also commonly assume occupants will behave in accordance with ideal (design) thermal conditions and ventilation rates.[441]

Educated placement of the signaling devices also plays a significant roll in its successful implementation. The decision to place the devices in workstations or common areas was also in most cases a matter of designers' best judgment and/or cost savings.[442] Several design teams elected to place the signals in places where occupants walk while others thought visibility from as many workstations as possible was preferable.[443] In the CBE survey, one of the most common comments was that occupants reported being more likely to use the signals if they could see them from their desk.[444]

For the most part, attempts to characterize human interactions with windows and other controls are grounded in the principle of adaptation, which states: "If a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort."[445] Adaptive actions either fall into the category of modifying the environment – such as adjusting the thermostat, ceiling fan or window – or modifying one's clothing or activities to adapt to changing conditions.[446]

Additionally, the latest advances in window control modeling struggle to account for multiple interacting variables.[447] It must be coupled with a weather station, which is able to track wind speed, direction, temperature, humidity, and then linked with the BMS. The more systems required to cross-integrate, the less predictable. The figure below illustrates the many types of signaling devices available:

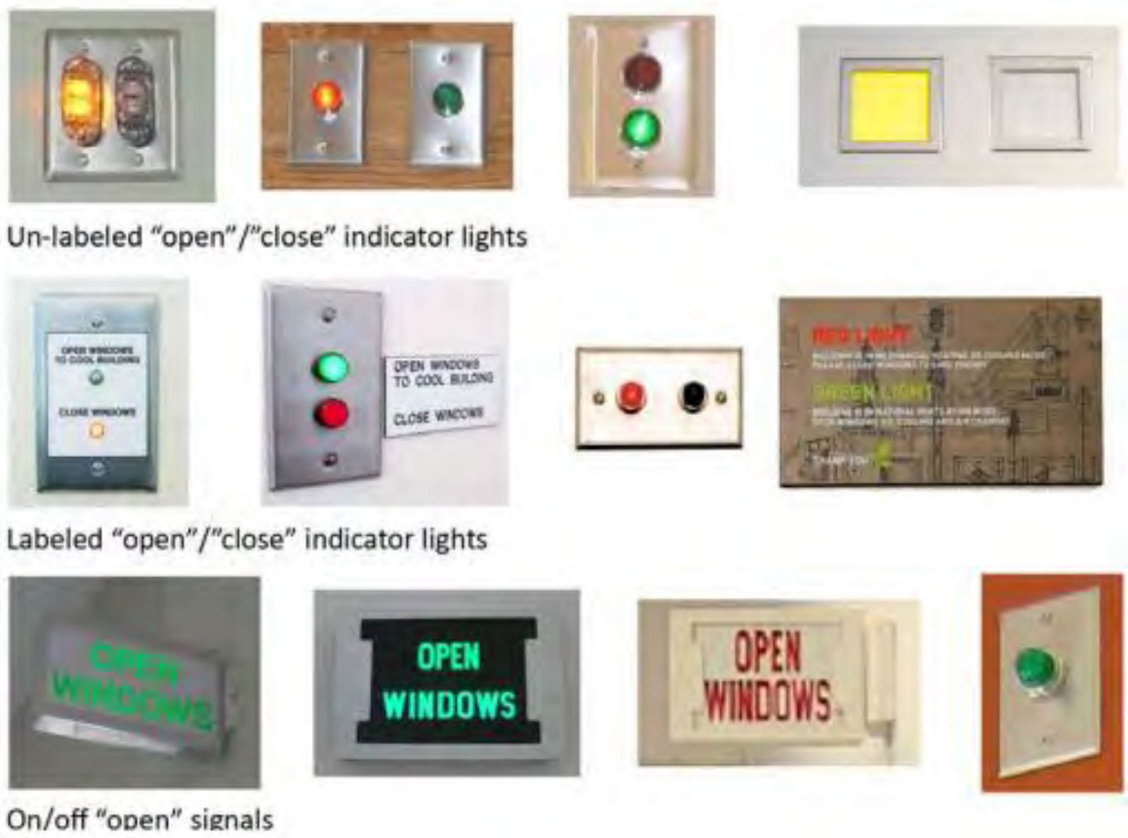


Figure 60: Signal Device Types

9.18 ELECTRICAL - GREEN REVOLUTION: GYM EQUIPMENT HARVESTS ENERGY FROM WORKOUTS

Rationale

This technology is offered by Green Revolution Company and is a form of motion energy harvesting tool. It basically converts the human energy produced through use of exercise equipment into clean renewable energy. The motion or effort created by an individual's workout through the use of cardio equipment is captured, converted to electricity and transferred to a storage cabinet which then will be connected to the grid through a grid-tied inverter.

Figure 61: Green Revolution Exercise Bike

This technology can be retrofitted to most existing or new cardio equipment, including elliptical, cross-trainers, stepping machines, and stationary and recumbent bicycles. The benefits of this technology at NRDC are many fold. Not only does it provide for a renewable source of clean energy generation through human-produced energy, but also employees gain considerable health benefits from its implementation and use. The amount of energy harvested depends directly on the level of resistance set when using the equipment. The higher the resistance of gym equipment, the more rigorous the workout will be and the more electricity is generated.[448] Most fitness enthusiasts have reported increased stamina and health benefits as well as more interest in their energy consumption habits using these retrofitted gym equipment. This technology can be added to any individual bike however due to the cost of retrofit and connection to the power grid, it is most economical when a group of bikes or exercise machines are connected. The suggested number of equipment for a facility of this size is between 13-20 indoor machines.

The two main benefits of implementing this technology at NRDC are as follows:

1. Each group cycling class with 20 bikes can create about 3 kilowatts (kW) per session. If group cycling classes run four times a day, the energy created will be close to 300kW per month. To put this in perspective, a cyclist pedaling for an hour can produce enough energy to power two laptops. The more classes are held, the more the facility will reap the rewards.[449]

2. This is one of the most unique forms of energy generation among others that truly engages employees toward energy consumption and motivates them toward behavior modification. When an individual feels the level of effort required to pedal one hour with high resistance on a spinning bike, he would be more inclined to engage in energy consuming habits, i.e. turning computers or other electrical equipment off when not in use or overnight to prevent vampire loads.

Benchmark/Case Studies

This technology has been implemented successfully in several fitness and Athletic clubs across the country. Columbia Athletic Club in Washington has 28 Green revolution energy producing stationary bicycles. The Green Microgym in Portland is another one. Although the gym isn't capable of generating enough electricity to be carbon-neutral yet, through the use of all the equipment at once, it can produce 10 times the amount of electricity needed to run the facility at any given moment.

Tech Development Forecast

The Green Revolution Company is planning to provide an interactive carbon calculator to help calculate the carbon footprint of its users and to measure their impact on the environment. It is also considering incentives to institute green points system for the fitness equipment users to exchange their collected green points for merchandise discounts or free classes.[450]

Figure 62: Power Bikes are generator-retrofitted stationary cycles that convert motion into electricity

The technology of motion energy harvesting is a topic well deserved of increased research. With the technology still in its infancy and market immature, this state-of-the-art technology is being tested in a wide range of devices and applications such as micro generators and has a great deal of potential for improvement such as in vibration harvesting devices. One of the applications for motion energy harvesting is currently being tested on running shoes as a method of generating power for wearable electronics.[451]The harvested power is used to supply an electromagnetic generator through walking or running. A key issue with energy harvesting technology is figuring out the performance metrics for comparison and benchmarking of different devices and design approaches.

Green Revolution CEO Jay Wheelen and others have forecasted that the technology is likely to become cheaper and easily adaptable to more devices in the future.[452]

Finance

There are no creative financing strategies for implementing a fitness center at a facility at this time, however organizations might consider negotiating better health insurance rates with their health insurance providers since their facility is providing in-house health and fitness program where employees would greatly reap benefits from improved health and illness prevention.

Quantity	Cost of gym equipment	Cost of Green Revolution retrofit	Total Cost	Energy impact per year (kwh)
1	$1200	$750	$1950	117
15	$18,750	$11,250	$29,250	1755

Table 16: Cost structure for the Green Revolutionary technology

Green Revolution recommends at least 15 bikes or retrofit-able gym equipment to hold classes 3 times a day for the realized energy production indicated in the table. The total cost does not include the cost of required renovation to create a fitness center.

9.19 ELECTRICAL – PHOTOVOLTAIC INSULATING GLASS UNITS (‘PVGUS’)

The rooftop space available to install classic photovoltaic (‘PV’) panels has already been optimized by NRDC in previous projects. We therefore looked into ‘Building Integrated Solar Photovoltaics’ (‘BIPV’) options to optimize other possible areas of the building’s surface to generate additional energy. We noted that there was an opportunity to install PV solar systems on the roof’s skylights (6 skylights of 216 square foot each and 1 skylight of 72 square foot), as well as on windows belonging to NRDC on the building’s southwest façade (98 windows estimated to represent about 2,205 square foot)[453] that receives the most sunlight during the day.

Among ‘BIPV’ options available on the market today, we selected the Photovoltaic Insulating Glass Units (‘PVGUs’) manufactured by Pythagoras Solar. PVGUs simultaneously provide solar power generation, energy efficiency savings and modular day lighting without significantly altering the appearance of conventional windows and hence the building facade.[454]

Commodity crystalline photovoltaic cells are perpendicularly embedded between the two glass panes that make up the PVGU. Optics are then used to attract light onto the photovoltaic cells (i.e. prisms focus sunlight onto the photovoltaic cells), while blocking out some of the sun’s heat, thus reducing air conditioning needs. The optical system enables to cut by half the surface area of photovoltaic cells necessary to generate a given amount of energy.[455]

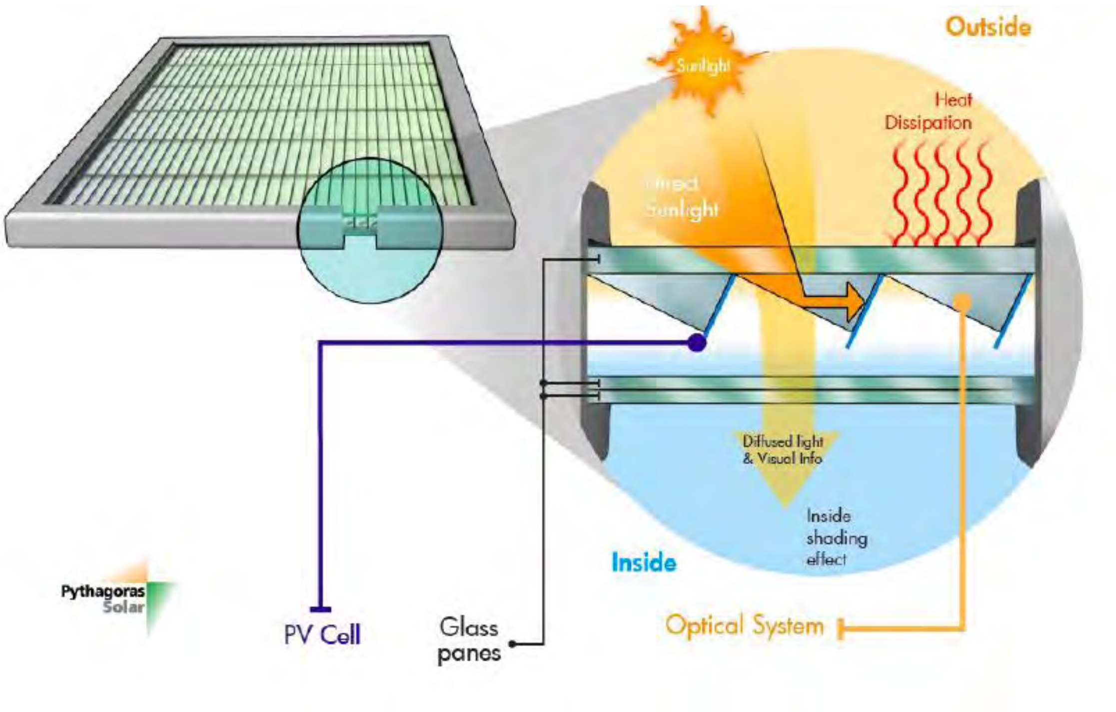


Figure 63: Description of Pythagoras Solar PVGU system

The PVGUs generate energy up to 13.0% module efficiency, while also acting as a shading device with a solar heat gain coefficient (‘SHGC’) as low as 0.14.[456]
The lifespan of the PVGUs is between 20 and 25 years according to Pythagoras Solar and the standard warranty is 10 years.[4]

The combination of energy efficiency, energy generation and daylight modulating features make these PVGUs particularly interesting for building owners aiming to reach Net Zero Energy. This would imply, however, in NRDC’s case replacing windows and skylights that it has already changed in recent renovations.

Benchmark/case studies used

Pythagoras Solar's PVGUs were selected by the Willis Tower (former Sears Tower) in Chicago in 2011, as part of a pilot project to help the building achieve its renewable energy generation and energy efficiency optimization targets. The project, which was rolled out in November 2010, involved installing PVGUs on the 56th floor of the southern façade of the tower.[457]

Pythagoras Solar also entirely equipped with its solar units the cooperative organic farmers, Organic Valley's, headquarters in La Farge, Wisconsin in 2012.[458]

Tech Development Forecast

Pythagoras Solar uses conventional crystalline PV cells that have experienced a rapid decline in their price over the years. As PV cell prices are likely to continue declining going forward, it is likely that Pythagoras Solar's PVGUs' price will decline as well.

Moreover, Pythagoras Solar was a laureate of General Electric's 2011 Ecomagination Challenge that rewards best-in-class energy innovations for buildings. It received a $100,000 prize from General Electric[459] and concurrently a $63 million investment from venture capital partners and GE[460]. It is likely that it will use the capital and the $100,000 prize to improve its technology and scale its business. Furthermore, Pythagoras Solar has gained in visibility and reputation by winning this award. The combination of these factors seriously improves chances that this technology will breakthrough as a useful supplement to conventional PV arrays for buildings that have insufficient roof space.

Finance

Pythagoras Solar PVGUs are eligible for the 30% Federal Investment Tax Credit and also for the accelerated depreciation (MACRS). Thanks to these mechanisms, the price of PVGUs could be brought down from ca. $125 per square foot to ca. $75 per square foot. This estimate does not include State or local incentives that would be available for such technologies.[461]

In addition to the tax incentives, you should also account for the energy savings provided by the units that have a very low SHGC (0.14) and a high visual light transmission for daylight harvesting. These savings should both impact on the HVAC capital cost and on the annual energy use for cooling. [462]
Taking into account these incentives, along with energy savings provided by the technology, the payback period for office buildings in the US is around 3 to 5 years. [463]

9.20 Financial Model Cash Flow Analysis for Each Technology

Please see following tables for all detailed analyses.

Advanced Lighting Controls Cashflow Analysis

Advanced Lighting Controls 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2049	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10	37		
Total Installed Cost	-$713,728	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$713,728	-$713,728
Equipment Cost												$0	$0
Installation Cost												$0	$0
Rebates & Incentives	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Rebate												$0	$0
Incentives												$0	$0
Savings	$10,883	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$31,542	$396,787	$124,762
Energy impact in kWh equivalent	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	51,335	1,283,376	513,350
Cost ($)	$10,883	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$31,542	$396,787	$124,762
Total Cashflows	-$702,844	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$31,542	-$316,940	-$588,966
Cumulative Cashflows	*-$702,844*	*-$691,635*	*-$680,089*	*-$668,197*	*-$655,948*	*-$643,332*	*-$630,337*	*-$616,952*	*-$603,166*	*-$588,966*	*$6,448*		

Simple Payback Period after incentives	**36.8**	**years**
Simple Payback Period before incentives	**36.8**	**years**

Net Present Value 10Y	**-$586,046**
IRR 10Y	**-25.8%**
Net Present Value 25Y	**-$452,739**
IRR	**-4.0%**

Rooftop Solar Concentrated PV @ NRDC 2017	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2038	2039	2047	2048	2049	TOTAL 25Y	TOTAL 10Y
					1	2	3	4	5	6	7	8	9	10	22	23	31	32	33		
Total Installed Cost	$0	$0	$0		-$854,297	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$854,297	-$854,297
Equipment Cost																				$0	$0
Installation Cost																				$0	$0
Rebates & Incentives	$0	$0	$0	$0	$75,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$75,000	$75,000
Rebate																				$0	$0
Incentives					$75,000															$75,000	$75,000
Savings	$0	$0	$0	$0	$24,152	$24,876	$25,623	$26,391	$27,183	$27,999	$28,839	$29,704	$30,595	$31,513	$44,930	$46,278	$58,623	$60,382	$62,193	$880,560	$276,874
Energy impact in kWh equivalent					101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	101,220	2,530,500	1,012,200
Cost ($)					$24,152	$24,876	$25,623	$26,391	$27,183	$27,999	$28,839	$29,704	$30,595	$31,513	$44,930	$46,278	$58,623	$60,382	$62,193	$880,560	$276,874
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**-$755,145**	**$24,876**	**$25,623**	**$26,391**	**$27,183**	**$27,999**	**$28,839**	**$29,704**	**$30,595**	**$31,513**	**$44,930**	**$46,278**	**$58,623**	**$60,382**	**$62,193**	**$101,263**	**-$502,423**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*-$755,145*	*-$730,269*	*-$704,646*	*-$678,254*	*-$651,071*	*-$623,073*	*-$594,234*	*-$564,530*	*-$533,935*	*-$502,423*	*-$41,776*	*$4,502*	*$428,362*	*$488,744*	*$550,937*		
Simple Payback Period after incentives	**22.9**	**years**																			
Simple Payback Period before incentives	**24.5**	**years**																			
Loan & Loan Service	$0	$0	$0	$0	$533,516	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	$0	$0	$0	$0	$0	-$434,667	$74,903
Loan amount					$584,473															584,473	584,473
Principal repayment					-$15,889	-$16,842	-$17,852	-$18,924	-$20,059	-$21,263	-$22,538	-$23,891	-$25,324	-$26,844						-$584,473	-$209,425
Interest payment					-$35,068	-$34,115	-$33,105	-$32,033	-$30,898	-$29,694	-$28,419	-$27,066	-$25,633	-$24,113						-$434,667	-$300,145
Total Cashflows including loan	**$0**	**$0**	**$0**	**$0**	**-$221,629**	**-$26,081**	**-$25,334**	**-$24,566**	**-$23,774**	**-$22,958**	**-$22,118**	**-$21,253**	**-$20,362**	**-$19,444**	**$44,930**	**$46,278**	**$58,623**	**$60,382**	**$62,193**	**-$333,404**	**-$427,520**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*-$221,629*	*-$247,710*	*-$273,044*	*-$297,610*	*-$321,383*	*-$344,342*	*-$366,460*	*-$387,713*	*-$408,075*	*-$427,520*	*-$476,443*	*-$430,166*	*-$6,305*	*$54,077*	*$116,270*		
Simple Payback Period after incentives & with loan	**31.1**	**years**																			
Simple Payback Period before incentives & with loan	**32.3**	**years**																			

Net Present Value 10Y	**-$526,889**	**-$378,203**
IRR 10Y	**-17.2%**	**#NUM!**
Net Present Value 25Y	**-$231,052**	**-$361,581**
IRR	**0.9%**	**-5.4%**

Rooftop Solar Concentrated PV @ NRDC or @ neighbor 2017	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2039	2040	2047	2048	TOTAL 25Y	TOTAL 10Y
					1	2	3	4	5	6	7	8	9	10	23	24	31	32		
Total Installed Cost	**$0**	**$0**	**$0**	**$0**	**-$1,563,827**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1,563,827**	**-$1,563,827**
Installed Cost					-$1,563,827														-$1,563,827	-$1,563,827
Equipment Cost					$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0			$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$75,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$75,000**	**$75,000**
Rebate																			$0	$0
Incentives					$75,000														$75,000	$75,000
Savings	**$0**	**$0**	**$0**	**$0**	**$44,569**	**$45,906**	**$47,283**	**$48,702**	**$50,163**	**$51,668**	**$53,218**	**$54,814**	**$56,458**	**$58,152**	**$85,399**	**$87,960**	**$108,180**	**$111,426**	**$1,624,947**	**$510,932**
Energy impact in kWh equivalent					186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	4,669,675	1,867,870
Cost ($)					$44,569	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$85,399	$87,960	$108,180	$111,426	$1,624,947	$510,932
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**-$1,444,258**	**$45,906**	**$47,283**	**$48,702**	**$50,163**	**$51,668**	**$53,218**	**$54,814**	**$56,458**	**$58,152**	**$85,399**	**$87,960**	**$108,180**	**$111,426**	**$136,120**	**-$977,895**
Cumulative Cashflows					*-$1,444,258*	*-$1,398,352*	*-$1,351,069*	*-$1,302,368*	*-$1,252,205*	*-$1,200,538*	*-$1,147,320*	*-$1,092,506*	*-$1,036,048*	*-$977,895*	*-$42,440*	*$45,521*	*$739,735*	*$851,160*		
Loan & Loan Service	**$0**	**$0**	**$0**	**$0**	**$1,019,268**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**-$97,352**	**$0**	**$0**	**$0**	**$0**	**-$830,421**	**$143,100**
Loan amount					**$1,116,620**														1,116,620	1,116,620
Principal repayment					-$30,355	-$32,176	-$34,107	-$36,153	-$38,322	-$40,622	-$43,059	-$45,642	-$48,381	-$51,284					-$1,116,620	-$400,101
Interest payment					-$66,997	-$65,176	-$63,245	-$61,199	-$59,030	-$56,730	-$54,293	-$51,710	-$48,971	-$46,068					-$830,421	-$573,420
Total Cashflows including loan	**$0**	**$0**	**$0**	**$0**	**-$424,990**	**-$51,446**	**-$50,069**	**-$48,650**	**-$47,189**	**-$45,685**	**-$44,135**	**-$42,538**	**-$40,894**	**-$39,200**	**$85,399**	**$87,960**	**$108,180**	**$111,426**	**-$694,301**	**-$834,795**
Cumulative Cashflows					*-$424,990*	*-$476,436*	*-$526,505*	*-$575,156*	*-$622,345*	*-$668,030*	*-$712,164*	*-$754,702*	*-$795,596*	*-$834,795*	*-$872,860*	*-$784,900*	*-$90,686*	*$20,739*		

Simple Payback Period after incentives	**23.5**	**years**
Simple Payback Period before incentives	**24.3**	**years**
Simple Payback Period after incentives & with loan	**31.8**	**years**
Simple Payback Period before incentives & with loan	**32.5**	**years**

Net Present Value 10Y	**-$1,021,093**	**-$737,032**
IRR 10Y	**-17.7%**	**#NUM!**
Net Present Value 25Y	**-$475,167**	**-$724,540**
IRR 25Y	**0.7%**	**-6.0%**

Rooftop Solar Concentrated PV @ NRDC or @ neighbor 2017	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2052	2053	2058	2059	TOTAL 25Y	TOTAL 10Y
					1	2	3	4	5	6	7	8	9	10	36	37	42	43		
Total Installed Cost	$0	$0	$0	$0	-$1,563,827	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$1,563,827	-$1,563,827
Installed Cost					-$1,563,827														-$1,563,827	-$1,563,827
Equipment Cost					$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0	$0
Rebates & Incentives	$0	$0	$0	$0	$75,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$75,000	$75,000
Rebate																			$0	$0
Incentives					$75,000														$75,000	$75,000
Savings	$0	$0	$0	$0	$44,569	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$125,411	$129,173	$149,747	$154,239	$1,624,947	$510,932
Energy impact in kWh equivalent					186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	186,787	4,669,675	1,867,870
Cost ($)					$44,569	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$125,411	$129,173	$149,747	$154,239	$1,624,947	$510,932
Lease Option (4,632 sq. feet neighboring roof)					-$55,584	-$55,584	-$55,584	-$55,584	-$55,584	-$55,584	-$55,584	-$55,584	-$55,584	-$55,584					-$1,389,600	-$555,840
Total Cashflows	$0	$0	$0	$0	-$1,499,842	-$9,678	-$8,301	-$6,882	-$5,421	-$3,916	-$2,366	-$770	$874	$2,568	$125,411	$129,173	$149,747	$154,239	$136,120	-$977,895
Cumulative Cashflows					*-$1,499,842*	*-$1,509,520*	*-$1,517,821*	*-$1,524,704*	*-$1,530,125*	*-$1,534,042*	*-$1,536,408*	*-$1,537,178*	*-$1,536,304*	*-$1,533,735*	*-$58,291*	*$70,882*	*$777,252*	*$931,491*		
Loan & Loan Service	$0	$0	$0	$0	$1,019,268	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	$0	$0	$0	$0	-$830,421	$143,100
Loan amount					$1,116,620														1,116,620	1,116,620
Principal repayment					-$30,355	-$32,176	-$34,107	-$36,153	-$38,322	-$40,622	-$43,059	-$45,642	-$48,381	-$51,284					-$1,116,620	-$400,101
Interest payment					-$66,997	-$65,176	-$63,245	-$61,199	-$59,030	-$56,730	-$54,293	-$51,710	-$48,971	-$46,068					-$830,421	-$573,420
Total Cashflows including loan	$0	$0	$0	$0	-$480,574	-$107,030	-$105,653	-$104,234	-$102,773	-$101,269	-$99,719	-$98,122	-$96,478	-$94,784	$125,411	$129,173	$149,747	$154,239	-$694,301	-$834,795
Cumulative Cashflows					*-$480,574*	*-$587,604*	*-$693,257*	*-$797,492*	*-$900,265*	*-$1,001,534*	*-$1,101,252*	*-$1,199,374*	*-$1,295,852*	*-$1,390,635*	*-$888,712*	*-$759,539*	*-$53,169*	*$101,071*		

Simple Payback Period after incentives	36.5	years
Simple Payback Period before incentives	37.0	years
Simple Payback Period after incentives & with loan	42.3	years
Simple Payback Period before incentives & with loan	42.8	years

Net Present Value 10Y	$19,780
IRR 10Y	#NUM!
Net Present Value 25Y	$80,295
IRR 25Y	-8.3%

Rooftop Vertical PV Solar Panels (VPV) 2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL 25Y	TOTAL 10Y
									1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$94,977**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$94,977**	**-$94,977**
Equipment Cost																			$0	$0
Installation Cost																			$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$75,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$75,000**	**$75,000**
Rebate																			$0	$0
Incentives									$75,000										$75,000	$75,000
Savings	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$17,375**	**$17,896**	**$18,433**	**$18,986**	**$19,556**	**$20,142**	**$20,747**	**$21,369**	**$22,010**	**$22,671**	**$633,483**	**$199,186**
Energy impact in kWh equivalent									64,698	64,698	64,698	64,698	64,698	64,698	64,698	64,698	64,698	64,698	1,617,458	646,983
Cost ($)									$17,375	$17,896	$18,433	$18,986	$19,556	$20,142	$20,747	$21,369	$22,010	$22,671	$633,483	$199,186
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$2,602**	**$17,896**	**$18,433**	**$18,986**	**$19,556**	**$20,142**	**$20,747**	**$21,369**	**$22,010**	**$22,671**	**$613,506**	**$179,209**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*-$2,602*	*$15,295*	*$33,728*	*$52,714*	*$72,270*	*$92,412*	*$113,159*	*$134,528*	*$156,539*	*$179,209*		

Simple Payback Period after incentives	**1.15**	**years**
Simple Payback Period before incentives	**5.14**	**years**

Net Present Value 10Y	**$140,813**
IRR 10Y	**690.9%**
Net Present Value 25Y	**$353,641**
IRR	**690.9%**

Smart Metering System (Floors 6-7)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	TOTAL 25Y	TOTAL 10Y
2018						1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**-$15,600**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$15,600**	**-$15,600**
Equipment Cost																$0	$0
Installation Cost																$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebate																$0	$0
Incentives																$0	$0
Savings	**$0**	**$0**	**$0**	**$0**	**$0**	**$7,882**	**$8,118**	**$8,362**	**$8,613**	**$8,871**	**$9,137**	**$9,411**	**$9,694**	**$9,984**	**$10,284**	**$287,361**	**$90,355**
Energy impact in kWh equivalent						32,070	32,070	32,070	32,070	32,070	32,070	32,070	32,070	32,070	32,070	801,749	320,700
Cost ($)						$7,882	$8,118	$8,362	$8,613	$8,871	$9,137	$9,411	$9,694	$9,984	$10,284	$287,361	$90,355
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**$0**	**-$7,718**	**$8,118**	**$8,362**	**$8,613**	**$8,871**	**$9,137**	**$9,411**	**$9,694**	**$9,984**	**$10,284**	**$271,761**	**$74,755**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*$0*	*-$7,718*	*$400*	*$8,762*	*$17,374*	*$26,245*	*$35,382*	*$44,793*	*$54,487*	*$64,471*	*$74,755*		

Simple Payback Period after incentives	**1.95**	**years**
Simple Payback Period before incentives	**1.95**	**years**
Net Present Value 10Y	**$57,589**	
IRR 10Y	**108.0%**	
Net Present Value 25Y	**$154,133**	
IRR	**108.2%**	

Smart Metering System (Floors 8-12) Cashflow Analysis

Smart Metering System (Floors 8-12) 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$39,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$39,000**	**-$39,000**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$26,533**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$26,533**	**$26,533**
Rebate											$0	$0
Incentives	$26,533										$26,533	$26,533
Savings	**$7,401**	**$7,623**	**$7,852**	**$8,088**	**$8,330**	**$8,580**	**$8,837**	**$9,103**	**$9,376**	**$9,657**	**$269,844**	**$84,847**
Energy impact in kWh equivalent	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912	34,912	872,788	349,115
Cost ($)	$7,401	$7,623	$7,852	$8,088	$8,330	$8,580	$8,837	$9,103	$9,376	$9,657	$269,844	$84,847
Total Cashflows	**-$5,065**	**$7,623**	**$7,852**	**$8,088**	**$8,330**	**$8,580**	**$8,837**	**$9,103**	**$9,376**	**$9,657**	**$257,377**	**$72,380**
Cumulative Cashflows	*-$5,065*	*$2,558*	*$10,410*	*$18,497*	*$26,828*	*$35,408*	*$44,245*	*$53,348*	*$62,723*	*$72,380*		

Simple Payback Period after incentives	**1.66**	**years**
Simple Payback Period before incentives	**4.96**	**years**

Net Present Value 10Y	**$56,177**
IRR 10Y	**153.5%**
Net Present Value 25Y	**$146,835**
IRR	**153.5%**

VFDs on Blower Fans	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
2013	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$25,860**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$25,860**	**-$25,860**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$8,400**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$8,400**	**$8,400**
Rebate											$0	$0
Incentives	$8,400										$8,400	$8,400
Savings	**$13,162**	**$13,557**	**$13,963**	**$14,382**	**$14,814**	**$15,258**	**$15,716**	**$16,187**	**$16,673**	**$17,173**	**$479,870**	**$150,885**
Energy impact in kWh equivalent	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084	62,084	1,552,100	620,840
Cost ($)	$13,162	$13,557	$13,963	$14,382	$14,814	$15,258	$15,716	$16,187	$16,673	$17,173	$479,870	$150,885
Total Cashflows	**-$4,298**	**$13,557**	**$13,963**	**$14,382**	**$14,814**	**$15,258**	**$15,716**	**$16,187**	**$16,673**	**$17,173**	**$462,410**	**$133,425**
Cumulative Cashflows	*-$4,298*	*$9,258*	*$23,222*	*$37,604*	*$52,418*	*$67,676*	*$83,392*	*$99,579*	*$116,252*	*$133,425*		

Simple Payback Period after incentives	**1.32**	**years**
Simple Payback Period before incentives	**1.94**	**years**
Net Present Value 10Y	**$104,429**	
IRR 10Y	**318.4%**	
Net Present Value 25Y	**$265,649**	
IRR	**318.4%**	

$9,900

VFDs on Condensor Pump 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$3,890**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$3,890**	**-$3,890**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$1,500**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,500**	**$1,500**
Rebate											$0	$0
Incentives	$1,500										$1,500	$1,500
Savings	**$1,065**	**$1,097**	**$1,130**	**$1,164**	**$1,199**	**$1,235**	**$1,272**	**$1,310**	**$1,349**	**$1,390**	**$38,832**	**$12,210**
Energy impact in kWh equivalent	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024	5,024	125,600	50,240
Cost ($)	$1,065	$1,097	$1,130	$1,164	$1,199	$1,235	$1,272	$1,310	$1,349	$1,390	$38,832	$12,210
Total Cashflows	**-$1,325**	**$1,097**	**$1,130**	**$1,164**	**$1,199**	**$1,235**	**$1,272**	**$1,310**	**$1,349**	**$1,390**	**$36,442**	**$9,820**
Cumulative Cashflows	*-$1,325*	*-$228*	*$902*	*$2,066*	*$3,265*	*$4,499*	*$5,771*	*$7,081*	*$8,430*	*$9,820*		

Simple Payback Period after incentives	**2.20**	**years**
Simple Payback Period before incentives	**3.51**	**years**

Net Present Value 10Y	**$7,511**
IRR 10Y	**85.4%**
Net Present Value 25Y	**$20,558**
IRR 25Y	**85.8%**

Energy Recovery Ventilator (ERV) 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$20,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$20,000**	**-$20,000**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebate											$0	$0
Incentives											$0	$0
Savings	**$13,445**	**$13,848**	**$14,264**	**$14,692**	**$15,132**	**$15,586**	**$16,054**	**$16,536**	**$17,032**	**$17,543**	**$490,193**	**$154,131**
Energy impact in kWh equivalent	63,420	63,420	63,420	63,420	63,420	63,420	63,420	63,420	63,420	63,420	1,585,491	634,196
Cost ($)	$13,445	$13,848	$14,264	$14,692	$15,132	$15,586	$16,054	$16,536	$17,032	$17,543	$490,193	$154,131
Total Cashflows	**-$6,555**	**$13,848**	**$14,264**	**$14,692**	**$15,132**	**$15,586**	**$16,054**	**$16,536**	**$17,032**	**$17,543**	**$470,193**	**$134,131**
Cumulative Cashflows	*-$6,555*	*$7,293*	*$21,557*	*$36,249*	*$51,381*	*$66,968*	*$83,022*	*$99,557*	*$116,589*	*$134,131*		

Simple Payback Period after incentives	**1.47**	**years**
Simple Payback Period before incentives	**1.47**	**years**

Net Present Value 10Y	**$104,595**
IRR 10Y	**214.3%**
Net Present Value 25Y	**$269,283**
IRR 25Y	**214.3%**

Air Sealing 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$25,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$25,000**	**-$25,000**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$6,862**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$6,862**	**$6,862**
Rebate	$6,862										$6,862	$6,862
Incentives											$0	$0
Savings	**$12,123**	**$12,487**	**$12,861**	**$13,247**	**$13,645**	**$14,054**	**$14,475**	**$14,910**	**$15,357**	**$15,818**	**$441,995**	**$138,976**
Energy impact in kWh equivalent	57,184	57,184	57,184	57,184	57,184	57,184	57,184	57,184	57,184	57,184	1,429,596	571,838
Cost ($)	$12,123	$12,487	$12,861	$13,247	$13,645	$14,054	$14,475	$14,910	$15,357	$15,818	$441,995	$138,976
Total Cashflows	**-$6,015**	**$12,487**	**$12,861**	**$13,247**	**$13,645**	**$14,054**	**$14,475**	**$14,910**	**$15,357**	**$15,818**	**$423,857**	**$120,838**
Cumulative Cashflows	*-$6,015*	*$6,472*	*$19,333*	*$32,580*	*$46,225*	*$60,278*	*$74,754*	*$89,664*	*$105,021*	*$120,838*		

Simple Payback Period after incer	**1.48**	**years**
Simple Payback Period before inc	**2.03**	**years**

Net Present Value 10Y	**$94,210**
IRR 10Y	**210.6%**
Net Present Value 25Y	**$242,705**
IRR 25Y	**210.6%**

Phase Change Material (PCM) Cashflow Analysis

Phase Change Material (PCM) 2014	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL 25Y	TOTAL 10Y
		1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	$0	-$232,740	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$232,740	-$232,740
Equipment Cost												$0	$0
Installation Cost												$0	$0
Rebates & Incentives	$0	$117,344	$0	$0	$0	$0	$0	$0	$0	$0	$0	$117,344	$117,344
Rebate												$0	$0
Incentives		$117,344										$117,344	$117,344
Savings	$0	$33,714	$34,725	$35,767	$36,840	$37,945	$39,084	$40,256	$41,464	$42,708	$43,989	$1,229,187	$342,504
Energy impact in kWh equivalent		154,396	154,396	154,396	154,396	154,396	154,396	154,396	154,396	154,396	154,396	3,859,909	1,389,567
Cost ($)		$33,714	$34,725	$35,767	$36,840	$37,945	$39,084	$40,256	$41,464	$42,708	$43,989	$1,229,187	$342,504
Total Cashflows	**$0**	**-$81,682**	**$34,725**	**$35,767**	**$36,840**	**$37,945**	**$39,084**	**$40,256**	**$41,464**	**$42,708**	**$43,989**	**$1,113,792**	**$227,108**
Cumulative Cashflows	*$0*	*-$81,682*	*-$46,956*	*-$11,189*	*$25,651*	*$63,596*	*$102,680*	*$142,936*	*$184,400*	*$227,108*	*$271,097*		

Simple Payback Period after incentives	**3.30**	**years**
Simple Payback Period before incentives	**6.36**	**years**

Net Present Value 10Y	**$199,543**
IRR 10Y	**43.3%**
Net Present Value 25Y	**$612,507**
IRR 25Y	**45.5%**

Exterior Insulated Panels (EIFS) 2015	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2035	2036	2037	TOTAL 25Y	TOTAL 10Y
			1	2	3	4	5	6	7	8	9	10	21	22	23		
Total Installed Cost	$0	$0	-$529,710	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$529,710	-$529,710
Equipment Cost																$0	$0
Installation Cost																$0	$0
Rebates & Incentives	$0	$0	$54,761	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$54,761	$54,761
Rebate																$0	$0
Incentives			$54,761													$54,761	$54,761
Savings	$0	$0	$16,205	$16,691	$17,192	$17,708	$18,239	$18,786	$19,350	$19,930	$20,528	$21,144	$29,268	$30,146	$31,051	$590,829	$185,774
Energy impact in kWh equivalent			72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	72,052	1,801,291	720,516
Cost ($)			$16,205	$16,691	$17,192	$17,708	$18,239	$18,786	$19,350	$19,930	$20,528	$21,144	$29,268	$30,146	$31,051	$590,829	$185,774
Total Cashflows	**$0**	**$0**	**-$458,744**	**$16,691**	**$17,192**	**$17,708**	**$18,239**	**$18,786**	**$19,350**	**$19,930**	**$20,528**	**$21,144**	**$29,268**	**$30,146**	**$31,051**	**$115,880**	**-$289,175**
Cumulative Cashflows	*$0*	*$0*	*-$458,744*	*-$442,053*	*-$424,861*	*-$407,153*	*-$388,914*	*-$370,128*	*-$350,778*	*-$330,847*	*-$310,319*	*-$289,175*	*-$10,241*	*$19,905*	*$50,956*		

Simple Payback Period after incentives	**21.34**	**years**
Simple Payback Period before incentives	**23.12**	**years**

Net Present Value 10Y	**-$307,435**
IRR 10Y	**-15.9%**
Net Present Value 25Y	**-$108,937**
IRR 25Y	**1.7%**

Geo-Exchange System (Geothermal)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2038	2039	2040	TOTAL 25Y	TOTAL 10Y
2015			1	2	3	4	5	6	7	8	9	10	24	25	26		
Total Installed Cost	**$0**	**$0**	**-$1,570,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1,570,000**	**-$1,570,000**
Equipment Cost																$0	$0
Installation Cost																$0	$0
Rebates & Incentives	**$0**	**$0**	**$9,435**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$9,435**	**$9,435**
Rebate																$0	$0
Incentives			$9,435													$9,435	$9,435
Savings	**$0**	**$0**	**$43,017**	**$44,308**	**$45,637**	**$47,006**	**$48,416**	**$49,869**	**$51,365**	**$52,906**	**$54,493**	**$56,128**	**$84,898**	**$87,445**	**$90,069**	**$1,568,377**	**$493,144**
Energy impact in kWh equivalent			191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	191,264	4,781,589	1,912,636
Cost ($)			$43,017	$44,308	$45,637	$47,006	$48,416	$49,869	$51,365	$52,906	$54,493	$56,128	$84,898	$87,445	$90,069	$1,568,377	$493,144
Total Cashflows	**$0**	**$0**	**-$1,517,548**	**$44,308**	**$45,637**	**$47,006**	**$48,416**	**$49,869**	**$51,365**	**$52,906**	**$54,493**	**$56,128**	**$84,898**	**$87,445**	**$90,069**	**$7,812**	**-$1,067,421**
Cumulative Cashflows	*$0*	*$0*	*-$1,517,548*	*-$1,473,240*	*-$1,427,603*	*-$1,380,597*	*-$1,332,181*	*-$1,282,312*	*-$1,230,947*	*-$1,178,041*	*-$1,123,548*	*-$1,067,421*	*-$79,633*	*$7,812*	*$97,880*		

Simple Payback Period after incentives	**24.91**	**years**
Simple Payback Period before incentives	**25.02**	**years**
Net Present Value 10Y	**-$1,104,362**	
IRR 10Y	**-18.7%**	
Net Present Value 25Y	**-$577,442**	
IRR 25Y	**0.0%**	

DC Microgrid P1 - Lighting & VFDs 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2042	2043	2044	2045	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10	30	31	32	33		
Total Installed Cost	-$117,875	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$117,875	-$117,875
Equipment Cost															$0	$0
Installation Cost															$0	$0
Rebates & Incentives	$7,899	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,899	$7,899
Rebate															$0	$0
Incentives	$7,899														$7,899	$7,899
Savings	$2,203	$2,269	$2,337	$2,408	$2,480	$2,554	$2,631	$2,710	$2,791	$2,875	$5,192	$5,348	$5,508	$5,674	$80,331	$25,259
Energy impact in kWh equivalent	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	10,393	259,825	103,930
Cost ($)	$2,203	$2,269	$2,337	$2,408	$2,480	$2,554	$2,631	$2,710	$2,791	$2,875	$5,192	$5,348	$5,508	$5,674	$80,331	$25,259
Total Cashflows	**-$107,773**	**$2,269**	**$2,337**	**$2,408**	**$2,480**	**$2,554**	**$2,631**	**$2,710**	**$2,791**	**$2,875**	**$5,192**	**$5,348**	**$5,508**	**$5,674**	**-$29,645**	**-$84,718**
Cumulative Cashflows	*-$107,773*	*-$105,503*	*-$103,166*	*-$100,758*	*-$98,278*	*-$95,724*	*-$93,093*	*-$90,383*	*-$87,592*	*-$84,718*	*-$5,152*	*$196*	*$5,704*	*$11,378*		

Simple Payback Period after incentives	**30.96**	**years**
Simple Payback Period before incentives	**32.39**	**years**

Net Present Value 10Y	**-$85,454**
IRR 10Y	**-22.7%**
Net Present Value 25Y	**-$58,466**
IRR	**-2.2%**

DC Microgrid P2 - Solar & Workspace 2017	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	TOTAL 25Y	TOTAL 10Y
					1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**$0**	**$0**	**$0**	**$0**	**-$30,125**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$30,125**	**-$30,125**
Equipment Cost															$0	$0
Installation Cost															$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$13,772**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$13,772**	**$13,772**
Rebate															$0	$0
Incentives					$13,772										$13,772	$13,772
Savings	**$0**	**$0**	**$0**	**$0**	**$4,324**	**$4,453**	**$4,587**	**$4,724**	**$4,866**	**$5,012**	**$5,163**	**$5,317**	**$5,477**	**$5,641**	**$157,634**	**$49,565**
Energy impact in kWh equivalent					18,120	18,120	18,120	18,120	18,120	18,120	18,120	18,120	18,120	18,120	453,000	181,200
Cost ($)					$4,324	$4,453	$4,587	$4,724	$4,866	$5,012	$5,163	$5,317	$5,477	$5,641	$157,634	$49,565
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**-$12,030**	**$4,453**	**$4,587**	**$4,724**	**$4,866**	**$5,012**	**$5,163**	**$5,317**	**$5,477**	**$5,641**	**$141,281**	**$33,211**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*-$12,030*	*-$7,577*	*-$2,990*	*$1,735*	*$6,601*	*$11,613*	*$16,776*	*$22,093*	*$27,570*	*$33,211*		

Simple Payback Period after incentives	**3.63**	**years**
Simple Payback Period before incentives	**6.42**	**years**

Net Present Value 10Y	**$24,095**
IRR 10Y	**37.2%**
Net Present Value 25Y	**$77,055**
IRR 25Y	**40.0%**

Energy-aligned leases 2018	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	TOTAL 25Y	TOTAL 10Y
						1	2	3	4	5	6	7	8	9	10	25	
Total Installed Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1**	**-$1**
Equipment Cost																$0	$0
Installation Cost																$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebate																$0	$0
Incentives																$0	$0
Savings	**$0**	**$0**	**$0**	**$0**	**$0**	**$18,621**	**$19,179**	**$19,755**	**$20,347**	**$20,958**	**$21,587**	**$22,234**	**$22,901**	**$23,588**	**$24,296**	**$678,902**	**$213,467**
Energy impact in kWh equivalent						75,766	75,766	75,766	75,766	75,766	75,766	75,766	75,766	75,766	75,766	1,894,162	757,665
Cost ($)						$18,621	$19,179	$19,755	$20,347	$20,958	$21,587	$22,234	$22,901	$23,588	$24,296	$678,902	$213,467
Total Cashflows	**$0**	**$0**	**$0**	**$0**	**$0**	**$18,620**	**$19,179**	**$19,755**	**$20,347**	**$20,958**	**$21,587**	**$22,234**	**$22,901**	**$23,588**	**$24,296**	**$678,901**	**$213,466**
Cumulative Cashflows	*$0*	*$0*	*$0*	*$0*	*$0*	*$18,620*	*$37,799*	*$57,554*	*$77,902*	*$98,860*	*$120,446*	*$142,680*	*$165,582*	*$189,170*	*$213,466*		

Simple Payback Period after incentives	**Immediate Payback**
Simple Payback Period before incentives	**Immediate Payback**
Net Present Value 10Y	**$171,494**
IRR 10Y	**#NUM!**
Net Present Value 25Y	**$399,581**
IRR 25Y	**#NUM!**

AC Schedule Shift 2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL 25Y	TOTAL 10Y
	1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**-$1**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1**	**-$1**
Equipment Cost											$0	$0
Installation Cost											$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebate											$0	$0
Incentives											$0	$0
Savings	**$2,010**	**$2,070**	**$2,132**	**$2,196**	**$2,262**	**$2,330**	**$2,400**	**$2,472**	**$2,546**	**$2,622**	**$73,268**	**$23,038**
Energy impact in kWh equivalent	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479	9,479	236,980	94,792
Cost ($)	$2,010	$2,070	$2,132	$2,196	$2,262	$2,330	$2,400	$2,472	$2,546	$2,622	$73,268	$23,038
Total Cashflows	**$2,009**	**$2,070**	**$2,132**	**$2,196**	**$2,262**	**$2,330**	**$2,400**	**$2,472**	**$2,546**	**$2,622**	**$73,267**	**$23,037**
Cumulative Cashflows	*$2,009*	*$4,078*	*$6,210*	*$8,406*	*$10,668*	*$12,998*	*$15,397*	*$17,869*	*$20,415*	*$23,037*		

Simple Payback Period after incentives	**Immediate Payback**
Simple Payback Period before incentives	**Immediate Payback**

Net Present Value 10Y	**$18,507**
IRR 10Y	**#NUM!**
Net Present Value 25Y	**$43,123**
IRR 25Y	**#NUM!**

Biofuel in Existing Boiler 2015	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL 25Y	TOTAL 10Y
			1	2	3	4	5	6	7	8	9	10		
Total Installed Cost	**$0**	**$0**	**-$1**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**-$1**	**-$1**
Equipment Cost													$0	$0
Installation Cost													$0	$0
Rebates & Incentives	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebate													$0	$0
Incentives													$0	$0
Savings	**$0**	**$0**	**$2,024**	**$2,085**	**$2,148**	**$2,212**	**$2,279**	**$2,347**	**$2,417**	**$2,490**	**$2,564**	**$2,641**	**$73,809**	**$23,208**
Energy impact in kWh equivalent			9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	225,025	90,010
Cost ($)			$2,024	$2,085	$2,148	$2,212	$2,279	$2,347	$2,417	$2,490	$2,564	$2,641	$73,809	$23,208
Total Cashflows	**$0**	**$0**	**$2,023**	**$2,085**	**$2,148**	**$2,212**	**$2,279**	**$2,347**	**$2,417**	**$2,490**	**$2,564**	**$2,641**	**$73,808**	**$23,207**
Cumulative Cashflows	*$0*	*$0*	*$2,023*	*$4,109*	*$6,256*	*$8,468*	*$10,747*	*$13,094*	*$15,511*	*$18,001*	*$20,565*	*$23,207*		

Simple Payback Period after incentives	**Immediate Payback**
Simple Payback Period before incentives	**Immediate Payback**
Net Present Value 10Y	**$18,644**
IRR 10Y	**#NUM!**
Net Present Value 25Y	**$43,441**
IRR 25Y	**#NUM!**

9.21 Overall Cashflow Analysis

Please see following tables for all detailed analyses.

Financial Model Assumptions

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	1	2	3	4	5	6	7	8	9	10
Budget	$5,000,000									
Utility base rate ($ per kWh)	$0.212	$0.218	$0.225	$0.232	$0.239	$0.246	$0.253	$0.261	$0.269	$0.277
Escalation rate (%)		3%	3%	3%	3%	3%	3%	3%	3%	3%
Internal cost of capital (NPV/ IRR)	4%									
Lease of neighboring rooftop YES (1) NO (0)	0	Estimated lease 25Y 4,632 sq. feet:		$1,389,600	Annual lease	$55,584				

Technology Name	Installed Cost ($)	Energy Impact per annum in kWh eq.	Timing	Incentives/ Rebates	NYSERDA Incentive Programs
Advanced Lighting Controls	$713,728	51,335	2013	$0	No NYSERDA incentive
Rooftop Solar Concentrated PV @ NRDC	$854,297	101,220	2017	$75,000	NYSERDA PV Incentive Program // Possibly PV Expenditure Property Tax Credit
Rooftop Solar Concentrated PV @ NRDC or @ neighbor	$1,563,827	186,787	2017	$75,000	NYSERDA PV Incentive Program // Possibly PV Expenditure Property Tax Credit
Rooftop Vertical PV Solar Panels (VPV)	$94,977	64,698	2021	$75,000	NYSERDA PV Incentive Program // Possibly PV Expenditure Property Tax Credit
Smart Metering System (Floors 6-7)	$15,600	32,070	2018	$0	No NYSERDA incentive
Smart Metering System (Floors 8-12)	$39,000	34,912	2013	$26,533	NYSERDA New Construction Program Incentive
VFDs on Blower Fans	$25,860	62,084	2013	$8,400	NYSERDA Existing Facilities Incentive - Prequalified Measure "VFDs"
VFDs on Condensor Pump	$3,890	5,024	2013	$1,500	NYSERDA Existing Facilities Incentive - Prequalified Measure "VFDs"
Energy Recovery Ventilator (ERV)	$20,000	63,420	2013	$0	No NYSERDA incentive
Air Sealing	$25,000	57,184	2013	$6,862	Conedison Rebate - $0.12/kWh saved (first year) up to 70% of total cost
Phase Change Material (PCM)	$232,740	154,396	2014	$117,344	NYSERDA New Construction Program Incentive
Exterior Insulated Panels (EIFS)	$529,710	72,052	2015	$54,761	NYSERDA New Construction Program Incentive
3 Geo-Exchange Wells in Sidewalk (Geothermal)	$1,470,000	225,126	2015	$0	No NYSERDA incentive
Geo-Exchange - Large Heat Pump in Basement (Geothermal)	$0	-36,805	2015	$0	No NYSERDA incentive
Geo-Exchange Water Pump from 1,500 Below Surface (Geothermal)	$0	-9,472	2015	$0	No NYSERDA incentive
Geo-Exchange Water DX Unit 6&7 (Geothermal)	$100,000	12,414	2015	$9,435	NYSERDA New Construction Program Incentive
DC Microgrid P1 - Lighting & VFDs	$117,875	10,393	2013	$7,899	NYSERDA New Construction Program Incentive
DC Microgrid P2 - Solar & Workspace	$30,125	18,120	2017	$13,772	NYSERDA New Construction Program Incentive
Energy-aligned leases	$1	75,766	2018	$0	No NYSERDA incentive
AC Schedule Shift	$1	9,479	2013	$0	No NYSERDA incentive
Biofuel in Existing Boiler	$1	9,001	2015	$0	No NYSERDA incentive
TOTAL		**$5,836,631**	**1,199,205**		**$471,506**

Maximizing NYSERDA New Construction Portfolio (Max $1.575 mn): **$0.76 kWh**

Testing portfolios of combined technologies:	Cost Portfolio Tech ($)	Energy Impact Portfolio (kWh)	Potential NYSERDA Incentive ($)	% Cost Covered (50-75%)
Smart Metering System (Floors 8-12), Phase Change Materials, EIFS, Geo-Exchange DX Unit, DC Microgrids P1 & P2	$1,049,450	302,287 kWh	$229,744	22%
Advanced Lighting Controls, Phase Change Material, EIFS	$1,506,303	295,903 kWh	$224,892	15%
Geo-Exchange System (Entire System)	$1,570,000	191,264 kWh	$145,364	9%

Split $0.76 kWh incentive per technology (Max incentive 75% of incremental cost)	Cost Portfolio Tech ($)	Energy Impact Portfolio (kWh)	Potential NYSERDA Incentive ($)	% Cost Covered (50-75%)
Advanced Lighting Controls	$713,728	51,335 kWh	$39,016	5%
Smart Metering System (Floors 6-7)	$15,600	32,070 kWh	$24,374	156%
Smart Metering System (Floors 8-12)	$39,000	34,912 kWh	$26,533	68%
Energy Recovery Ventilator (ERV)	$20,000	63,420 kWh	$48,200	241%
Phase Change Material (PCM)	$232,740	154,396 kWh	$117,344	50%
Exterior Insulated Panels (EIFS)	$529,710	72,052 kWh	$54,761	10%
Geo-Exchange (Entire System excl. Water DX Unit 6 & 7)	$1,470,000	178,850 kWh	$135,929	9%
Geo-Exchange Water DX Unit 6&7 (Geothermal)	$100,000	12,414 kWh	$9,435	9%
DC Microgrid P1 - Lighting & VFDs	$117,875	10,393 kWh	$7,899	7%
DC Microgrid P2 - Solar & Workspace	$30,125	18,120 kWh	$13,772	46%

NYSERDA New Construction Program Case Studies 2011-2012

Max Incentive of $1.575 million for Con Edison customers	AVERAGE	NRDC	Hage & Hage, LLC	St. Johns University	Rensselaer Polytechnic Institute	Paul Smiths College Residence Hall	Hudson Valley Community College	Union Graduate College	Ithaca MaineSource	Empire Merchants Headquarters & Distribution Center	Gourmet Guru
50-75% of incremental costs, depending on type of project		**2012 (Office)**	**2010 (Office)**	**2012 (University)**	**2012 (University)**	**2012 (University)**	**2012 (University)**	**2011 (University)**	**2011 (Retail)**	**2011 (Retail)**	**2011 (Retail)**
Annual energy savings (kWh)		36,797	60,158	1,092,274	1,158,983	87,272	251,698	172,093	231,830	1,036,698	241,181
Annual energy cost savings ($)		$8,228	$16,886	$244,639	$221,778	$15,034	$47,600	$17,928	$40,657	$193,719	$43,510
NYSERDA incentive ($)		$36,875	$54,058	$482,661	$404,491	$77,171	$616,636	$83,292	$46,925	$310,712	$141,888
NYSERDA incentive ($/kWh)	**$0.76**	**$1.00**	**$0.90**	**$0.44**	**$0.35**	**$0.88**	**$2.45**	**$0.48**	**$0.20**	**$0.30**	**$0.59**

Summary Table of Recommended Technologies

Technology Recommendations	Technology Cost ($)	Incentives/Rebates ($)	Net Technology Cost ($)	Savings per annum in kWh equivalent	Cumulated Savings 2013-2023 ($)	Simple Payback Period before incentives (years)	Simple Payback Period after incentives (years)	NPV 10Y	IRR 10Y	NPV 25Y	IRR 25Y
Advanced Lighting Controls	$713,728	$0	$713,728	51,335	$124,762	36.8	36.8	-586,046	-26%	-452,739	-4%
Rooftop Solar Concentrated PV @ NRDC	$854,297	$75,000	$779,297	101,220	$276,874	24.5	22.9	-526,889	-17%	-231,052	1%
Rooftop Solar Concentrated PV @ NRDC or @ neighbor	$1,563,827	$75,000	$1,488,827	186,787	$510,932	24.3	23.5	-1,021,093	-18%	-737,032	na
Rooftop Vertical PV Solar Panels (VPV)	$94,977	$75,000	$19,977	64,698	$199,186	5.1	1.1	140,813	691%	353,641	691%
Smart Metering System (Floors 6-7)	$15,600	$0	$15,600	32,070	$90,355	2.0	2.0	57,589	108%	154,133	108%
Smart Metering System (Floors 8-12)	$39,000	$26,533	$12,467	34,912	$84,847	5.0	1.7	56,177	153%	146,835	153%
VFDs on Blower Fans	$25,860	$8,400	$17,460	62,084	$150,885	1.9	1.3	104,429	318%	265,649	153%
VFDs on Condensor Pump	$3,890	$1,500	$2,390	5,024	$12,210	3.5	2.2	7,511	85%	20,558	86%
Energy Recovery Ventilator (ERV)	$20,000	$0	$20,000	63,420	$154,131	1.5	1.5	104,595	214%	269,283	214%
Air Sealing	$25,000	$6,862	$18,138	57,184	$138,976	2.0	1.5	94,210	211%	242,705	211%
Phase Change Material (PCM)	$232,740	$117,344	$115,396	154,396	$386,493	6.4	3.3	199,543	43%	612,507	46%
Exterior Insulated Panels (EIFS)	$529,710	$54,761	$474,949	72,052	$185,774	23.1	21.3	-307,435	-16%	-108,937	2%
Geo-Exchange System (Entire System)	$1,570,000	$9,435	$1,560,565	191,264	$493,144	25.0	24.9	-1,104,362	-19%	-577,442	0%
DC Microgrid P1 - Lighting & VFDs	$117,875	$7,899	$109,976	10,393	$25,259	32.4	31.0	-85,454	-23%	-58,466	-2%
DC Microgrid P2 - Solar & Workspace	$30,125	$13,772	$16,353	18,120	$49,565	6.4	3.6	24,095	37%	77,055	40%
Energy-aligned leases	$1	$0	$1	75,766	$213,467	Immediate Payback	Immediate Payback	171,494	na	399,581	na
AC Schedule Shift	$1	$0	$1	9,479	$23,038	Immediate Payback	Immediate Payback	18,507	na	43,123	na
Biofuel in Existing Boiler	$1	$0	$1	9,001	$23,208	Immediate Payback	Immediate Payback	18,644	na	43,441	na
TOTAL	**$5,836,631**	**$471,506**	**$5,365,125**	**$1,199,205**	**$3,143,107**	**18.9**	**18.0**				

Global Portfolio of Technologies	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Cashflows (Cost net of savings) before incentives	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Advanced Lighting Controls	-$702,844	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$14,626	$15,065	$15,517	$15,982	$16,462	$16,955	$17,464	$17,988	$18,528	$19,083	$19,656
Rooftop Solar Concentrated PV @ NRDC	$0	$0	$0	$0	-$830,145	$24,876	$25,623	$26,391	$27,183	$27,999	$28,839	$29,704	$30,595	$31,513	$32,458	$33,432	$34,435	$35,468	$36,532	$37,628	$38,757
Rooftop Solar Concentrated PV @ NRDC or @ neighbor	$0	$0	$0	$0	-$1,519,258	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$59,897	$61,694	$63,545	$65,451	$67,414	$69,437	$71,520
Rooftop Vertical PV Solar Panels (VPV)	$0	$0	$0	$0	$0	$0	$0	$0	-$2,602	$17,896	$18,433	$18,986	$19,556	$20,142	$20,747	$21,369	$22,010	$22,671	$23,351	$24,051	$24,773
Smart Metering System (Floors 6-7)	$0	$0	$0	$0	$0	-$7,718	$8,118	$8,362	$8,613	$8,871	$9,137	$9,411	$9,694	$9,984	$10,284	$10,592	$10,910	$11,237	$11,575	$11,922	$12,279
Smart Metering System (Floors 8-12)	-$31,599	$7,623	$7,852	$8,088	$8,330	$8,580	$8,837	$9,103	$9,376	$9,657	$9,947	$10,245	$10,552	$10,869	$11,195	$11,531	$11,877	$12,233	$12,600	$12,978	$13,367
VFDs on Blower Fans	-$12,698	$13,557	$13,963	$14,382	$14,814	$15,258	$15,716	$16,187	$16,673	$17,173	$17,688	$18,219	$18,766	$19,329	$19,908	$20,506	$21,121	$21,754	$22,407	$23,079	$23,772
VFDs on Condensor Pump	-$2,825	$1,097	$1,130	$1,164	$1,199	$1,235	$1,272	$1,310	$1,349	$1,390	$1,431	$1,474	$1,519	$1,564	$1,611	$1,659	$1,709	$1,760	$1,813	$1,868	$1,924
Energy Recovery Ventilator (ERV)	-$6,555	$13,848	$14,264	$14,692	$15,132	$15,586	$16,054	$16,536	$17,032	$17,543	$18,069	$18,611	$19,169	$19,744	$20,337	$20,947	$21,575	$22,222	$22,889	$23,576	$24,283
Air Sealing	-$12,877	$12,487	$12,861	$13,247	$13,645	$14,054	$14,475	$14,910	$15,357	$15,818	$16,292	$16,781	$17,284	$17,803	$18,337	$18,887	$19,454	$20,037	$20,639	$21,258	$21,895
Phase Change Material (PCM)	$0	-$199,026	$34,725	$35,767	$36,840	$37,945	$39,084	$40,256	$41,464	$42,708	$43,989	$45,309	$46,668	$48,068	$49,510	$50,995	$52,525	$54,101	$55,724	$57,396	$59,118
Exterior Insulated Panels (EIFS)	$0	$0	-$513,505	$16,691	$17,192	$17,708	$18,239	$18,786	$19,350	$19,930	$20,528	$21,144	$21,778	$22,432	$23,105	$23,798	$24,512	$25,247	$26,005	$26,785	$27,588
3 Geo-Exchange Wells in Sidewalk (Geothermal) Geo-Exchange - Large Heat Pump in Basement (Geothermal) Geo-Exchange Water Pump from 1,500 Below Surface (Geothermal) Geo-Exchange Water DX Unit 6&7 (Geothermal)	$0	$0	-$1,526,983	$44,308	$45,637	$47,006	$48,416	$49,869	$51,365	$52,906	$54,493	$56,128	$57,812	$59,546	$61,332	$63,172	$65,067	$67,019	$69,030	$71,101	$73,234
DC Microgrid P2 - Solar & Workspace	$0	$0	$0	$0	-$25,801	$4,453	$4,587	$4,724	$4,866	$5,012	$5,163	$5,317	$5,477	$5,641	$5,811	$5,985	$6,164	$6,349	$6,540	$6,736	$6,938
Energy-aligned leases	$0	$0	$0	$0	$0	$18,620	$19,179	$19,755	$20,347	$20,958	$21,587	$22,234	$22,901	$23,588	$24,296	$25,025	$25,776	$26,549	$27,345	$28,166	$29,011
AC Schedule Shift	$2,009	$2,070	$2,132	$2,196	$2,262	$2,330	$2,400	$2,472	$2,546	$2,622	$2,701	$2,782	$2,865	$2,951	$3,040	$3,131	$3,225	$3,322	$3,421	$3,524	$3,630
Biofuel in Existing Boiler	$0	$0	$2,023	$2,085	$2,148	$2,212	$2,279	$2,347	$2,417	$2,490	$2,564	$2,641	$2,721	$2,802	$2,886	$2,973	$3,062	$3,154	$3,249	$3,346	$3,446
Total Cashflows	**-$767,390**	**-$137,135**	**-$1,939,991**	**$164,512**	**-$2,205,757**	**$260,668**	**$284,557**	**$293,094**	**$299,285**	**$328,839**	**$338,705**	**$348,866**	**$359,332**	**$370,112**	**$381,215**	**$392,652**	**$404,431**	**$416,564**	**$429,061**	**$441,933**	**$455,191**
Cumulative Cashflows	*-$767,390*	*-$904,524*	*-$2,844,515*	*-$2,680,003*	*-$4,885,761*	*-$4,625,093*	*-$4,340,536*	*-$4,047,442*	*-$3,748,157*	*-$3,419,318*	*-$3,080,613*	*-$2,731,747*	*-$2,372,415*	*-$2,002,304*	*-$1,621,089*	*-$1,228,437*	*-$824,006*	*-$407,442*	*$21,619*	*$463,552*	*$918,742*
Simple Payback Period	**18.95**	**years**																			
$5mn budget evolution	**$4,232,610**	**$4,095,476**	**$2,155,485**	**$2,319,997**	**$114,239**	**$374,907**	**$659,464**	**$952,558**	**$1,251,843**	**$1,580,682**	**$1,919,387**	**$2,268,253**	**$2,627,585**	**$2,997,696**	**$3,378,911**	**$3,771,563**	**$4,175,994**	**$4,592,558**	**$5,021,619**	**$5,463,552**	**$5,918,742**
Loan Tech 2 cashflows	$0	$0	$0	$0	$533,516	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957
Loan Tech 3 cashflows	$0	$0	$0	$0	$1,019,268	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352
Total Cashflows with loan	**-$767,390**	**-$137,135**	**-$1,939,991**	**$164,512**	**-$652,973**	**$112,359**	**$136,248**	**$144,785**	**$150,976**	**$180,530**	**$190,396**	**$200,557**	**$211,023**	**$221,803**	**$232,906**	**$244,342**	**$256,122**	**$268,255**	**$280,752**	**$293,624**	**$306,882**
Cumulative Cashflows	*-$767,390*	*-$904,524*	*-$2,844,515*	*-$2,680,003*	*-$3,332,977*	*-$3,220,618*	*-$3,084,370*	*-$2,939,585*	*-$2,788,609*	*-$2,608,079*	*-$2,417,683*	*-$2,217,126*	*-$2,006,104*	*-$1,784,301*	*-$1,551,395*	*-$1,307,053*	*-$1,050,931*	*-$782,676*	*-$501,924*	*-$208,300*	*$98,582*
Simple Payback Period	**20.68**	**years**																			
$5mn budget evolution	**$4,232,610**	**$4,095,476**	**$2,155,485**	**$2,319,997**	**$1,667,023**	**$1,779,382**	**$1,915,630**	**$2,060,415**	**$2,211,391**	**$2,391,921**	**$2,582,317**	**$2,782,874**	**$2,993,896**	**$3,215,699**	**$3,448,605**	**$3,692,947**	**$3,949,069**	**$4,217,324**	**$4,498,076**	**$4,791,700**	**$5,098,582**

Net Present Value 10Y	**-$435,326**
IRR 10Y	**-23.2%**

Net Present Value 25Y	**-$435,326**
IRR	**3.8%**

Net Present Value 25Y	**-$435,326**
IRR	**4.6%**

Global Portfolio of Technologies	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Cashflows (Cost net of savings) after incentives	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Advanced Lighting Controls	-$702,844	$11,210	$11,546	$11,892	$12,249	$12,616	$12,995	$13,385	$13,786	$14,200	$14,626	$15,065	$15,517	$15,982	$16,462	$16,955	$17,464	$17,988	$18,528	$19,083
Rooftop Solar Concentrated PV @ NRDC	$0	$0	$0	$0	-$755,145	$24,876	$25,623	$26,391	$27,183	$27,999	$28,839	$29,704	$30,595	$31,513	$32,458	$33,432	$34,435	$35,468	$36,532	$37,628
Rooftop Solar Concentrated PV @ NRDC or @ neighbor	$0	$0	$0	$0	-$1,444,258	$45,906	$47,283	$48,702	$50,163	$51,668	$53,218	$54,814	$56,458	$58,152	$59,897	$61,694	$63,545	$65,451	$67,414	$69,437
Rooftop Vertical PV Solar Panels (VPV)	$0	$0	$0	$0	$0	$0	$0	$0	-$2,602	$17,896	$18,433	$18,986	$19,556	$20,142	$20,747	$21,369	$22,010	$22,671	$23,351	$24,051
Smart Metering System (Floors 6-7)	$0	$0	$0	$0	$0	-$7,718	$8,118	$8,362	$8,613	$8,871	$9,137	$9,411	$9,694	$9,984	$10,284	$10,592	$10,910	$11,237	$11,575	$11,922
Smart Metering System (Floors 8-12)	-$5,065	$7,623	$7,852	$8,088	$8,330	$8,580	$8,837	$9,103	$9,376	$9,657	$9,947	$10,245	$10,552	$10,869	$11,195	$11,531	$11,877	$12,233	$12,600	$12,978
VFDs on Blower Fans	-$4,298	$13,557	$13,963	$14,382	$14,814	$15,258	$15,716	$16,187	$16,673	$17,173	$17,688	$18,219	$18,766	$19,329	$19,908	$20,506	$21,121	$21,754	$22,407	$23,079
VFDs on Condensor Pump	-$1,325	$1,097	$1,130	$1,164	$1,199	$1,235	$1,272	$1,310	$1,349	$1,390	$1,431	$1,474	$1,519	$1,564	$1,611	$1,659	$1,709	$1,760	$1,813	$1,868
Energy Recovery Ventilator (ERV)	-$6,555	$13,848	$14,264	$14,692	$15,132	$15,586	$16,054	$16,536	$17,032	$17,543	$18,069	$18,611	$19,169	$19,744	$20,337	$20,947	$21,575	$22,222	$22,889	$23,576
Air Sealing	-$6,015	$12,487	$12,861	$13,247	$13,645	$14,054	$14,475	$14,910	$15,357	$15,818	$16,292	$16,781	$17,284	$17,803	$18,337	$18,887	$19,454	$20,037	$20,639	$21,258
Phase Change Material (PCM)	$0	-$81,682	$34,725	$35,767	$36,840	$37,945	$39,084	$40,256	$41,464	$42,708	$43,989	$45,309	$46,668	$48,068	$49,510	$50,995	$52,525	$54,101	$55,724	$57,396
Exterior Insulated Panels (EIFS)	$0	$0	-$458,744	$16,691	$17,192	$17,708	$18,239	$18,786	$19,350	$19,930	$20,528	$21,144	$21,778	$22,432	$23,105	$23,798	$24,512	$25,247	$26,005	$26,785
3 Geo-Exchange Wells in Sidewalk (Geothermal) Geo-Exchange - Large Heat Pump in Basement (Geothermal) Geo-Exchange Water Pump from 1,500 Below Surface (Geothermal) Geo-Exchange Water DX Unit 6&7 (Geothermal)	$0	$0	-$1,517,548	$44,308	$45,637	$47,006	$48,416	$49,869	$51,365	$52,906	$54,493	$56,128	$57,812	$59,546	$61,332	$63,172	$65,067	$67,019	$69,030	$71,101
DC Microgrid P2 - Solar & Workspace	$0	$0	$0	$0	-$12,030	$4,453	$4,587	$4,724	$4,866	$5,012	$5,163	$5,317	$5,477	$5,641	$5,811	$5,985	$6,164	$6,349	$6,540	$6,736
Energy-aligned leases	$0	$0	$0	$0	$0	$18,620	$19,179	$19,755	$20,347	$20,958	$21,587	$22,234	$22,901	$23,588	$24,296	$25,025	$25,776	$26,549	$27,345	$28,166
AC Schedule Shift	$2,009	$2,070	$2,132	$2,196	$2,262	$2,330	$2,400	$2,472	$2,546	$2,622	$2,701	$2,782	$2,865	$2,951	$3,040	$3,131	$3,225	$3,322	$3,421	$3,524
Biofuel in Existing Boiler	$0	$0	$2,023	$2,085	$2,148	$2,212	$2,279	$2,347	$2,417	$2,490	$2,564	$2,641	$2,721	$2,802	$2,886	$2,973	$3,062	$3,154	$3,249	$3,346
Total Cashflows	**-$724,094**	**-$19,790**	**-$1,875,795**	**$164,512**	**-$2,041,986**	**$260,668**	**$284,557**	**$293,094**	**$299,285**	**$328,839**	**$338,705**	**$348,866**	**$359,332**	**$370,112**	**$381,215**	**$392,652**	**$404,431**	**$416,564**	**$429,061**	**$441,933**
Cumulative Cashflows	*-$724,094*	*-$743,885*	*-$2,619,680*	*-$2,455,168*	*-$4,497,154*	*-$4,236,486*	*-$3,951,929*	*-$3,658,835*	*-$3,359,550*	*-$3,030,711*	*-$2,692,006*	*-$2,343,140*	*-$1,983,808*	*-$1,613,697*	*-$1,232,482*	*-$839,830*	*-$435,399*	*-$18,835*	*$410,226*	*$852,159*
Simple Payback Period	**18.04**	**years**																		
$5mn budget evolution	**$4,275,906**	**$4,256,115**	**$2,380,320**	**$2,544,832**	**$502,846**	**$763,514**	**$1,048,071**	**$1,341,165**	**$1,640,450**	**$1,969,289**	**$2,307,994**	**$2,656,860**	**$3,016,192**	**$3,386,303**	**$3,767,518**	**$4,160,170**	**$4,564,601**	**$4,981,165**	**$5,410,226**	**$5,852,159**
Loan Tech 2 cashflows	$0	$0	$0	$0	$533,516	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957	-$50,957
Loan Tech 3 cashflows	$0	$0	$0	$0	$1,019,268	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352	-$97,352
Total Cashflows with loan	**-$724,094**	**-$19,790**	**-$1,875,795**	**$164,512**	**-$489,202**	**$112,359**	**$136,248**	**$144,785**	**$150,976**	**$180,530**	**$190,396**	**$200,557**	**$211,023**	**$221,803**	**$232,906**	**$244,342**	**$256,122**	**$268,255**	**$280,752**	**$293,624**
Cumulative Cashflows	*-$724,094*	*-$743,885*	*-$2,619,680*	*-$2,455,168*	*-$2,944,370*	*-$2,832,011*	*-$2,695,763*	*-$2,550,978*	*-$2,400,002*	*-$2,219,472*	*-$2,029,076*	*-$1,828,519*	*-$1,617,497*	*-$1,395,694*	*-$1,162,788*	*-$918,446*	*-$662,324*	*-$394,069*	*-$113,317*	*$180,307*
Simple Payback Period	**19.39**	**years**																		
$5mn budget evolution	**$4,275,906**	**$4,256,115**	**$2,380,320**	**$2,544,832**	**$2,055,630**	**$2,167,989**	**$2,304,237**	**$2,449,022**	**$2,599,998**	**$2,780,528**	**$2,970,924**	**$3,171,481**	**$3,382,503**	**$3,604,306**	**$3,837,212**	**$4,081,554**	**$4,337,676**	**$4,605,931**	**$4,886,683**	**$5,180,307**

Net Present Value 10Y	**-$435,326**
IRR 10Y	**-21.8%**
Net Present Value 25Y	**-$435,326**
IRR	**4.5%**
Net Present Value 25Y	**-$435,326**
IRR	**5.3%**

9.22 Creative Finance Solutions that are Currently Unavailable

9.22.1 Property Assessed Clean Energy (PACE) Financing

This type of financing that offers an alternative to a loan. PACE financing helps customers overcome the financial barriers created by high up-front equipment costs associated with the installation of renewable energy and energy efficient technologies[464]. This financing allows a local government to loan funding to the property owner to pay for renewable energy and/or energy-efficiency improvements[465]. Repayment of the amount borrowed is typically done via a special assessment on property taxes, or another locally-collected tax or bill, such as utility bills, or water or sewer bills[466]. PACE financing is not available in New York State as of yet, therefore are not included in this project.

9.22.2 Clean Renewable Energy Bonds (CREBs)

CREBs are primarily used by the public sector entities to finance renewable energy projects. Technologies qualifying for these bonds are generally the same as those that qualify the federal renewable energy production tax credit (PTC)[467]. In lieu of a portion of the traditional bond interest, the bondholder receives federal tax credits. This effectively results in a lower interest rate for the borrower[468]. The principal on the bond is repaid by the issuer[469]. The number of bonds allocated by Congress limits participation in the program[470]. Entities wanting to participate in the bond program must first apply to the Internal Revenue Service for a CREBs allocation, and then issue the bonds within a specified period of time[471]. This program has expired; therefor it is not applicable to this project.

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