# Large Office Renovation and Addition
# Energy Analysis Report for
# Net-Zero Ready and Code Compliant options

June 11, 2014

## SECTION 1.0 Executive Summary

The following three sections include the executive summary: recommendations, benefits and unique accomplishments.

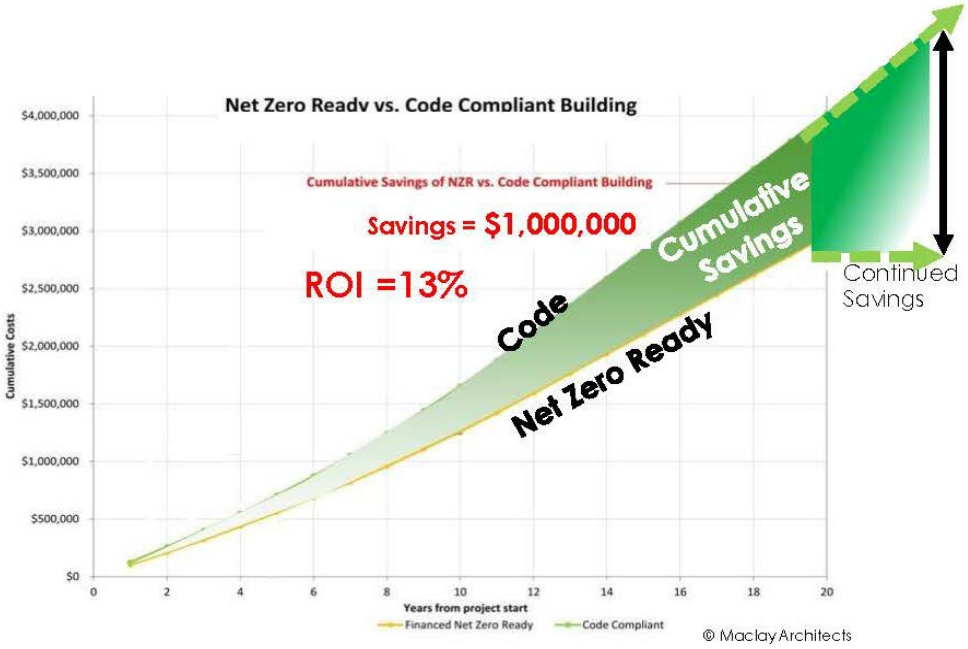
## SECTION 1.1 Recommendations

Based on our analysis, the net zero ready (NRZ) energy option is a prudent investment. First year energy monitoring has documented energy consumption per square foot (EUI) of 25.6 kBtu/sf-yr. The NZR building offers reduced 20 year capital and operating costs as well as positive cash flow from year one when energy and financing costs are considered and analyzed against the code compliant energy costs.

## SECTION 1.2 Benefits

The net zero ready energy building achieves the following:

- 79% improved energy consumption per building area when compared to the existing EUI




See Section 6.0 for the cumulative energy and capital cost graph

- 74% improved energy consumption per building area when compared to the national average office building

- 39% improved energy consumption per building area when compared to the code building
- An additional capital cost of under $6/SF
- Over $1,000,000 in savings over the code compliant building after twenty years including capital and operating costs
- If financed: $25,000 of savings in the first year with the net zero ready building above the code compliant building, thus a positive cash flow from year one
- The 20 year internal rate of return for the building, as compared to a code compliant renovation is 13% when based on a 6% fuel escalation rate
- Annual reduced carbon dioxide emissions of 210,000 lbs, which is equivalent to the amount of carbon sequestered in 78 acres of US forests in one year or the carbon emitted by driving a passenger car 220,000 miles (nearly 9 times around the world)
- Twenty year reduced carbon dioxide emissions equal 4,200,000 lbs, which is equivalent to the amount of carbon sequestered in 1,560 acres of US forests in one year or the carbon emitted by driving a passenger car 4,400,000 miles[1] (176 times around the world)

**SECTION 1.3 Unique Accomplishments**

Often public perception is that net zero ready buildings are expensive and poor investments, particularly when dealing with existing building and office space. This publicly bid project cost $6/sf more than a code compliant building including the renovation and addition and is net zero ready.

The project consisted of a major renovation and addition to an existing building. During the initial schematic design, we identified a significant opportunity to adapt the renovation concept: rather than renovating both the existing one-story and three-story sections, we could demolish the one-story portion and build a three-story addition to provide needed square footage. This change reduced the surface area of the building by 31 percent on the above ground five sides and by 45 percent when including the slab. This reduction in surface area will significantly reduce the heating demand. Cost analysis during phase one of the project determined that this building massing change would add no capital cost to the project while providing energy savings, which results in an infinite return on investment.

**SECTION 2.0 Summary**

The following document summarizes the Cost Benefit Energy Analysis which was performed for a code compliant building compared to a net zero ready building for a large office renovation and addition project. The steps to arrive at our final results included the following:

-Utilizing an hourly building energy simulation model to simulate ventilation, heating and cooling, hot water, lighting and other electrical loads. This results in a building model to estimate the energy performance for the various building and mechanical system approaches.

-Utilizing the energy models and historic fuel cost data to project estimated operating costs and comparing those to one another.

-Preparing a cost estimate for each of the considered options to determine additional energy capital costs.

-Consideration of the capital and operating costs for the options over a 20 year timeline.

[1] The net annual energy use was used for the CO2 calculation from the Net Zero Ready Energy option above the base case. Greenhouse Gas Equivalencies Calculator used on the US EPA website.

## SECTION 3.0 Considered Systems and Options

We considered two options that involved removal of the existing brick and insulating the envelope to different levels, these levels were code compliant and net zero ready. We also considered other energy improvements, including more detailed enclosure commissioning and the installation of a high-performance ground-source heat pump system detailed in the Appendix.

## SECTION 4.0 Energy Usage Intensity Comparison

The following table summarizes the Energy Usage Intensity (EUI) [2] of each of the options.

**Energy Usage Intensity Comparison**

| | | Net Zero Ready (modeled as built) | Code Compliant | Existing Facility | EIA National Ave. Existing Office |
|---|---|---|---|---|---|
| **Electricity** | **kBtu/yr** | 1,521,000 | 2,481,000 | 3,276,000 | N/A |
| **Fossil Fuels** | **kBtu/yr** | 24,000 | 52,000 | 4,080,000 | N/A |
| **Total** | **kBtu/yr** | 1,545,000 | 2,533,000 | 7,356,000 | N/A |
| **EUI** | **kBtu/sf-yr** | 24 | 39 | 113 | 92 |
| | | **Percent better than existing EUI:** | | | |
| | | 79% | 66% | 0% | |
| | | Source: Maclay Architects' File "BldgEnergyFinance" | | | |

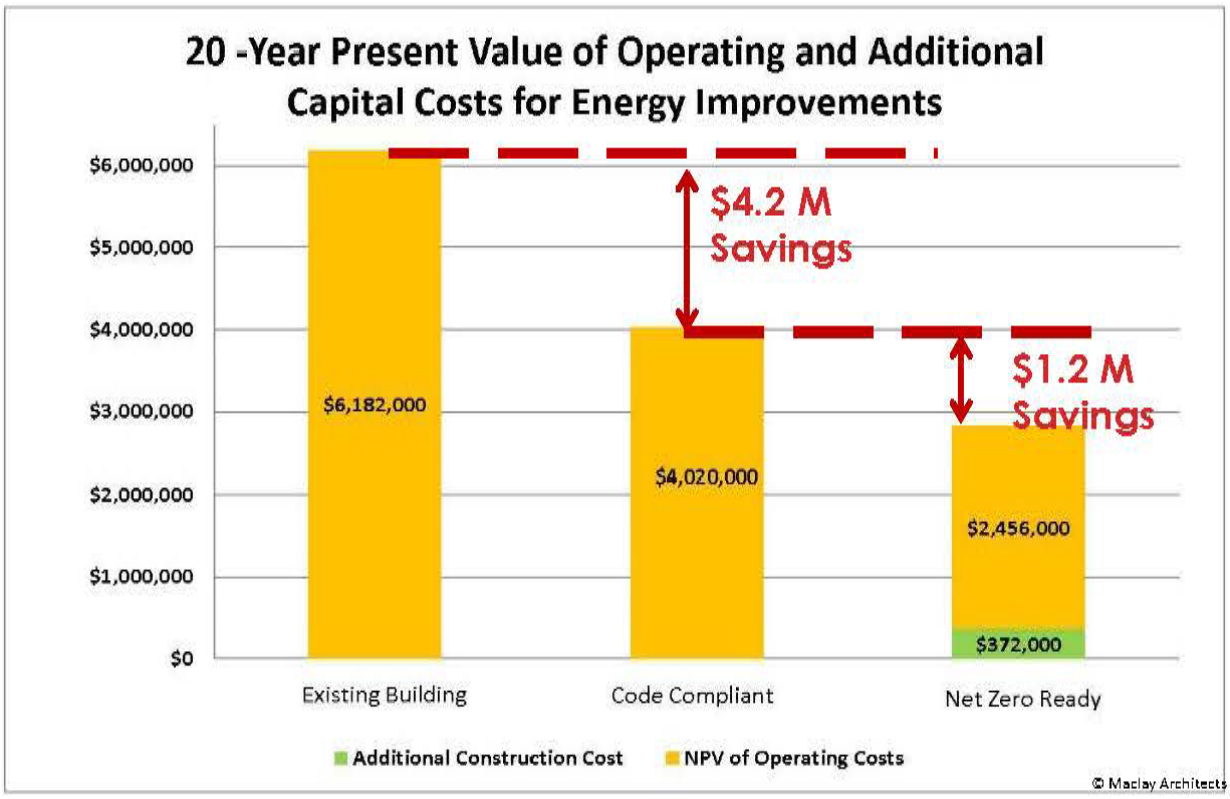
The US Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) indicates a Median Site EUI for Office as being 92 kBtu/sf-yr as indicated in the chart above. The existing building before renovation has an EUI of 113 kBtu/sf-yr. The comparative percentages in the chart state the percent better (positive value) or worse (negative value) than the typical office building site EUI value that each option achieves. The Net Zero Ready building is approximately 79% better than the average existing office building, while the code compliant building is 66% better. The net zero ready building is 39% better when compared to the code building.

[2] Energy Usage Intensity is a metric that is used to bring a building's energy usage into terms that can be easily compared. EUI is stated as a ratio of energy used in a building (in kBtus) over the area of the building (in square feet).

## SECTION 5.0 Capital vs. Operating Cost Analysis

The following graph summarizes additional energy capital costs (green) and the net present value of 20 year operating costs (yellow) for the existing, code compliant, and net zero ready buildings. For this analysis we used 6% fuel escalation rate. The yellow portion of the bars represents the portion of operating energy that is electric and fossil fuel use.

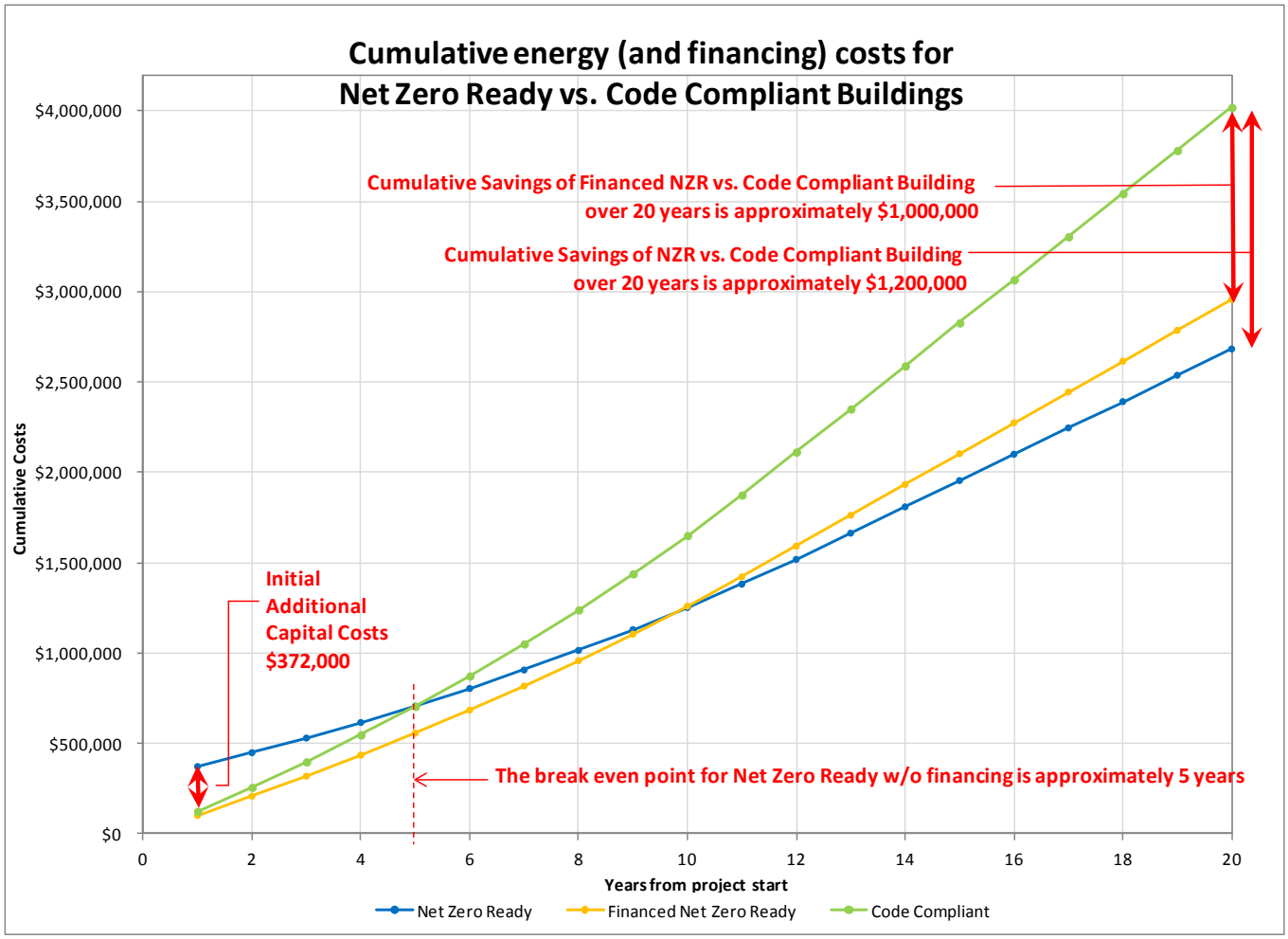
Net zero is defined here as all electric energy use for the building with annual average production from photovoltaics (PV) to exceed annual usage of electricity in the building. Net zero ready is the term used to describe the building and associated systems that do not yet fully include PV provided electricity to offset the buildings' usage and therefore accumulates the cost of electricity per year.



## SECTION 6.0 Cumulative Cash Flow Analysis

For the cash flow analysis for this project, we considered the energy savings of the net zero ready building above the code compliant. This analysis assesses whether investing in the proposed energy improvements is a prudent investment. There are two options to pay for the additional costs to make the building net zero: additional capital costs or financing. In this project the additional energy conservation measures were included in the total project costs and financed.

Financing spreads out the capital cost to make the project net zero ready without the necessary upfront capital costs. First year savings for the financed net zero ready option above the code compliant building are approximately $25,000 and therefore a prudent investment from year one. In certain cases it makes sense to consider the funds for the energy improvements in one lump sum at the beginning of the project.




This cash flow analysis indicated a 20 year cumulative savings of approximately $1,000,000 for the net zero ready option with financing and an estimated savings of $1,200,000 for the net zero ready option without financing over the code compliant building. The graph above tracks the cumulative capital and operating cost over a 20 year period.

The first year values reflect:

- The incremental capital cost plus the first year energy cost for the net zero ready building (blue)
- The first year energy costs and first year bond payments for the financed net zero ready building (yellow)
- The first year energy costs for the code building (green)

Subsequent years add one year's energy and bond payment cost to that cumulating total. This comparison illustrates the additional upfront capital cost required by the NZR building and lower ongoing energy costs. This is shown in contrast to the code compliant building case (green), which has no additional upfront building costs but would require additional energy costs over time. The cumulative savings is estimated at $1,000,000 for a financed NZR building and $1,200,000 for NZR when compared with the code compliant building.

The breakeven point where the savings in energy costs equal the initial capital costs for the net zero ready building is estimated at 5 years. If financed, the savings are $25,000 in the first year for the net zero ready building above the code compliant building, therefore a positive cash flow from year one.

The following assumptions were made to arrive at this analysis:

| | |
|---|---|
| Financing Terms: | 20 years at 3% borrowing rate |
| Financed Amount: | Added Capital Cost of the NZR Energy Improvements: |
| | Net Zero Ready - $372,097 |

Inflation is assumed to equal the nominal discount rate, therefore 0% is used.

Energy Assumptions:

All Energy Purchased (No Solar Electric net-metering or offset assumed)
6% Fuel Escalation Rate

**APPENDIX**

**Building Design**

The following assumptions were used to model the buildings for comparison.
net zero ready building design profile:

| | | | |
|---|---|---|---|
| Building Profile | Occupancy Date: | April, 2012 | |
| | Square Footage: | 65,032 | |
| | Certification | LEED Gold anticipated | |
| Energy Profile | | Modeled: | 24 kBtu/sf-yr |
| | | Actual 1 yr data: | 25.6 kBtu/sf-yr |
| Building Envelope | Construction Type: | Steel structure, DensGlass, air/moisture barrier, 4" polyiso, masonry and panels | |
| | Insulation Values: | Walls: | R-27, 4" continuous polyisocyanurate |
| | | Roof: | R-60, 9" continuous polyisocyanurate |
| | | Foundation (slab perimeter): | R-20, 4" XPS panel to 36" depth |
| | | Foundation (slab edge joint): | R-20, 4" XPS |
| | | Foundation (sub-slab): | R-20, 4" XPS under whole slab |
| | Air Infiltration: | Final Blower Door: | 6,298 cfm50 |
| | | | 0.114 cfm50/sf exterior surface area |
| | Windows/Skylights: | Windows: | U-value: 0.19, SHGC: 0.34, VT: 0.41 |
| | | Skylights (offices): | U-value: 0.1 (C.O.G.) 0.3 (unit, estimated), SHGC: 0.54, VT: 0.5 |
| Mechanical/ Electrical Systems | Heating System: | Open-loop ground-source shallow aquifer with plate and frame heat exchangers and console heat pumps | |
| | | Annual COP (estimated): | 3.6 |
| | Cooling System: | Open-loop ground-source shallow aquifer with plate and frame heat exchangers and console heat pumps | |
| | Ventilation System: | Dedicated ventilation, constant volume in private offices and lobbies, variable volume in all other spaces, controlled by occupancy sensors in small meeting rooms and $CO_2$ sensor in large meeting areas (occupancy over four) | |
| | Energy Recovery System: | Thermotech enthalpy wheel | |
| | | Average Effectiveness: | 70 percent |
| | Lighting System/Controls: | High-efficiency fluorescent and LED lamps throughout, open-loop daylight harvesting in all third-floor conference and courtrooms and north-facing offices, dual switching in all other rooms, Lutron GRAFIK Eye with EcoSystem | |
| | Hot Water: | 60 percent SDHW, 40 percent propane | |

Code Compliant Building:

Code Compliant building envelope

| | |
|---|---|
| Windows: double glazed Accurate Dorwin, | U-0.27 |
| Floor: 2" of rigid insulation under slab, | R-10 |
| Walls: 3" of rigid insulation on exterior face of wall framing, | R-20 |
| Roof: 6" of polyisocyanurate on the roof, | R-40 |
| Infiltration: Vapor barrier only[3] | |

Mechanical System: High efficiency boiler and chiller for cooling

[3] CFM50/SF is a measure of building envelope airtightness. The number of cfm50 is rate of airflow in cubic feet per minute measured with a pressure difference of 50 Pascals between the interior and exterior of the building envelope. This rate is then divided by the SF of the building envelope surface and therefore indicates the amount of air moving across the building envelope.

## Cost Estimate/Capital Cost Comparison

Cost estimates were prepared for the building envelope and mechanical systems to compare the capital costs of a code compliant building to the net zero ready building. Increased enclosure performance added $36,097 to the project costs, and the high-efficiency ground-source heat pump and the addition of a solar hot water system added $136,000. These features save $49,000 annually in operating costs. In total these net zero ready improvements added $5.72/sf to the project cost, an increase of only 3 percent to the project budget. The charts below summarize these relative costs.

| | Building Component | 1. Code Compliant Building | 2. Net Zero Ready building/GSHP | Added Cost | Added Cost |
|---|---|---|---|---|---|
| Envelope | Windows | Double-glazed windows | Triple-glazed windows | $30,557 | $209,097 |
| | Air/Vapor Barrier | Vapor barrier only | Combined air barrier and drainage plane | $39,000 | |
| | Insulation | Install 2" of rigid insulation under slabs | Install 4" of rigid insulation on exterior face of wall framing | $32,500 | |
| | | Install 3" of rigid insulation on exterior face of wall framing | Install 4" of rigid insulation under slabs | $22,500 | |
| | | Insulate seismic joint between new and existing wings to to R-9 | Insulate seismic joint between new and existing wings to maximum R-value | $22,500 | |
| | | Standard detailing of steel support for exterior sun shades | Custom detailing of steel support for exterior sun shades to minimize thermal bridging | $8,000 | |
| | | Standard detailing of steel relieving angles for brick veneer | Custom detailing of steel relieving angles for brick veneer to minimize thermal bridging | $14,000 | |
| | | 6" isocyanurate on the roof | 9" minimum isocyanurate on the roof | $40,040 | |
| Mechanical | Commissioning | NA | Full envelope commissioning & blower door testing | $27,000 | $163,000 |
| | Solar Hot Water | Not a required system | Solar Hot Water System installed | $31,000 | |
| | HVAC | Standard HVAC Replacement | High-efficiency Ground Source Heat Pump HVAC replacement | $105,000 | |
| | | | | **Total Added Cost** | **$372,097** |
| | | | | Added Envelope Cost Per Square Foot | $3.22 |
| | | | | Added Mechanical Cost Per Square Foot | $2.51 |
| | | | | **Total Added Cost Per Square Foot** | **$5.72** |
| | | | | **Total Added Cost As A Percentage Of Total Construction Cost** | **2.76%** |

Source: Maclay Architects' File "BldgEnergyFinance"

NOTES:
9% more for triple glazed windows than double glazed as of Accurate Dorwin
Polyiso cost from Means - $1.82/sf per 3" thickness
Vapor barrier only = 50% cost of combined air and vapor barrier
Standard HVAC Replacement = High efficiency boiler and chiller for cooling
Original Cost without Owner elected Change Orders = $12,246,000, or $188.40/SF

**Other Financial Analysis Metrics**

**Internal Rate of Return**

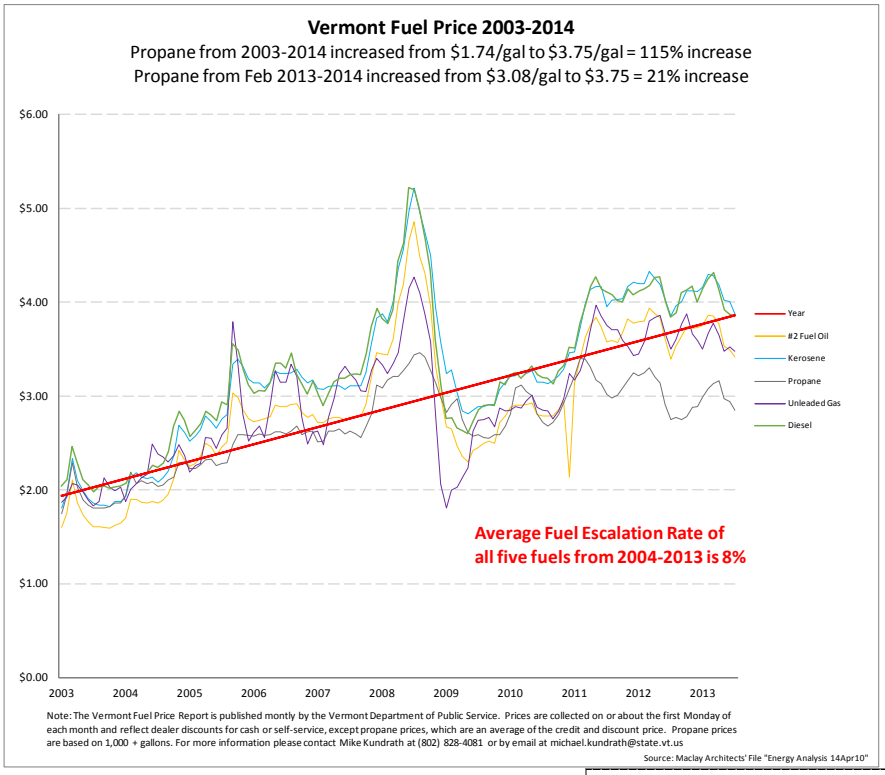
The internal rate of return of an investment makes a comparison of investment potential related to other opportunities utilizing the same money. The Internal Rate of Return for the net zero ready building compared to code compliant is 16% (with 6% fuel escalation rate).

**Renewable Energy**

The client is currently working with a solar installation company to sign a Power Purchase Agreement on a solar PV system to cover the entire building energy use in order to make the building net zero. The current hot water back up uses propane and would be converted to electric to make the building fully net zero energy use.

**Historic Fuel Rate Trends and Escalation Rate Justification**

The following graph summarizes actual fuel prices per gallon for five types of fuel from 2003 to 2013 in Vermont. The data in the graph is from the Vermont Fuel Price Report. While fuel prices will differ somewhat in New Hampshire compared to those in Vermont for this timeframe, the trend is likely similar and therefore we can utilize this data to formulate reasonable assumptions related to probable fuel escalation rates in the coming years.




Taking a closer look at the Vermont Fuel Price Report data, we also generated the percent change of each fuel cost from the year prior. The annual rates of escalation are shown in the chart to the right and the average fuel escalation rate for each fuel is shown below for the past nine years. The fuel escalation rates vary from as low as 5% for propane to 11% for #2 Fuel Oil.

The average fuel escalation rate of all fuels was 8% over this 9 year period. For this analysis we have assumed a 6% high fuel escalation rate.[4]

**Vermont Fuel Escalation Rates**

Percent Change in Fuel Cost from Previous Year

| | Fuel Type | | | | |
|---|---|---|---|---|---|
| | #2 Fuel Oil | Kerosene | Propane | Unleaded Gas | Diesel |
| 2004 | 41% | 39% | 24% | 17% | 35% |
| 2005 | 19% | 22% | 12% | 6% | 13% |
| 2006 | 1% | 0% | 2% | 4% | 1% |
| 2007 | 24% | 21% | 19% | 30% | 24% |
| 2008 | -13% | -7% | -4% | -39% | -21% |
| 2009 | -7% | -12% | -10% | 38% | 0% |
| 2010 | -23% | 10% | 15% | 14% | 13% |
| 2011 | 77% | 22% | 6% | 6% | 16% |
| 2012 | -1% | -2% | -11% | 5% | -2% |
| 2013 | -2% | -1% | -3% | -5% | -2% |
| Average Fuel Escalation Rate from 2004-2013 | 11% | 9% | 5% | 8% | 8% |

Source: Maclay Architects' File "Energy Analysis 14Apr10"

[4] We also assumed that when fuel prices double from current levels, renewable fuels will be less costly than conventional fuels, and either conventional fuel prices will have to level off or one would likely switch to a renewable fuel. At that point, we do not escalate fuel prices further in our analysis.