Are Net Zero Buildings too Expensive?

Getting to Zero National Forum

October 12-14, 2016

Bill Maclay, AIA, LEED AP, Principal Maclay Architects
Maclay Architects’ Net Zero and Net Zero Ready Projects

*Dining Hall with process loads

The Putney School Net Zero Fieldhouse
The Putney School Net Zero Fieldhouse

- Net Zero since 2011

The Putney School Net Zero Fieldhouse

- Net Zero since 2011
- Financial paradigm shift
The Putney School Net Zero Fieldhouse

- Net Zero since 2011
- Financial paradigm shift
- Net Zero Design Strategy

- SF: 16,800
The Putney School Net Zero Fieldhouse

- Net Zero since 2011
- Financial paradigm shift
- Net Zero Design Strategy

SF: 16,800
EUI: 9 kBtu/sf-yr (actual)

EUI with renewables: 0 kBtu/sf-yr
Integrated Design

35.8 kW of solar electric photovoltaics

minimize energy loads

Net Zero Strategy

RENEWABLES

Net Zero

MINIMIZE ENERGY LOADS

Net-zero energy equation
What Is Net Zero Ready?

MINIMIZED ENERGY LOADS - NO RENEWABLES

NET ZERO READY

Fuel Mileage for Buildings?

EPA Fuel Economy Estimates

CITY MPG 18
Estimated Annual Fuel Cost $2,039
Expected range for most drivers 16 to 24 miles

HIGHWAY MPG 25
Expected range for most drivers 21 to 30 miles

Energy Use Intensity (EUI)
Net Zero Building Metrics

**PERFORMANCE METRICS**
10-25 EUI kBTU/sf
*without process loads

**PRESCRIPTIVE METRICS**
- **ROOF**
  - Maximum 0.1 cfm/sf above grade surface area @ 50 Pascals
- **WINDOWS**
  - R-5
- **ABOVE-GR ADE WALLS**
  - R-40
- **SLAB + BELOW GRADE WALLS**
  - R-20

Optimum Prescriptive measures will vary in zones 1-4

US Climate Zones

- **Marine (C)**
- **Dry (B)**
- **M ost (A)**

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Key Elements

Conservation + High-Efficient Systems + Renewables

- Energy Use Intensity (EUI)
- Heat Pumps (COP 2.3-3.0)
- Usually Photovoltaics (sized for annual load)

Best Investment Today

- $5-$20/sf Capital Cost
Best Investment Today

• $5-$20/sf Capital Cost
• 3-10% of Construction Cost

Best Investment Today

• $5-$20/sf Capital Cost
• 3-10% of Construction Cost
• Solar Financing
Best Investment Today

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• Envelope + ROI

• Heat Pumps + ROI
Best Investment Today

- $5-$20/sf Capital Cost
- 3-10% of Construction Cost
- Solar Financing
- Envelope + ROI
- Heat Pumps + ROI
- Renewables + ROI

Financial Analysis Methodology

INPUTS
- Energy Consumption
- Increased Capital Costs for Efficiency
- Capital Cost for PV
- Financing Assumptions

OUTCOMES
- Capital and operating costs
- Cash Flow
Single Family Home

- 1,600 sf
- $16/sf Additional construction costs
- $14/sf additional solar costs

Financial Analysis – Energy Consumption

INPUTS: Energy Model

<table>
<thead>
<tr>
<th>CODE</th>
<th>Heat</th>
<th>Hot Water</th>
<th>Cooling</th>
<th>Lighting</th>
<th>Other Elec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td>19,826</td>
<td>5,000</td>
<td>--</td>
<td>585</td>
<td>3,878</td>
<td>29,289</td>
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<tr>
<td>Hot Water</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
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</table>

<table>
<thead>
<tr>
<th>NET ZERO READY</th>
<th>Heat</th>
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<tr>
<td>NET ZERO READY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td>2,406</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hot Water</td>
<td></td>
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</table>

Total 29,289
Total 9,611

% ENERGY SAVINGS ABOVE CODE 67%

Energy Usage, kWh/yr
Financial Analysis–Increased Net Zero Ready Cost

### Residential Capital Costs

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Code Single Family</th>
<th>NZR Single Family</th>
<th>Added Cost</th>
<th>Category Added Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>Double-glassed</td>
<td>Triple-glassed</td>
<td>$6,792</td>
<td>$25,724</td>
</tr>
<tr>
<td></td>
<td>windows; U=0.32</td>
<td>windows; U=0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air/Vapor Barrier</td>
<td>Air infiltration</td>
<td>Air infiltration is 0.1</td>
<td>$2,172</td>
<td>$25,724</td>
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<tr>
<td></td>
<td>of 0.5 cfm/50 sf</td>
<td>of 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>above grade</td>
<td>above grade area</td>
<td></td>
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<tr>
<td>Insulation</td>
<td>Basement Walls, R-21; basement slab none</td>
<td>Basement Walls, R-20; R-30 slab wise; basement slab R-20</td>
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<td>$25,724</td>
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<tr>
<td></td>
<td>Rim insulation R21</td>
<td>Rim insulation R42</td>
<td>$616</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walls: R-25</td>
<td>Walls: R-40</td>
<td>$8,064</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attic: R-40</td>
<td>Attic: R-40</td>
<td>$1,824</td>
<td></td>
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<tr>
<td>Ventilation</td>
<td>Rate: (# BR's + 1)*25 cfm, exhaust only</td>
<td>Rate: (# BR's + 1)*25 cfm, heat recovery ducted</td>
<td>$3,800</td>
<td>$500</td>
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<td>ASHP, annual heat COP 2.3</td>
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<td>$500</td>
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<tr>
<td>HVAC</td>
<td>propane 85% sealed combustion boiler</td>
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<td>$500</td>
</tr>
<tr>
<td>Solar PV</td>
<td>none</td>
<td>2.7 kW system</td>
<td>$23,332</td>
<td>$23,332</td>
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**Total Added Cost without PV** $26,000
**Total Added Cost Per Square Foot** $16

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Financial Analysis–Increased Net Zero Ready Cost

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**Total Added Cost without PV** $26,000
**Total Added Cost Per Square Foot** $16
Financial Analysis – Increased Net Zero Ready Cost

**INPUTS**

- Capital costs for Net Zero over Code

### Residential Capital Costs

#### SINGLE FAMILY

<table>
<thead>
<tr>
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<th>N2Z Single Family</th>
<th>Added Cost</th>
<th>Category Added Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>Double-glazed windows, U=0.32</td>
<td>Triple-glazed windows, U=0.20</td>
<td>$6,792</td>
<td>$25,724</td>
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<tr>
<td>Air/Vapor Barrier</td>
<td>Air infiltration of 0.5 cfm/50 sq ft above grade surface area</td>
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<td>$2,172</td>
<td>$2,172</td>
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<tr>
<td>Insulation</td>
<td>Basement Walls, R-25; basement slab none</td>
<td>Basement Walls, R-20; R-20 slab, R-30 slab, R-20 slab, R-20 slab</td>
<td>$6,196</td>
<td>$6,196</td>
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<tr>
<td></td>
<td>Rim insulation R21</td>
<td>Rim insulation R42</td>
<td>$496</td>
<td>$496</td>
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<tr>
<td></td>
<td>Walls: R-25</td>
<td>Walls: R-40</td>
<td>$8,064</td>
<td>$8,064</td>
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<td></td>
<td>Attic R-49</td>
<td>Attic R-40</td>
<td>$1,824</td>
<td>$1,824</td>
</tr>
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### Ventilation

- Rate: (# BR's + 1) * 25 cfm, exhaust only
- Rate: (# BR's + 1) * 25 cfm, heat recovery ducted

### Domestic Hot Water

- From boiler
- ASHP with a net COP of 1.5 (1)

### HVAC

- Propane 85% sealed combustion boiler
- ASHP, annual heat COP 2.3

### Solar PV

- 2.7 kW system
- $23,332

**Total Added Cost without PV**: $26,000

**Total Added Cost Per Square Foot**: $16

---

Financial Analysis – Financial Assumptions

**INPUTS**

- Interest Rate
- Loan Duration
- Fuel Escalation Rate

[Image: Vermont Fuel Price 2003-2014]
Solar Costs
Additional Building Costs
Interest Costs
Single Family 30-year Costs

30-Year Cash Flow

- 30-Year savings

Cumulative energy and financing costs for net zero Single Family Home

*in 2014 dollars

CUMULATIVE SAVINGS OF NET ZERO ABOVE CODE

$60,000

Cumulative Savings

Code

Net Zero

Years from project start

Cumulative Costs

$0

$20,000

$40,000

$60,000

$80,000

$100,000

$120,000

$140,000

$160,000

0 5 10 15 20 25 30

Financing Net Zero residential are net positive from year one

Source: McCullough Consultants

Code Single Family

Net Zero Single Family
30-Year Cash Flow

- Savings after 30 years

Bennington Courthouse and State Office Building

- 65,000 SF Renovation/Addition
Bennington Courthouse and State Office Building

- 65,000 SF Renovation/Addition
- $6 / sf additional cost

Bennington Courthouse and State Office Building

- 65,000 SF Renovation/Addition
- $6 / sf additional cost
- 3% additional construction cost
### Energy Use Intensity Comparison

<table>
<thead>
<tr>
<th></th>
<th>Typical Existing Office</th>
<th>Existing Facility</th>
<th>Code Compliant</th>
<th>Net Zero Ready (actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Use Intensity Comparison</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kBtu/sf-yr</td>
<td>92</td>
<td>113</td>
<td>39</td>
<td>26</td>
</tr>
</tbody>
</table>

### Percent Improvement for Net Zero Ready

- Typical Existing Office: 254%
- Existing Facility: 335%
- Code Compliant: 50%
- Net Zero Ready (actual): 0%
Cost estimate - Total Additional Capital Cost

<table>
<thead>
<tr>
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<tbody>
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<td>Double-glazed windows</td>
<td></td>
<td></td>
<td>$8,575</td>
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<tr>
<td>Air/Vapor Barrier</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Major barrier only</td>
<td></td>
<td></td>
<td>$66,100</td>
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</tr>
<tr>
<td>Insulation</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Install 3&quot; of rigid insulation on exterior face of wall.</td>
<td></td>
<td></td>
<td>$17,900</td>
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<tr>
<td>Mechanical</td>
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<tr>
<td>Commissioning</td>
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<td>$140,000</td>
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<tr>
<td>Solar Hot Water</td>
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<td></td>
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<tr>
<td>Not required system</td>
<td></td>
<td></td>
<td>$31,000</td>
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</tr>
<tr>
<td>HVAC</td>
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<tr>
<td>Standard HVAC replacement</td>
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<td></td>
<td>$355,000</td>
<td></td>
</tr>
</tbody>
</table>

Total Added Cost $372,970

Total Added Cost Per Square Foot $5.72

Total Added Cost As A Percentage Of Total Construction Cost 2.76%

20-year Present Value

Financial Analysis

20-Year Present Value of Operating and Additional Capital Costs for Energy Improvements

- $4 Million Savings
- $750,000 Savings

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Cumulative Savings of Net Zero Ready vs Code

Savings = $750,000
ROI = 13%
Renewable NRG Systems
Model Renewable Office and Manufacturing Facility

- SF: 77,000 sf
- EUI: 18 kBtu/sf/yr (actual)
- EUI w/ Renewables: 11 kBtu/sf-yr
300,000 SF Mixed Use Masterplan

Net Zero Energy Feasibility Study
2.3 MW of PV to be NZ
• Rooftops and carports maximized
• +3 acres of ground mounted

Community Residential 30-Year Costs

NZ with Federal Tax Credit: $3,500,000

With 30% Federal Tax Credit for PV
Community Commercial 20-Year Costs
Office and Manufacturing

- NZ with the federal tax credit saves $4.8 million over 20 years

With 30% Federal Tax Credit for PV

So why isn’t everyone doing this?
Paradigm Shift Payback v. Cash Flow

Payback → Cash Flow

Achievable

Photo by Jim Westphalen
The time is NOW

Thank you

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