Multifamily Net Zero Retrofit Market:
Technical and Cost Benchmarks for San Francisco
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• Technical Analysis Details
  – 6 Unit Building Analysis Results
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**Acronym Key**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACEEE</td>
<td>American Council for an Energy Efficient Economy</td>
</tr>
<tr>
<td>ACH50</td>
<td>Air Changes Per Hour Taken at 50 Pascals</td>
</tr>
<tr>
<td>AFUE</td>
<td>Annual Fuel Utilization Efficiency</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigerating, and Air-Conditioning Engineers</td>
</tr>
<tr>
<td>BAU</td>
<td>Business As Usual</td>
</tr>
<tr>
<td>BB</td>
<td>Baseboard</td>
</tr>
<tr>
<td>BEopt</td>
<td>NREL’s Building Energy Optimization Model</td>
</tr>
<tr>
<td>CFL</td>
<td>Compact Fluorescent Lamp</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>DHW</td>
<td>Domestic Hot Water</td>
</tr>
<tr>
<td>ECM</td>
<td>Energy Conservation Measure</td>
</tr>
<tr>
<td>EE</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>EIA</td>
<td>Energy Information Administration</td>
</tr>
<tr>
<td>EUI</td>
<td>Energy Use Intensity</td>
</tr>
<tr>
<td>GPM</td>
<td>Gallons Per Minute</td>
</tr>
<tr>
<td>HP</td>
<td>Heat Pump</td>
</tr>
<tr>
<td>HPHW</td>
<td>Heat Pump Hot Water</td>
</tr>
<tr>
<td>HSPF</td>
<td>Heating Seasonal Performance Factor</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>HW</td>
<td>Hot Water</td>
</tr>
<tr>
<td>ITC</td>
<td>Solar Investment Tax Credit</td>
</tr>
<tr>
<td>kBTU</td>
<td>Kilo British Thermal Unit</td>
</tr>
<tr>
<td>kW</td>
<td>Kilo Watt</td>
</tr>
<tr>
<td>LB</td>
<td>Pound</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>LIHTC</td>
<td>Low Income Housing Tax Credit</td>
</tr>
<tr>
<td>Low-E</td>
<td>Low-emittance</td>
</tr>
<tr>
<td>NREL</td>
<td>National Renewable Energy Lab</td>
</tr>
<tr>
<td>NZE&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Net Zero Carbon</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>PG&amp;E MUP</td>
<td>Pacific Gas &amp; Electric Multifamily Upgrade Program</td>
</tr>
<tr>
<td>PV</td>
<td>Present Value</td>
</tr>
<tr>
<td>SAM</td>
<td>System Advisor Model</td>
</tr>
<tr>
<td>SEER</td>
<td>Seasonal Energy Efficiency Ratio</td>
</tr>
<tr>
<td>SF</td>
<td>Square Foot</td>
</tr>
<tr>
<td>Solar PV</td>
<td>Solar Photovoltaic</td>
</tr>
<tr>
<td>STD</td>
<td>Standard</td>
</tr>
<tr>
<td>YR</td>
<td>Year</td>
</tr>
</tbody>
</table>
Analysis Process
Retrofit Technical and Cost Benchmark Process

A detailed “how-to” guide is available that explains key considerations and gives resources to complete each step

<table>
<thead>
<tr>
<th>Step 1: Determine Scope of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable multifamily buildings in greater San Francisco were analyzed for net zero carbon</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2: Identify Appropriate Modeling Tools and Data Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Energy Optimization (BEopt) and System Advisor Model (SAM) were the modeling tools used</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3: Select Prototypical Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three prototype buildings were selected: 6 unit, 15 unit, and 65 unit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4: Energy Conservation Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included envelope, lighting, HVAC, rooftop PV, offsite renewables, and appliances in analysis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 5: Solar Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used SAM to determine carbon offset of solar arrays with different efficiency and racking configurations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 6: Utility Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determined utility escalation rates, typical rate structure, and carbon produced from electricity and natural gas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 7: Financing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used a 15 and 25 year analysis period and 5% discount rate; incentives included LIHTC, PG&amp;E MUP, and ITC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 8: Optimize Analysis To Hit Net Zero In The Most Cost Effective Way</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used BEopt to optimize efficiency package</td>
</tr>
</tbody>
</table>
Modeling Tools Used

BEopt was used to optimize EE measures and SAM was used to do a detailed solar analysis. Because these were done in two separate programs a degree of manual optimization was required.
This analysis defined net zero as net zero carbon, which is achieved when an equivalent unit of carbon-free renewable energy is produced (on or off site) to offset each unit of fossil fuel energy used by the building.

Building CO₂ Production:
- Electricity: 36 tons/yr
- Gas: 4 tons/yr

Renewable CO₂ Offset:
- 40 tons/yr

BEopt uses site energy to calculate carbon:
- Electric: Carbon Factor: 0.427 lb/kWh from PG&E 2013 (last verified)
- Gas: Carbon Factor: 14.150 lb/therm from ASHRAE STD 105
The majority of affordable multifamily buildings in San Francisco were constructed prior to 1980, have gas furnace heating, and are three stories or less.

### 6 Unit Prototype
- Built pre-1980s
- 4,725 sf
- 3 stories
- Row home
- Furnace, no cooling*
- Individual gas HW heater

### 15 Unit Prototype
- Built pre-1980s
- 11,270 sf
- 3 stories
- Stand alone building
- Furnace, no cooling*
- Central gas HW heater

### 65 Unit Prototype
- Built pre-1980s
- 40,900 sf
- 5 stories
- Stand alone building
- Central boiler, no cooling*
- Central gas HW heater

*Greater San Francisco Bay Area has 69,857 affordable housing units
*58% of San Francisco homes use natural gas, 36% electricity according to an ACEEE 2017 report
Results Summary

For the 6 and 15 unit prototypes, there are many existing cost-effective paths to net zero via custom retrofits. Net zero is technically feasible for 65 units, but not cost effective.
# 6 Unit Prototype: Analysis Key Take-aways

Several retrofit paths to net zero are cost effective now. Further cost-reduction would be helpful to make the business case even more compelling.

<table>
<thead>
<tr>
<th>NZE&lt;sub&gt;c&lt;/sub&gt; Mini-Split Retrofit</th>
<th>NZE&lt;sub&gt;c&lt;/sub&gt; Baseboard + Envelope Retrofit</th>
<th>NZE&lt;sub&gt;c&lt;/sub&gt; Envelope Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Site EUI of 17.6 kBtu/sf</td>
<td>• Site EUI of 17.4 kBtu/sf</td>
<td>• Site EUI of 17.8 kBtu/sf</td>
</tr>
<tr>
<td>• No offsite renewables required</td>
<td>• No offsite renewables required</td>
<td>• No offsite renewables required</td>
</tr>
<tr>
<td>• No envelope upgrades required; great for buildings with complex envelope</td>
<td>• Great for buildings that want to electrify</td>
<td>• No HVAC upgrade required; great for buildings with recently replaced HVAC or improving aesthetics</td>
</tr>
<tr>
<td>• Provides optional cooling</td>
<td>• Market-ready technology</td>
<td>• Market-ready technology</td>
</tr>
<tr>
<td>• Market-ready technology</td>
<td>• All electric solution</td>
<td>• 25 YR NPV* with incentives: $62,900</td>
</tr>
<tr>
<td>• All electric solution</td>
<td>• 25 YR NPV* with incentives: $64,400</td>
<td>• 8.2 year simple payback period</td>
</tr>
<tr>
<td>• 8.7 year simple payback period</td>
<td>• 8.1 year simple payback period</td>
<td>• 8.1 year simple payback period</td>
</tr>
</tbody>
</table>

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
Several retrofit paths to net zero are cost effective now. Further cost-reduction would be helpful to make the business case even more compelling.

<table>
<thead>
<tr>
<th>NZEₐ Mini-Split Retrofit</th>
<th>NZEₐ Baseboard + Envelope Retrofit</th>
<th>NZEₐ Envelope Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site EUI of 19.5 kBtu/sf</td>
<td>Site EUI of 20.9 kBtu/sf</td>
<td>Site EUI of 20.6 kBtu/sf</td>
</tr>
<tr>
<td>No offsite renewables required</td>
<td>No offsite renewables required</td>
<td>No offsite renewables required</td>
</tr>
<tr>
<td>No envelope upgrades required; great for buildings with complex envelope</td>
<td>Great for buildings that want to electrify</td>
<td>Great for buildings with recently replaced HVAC or improving aesthetics</td>
</tr>
<tr>
<td>Provides optional cooling</td>
<td>Market-ready technology</td>
<td>Market-ready technology</td>
</tr>
<tr>
<td>Market-ready technology</td>
<td>All electric solution</td>
<td>25 YR NPV* with incentives: $213,000</td>
</tr>
<tr>
<td>25 YR NPV* with incentives: $187,000</td>
<td>7.1 year simple payback period</td>
<td>25 YR NPV* with incentives: $189,000</td>
</tr>
<tr>
<td>8.5 year simple payback period</td>
<td></td>
<td>8.1 year simple payback period</td>
</tr>
</tbody>
</table>

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
65 Unit Prototype: Analysis Key Take-aways

Net zero retrofits for this prototype require cost reductions in order to achieve payback during a typical investment cycle of 15 years, but are cost effective in a 25 year analysis.

- Site EUI is 16.8 kBtu/sf
- Can achieve NZE_c with efficient rooftop solar PV
- Measures less cost effective than solar PV required to reduce load
- All electric solution
- 25 YR NPV* with incentives: $295,000
- 14.9 year simple payback period

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.48%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
## NZEc Retrofit Cost Benchmarks and Targets

Benchmarks and targets were determined by averaging results from the selected net zero carbon retrofit packages for each prototype.

<table>
<thead>
<tr>
<th></th>
<th>6 Unit Prototype</th>
<th>15 Unit Prototype</th>
<th>65 Unit Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Net Zero Carbon Retrofit Cost ($/Unit)</td>
<td>$19,013</td>
<td>$22,255</td>
<td>$22,296</td>
</tr>
<tr>
<td>Cost With Current Incentives ($/Unit)</td>
<td>$7,527</td>
<td>$8,985</td>
<td>$11,329</td>
</tr>
<tr>
<td>Price Point Using 25 Year Present Value* Utility Bill Savings ($/Unit)</td>
<td>$17,997</td>
<td>$22,053</td>
<td>$12,189</td>
</tr>
<tr>
<td>Cost Reduction Required to be Paid for Through 25YR Utility Bill Savings (Without Incentives/With Incentives)</td>
<td>5.34% / 0%</td>
<td>0.9% / 0%</td>
<td>45.3% / 0%</td>
</tr>
<tr>
<td>Price Point for 10 Year Simple Payback Period ($/Unit)</td>
<td>$9,045</td>
<td>$11,371</td>
<td>$5,867</td>
</tr>
<tr>
<td>Cost Reduction Required for 10 Year Simple Payback Period (Without Incentives/With Incentives)</td>
<td>52.4% / 0%</td>
<td>48.9% / 0%</td>
<td>48.2%</td>
</tr>
</tbody>
</table>

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35% for the 6 unit prototype, 2.28% for the 15 unit prototype, and 2.48% for the 65 unit prototype. Escalation rates are a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
### 6 Unit Prototype: Retrofit Packages

<table>
<thead>
<tr>
<th><strong>NZEc Mini-Split Retrofit</strong></th>
<th><strong>NZEc Baseboard + Envelope Retrofit</strong></th>
<th><strong>NZEc Envelope Retrofit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• No wall upgrades</td>
<td>• R-15 wall insulation</td>
<td>• R-15 wall insulation</td>
</tr>
<tr>
<td>• No roof upgrades</td>
<td>• R-15 roof insulation</td>
<td>• R-15 roof insulation</td>
</tr>
<tr>
<td>• No air sealing improvements, no mechanical ventilation added</td>
<td>• 6 ACH50 air leakage, no mechanical vent</td>
<td>• 4 ACH50 air leakage, no mechanical vent</td>
</tr>
<tr>
<td>• No window improvements</td>
<td>• Single pane windows</td>
<td>• Single pane windows</td>
</tr>
<tr>
<td>• Mini-split HP, 29.3 SEER, 14 HSPF</td>
<td>• Electric baseboards</td>
<td>• Keep existing furnace, natural gas, 72% AFUE</td>
</tr>
<tr>
<td>• Heat pump hot water heater, individual</td>
<td>• No cooling</td>
<td>• No cooling</td>
</tr>
<tr>
<td>• 100% LED lights</td>
<td>• Heat pump hot water heater, individual</td>
<td>• Heat pump hot water heater, individual</td>
</tr>
<tr>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
<td>• 100% LED lights</td>
<td>• 100% LED lights</td>
</tr>
<tr>
<td>• ENERGY STAR clothes washer</td>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
</tr>
<tr>
<td>• Electric cooking range</td>
<td>• ENERGY STAR clothes washer</td>
<td>• ENERGY STAR clothes washer</td>
</tr>
<tr>
<td></td>
<td>• 17.8 kW rooftop solar PV</td>
<td>• 17.5 kW rooftop solar PV</td>
</tr>
<tr>
<td></td>
<td>• Electric cooking range</td>
<td>• Electric cooking range</td>
</tr>
</tbody>
</table>
All three packages are comparable. The baseboard + envelope package would be the most cost-effective maximizing financial benefits of solar under CA NEM, with lowest total cost. However, California Energy Code discourages electric resistance heating due to cost of grid electricity during peak periods (i.e. Time Dependent Valuation), so this solution may not be permitted.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
Solar, HVAC, envelope, and hot water heater are the biggest cost drivers, and, therefore, are likely the best targets for cost savings through industrialized solutions.
With existing incentives, the NZE<sub>c</sub> retrofits are more cost effective than business as usual.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
The most cost effective measures reduce DHW load and heating load. These independently modeled measures don’t account for reduced carbon savings from interactive effects.
Currently, incentives cut cost of net zero retrofit by almost two thirds.
The net zero retrofits eliminate the annual energy utility bill, except for fixed costs.
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle. As noted previously, this solution may not pass Title 24 Energy Code, which discourages electric resistance heating.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.35%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.*
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle.

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## 15 Unit Prototype: Retrofit Packages

<table>
<thead>
<tr>
<th><strong>NZEc Mini-Split Retrofit</strong></th>
<th><strong>NZEc Baseboard + Envelope Retrofit</strong></th>
<th><strong>NZEc Envelope Retrofit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• R-12 Wall Insulation</td>
<td>• R-12 wall insulation</td>
<td>• R-15 wall insulation</td>
</tr>
<tr>
<td>• No roof upgrades</td>
<td>• R-15 roof insulation</td>
<td>• R-15 roof insulation</td>
</tr>
<tr>
<td>• No air sealing improvements, no mechanical ventilation added</td>
<td>• No air sealing improvements, no mechanical ventilation added</td>
<td>• 5 ACH50 air leakage, no mechanical vent</td>
</tr>
<tr>
<td>• No window improvements</td>
<td>• No window improvements</td>
<td>• No window improvements</td>
</tr>
<tr>
<td>• Mini-split HP, 29.3 SEER, 14 HSPF</td>
<td>• Electric baseboards</td>
<td>• Keep existing furnace, natural gas, 72% AFUE</td>
</tr>
<tr>
<td>• Smart thermostat</td>
<td>• No cooling</td>
<td>• No cooling</td>
</tr>
<tr>
<td>• Heat pump hot water heater, central</td>
<td>• Heat pump hot water heater, individual</td>
<td>• Heat pump hot water heater, individual</td>
</tr>
<tr>
<td>• 100% LED lights</td>
<td>• 100% LED lights</td>
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</tr>
<tr>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
<td>• Low flow water fixtures (1.8 gpm shower, 1.5 gpm sink)</td>
</tr>
<tr>
<td>• ENERGY STAR clothes washer</td>
<td>• ENERGY STAR clothes washer</td>
<td>• ENERGY STAR clothes washer</td>
</tr>
<tr>
<td>• Electric cooking range</td>
<td>• Electric cooking range</td>
<td>• Electric cooking range</td>
</tr>
<tr>
<td>• 51.9 kW rooftop solar PV</td>
<td>• 55.6 kW rooftop solar PV</td>
<td>• 55.6 kW rooftop solar PV</td>
</tr>
</tbody>
</table>
All three packages are comparable. The baseboard + envelope package would be the most cost-effective – maximizing financial benefits of solar under CA Net Energy Metering, with lowest total cost. However, California Energy Code discourages electric resistance heating due to cost of grid electricity during peak periods (i.e. Time Dependent Valuation), so this solution may not be permitted.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
Solar, HVAC, and envelope are the biggest cost drivers, and, therefore, are likely the best targets for cost savings through industrialized solutions.
With current incentives, the NZE<sub>c</sub> retrofits are more cost effective than business as usual.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
The most cost effective measures reduce DHW load and heating load. These independently modeled measures don’t account for reduced carbon savings from interactive effects.

Note: All measures compared to baseline building with furnace. Does not take into account interactive effects of each measure.
Current incentives drastically reduce the cost of net zero retrofits.
The net zero retrofits eliminate the annual energy utility bill except for fixed costs.
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle. As noted previously, this solution may not pass Title 24 Energy Code, which discourages electric resistance heating.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
The NPV of the net zero retrofit will result in positive savings in the typical 15 year investment cycle.

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*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.28%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
### Baseline Building

- Masonry walls, uninsulated
- 2x6 wood framed roof
- 7 ACH50 air leakage, no mechanical vent
- Single pane windows
- Central hot water boiler serving radiators
- No cooling
- Non-programmable thermostat
- Hot water heater, natural gas, central
- 67% incandescent, 33% CFL lights
- Standard water fixtures (2.5 gpm shower, 2.2 gpm sink)
- Conventional appliances
- Gas cooking range

### Proposed Net-Zero Retrofit

- R-15 continuous exterior insulation
- R-35 roof
- 4 ACH50 air leakage, no mechanical vent
- Low-E, double pane windows
- Minisplit HP, 29.3 SEER, 14 HSPF
- Smart thermostat
- Heat pump hot water heater, central
- 100% LED lights
- Low flow water fixtures
- ENERGY STAR clothes washer
- ENERGY STAR refrigerator
- Heat pump dryer
- Electric induction cooking range
- 167 kW rooftop solar PV or 208,000 kWh from community choice aggregator
Solar, HVAC, envelope, and appliances are the biggest cost drivers, and, therefore, are likely the best targets for cost savings through industrialized solutions.
The NZE$_c$ retrofits are comparable to business as usual during the life of the retrofit package.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.48%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
65 Unit Prototype: ECMs Savings And Cost

The most cost effective measures reduce DHW load and heating load. These independently modeled measures don’t account for reduced carbon savings from interactive effects.

Note: All measures compared to baseline building with furnace. Does not take into account interactive effects of each measure.
Incentives cut the cost of a net zero retrofit by half.
65 Unit Prototype: Renewable Program vs. Rooftop Solar PV

CleanPowerSF allows for lower upfront costs and rooftop solar PV provides lower total cost of ownership.

**Approach 1: Rooftop Photovoltaics**
Using this approach requires investment in deep energy efficiency measures and rooftop solar

**Approach 2: CleanPowerSF (Offsite Renewables)**
CleanPowerSF avoids upfront cost of rooftop PV, creating a fairly easy path to NZE<sub>c</sub> even in high rise buildings, but adds ~2 cents/kWh to utility bill
Renewable power programs almost eliminate utility bill savings from energy efficiency.
The NPV of the net zero retrofit will not break even in the typical 15 year investment cycle, but saves money over life of the retrofit.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.48%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.
Although CleanPowerSF allows for lower upfront costs, the reduction in energy savings make it far less cost effective than rooftop solar PV.

*Energy savings PV calculated using a 5% discount rate and an escalation rate of 2.48%, which is a blended average based on 10 years of gas and electric escalation in California from the EIA. 25 years selected as life of retrofit package. 15 years selected as typical investment cycle for affordable housing. Water and sewage savings calculated assuming 5% discount rate and 5% escalation rate.