Title 24, Parts 6 and 11
Code Readiness

Design Analysis of the Creekside Affordable Housing Project

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1. Project Description

The Creekside project is a 90-unit workforce and special needs housing project with the goal of being the first zero net energy (ZNE) affordable multifamily project in the city of Davis, CA. The resident population will include extremely low-income (25% AMI), very low-income and lower income households. Forty percent of the units will be prioritized for individuals who are disabled and/or currently homeless. The HUD 811 PRA Program will provide rent subsidies to 22 of the extremely low-income units. Located at 2990 Fifth Street, the project is on the east end of Davis on a 2.27-acre parcel currently owned by the city (APN: 071-100-025).

The project applied for a building permit in the spring of 2018. Construction started in November 2018 with construction expected to be complete in March of 2020.

The apartment complex will be composed of 81 one-bedroom units and 8 two-bedroom units in two-, three- and four-story buildings. In addition, there will be a 3,391 square foot community building, composed of a large meeting room, smaller gathering areas, staff offices, and a laundry room. A 982 square foot, two-bedroom manager's apartment will be located on the second floor of the community building.

The design of Creekside will incorporate passive solar site planning and building strategies including north/south orientation for winter heat gain, simple summer shading, cross ventilation and a high efficiency envelope. As a strategy to meet ZNE and offset all of the project's energy use with on-site renewables, Creekside is designed with no natural gas service to the site. The all-electric strategy includes heat pump technologies for both space and water heating. The project will also be certified through the GreenPoint Rated (GPR) program and is participating in PG&E's California Multifamily New Homes (CMFNH) incentive program.

The project is located directly on a bus route with service every 15 minutes during peak hours. The site is located adjacent to a network of off-street bike paths that connect to every part of Davis. On-site food production will be encouraged by providing gardening space and large quantities of fruit trees. No water intensive turf will be used at the project. Landscaping will feature drought-tolerant and low maintenance species.

There will be three elevators on the site, providing handicapped access to all 89 of the resident units. In addition, each unit will be fully accessible, including a roll-in shower, accessible kitchen and bathroom sinks, countertops and light switches.

Creekside is being developed by Neighborhood Partners LLC, Davis Community Meals and Housing and the John Stewart Company. The project will be managed by the John Stewart Company, which is the largest manager of affordable housing and special needs housing in California, managing over 350 projects composed of more than 30,000 units. The on-site staff will include a full-time resident manager, a half-time assistant manager, a full-time services coordinator and a full-time maintenance person.

The design team is all based in Davis or the greater Sacramento region and include the following members:

- James Zanetto – architect
- Brown Construction – general contractor
- Geocon Consultants – geotechnical engineer
- Cunningham Engineering – civil engineer & landscape architect

- Pemberton Engineering – structural engineer
- KC Engineering – mechanical engineer
- Iron Mechanical – plumbing engineer
- Barnum & Celillo Electric, Inc. – electrical engineer
- Premier Utility Group – joint trench design
- Frontier Energy – Title 24, Part 6 energy consultant

Funding sources include the HCD Affordable Housing and Sustainable Communities Program, Affordable Housing Program of the Federal Home Loan Bank, Section 811 Project Rental Assistance Demonstration Program, 4% tax credits and tax-exempt bond financing. There will also be a construction loan from Wells Fargo Bank and a permanent loan from the California Housing Finance Agency. The limited partner investor utilizing the low-income housing tax credits is Enterprise Community Investment.

2. Methodology

1.1 General Approach

Frontier Energy and the design team evaluated several design options for optimization of building performance while aiming to keep first costs to a minimum, critical for this affordable housing project. Initial cost effectiveness evaluations were conducted in mid-2017 using the National Renewable Energy Laboratory's (NREL's) BEopt energy simulation software, based on the project goal of ZNE. The west half of Building D comprised of 16 units was modeled for this purpose and results were evaluated on an averaged per unit basis. Cost effectiveness compared the incremental cost of each efficiency measure with the cost savings from the estimated reduction in PV capacity resulting from each measure's energy savings. Incremental measure costs were provided by the contractor for most measures.

The project basecase, summarized in

Table 2, is based on the design of prior projects by the developer and design team. It assumes central gas water heating. In order to evaluate zero net energy and the impacts of fuel switching, PV was sized to offset the total estimated source energy consumption including both electricity and natural gas. A source energy multiplier of 2.41 Btu/Btu was used for electricity, both consumption and generation, and a multiplier of 1.09 Btu/Btu was used for natural gas consumption[1]. While from a computational standpoint this is straightforward, there is no mechanism for offsetting the cost of natural gas consumed with onsite PV. This was a significant factor in evaluating and deciding to convert the project to all-electric. PV performance was evaluated based on a specific production of standard efficiency modules in the Sacramento region (1,450 kWh/kW based on on-site azimuth and tilt of the building roof areas) and a cost of $2.45/Watt[2].

Preliminary design decisions were made based on the BEopt analysis results. Compliance simulation tools were used to evaluate compliance with the Title 24, Part 6 (hereafter referred to as Title 24)

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[1] Source energy multipliers for electricity are based upon 2016 PG&E generation fuel mix (https://www.pge.com/en_US/about-pge/environment/what-we-are-doing/clean-energy-solutions/clean-energy-solutions.page) and site-to-source multipliers for various fuels (http://www.nrel.gov/docs/fy07osti/38617.pdf).

[2] Source: Tracking the Sun IX. (https://emp.lbl.gov/sites/default/files/tracking_the_sun_ix_report.pdf). An average of residential and small commercial system costs @ $3.75/watt was used. Systems are expected to be typically greater than 10 kW, although not as large as some commercial systems reported on in the database. Costs assume a $0.25/Watt NSHP incentive and 30 percent for the solar investment tax credit.

building energy code, the City of Davis reach code ordinance, GPR program requirements, and eligibility for the CMFNH program. CBECC-RES 2016.3.0 (SP2) was used for the 2-story Building A and 3-story Building B as well as the manger's apartment (modeled separately from the rest of the community building). CBECC-COM 2016.3.0 (SP1) was used for the 4-story Building C and Building D. The minimum performance requirements for the project are summarized in Table 1. Additional design decisions were made to ensure that the final design met all project performance requirements. Based on optimization runs and recommendations, design changes were made resulting in an upgraded cost-effective design that complied with all project performance specifications.

Table 1: Summary of Project Performance Requirements

	2016 Title 24 Target		***Notes***
	Residential	***Non-residential***	
Code Compliance	0%	0%	
City of Davis Reach Code	25%	n/a	Evaluated assuming no natural gas onsite
GreenPoint Rating (GPR)	3%	3%	All electric compliance option
CMFNH	Delta EDR of 3	10%	The residential PV compliance credit cannot be included

Once the design was finalized, projected annual energy use was estimated in order to size the PV systems for ZNE. Estimates were based on a combination of energy modeling results from CBECC-Res, CBECC-Com, & BEopt. The design team specified SunPower modules to maximize PV output on the building roofs. The project team engaged SunPower and updated the PV performance values to reflect the higher efficiency SunPower modules with a specific production of 1,648 kWh/kW. Final PV selection is Seraphim SEG-GMA-370WW modules by Spectrum Energy.

1.2 Measures

The project basecase assumptions are presented in

Table 2. These specifications reflect the developer's standard construction practices used on other recent multifamily projects.

Table 2: Base Efficiency Specifications

Building Component Efficiency Feature	**Base Specification**
Envelope	
Exterior Walls	2x6 16"oc walls, R21 cavity. No exterior insulation
Demising Walls	2x6 walls, R-21 cavity
Foundation Type & Insulation	Uninsulated slab
Floor (above unconditioned space)	R-21 cavity insulation

Building Component Efficiency Feature	**Base Specification**
Roof/Ceiling Insulation & Attic Type	Vented attic w/ R-38 at ceiling
Roofing Material & Color	Comp. shingles, cool roof material 0.20 aged solar reflectance, 0.85 thermal emittance
Radiant Barrier	Yes
Window Properties: U-Factor / Solar Heat Gain Coefficient (SHGC)	U-factor = 0.30 Btu/ft2-hr-F SHCG = 0.23
Opaque Doors	Insulated steel door
Quality Insulation Inspection Credit (HERS)	Yes
House Infiltration - Blower Door Test (HERS)	n/a
HVAC Equipment	
System Type, Description & Efficiency	Non-ducted thru-the-wall Packaged Terminal Heat Pumps (14.2 kBtuh, 3.0 COP, 9.7 EER) & In-line fan for heat transfer to bedroom(s)
Duct Location & Insulation	no ducts
Mechanical Ventilation	Continuous exhaust per ASHRAE 62.2. Located in bathroom
Nightime Ventilation Cooling	None
HERS Verified Refrigerant Charge	n/a
HERS Verified Cooling Airflow >= 350 cfm/ton	n/a
HERS Verified Fan Watt Draw <= 0.58 W/cfm	n/a
Water Heating Equipment	
System Type, Description & Efficiency	Gas central DHW: 100 gal condensing storage, 95% efficiency
Solar Water Heating	None
Distribution Type	Central recirc w/ demand controls per code: All pipes in unit insulated per code
Hot Water Fixtures	Per CalGreen
Appliance & Lighting	
Lighting Type	100% LED lighting (per code)
Lighting Controls	Per code
EnergyStar Appliances	Refrigerator, no dishwasher in units

Building Component Efficiency Feature	Base Specification
Cooking	Electric
Clothes Washer/Dryer	None in units, central facility
Home Energy Management System	n/a

Additional efficiency measures were evaluated to determine cost effectiveness and constructability and identify any potential barriers. Descriptions of each of the efficiency measure upgrades evaluated in this analysis are summarized below. Measures to evaluate were selected based on feedback from Frontier Energy, the project team, and PG&E. Unless otherwise described all measures were evaluated using the BEopt software.

***High Performance Windows*:** Two window upgrades were evaluated.

1. Lower U-factor dual-pane windows: U-factor = 0.24 Btu/hr-ft^2-F.
2. Triple-pane windows: U-Factor = 0.21 Btu/hr-ft^2-F.

***High Performance Walls*:** The basecase wall was a 2x6 wood framed wall with R-21 high density batt cavity insulation and no exterior insulation. Six wall upgrades were evaluated, as described below:

1. Add one-inch of exterior continuous insulation.
    a. 1-inch EPS
    b. 1-inch mineral wool
2. Convert to Premier SIP walls with either a 5.5” EPS core (R-value of 22.7) or a 7.25” EPS core (R-value of 29.5). The SIPs are sheathed with ½” of OSB on each side.
    a. 5.5” EPS core
    b. 7.25” EPS core
3. Convert to Bamcore structural bamboo wall systems[3] with either 5” (R-value of 20.7) or 6” (R-value of 24.2) blown cellulose or fiberglass between 1-¼” bamboo skins.
    a. 5” Bamcore
    b. 6” Bamcore

***Mini-split heat pumps (MSHPs)*:** The basecase design was through-the-wall packaged terminal heat pumps (PTHPs) located on the exterior wall in the living room of each apartment. To assist in distributing the heating and cooling a 10-Watt continuously operating transfer fan would be installed to direct air to the bedrooms. The following three MSHP upgrades were evaluated.

1. Non-ducted single zone MSHP installed in the living room with the same transfer fan as in the basecase. SEER 23.2, HSPF 11.0 (based on Mitsubishi product).
2. Non-ducted multi-zone MSHP with one indoor unit installed in the living room and one per bedroom. SEER 18.0, HSPF 8.9 (based on Mitsubishi product).
3. Ducted MSHP with a single indoor unit and short duct runs serving the living room and each bedroom. SEER 21.5, HSPF 12.2 (based on Fujitsu product).

***Heat pump water heaters (HPWHs)*:** The basecase design included a central gas condensing boiler. To more easily offset building energy use with onsite PV production, electric water heating options were

[3] http://bamcore.com/

considered. Four central HPWH products were evaluated as an alternative to central gas boiler, as well as an option that included individual water heaters.

1. Colmac HPA9 – R-134a, fixed capacity, single-pass, 130-160°F supply temperature
2. Aermec ANL100HA – R-410A, fixed capacity, multi-pass, 120°F max supply temperature
3. Sanden GUA-A45HPA & 83gal storage tank, 2 units per 4-story building – CO2 refrigerant, variable capacity, single-pass, up to 175°F supply temperature.
4. Rheem PROPH80 – hybrid approach with clustered 80gal unit serving 2-4 apartments
5. Rheem PROPH80 – individual HPWH serving each apartment

Due to the inability to evaluate central HPWHs (options 1-3 above) in either Beopt or CBECC-Res, Frontier estimated HPWH energy consumption using BEopt's hourly hot water demand, and seasonal heat pump efficiencies. Frontier Energy considered using the Department of Energy's EnergyPlus software to model central heat pump water heating, but in the absence of a validated central HPWH model, concluded that this would introduce too much uncertainty and would require substantial effort.

There was little information on actual field performance of central HPWHs when doing this analysis, so seasonal coefficient of performance (COP) was taken from field monitoring data of a central HPWH at the UC Davis West Village community. Based on performance data, an average COP of 2.3 for April through September and 2.0 for October through March was used to estimate hourly and annual electricity use[4]. Because there was no information on differences in actual performance between the three central HPWH designs, all three of the central heat pump options assumed the same performance.

***Drainwater heat recovery*:** Two drainwater heat recovery strategies were evaluated as described below.

1. Horizontal drainwater heat recovery units (EcoA1000-80, 44.5% efficiency) connected to shower drain on all floors.
2. Vertical drainwater heat recovery units (PP3-96, 67% efficiency) connected to shower drains on floors 2-4.

BEopt is not capable of modeling drainwater heat recovery. At the time of this analysis drainwater heat recovery was being added as a capability for the 2019 version of CBECC-Res. Frontier Energy developed the drainwater heat recovery scripts for CBECC-Res and has access to them as Python scripts. Frontier Energy also has Python scripts emulating the hot water draw profiles contained in CBECC-Res. These scripts were used to create the hot water draw profiles that CBECC-Res would use for the apartments at Creekside and evaluate the savings from the two specified drainwater heat recovery products.

***Laundry hot water*:** Eliminate water heating and hot water plumbing for clothes washing at central laundry facility. A small under-counter instant hot water heater would be provided at the sink.

***Energy recovery ventilators (ERV)*:** The basecase design included continuously operating exhaust fans in the bathrooms. To provide a balanced ventilation approach, an ERV with 0.58 W/cfm and 72% recovery efficiency (Panasonic FV-04EV1) located in the bathroom was evaluated.

***Elevator*:** Upgrade proposed hydraulic elevators to gearless traction elevators. Savings were based on the ThyssenKrupp's energy calculator[5], assuming 426 movements per day per elevator.

[4] Monitoring conducted by Frontier Energy Oct 2011- Feb 2013. COP was calculated as total hot water delivered / total HPWH system energy use.

[5] https://www.thyssenkruppelevator.com/tools/energy-calculator/

Plug Load Control Strategies: Strategies to control and reduce miscellaneous electric energy use were evaluated. Options considered included two off-the-shelf products, the Canary Instruments device and the SiteSage energy monitor, as well as in-unit wiring that would allow for select outlets to be controlled from a master switch by the front door. For all three options it was assumed that miscellaneous plug load energy use could be reduced by 5%.

3. Analysis & Results

1.3 Parametric Analysis

Results of the Beopt parametric analysis are presented in Table 3. Energy savings and incremental costs are presented for each upgrade measure evaluated. Incremental costs are broken out by the first cost of the efficiency upgrade and the first cost savings due to the decrease in PV capacity required to meet ZNE. The *Net Cost Change* reflects the sum of these two figures, a negative value indicates a first cost savings and a positive value indicates an increase in first cost. When measure costs were not provided by the contractor these cases are indicated with n/a for not available.

A description of the results by measure type and how they were factored into the final design decision is below.

High performance windows: Electricity savings from windows with a lower U-factor were estimated to be marginal and not sufficient to offset the incremental cost of just less than $400 per apartment. Based on the parametric analysis the project decided not to implement this measure. Later in the design process this measure was re-evaluated, the results of this are described in Section 1.5 below.

High performance walls: The six wall upgrade options resulted in estimated energy savings ranging from 25 to 68 kWh (equivalent 20 to 50 Watts of PV). The contractor did not price out the options with exterior continuous insulation due to concerns they had about implementation. Fire code and the builder's insurance requires that 5/8" gypsum wallboard be installed on the exterior for one-hour fire wall rating. The project has a mix of cementitious siding and 3-coat stucco on the building façade. Because of the 5/8" gypboard on the exterior, the cementitious siding product requires furring strips for exterior insulation greater than one-half inch per the manufacturer installation guidelines. For the stucco portion of the building the project team discussed using 1-coat stucco in order to easily incorporate the one-inch of insulation[6]. However, the project team had concerns about the durability of 1-coat stucco systems based on past experiences and were not comfortable specifying this product.

The project architect was interested in evaluating both structurally insulated panels (SIPs) and Bamcore structural bamboo wall systems and brought these options to the team[7]. A call was held with Bamcore to discuss their product and how it could be applied to this project. Advantages of both SIPs and Bamcore products included structural strength, improved air sealing, reduced labor time for installation with modular construction, and in the case of the Bamcore walls, the application of sustainable materials for building construction. The main disadvantage with these wall systems is that the project team has no

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[6] While there is nothing that precludes the use of exterior continuous insulation with 3-coat stucco, this is not a common system.

[7] http://bamcore.com/

experience using them. While there is a potential for reduced labor costs, because of lack of familiarity with both products, the project team felt that the marginal energy savings that were estimated weren't sufficient to pursue these options further.

Mini-split heat pumps (MSHPs)**:** The developer typically installs PTHPs on exterior walls in the living room for space conditioning of the apartments. While this strategy is low-cost and simple, it can cause comfort concerns in the bedrooms which do not have a dedicated source of conditioned air. Relying on conditioned air from the PTHP to heat and cool the bedrooms can result in overheating or overcooling the living space and closing the bedroom doors for privacy will further impact comfort concerns. On previous projects some occupants complained that the bedrooms were either too warm in the summer or too cold in the winter. To address these comfort concerns, the developer began installing in-line transfer fans between the living space and bedrooms to help distribute conditioned air to bedrooms and reduce temperature differences between rooms.

To improve comfort and reduce energy use, two MSHP strategies were evaluated: ducted MSHPs with ducts serving both living areas and bedrooms, and ductless MSHPs with multiple indoor units, one in the living room and one in each bedroom. A ductless MSHP with a single indoor unit in the living area alone, was also evaluated as a lower cost strategy. This option is more efficient than the PTHP but still requires an in-line transfer fan to help distribute conditioned air to bedrooms. The project team worked with a Panasonic sales representative and received quotes for discount pricing for Panasonic MSHPs. The mechanical contractor also received quotes for Mitsubishi MSHPs. Based on the energy savings alone the cost of this upgrade could not be justified. While the PV capacity could be reduced by about 1 panel per apartment, the incremental cost per apartment for the ducted MSHP option was over $4,500. This cost included ducting, furring down the hallway ceiling to install the unit, running refrigerant and condensate lines, and additional electrical circuiting. Incremental cost for ductless option with multiple indoor units was nearly as much as the ducted option for a one bedroom apartment and would be more expensive for the 2-bedroom units. The ductless MSHP with a single indoor unit reduced the incremental cost by about 50% compared to multiple indoor unit system, but the $2,600 added cost over a PTHP still did not justify the $530 in PV savings.

Frontier Energy also evaluated the impact of MSHP versus PTHPs from the perspective of compliance with the Title 24 energy code. For the low-rise buildings which fall under the residential energy code, the MSHPs must be ducted and HERS verified to receive credit for the equipment efficiency. While the ducted MSHP strategy improved compliance, code compliance and GPR goals could be met with the lower efficiency PTHPs, and the ducted MSHPs did not improve the compliance margin enough to meet the 25% required by the City of Davis ordinance, which therefore did not justify the $4,500 incremental cost. The approach to complying with the City of Davis reach code ordinance is discussed in Section 1.4.

The limitation on compliance credit for MSHPs relative to the ducting condition does not apply to the high-rise multifamily and non-residential buildings. Both ducted and ductless MSHPs were evaluated for these buildings. Because code compliance and GPR goals could not be met with the PTHPs, ductless MSHPs were proposed for the apartments in these buildings only. The result is that 25 apartments will have PTHPs and 64 apartments will have MSHPs,

Heat pump water heaters (HPWHs)**:** A variety of water heating strategies were considered including central HPWHs, individual HPWHs, and a hybrid approach where a single residential storage HPWH serves 2-4 apartments. The focus of the evaluation was on the feasibility of a low cost HPWH strategy in place of the proposed central gas boiler. There are limited product options for large HPWHs with the capacity to serve all apartments in one or multiple buildings. Some of the available products suffer from limited technical support; others pose operational challenges such as poor performance when combined with recirculation loops and operating in electric resistance mode at ambient air temperatures below 50°F. The project also wanted to minimize recirculation losses, which can represent 30-40% of total water heating energy use with traditional design strategies. Alternate recirculation designs were considered, such as insulating all supply pipes to R-20 as well as eliminating the pump and either adding heat tape on select supply piping or delivering hot water to distributed storage tanks throughout the building. The builder and construction team have no prior experience with HPWHs and had a lot of concerns with the performance of a central HPWH strategy. Central HPWH is a viable strategy that is gaining interest recently, but at the time design decisions were made there were very few examples of installed systems in the area or projects in the area with a proven track record. Incremental costs for all of the central HPWH strategies came in $4,000 to $5,000 per apartment above the base case gas boiler.

Individual residential storage HPWHs are a mature technology and more straightforward to implement with known reliability and performance. However, providing 50-80 gallons of storage for each single occupancy apartment can't be justified and would result in high storage losses, and high incremental costs. The selected strategy is a hybrid approach where a single 80-gallon Rheem residential HPWH serves clusters of 4 apartments. The selected water heater has sufficient capacity to serve four single occupancy apartments and has a Uniform Energy Factor (UEF) of 3.70. The design was changed to locate the water heaters in exterior closets close to the apartments they serve, minimizing storage and recirculation losses.

The Rheem HPWH meets the NEEA Advanced Water Heater Specification Tier 3 requirements when installed as an individual water heater. Since these water heaters are serving multiple apartments, they are considered a central water heating system and cannot be modeled in the Title 24 compliance software, and the efficiency of the equipment could not be used for compliance credit.

<u>Energy recovery ventilators (ERVs)</u>**:** ERVs were evaluated as a ventilation strategy for the apartments both as an energy efficiency measure and as an alternative to exhaust-only mechanical ventilation. Energy savings from an ERV in the Davis climate are small; it does reduce heating and cooling energy use but with higher fan energy use relative to a single exhaust fan. The balanced ventilation approach allows for other benefits including filtration of outdoor air and limiting depressurization of the apartments. The project team worked with the Panasonic sales representative for discount pricing on Panasonic ERVs, but due to the small energy savings the installed cost of the ERV, estimated at about $1,000 more per apartment than an exhaust fan, could not be justified. The ERV could not replace an exhaust fan for meeting intermittent ventilation in the bathroom.

The adopted strategy is to operate Panasonic bathroom exhaust fans continuously at a ventilation rate to meet minimum ventilation requirements by code, and also meet the intermittent ventilation requirements. In the high-rise buildings (Buildings C and D), the Title 24 mechanical ventilation requirements will be satisfied by the allowance for operable windows and natural ventilation. With the adoption of the 2019 Title 24, Part 6 (which will go into effect January 1, 2020), the allowance for operable windows to meet the ventilation requirements in non-residential multifamily buildings was eliminated and the ventilation requirements were aligned between low-rise and high-rise multifamily buildings.

<u>Miscellaneous Electric Load (MEL) Controls</u>**:** MEL energy use, based on estimates from the energy modeling, represents 38% of the baseline apartment total energy at approximately 1,100 kWh/yr. Control strategies with the potential to reduce this were considered, including two feedback devices (SiteSage and Canary Instruments) as well as wiring the apartments to control non-critical loads and plugs with a single switch located at the apartment entrance. Cost estimates were provided for the non-critical load control and the SiteSage, but the team was not able to obtain costs for the Canary

Instruments product. The SiteSage was $2,500, much more than the $100 in reduced PV capacity based on the estimated energy savings. The SiteSage does have additional features and capabilities that could not be factored into the cost analysis. The contractor estimated costs for the non-critical load control at $1,000. Frontier Energy considered this very high, as the additional labor and materials in new construction should be marginal. Based on these results no load controls were included in the project.

Elevators**:** The gearless tracking elevator was estimated to save a similar amount of energy per apartment as the MEL controls and the wall upgrade measures. The contractor estimated an incremental cost of just less than $2,000 which was too much to justify the investment from a cost effectiveness standpoint. Ultimately this measure was not adopted.

Table 3: Measure Upgrade Details

Scenario	Description	Details	Per Unit Metrics						
			PV Capacity (kW-DC)		Energy Savings		Incremental Cost		
			Electricity[1]	Natural Gas[2]	Electricity (kWh/yr)	Natural Gas (therms/yr)	Efficiency	PV[3]	Net Cost Change
Basecase	Basecase	Construction Identical to Heritage Phase 2. PV added to achieve ZNE	2.06	0.74					
Windows 1a	Advanced Windows	Lower U-factor 2-pane windows. U-factor ≤ 0.24 / SHGC ≤ 0.23.	2.04	0.74	22	-	$390	-$37	$353
Windows 1b	Advanced Windows	3-pane windows. U-factor ≤ 0.21 / SHGC ≤ 0.23	n/a	n/a	n/a	-	See Table 7	n/a	n/a
Walls 1a	1" EPS	1" EPS for exterior insulation. R-4/inch. (Requires furring at Hardie siding areas. 1/2" gypsum sheathing required for fire code.)	2.03	0.74	41	-	$1,613	-$69	$1,544
Walls 1b	1" Mineral Wool	1" Owens Corning Thermafiber Rain Barrier 45 for exterior insulation. R-4.3/inch (Requires furring at Hardie siding areas. 1/2" gypsum sheathing required for fire code.)	2.03	0.74	42	-	n/a	-$72	n/a
Walls 2a	Premier 6.5" SIPs walls	6 1/2" (165 mm) thick SIP with 5.5" EPS core (R-value of 22.7). 1/2in OSB on each side.	2.04	0.74	25	-	n/a	-$42	n/a
Walls 2b	Premier 8.25" SIPs walls	8 1/4" (210 mm) thick SIP with 7.25" EPS core (R-value of 29.5). 1/2in OSB on each side	2.02	0.74	57	-	n/a	-$96	n/a
Walls 3a	Bamcore 7.5" walls	7 1/2" wall w/ 5" blown cellulose/fiberglass @ R=17.5 & (2) 1-1/4" bamboo skins @ R=1.6	2.02	0.74	54	-	n/a	-$92	n/a
Walls 3b	Bamcore 8.5" walls	8 1/2" wall w/ 6" blown cellulose/fiberglass @ R=21 & (2) 1-1/4" bamboo skins @ R=1.6	2.01	0.74	68	-	n/a	-$115	n/a

Scenario	Description	Details	Per Unit Metrics						
			PV Capacity (kW-DC)		Energy Savings		Incremental Cost		
			Electricity[1]	Natural Gas[2]	Electricity (kWh/yr)	Natural Gas (therms/yr)	Efficiency	PV[3]	Net Cost Change
HVAC 1	Ductless MSHP - single zone	Non-ducted single-zone MSHP. Mitsubishi M-Series SEER/HSPF = 23.2 / 11.0. In-line fan for heat transfer to bedroom. (Assumes 10Watt transfer fan continuously operating same as in basecase.)	1.84	0.74	314	-	$2,667	-$531	$2,136
HVAC 2	Ductless MSHP 2 zone	Non-ducted 2-zone MSHP with 2 indoor units. Mitsubishi M-Series SEER/HSPF = 18.0 / 8.9	1.87	0.74	266	-	$4,022	-$449	$3,573
HVAC 3	Ducted MSHP	Ducted MSHP, single indoor unit with short duct runs in dropped ceiling. Fujitsu ARU9RLF/AOU9RLFC SEER/EER/HSPF=21.5/14.5/12.2	1.78	0.74	406	-	$5,278	-$686	$4,592

Scenario	Description	Details	Per Unit Metrics						
			PV Capacity (kW-DC)		Energy Savings		Incremental Cost		
			Electricity[1]	Natural Gas[2]	Electricity (kWh/yr)	Natural Gas (therms/yr)	Efficiency	PV[3]	Net Cost Change
DHW 1a	Central HPWH	Colmac HPA9	2.56	-	(732)	81	$4,155	-$585	$3,570
DHW 1b	Central HPWH	Aermec ANL100HA	2.56	-	(732)	81	$5,055	-$585	$4,470
DHW 1c	Central HPWH	Sanden GUA-A45HPA & 83-gal storage tank. 2 units per 4-story bldg	2.56	-	(732)	81	n/a	-$585	n/a
DHW 1d	Hybrid/ central HPWH	Rheem PROPH80. 80gal unit serving 2-4 apartments	2.56	-	(732)	81	-$105	-$585	-$690
DHW 1e	Individual HPWH	Rheem PROPH80. 50gal unit per apartment	2.56	-	(732)	81	n/a	-$585	n/a
DHW 2a	Horizontal drainwater heat recovery	Locate at drain drops for all showers tied to cold water shower supply. Horizontal EcoA1000-80 with 44.5% efficiency.	2.06	0.64		11	$3,000	-$252	$2,748
DHW 2b	Vertical drainwater heat recovery	Same as DHW2a but w/ vertical unit serving drains on floors 2-4 only. Vertical unit PP3-96 tied to drains from all units F2-4 with 67% efficiency.	2.06	0.63		13	$0	-$287	-$287
DHW 3	No hot water at Laundry	Cold water wash for washers only. Eliminate water heating and HW lines at laundry. Small under-counter instant hot heater at sink.	2.06	0.70		5	-$14	-$110	-$124

Scenario	Description	Details	Per Unit Metrics: PV Capacity (kW-DC): Electricity[1]	Per Unit Metrics: PV Capacity (kW-DC): Natural Gas[2]	Energy Savings: Electricity (kWh/yr)	Energy Savings: Natural Gas (therms/yr)	Incremental Cost: Efficiency	Incremental Cost: PV[3]	Incremental Cost: Net Cost Change
MV-1	Panasonic ERV	Panasonic FV-04EV1, 0.58 W/cfm 72% recovery efficiency. Located in bathroom. Include inlet and exhaust ducting to outside	2.01	0.74	61	-	$1,075	-$104	$971
MEL 1	Consumptio n Meter	Canary Instruments device in each apartment. (Savings assume 5% plug load reduction.)	2.02	0.74	55	-	n/a	-$92	n/a
MEL 2	Consumptio n Meter	SiteSage for Homes M-14h Energy Monitor (Savings assume 5% plug load reduction.)	2.02	0.74	55	-	$2,500	-$92	$2,408
MEL 3	Plug load Control	Unit wired w/ switch at entrance to shut off all non-critical loads (Savings assume 5% plug load reduction.)	2.02	0.74	55	-	$1,000	-$92	$908
Elevator 1	Gearless Traction Elevator	KONE Gearless traction	1.99	0.74	102	-	$1,956	-$172	$1,784

1.4 Project Performance

The City of Davis' adopted local ordinance for the 2016 code requires the low-rise residential buildings be 25% better than the 2016 Title 24 energy code. The all-electric strategy and the use of HPWHs for domestic hot water resulted in Title 24 code compliance challenges, due to modeling limitations with central HPWHs and the relatively high time dependent valuation (TDV) value of electricity compared to natural gas.

Frontier Energy evaluated several strategies to meet the 25% compliance margin for the low-rise buildings (Buildings A and B) while aiming to keep first costs to a minimum, critical for an affordable housing project. Incremental costs for the additional measures were too much for the project to fund. While all the buildings at the project comply with the 2016 Title 24 code, due to the compliance challenges described below in more detail, the low-rise buildings (Buildings A and B in the project) could not cost-effectively meet the 25% compliance margin.

Following is a description of the HPWH modeling constraints. These are specific to CBECC-Res 2016.3.0 and CBECC-Com 2016.3.0, the approved simulation tools for compliance with the 2016 Title 24 residential standards and the non-residential standards, respectively.

- Cannot model central HPWHs. The California Energy Commission (Energy Commission) allows a workaround for modeling central HPWHs by assuming the system is equivalent to a prescriptive central large gas water heater; however, this does not allow the project to take credit for the higher efficiency heat pump technology. It also subjects the project to a compliance penalty if solar thermal is not installed, which is assumed in the prescriptive standard.
- HPWH energy use can be directly offset with on-site solar but there is no mechanism in Title 24 to credit this approach. The proposed 2019 Title 24 standards include a prescriptive option path for HPWHs, but this is not in the 2016 standards.
- When individual (non-central) HPWHs are compared to the prescriptive gas tankless water heater, the HPWH has a higher TDV value and subsequently lower compliance performance in most cases.
- Indicating whether natural gas is available onsite or not has a significant impact on the compliance performance with electric water heating.

The project team met with the City of Davis to describe the modeling challenges and discuss how the project could meet the performance goals. Since the compliance software cannot directly model the proposed HPWH design in the project, the approach that was proposed and accepted by the City building official, included developing two separate models for the low-rise buildings. Case 1 shows compliance with the energy code as well as with GPR pre-requisites. Case 2 shows compliance with the City of Davis ordinance of 25% better than code. These two cases and the justification for them are described below. The energy efficiency features did not change between the cases, but the modeling methodology was different. The City agreed to the work around in which the low-rise buildings in the project met the City's 25% requirement using the proposed analytic approach as described in Case 2.

Case 1 – Code compliance: For this case all modeling rules according to the Alternative Calculation Methodology (ACM) Reference Manual are followed, specifically natural gas is indicated to be available onsite for the low-rise buildings. The residential compliance software includes an input which indicates whether natural gas is available at the site. Per section 2.2.10 of the 2016 Residential Alternative Calculation Method (ACM) Reference Manual, natural gas is available if "a gas service line can be connected to the site without a gas main extension." According to this definition natural gas is available at the Creekside project site, even though the project is not investing in any gas infrastructure.

Whenever natural gas is available the basecase in the compliance software is a natural gas water heater. If it is unavailable the basecase is a propane water heater. Because of differences in TDV, it is more difficult for all-electric buildings to meet the water heating compliance targets than mixed fuel buildings.

The proposed water heating strategy cannot be directly modeled in either the residential or non-residential compliance software. The Energy Commission advised the team on a workaround for modeling central HPWHs by assuming the system is equivalent to a prescriptive central large gas water heater; however, this does not allow the project to take credit for the higher efficiency heat pump technology. Additionally, since there is a single water heater serving multiple apartments this approach triggers the solar thermal prescriptive requirement and the workaround subjects the project to a compliance penalty when solar thermal is not installed.

Case 2 – City of Davis Ordinance: This case applies to Buildings A & B only which are subject to the City of Davis above code ordinance for low-rise residential buildings. For this case, the option that natural gas is not available onsite was chosen. The water heating is modeled with the proposed HPWHs, each one serving individual apartments to take credit for the HPWH performance. All other aspects of the model are the same as Case 1.

Table 4 summarizes performance of each building relative to the 2016 Title 24 code for these two cases. Also presented are available incentives through CMFNH. Because of the HPWH modeling assumptions, only 32 units were eligible for incentives.

Table 4: Compliance Results Summary

Building	***Compliance Margin***		***CMFNH Incentive***
	Case 1	***Case 2***	
Building A	12.7%	34.9%	n/a
Building B	11.7%	33.3%	n/a
Building C (East\West)	10.9 % \ 9.3%	n/a	$4,400 \ n/a
Building D (East\West)	10.9 % \ 9.2%	n/a	$4,400 \ n/a

PV was sized to offset 100% of the estimated on-site energy use on an annual basis, including site lighting, community center and elevators. PV systems, located on each building rooftop, will offset on-site apartment and common area electricity use through net generation output metering and virtual net energy metering (VNEM) accounting. Apartments will be individually metered. The HPWHs serving all of the apartments are on the building energy meter serving other common area loads, including elevators and exterior lighting. VNEM allows the electricity produced by a single solar installation to be credited toward multiple tenant accounts in a multifamily building without requiring the solar system to be physically connected to each tenant's meter.

Table 5 presents annual electricity use estimates for the entire community. 207.7 kW-DC of PV capacity is required to offset 100% of estimated annual electricity use.

Table 5: Estimated Electricity Use and PV Capacity Requirements

Building	Estimated Electricity Use (kWh) Apartment Meters	House Meter	Total	PV Capacity for ZNE (kW-DC) Apartment Meters	House Meter	Total
Building A (2-story)	27,927	3,485	31,411	16.9	2.1	19.1
Building B (3-story)	42,657	7,956	50,614	25.9	4.8	30.7
Building C (4-story)	91,065	14,285	105,349	55.3	8.7	63.9
Building D (4-story)	91,112	14,285	105,398	55.3	8.7	64.0
Community Center	4,375	48,119	52,495	2.7	22.4	31.9
Site Lighting	0	8,260	8,260	0.0	5.0	5.0
Total Energy	**257,136**	**96,391**	**353,527**	**156.0**	**58.5**	**214.5**

Notes:
1. Energy values are estimates based on CBECC-Res, CBECC-Com, & BEopt energy modeling tools and engineering judgements. Frontier Energy does not guarantee electric usage; energy use will vary based on occupancy and appliance usage by occupants, thermostat settings, and other occupancy variables.
2. PV capacity based on SunPower modules located on South facing 2:12 pitch roofs and 1,648 kWh/kW.
3. Lighting energy use is estimated based on prescriptive code requirements and assumptions in the compliance software.
4. House meters include water heating, exterior lighting, elevators, and support space energy loads.

The final building design specifications are summarized in

Table 6. Measures highlighted in red and underlined reflect where the specifications changed from the base design specifications.

Table 6: Final Efficiency Specifications

Building Component Efficiency Feature	Final Specification
Envelope	
Exterior Walls	2x6 16"oc walls, R21 cavity. No exterior insulation
Demising Walls	2x6 walls, R-21 cavity
Foundation Type & Insulation	Uninsulated slab
Floor (above unconditioned space)	R-21 cavity insulation
Roof/Ceiling Insulation & Attic Type	Vented attics: R-38 at ceiling + R-19 below roof deck Flat roof: R-38 in rafters
Roofing Material & Color	Comp. shingles, cool roof material

Building Component Efficiency Feature	**Final Specification**
	0.20 aged solar reflectance, 0.85 thermal emittance
Radiant Barrier	No
Window Properties: U-Value / SHGC	Operable: U-factor = 0.30 Btu/ft2-hr-F / SHCG = 0.22 Fixed: U-factor = 0.25 Btu/ft2-hr-F / SHCG = 0.22
Opaque Doors	Insulated steel door
Quality Insulation Inspection Credit (HERS)	Yes
House Infiltration - Blower Door Test (HERS)	n/a
HVAC Equipment	
System Type, Description & Efficiency	2- & 3-Story Buildings: Amana PTHP, 3.0 COP, 9.7 EER. 4-Story Buildings: MSHP, 22.6 SEER, 13.0 EER, 11.7 HSPF (Panasonic CU-XE15SKUA/CS-XE15SKUA)
Duct Location & Insulation	no ducts
Mechanical Ventilation	Continuous exhaust per ASHRAE 62.2. Located in bathroom
Nightime Ventilation Cooling	None
HERS Verified Refrigerant Charge	n/a
HERS Verified Cooling Airflow >= 350 cfm/ton	n/a
HERS Verified Fan Watt Draw <= 0.58 W/cfm	n/a
Water Heating Equipment	
System Type, Description & Efficiency	Apt Bldgs.: 80gal Rheem HPWHs serving 4 units Community Center: (2) 80gal Rheem units serving 1st floor & manager's apt.
Solar Water Heating	None
Distribution Type	No recirculation. All pipes in unit insulated per code
Hot Water Fixtures	Per CALGreen
Appliance & Lighting	

Building Component Efficiency Feature	**Final Specification**
Lighting Type	100% LED lighting (per code)
Lighting Controls	Per code
EnergyStar Appliances	Refrigerator, no dishwasher in units
Cooking	Electric
Clothes Washer/Dryer	None in units, central facility
Home Energy Management System	n/a
Notes: 1. Items underlined and in red reflect changes from the base design specifications	

1.5 High Performance Windows

In October of 2018, Frontier re-evaluated high performance windows. There was renewed interest from PG&E in supporting a project that implemented triple pane windows as a code readiness measure for the 2022 Title 24 code cycle. The general contractor worked with their window contractor to obtain bids for two fenestration products: a high-performance dual pane product with a 0.24 U-factor and a triple pane window option from Plygem with a 0.21 U-factor.

Table 7 summarizes the incremental window costs. The updated cost for the 0.24 U-factor product (Bid #2) was higher than the original bid (Bid #1) presented in Table 3, due to changes in supplier costs. The general contractor received two bids for the Plygem triple pane window option. Both are shown in Table 7 but the contractor felt that the lower bid was probably best to use. These costs are higher than those reported on in the May 2018 study on high performance windows by Frontier Energy for PG&E, which reported on average cost increase for triple pane windows with a U-factor of 0.21 of $7.00 per square foot of window.[8]

Table 7: High Performance Window Costs

Bid	Description	Total Cost[1]	Total Inc. Cost	Inc. Cost / sqft[2]	% Cost Increase
0. Baseline Spec	Dual Pane: U-factor = 0.30; SHGC = 0.23	$242,369			
1. 2017 Bid[3]	Dual Pane: U-factor = 0.24; SHGC = 0.23	$280,979	$38,610	$6.01	16%
2. Oct 2018 Bid	Dual Pane: U-factor = 0.24; SHGC = 0.23	$298,288	$55,920	$8.70	23%

[8] "Energy Savings Potential and Cost-Effectiveness Analysis of High Efficiency Windows in California", Frontier Energy, May 2018. http://title24stakeholders.com/wp-content/uploads/2018/07/HighPerformanceWindows.pdf

3. Oct 2018 - LOW Bid	Plygem Triple Pane: U-factor = 0.21; SHGC = 0.23	$304,335	$61,966	$9.64	26%
4. Oct 2018 - HIGH Bid	Plygem Triple Pane: U-factor = 0.21; SHGC = 0.23	$322,505	$80,136	$12.47	33%

[1]Costs include builder 10% O&P.

[2]Cost per square foot of window area. Based on total project glazing area less the community spaces at the community building and the round and pictures windows.

[3]Based on original optimization analysis in 2017 and incremental cost of $350/apartment + 10% O&P

TRC evaluated the impact on CMFNH incentives with windows that meet the program high performance window specification (0.24 U-factor). CMFNH also agreed to evaluate the energy models with prescriptive water heating and add in the 0.35 solar fraction, as long as the project agrees to install high performance windows. These two changes resulted in a substantial increase in the available incentive from $8,800 for the base incentive to $38,470. The majority of the incentive increase was due to the additional water heating credit and evaluating proposed water heating as equivalent to the prescriptive case.

Table 8: Summary of CMFNH Incentives for High Performance Windows

	Proposed Design	Prescriptive DHW	Prescriptive DHW + HPF
Building A (10 units)	--	**$2,600**	**$3,350**
Building B (16 units)	--	**$4,160**	**$5,360**
Building C1 (16 units)	**$4,400**	**$6,240**	**$7,440**
Building C2 (16 units)	--	**$6,240**	**$7,440**
Building D1 (16 units)	**$4,400**	**$6,240**	**$7,440**
Building D2 (16 units)	--	**$6,240**	**$7,440**
TOTAL CMFNH Incentive (90 units)	**$8,800**	**$31,720**	**$38,470**

Proposed Design = as submitted

Prescriptive DHW = *Proposed design with prescriptive DHW credit (Solar Fraction 35%)*

Prescriptive DHW + HPF = *Proposed design with prescriptive DHW credit (Solar Fraction 35%) & High Performance Fenestration (U-0.24/SHGC-0.23)*

Incentives through the CMFNH program would offset close to 50% of the incremental cost based on the low Plygem bid. While the developer was interested in upgrading the windows if there was no additional cost to the project, the final decision was to not install triple pane windows at Creekside and stick with the original window specifications. The project team felt that the schedule was too tight to pick up this change order and changing the windows would result in delays to the construction start date. The contractor also had concerns about whether the Plygem windows would meet all required specifications and testing requirements for four-story buildings.

4. Discussion

The Creekside project will be the first ZNE affordable multifamily project in the city of Davis. 100% of the project's estimated annual electricity use is designed to be offset by onsite solar PV generation. This benefits both the State of California and the City of Davis by supporting climate action plans and reducing operational greenhouse gas emissions, as well as the project's future occupants and building owner who will both benefit from low utility bills and safe and comfortable living conditions. By converting traditionally natural gas end uses (space heating, water heating, and cooking) to electricity, and offsetting those end uses with on-site renewable generation, significant greenhouse gas reductions are realized.

Using the cost effectiveness methodology, which compared the first cost of efficiency measures with savings in the first cost of PV required to offset the estimated energy use, very few measures were found to be cost effective. Low estimated energy loads, a relatively efficient baseline building design, as well as the continuing decline in the cost of PV made it difficult to justify the cost of additional efficiency measures on first cost alone. Most design decisions were made to ensure that the project met the Title 24 energy code performance requirements. The main driver in HVAC system selection was due to differences in compliance and modeling assumptions between CBECC-Res and CBECC-Com, which resulted in distinct designs across the two building types.

The ZNE goal drove the decision to be all-electric, replacing the basecase gas boiler with electric HPWHs. The all-electric strategy created compliance challenges with the 2016 Title 24 code surrounding the use of central HPWHs for domestic hot water. The challenges included both modeling limitations as well as the relatively high TDV value of electricity compared to natural gas. The latter issue has been resolved for the 2019 Title 24 code for individual water heaters with changes made so that projects with electric water heating are always compared to an electric water heating baseline. The modeling limitations still exist for central HPWHs. The Energy Commission is aware of the limitations and is currently working on developing this capability in the software, although the timing for this is unknown. There currently is no prescriptive option for central electric water heating in the Standards.