Appendix E

ZNE+ Energy Summary

Appendix E --ZNE+ Packages

ZNE+ For Avila Ranch

The State of California is on track to amend theCalifornia Energy Code (Title 24 Part 6, Residential Energy Efficiency Standards) in 2019 to require all low-rise residential buildings (3 stories or less) to be Zero Net Energy (ZNE) by 2020, using the California Energy Commission's Design Rating criteria for Time Dependent Valuation (TDV). These new regulations would require a higher level of energy efficiency for a residence's mechanical and envelope systems, and will require that there be onsite production of a residence's energy requirements. It is expected that these regulations would require that there be significant solar photovoltaicsystems (PV) on each unit, and that construction would involve higher efficiency appliances, advanced construction techniques to reduce space cooling and heating loss, and other measures.

The Avila Ranch Development Plan's Design Framework establishes energy efficiency and production goals that meet and exceed the expected 2019 ZNE regulations. The Design Framework refers to this as a "ZNE+" objective since the goal is to exceed the expected 2019 regulations, and to establish them for the Avila Ranch project area ahead of their expected implementationin 2020 and after. Three different ZNE+ packages were designed to identify compliance using an all-electric option, a natural gas heating option, and a hybrid option that included electric space heating and cooling with a heat pump.

Jennifer Rennick Architecture and Consulting (JRAC) was asked to study and develop these sample ZNE+ Packages for the Avila Ranch Development Plan with the intent of identifying energy efficiency improvements above the current 2016 Energy Code that would be cost effective for the consumer. That is, the intent was to identify improvements that would financially benefit owners and tenants over the long term. JRAC was also asked to identify the appropriate size of solar PV units for each product type in Avila Ranch to inform the Development Plan's design guidelines and to ensure that the solar PV units would be integrated into the house designs up front rather than added as a retrofit. This is the technical backup for Section 13 of the Development Plans Design Framework.

This Appendix summarizes the key outcomes of the study. For this analysis two single family (R-1 and R-2) houses and onemulti-family building (R-3or R-4) were studied. The energy use analysis was performed with Title 24 Compliant Software (CCBEC-Res with 2019 TDV) under climate zone 5, for San Luis Obispo. Each building was compared to a code compliant baseline building of the same size auto-generated through the CCBEC-Res software as required for code compliance.

These sample ZNE+ Packages are not meant to be prescriptive requirements, but are supporting documentation to illustrate the potential to meet and exceed zero net energy construction for the Avila Ranch Development. The actual package to achieve compliance with Avila Ranch's ZNE+ requirements will be made at the time that the building is designed and each permit application is submitted to the City for building permits. Therefore, the packages represented in Tables 1.1, 1.2 and 1.3 should be considered prototypical packages based on the prototypical building envelop and the building assumptions in the analysis.

ZNE+ Compliance Options

The goal was to demonstrate potential for ZNE+ packages that exceed the proposed 2019 TDV Energy Standards with a 100% annual energy offset with renewable energy, and to establish a factual basis for the implementation of the recommendations in Section 13 of the Design Framework for the Avila Ranch Development Plan. The team set an initial target of 15% better than the proposed 2019 Standards Energy Code. Three scenarios were tested: 1) natural gas as a primary fuel source; 2) an all-electric (no natural gas) option; and, 3) a hybrid option using a high efficiency heat pump for space conditioning and using a high efficiency instantaneous gas hot water heater (EF 96%) vs the tank-type heat pump water heater. The third, "hybrid" option was included to identify a ZNE+ 'package' that would meet the 15% Better than 2019 TDV Standard using less natural gas than the 'Package' listed in Table 1.1.

Results Summary

When natural gas is used as the primary fuel source for space heating or hot water heating, demonstrating 15% better than 2019 TDV baseline can be achieved in cost effective ways for single family and multi-family units. Typical construction would include R-38 roof insulation with 10" nominal heel height, Advanced Framing with 2"x6" stud walls with 24" spacing, and R-21 wall insulation with a R-5 continuous insulation membrane or sheathing, high efficiency gas furnace, with split AC system (if used), and instantaneous high efficiency tankless water heaters.Table 1.1 shows a ZNE+ package that would use natural gas as the primary fuel source.

When the team investigated all-electric options, as part of a possible strategy to reduce the carbon footprint and GHG emissions, the target goal of 15% better than 2019 TDV Standards was shown to be less cost effective. For all-electric strategies (i.e., electric heat pump for space heating and electric heat pump 50-gal tank for water heating), a ZNE+ goal of up to 5% better than 2019 Standards was found to be cost effective and achievable with some additional construction assembly improvements. The two most significant changes for the single-family units to achieve the ZNE+ goal was moving the ducts from the attic and placing them within the conditioned envelope and employing R-7 perimeter slab insulation. For the multi-family units, the most significant change was moving away from a ducted system to an efficient min-split VRF system. Table 1.2 shows the ZNE+ package for the all-electric option.

The third "hybrid" fuel scenario uses high efficiency heat pump for space conditioning and using a high efficiency instantaneous gas hot water heater (EF 96%) vs the tank-type heat pump water heater. Using the instantaneous high efficiency water heater was specifically considered for Avila Ranch because of lower water use planned for Avila Ranch and the latest research around the inefficiencies of tank-type water heaters for low-water use applications. Stand-by tank losses are proportionately high for low water users, and the actual efficiency of tank-type heat pump water heaters is often much lower than expected. High efficiency instantaneous gas water heater (EF 96%) is predicted to use approximately 100 therms/yr per household, compared to 1,100 KWh/yr for a high efficiency tank-type heat pump water heater (EF 2.75). Since the time dependent value of electric energy use is weighted differently than gas use, and that under the current standards gas instantaneous water heating is the baseline for domestic hot water (DHW), a gas DHW option is capable of exceeding the 2019 ZNE Energy Code standard by an additional 10% above that for the all-electric option represented in Table 1.2. See Table 1.3 for the prototypical ZNE+ package for this option.

Table 1.1 2019 TDV Construction Summary: min 15% Better than 2019 TDV Standard--Natural Gas Package

Building Type	One-Story R-1	One-Story R-2	Two-Story Multi-Family R-3
Dwelling Units	1	1	8
Floor Area (ft2)	1956	775	6960
Roof Area (ft2)	1956	775	3480
Window-to-Floor Area Ratio	11%	13%	15%
Window U-Factory	0.32		
Window SHGC*	0.50		
Attic/Roof Assembly	Light Weight Roof (asphalt) over wd Sheathing, R-38 Attic		
Wall Assembly	Advanced Framing: 2x6 with 24" spacing, R-21 Cavity + R-5 Continuous		
Floor Assembly	Slab on Grade		Slab on Grade, R-19 Wd Joist
Cooling System	Split DX SEER 13		Split DX SEER 13
Heating System	Gas Furnace AFUE 95.5%, Sealed unit		Gas Furnace AFUE 80%
HVAC Distribution	Attic, R-8 Ducts		Condition Space (Floor), R-6 Ducts
Domestic Water Heating	Instantaneous Tankless EF 96%, all pipes insulated		Instantaneous Tankless EF 96%, all pipes insulated

*** South facing "passive solar" glass --high Solar Heat Gain Coefficient (SHGC)**

Table 1.2 2019 TDV Construction Summary: 5% Better than 2019 TDV Standard --All Electric Package

Building Type	One-Story R-1	One-Story R-2	Two-Story Multi-Family R-3
Dwelling Units	1	1	8
Floor Area (ft2)	1956	775	6960
Roof Area (ft2)	1956	775	3480
Window-to-Floor Area Ratio	11%	13%	15%
Window U-Factory	0.32		
Window SHGC *	0.50		
Attic/Roof Assembly	Light Weight Roof (asphalt) over wd Sheathing, R-38 Attic + R-5 Continuous Deck Insulation		
Wall Assembly	Advanced Framing: 2x6 with 24" spacing, R-21 Cavity + R-5 Continuous,		
Floor Assembly	Slab on Grade, R-7 Perimeter		Slab on Grade, R-19 Wd Joist
Cooling System	Heat Pump		Heat Pump, VRF
Heating System	Heat Pump HSPF 9.5		Heat Pump HSPF 9.5
HVAC Distribution	Conditioned Space, Sealed and Tested		No Ducts
Domestic Water Heating	Heat Pump 50-galTank EF 2.73, HERS Compact Plumbing, all pipes insulated		2x Heat Pump 80-gal Tank EF 3.02, all pipes insulated

*** South facing "passive solar" glass --high Solar Heat Gain Coefficient (SHGC)**

Table 1.3 2019 TDV Construction Summary: min 15% Better than 2019 TDV Standard -- Electric Heat Pump Space Conditioning with Gas DHW Package

Building Type	One-Story R-1	One-Story R-2	Two-Story Multi-Family R-3
Dwelling Units	1	1	8
Floor Area (ft2)	1956	775	6960
Roof Area (ft2)	1956	775	3480
Window-to-Floor Area Ratio	11%	13%	15%
Window U-Factory	0.32		
Window SHGC *	0.50		
Attic/Roof Assembly	Light Weight Roof (asphalt) over wd Sheathing, R-38 + R-5 Deck Insulation		Light Weight Roof (asphalt) over wd Sheathing, R-38 Attic
Wall Assembly	Advanced Framing: 2x6 with 24" spacing, R-21 Cavity + R-5 Continuous		
Floor Assembly	Slab on Grade, R-7 Perimeter		Slab on Grade, R-19 Wd Joist
Cooling System	Heat Pump		Heat Pump, VRF
Heating System	Heat Pump HSPF 9.5		Heat Pump HSPF 9.5
HVAC Distribution	Conditioned Space, Sealed and HERS Tested		No Ducts
Domestic Water Heating	Instantaneous Tankless EF 96% , HERS Compact Plumbing, all pipes insulated		X8Instantaneous Tankless EF 96% HERS Compact Plumbing, all pipes insulated

*** South facing "passive solar" glass --high Solar Heat Gain Coefficient (SHGC)**

PV System Size

For Zero Net Energy (ZNE), the actual solar electric PV systems will be sized to offset the total predicted energy use (electricity and gas, as appropriate) using the Energy Design Rating (EDR) calculated by Title 24 complaint software. For this study, it was necessary to estimate the solar electric systemsize to meet the State's ZNE goals, given that the 2019 Rule Set has not yet been approved by the California Energy Commission (CEC). For the purposes of the table below, PV size was also considered on the higher end of the use range, and allow for the possible use of an all-electric (Option 2) energy/fuel approach. The Avila Development Plan will provide for primary electrical connections for clothes dryers, cooking appliances, and EV connections. This allowance will also permit the generation of an adequate amount of electricity for EV car charging (estimated at 3,500 kWh/year) and household use for Option packages 1 and 3. The Table below summarizes the approximate roof area required for a solar electric system meeting the project's Zero Net Energy goals.

Table 2.0 Roof Area Study for Solar Electric System Needed for ZNE

Neighborhood Plan Designation	Density Type	Total Unit Count	Total Buildings per Density Type	Roof Area per Building	Potential Roof Area Readily Available	Roof Area Needed per Building
R-1	Low	101	101	800-1000	280-350	300
R-2	Medium	297	297	775-1000	270-350	250
R-3	Med-High (multi-story)	161	12	3,850	2,310	3,208 **
R-3	Med-High (duplex)	36	18	2,000	800	500
R-4	High (65 unit)	65	1	26,600	19,950	16,250**
R-4	High (30 unit)	60	2	11,200	8,400	7,500**

Roof Area Readily Available based on the following:

Low and Medium density: Potential Roof Area is 35% of Building Roof Area
Med-High (multi-storey): Potential Roof Area is 60% of Building Roof Area; Assumes 3-story buildings
Med-High (duplex): Potential Roof Area is 40% of Building Roof Area
High density: Potential Roof is 75% of Building Roof Area; Assumes 2-story flat roof buildings

****** Additional covered carport will likely be needed in addition to building roof top solar. Solar canopies included in R-3 and R-4 for other design reasons and for parking lot shading.

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Avila Ranch Development Plan Energy Analysis of R-1 Single Family and R-2 Small Cluster Concept Plans

Jennifer Rennick Architecture and Consulting (JRAC) investigated the energy performance of several prototypical residential designs. Each of the designs were modeled 'as-is' under the 2016 CBECC Res standards with 2019 TDV. The 2019 TDV version of the CEC sanctioned software is for research purposes only, and is currently the best available tool for informing teams about future project requirements. All modeling is assumed to be in Climate Zone 5, San Luis Obispo.

JRAC looked at two residential building types: Single Family Res (R-2) approx 775 sq. ft. (see Table 1) and Single Family Res (R-1) approx 2,000 sq ft. (see Table 2)

For both building types, the energy models were based on actual projects built under prior code cycle (2013 standards) or a viable project designed/modeled with prior code cycle requirements. In each case, the projects were modeled with an initial Baseline to meet the current prescriptive requirements (2016 Standards). Under 2019 TDV CBECC-Res software the projects required several modifications in order to be considered compliant under the 2019 TDV CBECC-Res version of the software.

For projects built under the 2019 Standards (scheduled to be implemented Jan 2020), California's goal of all new Residential construction to be Zero Net Energy (ZNE) beginning 2020 will be in full swing. As the energy standards continue to raise the bar for energy efficiency, head toward ZNE, and *continue to favor gas over electric for space heating and DHW*, it may become increasingly expensive to set project goals and/or reach-codes in terms of a "% better than Title 24" for residential customers who would prefer to minimize their use of natural gas. In Tables 1 and 2, the electric heat pump options appear to be less efficient than their natural gas counterparts. In the midst of ZNE, beating Title 24 by a particular percentage or margin, may not be relevant as the PV system size will be nearly the same regardless of the fuel source.

Table 1. Efficiency Measure Cost & Performance Trade-offs

Avila Ranch - R-2 Sm Concept (775 sq ft)

***Baseline (2016 Prescriptive)**: Tankless DHW EF 82%, 80%AFUE forced air furnace, R-30 ceiling, 2x6 R-19 + R-5 continuous*

Window U-value 0.32, SHGC 0.25

Efficiency Measure	2019 TDV Standard (Title 24) Compliance Margin	Incremental Improvement	Cost Premium	Cost/Unit Note	Proj. ROI
Baseline (2016 Prescrptive)	-35.90%		n/a	Costs added to base	n/a
Tankless DHW EF 95.5%	-27.30%	8.60%	$ 350	.82=$850/.95=$1150	5.8%
95% AFUE (Low Leakage Unit -York brand)	-17.20%	10.10%	$ 700	Varies with sub	11%
Higher Solar Gain Windows (SHGC 0.5)	0.10%	17.30%	$ (100)	Limits suppliers	131%
Slab Edge Insulation (R-7)	5.60%	5.50%	$ 225	$150Mtl/75Lab.	17.0%
Increase Ceiling Insulation	8.60%	3.00%	$ 495	0.65/sf more	6%
Increase Ceiling Insulation with heel truss	9.10%	0.50%	$ 375	estimated	1.5%
Adv.R-28 Wall (2x6 BIBS+R5, QII)	13.30%	4.20%	$ 50	$1.55sf>R19batts*1	20%+
Adv.R-32 Wall(2x8 BIBS+DC14, QII)	13.20%	-0.10%	$ -	Less labor,better*2	0.0%
Sealed and Tested (Blower Door 2 ACH50)	13.40%	0.20%	$ 300	ACH=air chngs/hr	1%
SEER 20 MiniSplit	6.20%	-7.20%	$ -	40kBTU oversized*3	n/a
			$ 2,045	**Subtotal prior to solar**	15%
3kW PV			$ 10,500		8%
			$ 12,545	**Cumulative ROI Benefit to Customer/Home Buyer**	10%-13%

Footnote*1: This scenario combines an advanced framing upgrade which costs less than conventional 2x6 framing (after learning curves) with the increased performance of blown in blanket (BIB) Optima fiberglass walls which produces a 60% improvement in wall assembly performance for about the same cost of construction. We see this as significant added value that will result in a perceived difference in performance to the home owner, and a critical variable in achieving cost-effective zero energy. It is important to note that full advanced framing requires windows and doors to be designed on grid with framing that is 24" o.c. as much as possible.

Footnote*2: Significantly fewer install issues with higher R-value favoring 2x8 wall assembly with thinner R-1 foam rainscreen compared to 2x6 with exterior foam considering Hardie siding warranty requirements.

Footnote *3: Given higher building envelope insulation values required by code, the smallest single stage 40kBTU furnaces currently available on the market are are oversized for homes under 1200 s.f. and right sized for homes up to 1800 s.f. Given floor plans under 1000 s.f., an oversized 40kBTU furnace will short-cycle (turning on and off frequently) without reaching optimum efficiency and possibly pose potential combustion safety issues such as inadequate flow over the heat exchanger which can cause premature heat exchanger failure and possible CO hazards. For these reasons, minisplit heat pump systems become an appropriate solution which offer high-efficiency heating and cooling at a comparable cost to single stage 40kBTU furnaces. However, due to biases in the modeling algorithyms pertaining to source enrgy calcs, mini-splits appear to result in a lower overall efficiency when in fact they do not result in such an inefficiency when power is offset by rooftop PV solar panels.

Table 2. Efficiency Measures

Avila Ranch - R-1 Single Family (1956 sq ft)

***Baseline (2016 Prescriptive)** : Tankless DHW EF 82%, 80%AFUE forced air furnace, R-30 ceiling, 2x6 R-19 + R-5 continuous, Window U-value 0.32, SHGC 0.25*

Efficiency Measure (Cumulative)	2019 TDV Standard (Title 24) Compliance Margin	Incremental Improvement
Baseline (2016 Prescrptive)	-34.70%	
Tankless DHW EF 95.5%	-30.00%	4.70%
95% AFUE (Low Leakage Unit -York brand)	-17.70%	12.30%
Higher Solar Gain Windows (SHGC 0.5)	-5.50%	12.20%
Ducts in Conditioned Space	8.26%	13.76%
Adv.R-28 Wall (2x6 BIBS+R5, QII) *1	18.10%	9.84%
Adv.R-32 Wall(2x8 BIBS+DC14, QII) *1	18.00%	-0.10%
Slab Edge Insulation (R-7)	24.00%	6.00%
Add R-5 to Roof Deck	25.00%	1.00%
*Electric options*2:*		
above assemblies + Heat Pump 9.5 HSPF (no Furnace)*3	16.10%	-8.90%
above assemblies +Heat Pump 9.5 HSPF and Steibel 220e DHW Heat Pump (no gas)*3	6.00%	-10.10%

***1 Advanced Framing 2x8 with blown-in-blanket (BIBS) and continuous R-1 DC14 exterior insulation OR advanced framing 2x6 with blown-in-blanket (BIBS) and continuous R-5 exterior insulation have similar thermal performance.**

***2 Due to biases in the modeling algorithyms pertaining to source enrgy calcs, electric heat pumps appear to result in a lower overall efficiency when in fact they do not when energy use is off-set by solar PV's.**

***3 ZNE calculations will likely be based on Total TDV and as such will include an 'equivalent' PV off-set for natural gas use. Assuming 15 panels (Solar World 285) the system is estimated to produce 7,344 kWh anually and will require approx 275 sf ft of clear roof, excluding fire access routes.**

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BASIC CHARGING STATION CIRCUIT REQUIREMENTS

In accordance with the National Electrical Code (NEC), all residential plug-in vehicle charging circuits are required to or should include the following:

CIRCUIT BREAKER

Level 1 — A 15- or 20-amp, single-pole breaker is required.

Level 2 — A 40-amp, two-pole breaker and dedicated circuit are necessary.

ELECTRIC VEHICLE CHARGING STATIONS

Level 1 — A 15- or 20-amp standard residential wall plug and receptacle are acceptable for 120-volt charging.

Level 2 — According to the NEC, installation of 240-volt electric vehicle charging station should be wired permanently to the electrical supply circuit. The charging station may vary in design, depending on the manufacturer and vehicle type, but it must meet specifications set forth in the NEC. These specifications include:

- Equipment that is listed and labeled
- A connector in compliance with Society of Automotive Engineers standard J1772
- Ground fault protection
- Diagnostic capability to prohibit charging from taking place when the batteries or vehicle is damaged or an unsafe condition exists
- An interlock that de-energizes the charging cable when the vehicle is disconnected from the charging station or if excessive strain is placed on the cable/cord

Customers should check with the auto manufacturer to determine what type of plug-in vehicle charging station is required and should consult local code officials to determine specific installation requirements.

PERMITS

Local government permits may be required prior to installation or construction. The local building and safety department should be consulted to determine specific requirements. If an electrical contractor is hired to perform the work, it is still the homeowner's responsibility to ensure that the appropriate permits have been obtained.

INSPECTIONS

If permits are required, a city or county building inspection must be completed prior to activation of the new charging circuit for the plug-in vehicle. It is the homeowner's responsibility to verify that all required inspections are completed satisfactorily.

INSTALLATION COSTS

Installation costs for plug-in vehicle charging stations can vary greatly depending on the configuration of the home and electrical circuitry, local code requirements and the type of charging station installed. A licensed electrical contractor should be consulted for a cost estimate.

For questions regarding electric vehicles, call **(602) 236-9621**.

BASIC 10-1073-01 07/10

Energy Breakdown for R-1 Unit --approx 2000 sqft home

End Use	Standard with Elec HP HVAC (gas DHW +gas cook + gas cloths dry): Standard Design Site (kWh)	Standard Design Site (therms)	2019 Standard Design (kTDV/ft2-yr)	2016 Standard Design (kTDV/ft2-yr)	third option 'Hybrid' (gas DHW + gas cook+gas clothes dry): Design Site (kWh)	Design Site (therms)	2019 Design (kTDV/ft2-yr)	2016 Design (kTDV/ft2-yr)	second option ("all electric" w/ gas cook only): Design Site (kWh)	Design Site (therms)	2019 Design (kTDV/ft2-yr)
Space Heating	2157		28.51	20.37	1741		23.22	16.47	1741		23.22
Space Cooling	0				0		0		0		0
Indoor Fans (IAQ Ventilation)	110		1.56	1.23	110		1.56	1.23	110		1.56
Water Heating		118.8	12.08	10.11	23	101.8	10.68	8.92	1092		16.04
Compliance (Regulated TDV) Sub Total			***42.15***	*31.71*			***35.46***	*26.62*			***40.82***
compliance Margin			*0%*	*0%*			*15.87%*	*16.10%*			*3.16%*
Indoor Lighting	479		7.89	5.46	479		7.89	5.46	479		7.89
Appliances & Cooking	909	43.7	18.24	14.28	909	43.7	27.39	20.89	1705	13.9	27.39
Plug Loads	2026		30.07	22.93	2026		30.07	22.93	2026		30.07
Outdoor Lighting	112		1.72	1.19	112		1.72	1.19	112		1.72
TOTAL	**5,793.0**	**162.5**	**100.1**	**75.6**	**5,400.0**	**145.5**	**102.5**	**77.3**	**7,265.0**	**13.9**	**107.9**

Nominal Energy Cost

Notes:

HVAC HSPF 8.0 to 9.5 and ducts in conditioned space rec	5.29	and kWh:	416	
DHW EF 0.80 to 0.96 reduces 2019 TDV:	1.4	and Therms:	17	
Compact Plumbing reduces 2019 TDV:	0.74	and Therms:	4	(not shown above)

End Use	Standard (gas HVAC +gas cook + gas cloths dry): Standard Design Site (kWh)	Design Site (therms)	2019 Standard Design (kTDV/ft2-yr)	first option (gas HVAC +gas cook + gas cloths dry): Standard Design Site (kWh)	Design Site (therms)	2019 Standard Design (kTDV/ft2-yr)
Space Heating	165	191.7	23.28	161	159.4	19.58
Space Cooling	0			0		
Indoor Fans (IAQ Ventilation)	110		1.56	110		1.56
Water Heating		118.8	12.08		100.6	10.23
Compliance (Regulated TDV) Sub Total			***36.92***			***31.37***
compliance Margin			***0%***			***15%***
Indoor Lighting	479		7.89	479		7.89
Appliances & Cooking	909	43.7	18.24	909	43.7	18.24
Plug Loads	2026		30.07	2026		30.07
Outdoor Lighting	112		1.72	112		1.72
TOTAL	**3,801.0**	**354.2**	**94.8**	**3,797.0**	**303.7**	**89.3**