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MEMORANDUM

May 29, 2024

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Cc: Leila Silver (Integrated Design 360, Inc.)

From: Avani Goyal, Justin DeBlois, Antonea Frasier, Farhad Farahmand (TRC)

Re: Compliance Reality Testing for 2022 Palo Alto Reach Code

OVERVIEW

The City of Palo Alto requested a compliance reality testing analysis of actual building plans in the city to assess feasibility of reaching the proposed reach code margins per the Hourly Source Energy (HSE) Energy Performance approach.[1] TRC provides this memo to inform the methodology and results of the compliance testing of different building types based on the characteristics of the actual building plans shared by Palo Alto.

Cost-effectiveness studies produced by the California Investor-Owned Utilities (IOU) Codes and Standards Program serve as the primary source of information for proposed reach code HSE margins. For various measure packages, these studies demonstrate HSE compliance margins that are achievable for new construction in Palo Alto (Climate Zone 4) while meeting the two criteria:

1) Cost-effective, for approval by the California Energy Commission (CEC).
2) Technically feasible, using appliances with efficiencies set at the minimum federal requirements.

The statewide IOU team cost-effectiveness studies use representative building prototypes with commonly used building system configuration in California and prescriptive specifications per 2022 Title 24 code. The reality testing analysis made necessary modifications to the building prototypes based on the actual Palo Alto building plans to assess if the proposed HSE margins could be extended to actual construction practices in the city.

TRC evaluated four building types for the reality testing analysis, as prioritized by the City staff,

1. Accessory Dwelling Unit (ADU)
2. Standalone Retail
3. Midrise Mixed-Use Multifamily
4. Restaurant

TRC reviewed the building plans for the four building types, compared it to the statewide study assumptions, and modified the prototypes as necessary to evaluate corresponding HSE margins. Additional simulation packages with measures including high performance envelope, solar PV, space conditioning or water heating system configuration were evaluated where necessary to assess the feasibility of a compliant pathway of meeting proposed reach code.

[1] HSE is a new compliance metric introduced in 2022 California Building Energy Efficiency Standards representing the underlying fuel sources such as coal, natural gas or solar used to power building systems and equipment. Source energy includes transmission, delivery and production losses. A more thorough description of HSE compliance metric and relationship with other metrics is included in this Energy Code Ace document, excerpted at the end of this memo.

REALITY TESTING RESULTS

This section describes the testing approach for each building type and the corresponding results as it pertains to the proposed reach code.

Accessory Dwelling Unit (ADU)

In single family including ADUs, the HSE metric is instead referred to as Energy Design Rating 1 (EDR1). EDR1 margins meeting the two criteria listed above are contained in the 2022 Cost-Effectiveness Study: Single Family New Construction Study (Report) and workbook (SFNC Study Data) for a 2,400 sqft. single family building and a 675 sqft. detached ADU.

The statewide cost-effectiveness study results show 2.4 EDR1 to be cost-effective for all-electric detached ADU in climate zone 4 using City of Palo Alto Utilities (CPAU) rates, while the mixed-fuel ADUs can achieve up to 13 EDR1 with added measures including battery storage. The City proposes a reach code of 2.0 EDR1 to be conservative and account for small homes.

For reality testing, TRC reviewed the building plan shared by Palo Alto for a small all-electric 275 sqft. detached ADU, with a variable capacity heat pump, heat pump water heater and envelope specifications similar to 2022 Title24 code prescriptive requirements. The specifications are summarized in Table 1 below.

Table 1. ADU - Palo Alto Building Specification

Parameter	Palo Alto building specification
Conditioned Floor Area (sqft.)	275
HVAC system	Variable Capacity Heat Pump (VCHP) 8.2 HSPF2, 14 SEER2, 11 EER2
DHW system	Heat Pump (NEEA rated, 50 gal)
Envelope - External Walls	U-factor: 0.083 Cavity insulation: R15
Envelope - Roof	Asphalt shingle light roof R22 sheathing above-deck insulation
Envelope - Ceiling	Wood-framed Aged Solar Reflectance (ASR): 0.1 Thermal Emittance (TE): 0.85
Envelope - Windows	U factor: 0.29/0.28 SHGC: 0.21/0.25 Window-to-wall ratio: 30%
Solar PV (kW)	1.63
Battery Storage (kWh)	None

TRC built the Palo Alto 275 sqft. ADU in CBECC Res software version 2022.2.1 with base model per Table 1 above. The base all-electric model as-is was able to achieve an EDR1 of 1.2 due to low surface area and correspondingly

low energy savings, while it reaches 2.0 with added envelope measures - cool roof (0.63 ASR, 0.75 TE), high performance window (U-factor 0.24), increased wall insulation (U factor 0.048), above deck sheathing insulation (R30) and high efficiency equipment.

Table 2. ADU – EDR1 (HSE) Reality Testing Results

	Source Energy Compliance Margin (EDR1)
Package 1: (As-is) base model	1.2
Package 2: High performance envelope (*Cool Roof, Roof Above deck Sheathing Insulation, High Performance Window, Increased Wall insulation*)	2.0
Package 3: High performance envelope (*Cool Roof, Roof Above deck Sheathing Insulation, High Performance Window, Increased Wall insulation*), High Efficiency equipment	2.0

Takeaway:

All-electric ADU of 275 sf, per the actual building plan from Palo Alto, can achieve the proposed reach code EDR1 margin of 2.0 with added envelope efficiency measures and/or HVAC equipment efficiency above federal code minimum measure.

Midrise Mixed-use Multifamily Building

HSE margins meeting the two criteria listed above are contained in the 2022 Cost-Effectiveness Study: Multifamily New Construction (Report) and workbook (MFNC Study Data) for two multifamily family buildings (3-story, 39,372 ft^2 and 5-story, 140,925 ft^2). For the 5-story IOU study prototype,

- The All-Electric Code Minimum package for achieves an HSE margin of 6%.
- The Mixed Fuel Efficiency + PV package achieves 1%.

The City proposes a reach code requiring 1% HSE margin for both mixed-fuel and all-electric multifamily buildings for four or more habitable stories.

TRC reviewed the actual building plan shared by Palo Alto for an all-electric four story mixed-use multifamily building. It used Packaged Terminal Heat Pumps (PTHPs) in residential dwelling units and a central storage heat pump water heater. The detailed specifications for the Palo Alto mid-rise building plan along with the 5-story multifamily prototype used in statewide IOU cost-effectiveness study are shown in Table 3 below,

Table 3. Multifamily - Palo Alto Building Specification vs. IOU study prototype

	Palo Alto building plan	IOU Study Prototype
Conditioned Floor Area (sqft.)	44,098	95,028
Number of stories	4	5

HVAC system	VRF and DoAS (Nonresidential areas) and PTHP (Residential areas) EER 9.74, COP 3.8	PVAV with hot water reheat (Nonresidential areas) and SZHP (Residential areas) EER 11.7, COP 2.9
DHW system	Packaged single-pass central heat pump COP 2.4	Packaged multi-pass central heat pump COP 2.5
Envelope - External Walls	U – factor: 0.055 Cavity insulation: R5.00	U – factor: 0.059 Cavity insulation: R15
Envelope - Ceiling	U-factor: 0.025	U-factor: 0.028
Envelope - Windows	U - factor: 0.36 SHGC: 0.25	U - factor: 0.30 SHGC: 0.23
Solar PV (kW)	None	253.25 kW
Battery Storage (kWh)	None	61.41 kWh

To evaluate the compliance feasibility of a mixed-use multifamily building in proposed reach code, in four habitable stories or higher category, TRC modified the multifamily building prototype model built in CBECC software version 2022 3.1. and achieved the following results in Table 4 below.

Table 4. Multifamily - HSE Reality Testing Results

	Source Energy (HSE) Compliance Margin (%)
Package 1: (As-is) all-electric base model	-7%
Package 2: High efficiency envelope with cool roof and windows (U-0.24, SHGC-0.23)	-6%
Package 3: 84 kW PV (sized per prescriptive requirement limited by available roof area)	3%

Takeaway:

All-electric midrise multifamily building of 44,098 sqft., 4 stories per the actual building plan from Palo Alto, can achieve the proposed reach code source energy compliance margin of greater than 1% with added measures such as high performance envelope and solar PV.

Nonresidential - Retail

HSE margins meeting the two criteria listed above are contained in the 2022 Nonresidential New Construction Reach Code Cost-effectiveness Study (Report) and workbook (NRNC Study Data) for four nonresidential prototypes (Medium Office, Retail, Quick-Service Restaurant, and Small Hotel). For stand-alone retail building,

- The Mixed Fuel + Efficiency package achieves -15% HSE compliance margin, where the proposed is compared to an all-electric standard design.
- The All-Electric (HVAC + SHW) + Efficiency package achieves 12% HSE compliance margin.

For nonresidential buildings, the proposed reach code exempts Retail and other nonresidential buildings with single zone packaged conditioning systems, that fall under 2022 Title 24 Section 140.4(a)2, because a positive, cost-effective HSE compliance margin was not determined for the mixed-fuel building.

For reality testing, TRC reviewed the building plan shared by Palo Alto for a 28,714 sqft. 2-story retail building with packaged heat pump rooftop units, electric resistance water heaters and envelope specifications close to prescriptive requirements. The specifications are summarized in Table 5 below.

Table 5. Retail – Palo Alto Building Specification vs. IOU Study prototype

	Palo Alto Building Plan	IOU Study Prototype
Conditioned Floor Area (sqft.)	28,714	24,563
HVAC system	Single zone heat pumps (SZHP) and single zone VAV heat pumps (SZVAVHP)	Single zone heat pump RTUs
DHW system	Electric resistance	Electric resistance
Solar PV (kW)	None	61.4 kW (per prescriptive requirement)
Battery Storage (kWh)	None	None

TRC compared the 28,714 sf retail plan with the 24,563 sf retail prototype used in statewide cost-effectiveness analysis and noted the differences.: The retail plan included more detailed thermal zoning and a small second story area. The retail plan also did not include PV or variable speed drives on the larger HVAC systems.

To evaluate the compliance feasibility of retail buildings in the proposed reach code, TRC simulated the 28,714 sf retail model in CBECC software version 2022.3.1 and noted the following results in Table 6 below. Further runs were added with feasible measures to show compliance.

Table 6. Retail - HSE Reality Testing Results

	Source Energy (HSE) Compliance Margin
Package 1: (As-is) base model	-13%
Package 2: 62 kW standard efficiency solar PV system	-1%
Package 3: Variable flow variable speed fan control on heat pumps >65 kBtu/h	9%
Package 4: 62 kW Solar PV + Federal min efficiency heat pump water heaters	2%

Takeaway:

All-electric retail building of 28,714 sf, per the actual building plan from Palo Alto, can achieve the proposed reach code HSE margin of 0% with added measures such as variable speed fan control or photovoltaics with heat pump water heaters.

Nonresidential – Restaurant

HSE margins meeting the two criteria listed above are contained in the 2022 Nonresidential New Construction Reach Code Cost-effectiveness Study (Report) and workbook (NRNC Study Data) for four nonresidential prototypes (Medium Office, Retail, Quick-Service Restaurant, and Small Hotel). For quick service restaurant,

- The All-Electric Code Minimum package achieves 37%.
- The Mixed Fuel + Efficiency package achieves 12%.

The statewide IOU team used a 2,500 sqft. quick service restaurant (QSR) prototype for the statewide reach code analysis and achieved a cost-effective source energy compliance margin of 12% that could be achieved by both mixed-fuel and all-electric buildings.

The City of Palo Alto requested an analysis of small full service restaurant (FSR) and evaluate the feasibility of achieving the proposed reach code margins. TRC used a similar sized quick service restaurant prototype and made necessary modifications in HVAC system including exhaust hoods, water heating system to align with the Palo Alto full service restaurant building plan.

The Palo Alto restaurant had a gas water heater and prescriptive envelope specifications in the building plan. The specifications are summarized in Table 7 below.

Table 7. Restaurant - Palo Alto Building Specification vs. IOU Study prototype

	Palo Alto Building Plan (Full Service Restaurant)	IOU Study Prototype (Quick Service Restaurant)
Conditioned Floor Area (sqft.)	2,228	2,500
HVAC system	VRF heat pump 3.3 COP, 11.5 EER	Packaged heat pump 81% Et, 11.0 EER
Make up air unit	SZVAV	SZVAV
Exhaust	Two fans, Wall mounted canopy Hood length: 18 ft	One fan, Wall mounted canopy Hood length: 13 ft
DHW system	Condensing gas storage 100 gallon, 98% EF	Heat pump storage 100 gallon, 3.12 COP
Appliances	Full range of cooking appliances: Electric fryer, toaster, oven and gas broiler range, dishwasher	Limited appliances: Gas fryer, griddle and small oven
Solar PV (kW)	None	None
Battery Storage (kWh)	None	None

TRC then compared the 2,228 sf FSR plan with the 2,500 sf QSR IOU study prototype used in statewide cost-effectiveness analysis and noted the following differences - the restaurant plan included more extensive kitchen equipment and higher exhaust hood flowrates. The restaurant plan also used VRF systems and a condensing gas water heater.

To evaluate the compliance feasibility of FSR restaurant buildings in the proposed reach code, TRC simulated the 2,228 sf retail model in CBECC software version 2022.3.1 and noted the following results in Table 8 below. Further runs were added with alternate design scenarios to show compliance.

Table 8. HSE Reality Testing Results

	Source Energy (HSE) Compliance Margin
Package 1: (As-is) base model	35%
Package 2: All-electric with heat pump water heater	38%
Package 3: Gas furnace space conditioning	20%

Takeaway:

All-electric full-service restaurant of 2,228 sf, per the actual building plan from Palo Alto, can achieve the proposed reach code HSE margin of 12% with either the base mixed-fuel design, a design with electric water heating, or a design with gas furnace space conditioning. The source-energy savings were primarily due to demand controlled exhaust fans.

Conclusions and Limitations

The reality testing of four building types using Palo Alto specific building plans confirm the feasibility of achieving the proposed reach code HSE margins.

However, this was a quick analysis based on several assumptions and simplifications in energy modeling process. It typically uses a similar building prototype from the statewide reach code studies as the starting point and necessary modifications are made in system specifications to align more closely with Palo Alto building plans. The modifications mainly focus on HVAC and water heating, along with *some* considerations of geometry layout and envelope. It does not account for detailed HVAC controls, water heating plumbing distribution, process loads etc. Based on the high level comparison, the Palo Alto building specifications are not significantly different from the IOU study prototype. Other limitations include the level of detail provided in building plans, accuracy of information in provided compliance documents and software limitations.

Appendix: Single Family Building Summary of Source Energy and Other Metrics

Evolving Compliance Metrics

The 2022 Energy Code continues improvements in energy efficiency ratings in order to pivot new residential buildings toward technologies that will help the state meet its critical long-term climate and carbon neutrality goals.

Energy Code	New Construction	Additions	Alterations
2016	TDV	TDV	TDV
2019	EDRe, EDRt	TDV	TDV
2022	EDRs*, EDRe, EDRt	TDV	TDV

***EDRs** = source energy design; **EDRe** = efficiency energy design rating; **EDRt** = total energy design rating; **TDV** = time dependent valuation.*

The source EDR metric is new for 2022 and enables measure of emissions in some form.

***Table 1.** Evolving Building Energy Efficiency Ratings for Residential Construction*

The 2016 Energy Code used time dependent valuation (TDV) energy as a compliance metric in the Performance Approach for New Construction, Additions and Alterations. TDV energy is the time varying energy used by the building to provide space conditioning, water heating and specified building lighting. It accounts for the energy used at the building site and consumed in producing and delivering energy to a site, including, but not limited to, power generation, transmission and distribution losses.

The 2019 Energy Code replaced TDV with energy design rating (EDR) metrics for New Construction to express the energy performance of a home. In the EDR scoring system 100 represents the energy performance of a reference design building meeting the envelope requirements of the 2006 International Energy Conservation Code (IECC). A score of 0 represents the energy consumption of a building that has zero net energy consumption. The lower the score, the better. For a New Construction project to comply using the performance approach, the proposed Efficiency EDR and Total EDR must be lower than or equal to the standard Efficiency EDR and Total EDR.

The 2022 Energy Code adds a third metric to EDR for New Construction: source energy design rating ERD1 is a separate EDR metric based on hourly source energy which establishes a carbon-proxy analysis of the building in kBTU/sf-yr units to support decarbonization and electrification policy goals.

Source Energy Design Rating (EDR1)	Efficiency Energy Design Rating (EDR2)	Total Energy Design Rating (EDR Total)
A score representing the building energy efficiency expressed in terms of an **hourly source carbon-based metric**	A score representing the building energy efficiency expressed in terms of a **TDV energy-based metric**	A score representing the building's **total TDV energy while also factoring in photovoltaics (PV) and flexibility**
EDR1 includes: ✦ Envelope ✦ IAQ ✦ HVAC ✦ DHW ✦ Unregulated loads	EDR2 includes: ✦ Envelope ✦ IAQ ✦ HVAC ✦ DHW ✦ Unregulated loads	EDR Total includes: ✦ Efficiency measures ✦ Photovoltaics ✦ Batteries ✦ Precooling

***DHW** = domestic hot water; **HVAC** = heating, ventilation and air conditioning; **IAQ** = indoor air quality; **TDV** = time dependent valuation.*

***Table 2.** Energy Design Rating (EDR) as a Compliance Metric*

A building complies only if all three compliance scores are met, which means that each proposed design score is lower than or equal to the standard design score.

Source: Energy Code Ace – Single Family Buildings: What's New in 2022?