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City of Palo Alto
2019 Title 24 Energy Reach Code
Cost Effectiveness Analysis
DRAFT

September 13, 2018

Submitted To:

CITY OF PALO ALTO

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Executive Summary

The City of Palo Alto and California Energy Commission (CEC) require a cost effectiveness study be completed to implement an *energy reach code* in the Palo Alto Municipal Code. The energy reach code would require that residential and nonresidential new construction and alterations implement specific electrification or efficiency measures that exceed the requirements of 2019 Title 24 Building Energy Efficiency Standards (T24). Electrification means designing or converting a building to use only electricity instead of gas for some or all end uses.

TRC investigated measures proposed through the City's Zero Net Energy Roadmap, Green Building Summit, and Technical Advisory Committee (TAC) meetings. TRC attained incremental costs for equipment, installation, and maintenance of the proposed measures from retailers, contractors, manufacturers, industry experts, and RSMeans. To determine energy impacts, TRC simulated prototypes in CEC compliance software, though some measures required spreadsheet analysis outside of the software. TRC used a set of residential and nonresidential prototypes to determine cost-effectiveness in two ways: 1) using TDV as per the CEC Life Cycle Cost Methodology and 2) using bill impacts along with City of Palo Alto Utility rates. TDV Net Savings represent the TDV benefits of a measure minus the costs, and Bill Net Savings represent the on-bill benefits of a measure minus the costs. Measures with a positive Net Savings are cost effective and highlighted in green in the following tables.

TRC analyzed all-electric measures for residential and small office new construction, individually and as a package, as shown in Figure 1 and Figure 2. Each measure accounts for costs for upgrading electrical capacity if necessary. Figure 1 shows that both single family and low-rise multifamily residential new construction has both TDV and Bill Net Savings for the heat pump water heater measure individually. TRC packaged all four electrification measures in combination with the elimination of a natural gas pipe connection, which in a new construction or redevelopment scenario with iron piping (Package A: NC or RD-Iron) eliminates costs associated with a connection fees, meter, interior distribution and plan review costs. In a redevelopment scenario with polyethylene piping (Package B: RD-PolyE), cost savings associated with utility connection fees are significantly reduced. Both Package A and B show Bill Net Savings, though they do not generally show TDV Net Savings, suggesting that TDV rate assumptions do not align with Palo Alto Utility rates.

New Construction	Single-family		Low-rise Multifamily	
Measure	**TDV Net Savings**	**Bill Net Savings**	**TDV Net Savings**	**Bill Net Savings**
Induction Stove	-$2,760	-$1,905	-$19,132	-$12,646
Heat Pump Dryer	-$1,947	-$708	-$13,675	-$3,234
Heat Pump Space Heater	-$601	-$1,456	-$3,312	-$3,633
Heat Pump Water Heater	$175	$1,962	$1,943	$14,966
All-electric Package A (NC or RD-Iron)	$3,639	$7,694	-$12,431	$8,305
All-electric Package B (RD-PolyE)	-$282	$3,773	-$17,259	$3,477

Figure 1: New Construction Residential Summary

TRC analyzed all-electric new construction only for small offices, and solar ready and solar photovoltaic installations for both small office and medium office prototypes. Figure 2 shows that nonresidential buildings have TDV Net Savings and Bill Net Savings for most of the measures except solar ready.

New Construction	Small Office		Medium Office	
Measure	TDV Net Savings	Bill Net Savings	TDV Net Savings	Bill Net Savings
Heat Pump Space Heater	$99	$203	-	-
Heat Pump Water Heater	-$1,314	-$1,201	-	-
Solar Ready	-$984	-$984	-$1,970	-$1,970
PV to Achieve Zero Code	$21,997	$63,380	$178,129	$311,308
All-electric Package 1A (solar ready, greenfield)	$11,896	$27,959	-	-
All-electric Package 1B (solar ready, redevelopment)	$7,975	$24,038	-	-
All-electric Package 2A (PV, greenfield)	$35,912	$93,335	-	-
All-electric Package 2B (PV, redevelopment)	$31,991	$89,414	-	-

Figure 2: New Construction Nonresidential Summary

TRC analyzed all-electric capability measures for residential and nonresidential alterations, as well as two efficiency measures. The electrification capability measures involve only providing adequate electrical capacity to the building and appliances. Figure 3 shows the cost estimates of upgrading existing panels and branch circuits to the capacity required for the proposed equipment, including wall demolition, which are the same in either the TDV or Bill Net Savings approach because there are no energy benefits with upgrading electrical infrastructure.

TRC found that a 200A panel is needed adequately serve an all-electric single-family home, and this is also the typically installed size during single-family replacements. Because market practice is to install a 200A panel when a panel replacement is needed, there are no associated costs with this measure. However, in low-rise multifamily dwelling units, a 150A panel is required to serve an all-electric dwelling, while typical market practice is to install 125A panels. Thus, multifamily dwelling electrical panels do have associated incremental costs to be all-electric capable.

Alterations	Single-family		Low-rise Multifamily	
Measure	TDV Net Savings	Bill Net Savings	TDV Net Savings	Bill Net Savings
Electrical Panel all-electric capable	$0		-$4,256	
Induction Stove capable	-$962		-$5,129	
Heat Pump Dryer capable	-$845		-$4,508	
Heat Pump Space Heating capable	-$721		-$3,846	
Heat Pump Water Heating capable	-$783		-$4,177	
Ceiling Insulation + Radiant Barrier	-$4,212	-$4,599	-$4,686	-$6,354

Figure 3: Residential Alterations Summary

TRC found that in light commercial packaged rooftop air conditioners require the same electrical service as packaged heat pumps. Packaged heat pumps may require electric resistance heating to defrost the evaporator during the winter, but this does not impact the typical electrical service. Thus, the typical existing small office prototype can already be considered capable of accommodating a heat pump during an alteration without additional cost.

TRC recommends that the City of Palo Alto consider:

- Policies that encourage or require for all-electric residential and nonresidential new construction.

- Further examination of policies requiring higher capacity electrical requirements for residential buildings through amendments to Palo Alto’s electrical code.
- Policy that encourages or requires solar PV in nonresidential new construction.

1 Introduction

The City of Palo Alto (the City) Development Services department engaged TRC to research and analyze the cost effectiveness of energy reach code measures exceeding 2019 Title 24 Part 6 Building Energy Efficiency Standards (T24), effective January 1st, 2020. The T24 Standards are the minimum energy efficiency requirements for building construction in California.

Palo Alto has an active community that is passionate about sustainability and a utility that provides carbon-neutral electricity. Palo Alto has enacted an energy reach code since the 2005 Title 24 Standards were issued by investigating measures that allow a building to perform better than minimum T24 requirements while being cost effective over the lifetime of the measures, as per the requirements in Section 10-106 of the California Code of Regulations.

1.1 Scope

TRC has assessed the cost effectiveness of several measures, relevant to both new construction and alterations scenarios, in both residential and nonresidential buildings. TRC determined cost effectiveness by investigating and comparing the costs and energy savings benefits associated with several building energy efficiency measures, described in more detail in *Section 2: Methodology*.

Most of the measures researched in this cost-effectiveness study intend to support building electrification and help the City mitigate emissions associated with utility-provided natural gas. Electrification means designing or converting a building to use only electricity, instead of gas, for various end uses. For most of building end uses including space cooling, lighting, and plug loads, electricity is the typical fuel. Space heating, water heating, cooking, and clothes drying are among the higher energy-consuming building functions that typically use natural gas for fuel. Our analysis includes the infrastructural impact of electrification measures, such as larger panel capacities or the elimination of natural gas piping.

The City also provided a limited set of measures that focus on energy efficiency in alterations, not related to electrification.

1.2 Limitations

This study has the following limitations:

- **Location.** All analysis performed is intended to be relevant to Palo Alto climate, utility rates, and labor/material costs.
- **Prototypes.** The prototypes studied are only low-rise residential and offices. Findings may not pertain to accessory dwelling units, high-rise residential, or other commercial spaces, such as restaurants and fitness centers, which have much higher water and space heating loads.
- **Existing Conditions.** A wide range of existing conditions are possible, such as existing HVAC system, DHW system, and electrical infrastructure capacity, and each has a potential to impact measure cost effectiveness. Based on industry engagement and previous research, TRC performed the analysis using one set of assumptions for existing conditions. In some cases, software capabilities dictated existing conditions.
- **Federal Pre-emption.** The Department of Energy (DOE) regulates the minimum efficiencies required for all appliances, such as space conditioning or water heating equipment. State or city codes that mandate appliance efficiencies higher than the DOE's may risk litigation by industry organizations. Thus, TRC used

baseline equipment efficiencies for reach code measures, even though efficiency increases are often the simplest and most affordable ways to improve building performance.

- **Other Appliances.** Other end-uses that may commonly use natural gas, such as pool heaters, have been explicitly excluded from the scope of this study. Nonetheless, TRC assumed that natural gas is not being delivered to buildings in some scenarios.
- **Grid Upgrades.** TRC assumes that electrical grid upgrades that are in front of the meter are handled by the utility, such as transformer or service point upgrades.
- **Sensitivity.** The study assumes one set of market conditions at one specific point in time, including utility rates and equipment costs. This study does not analyze potential cost-effectiveness outcomes under a variety of market conditions.

2 Methodology

TRC analyzed the cost effectiveness of potential reach code measures by applying them to building prototypes (when applicable) using the life cycle cost (LCC) methodology, which is approved and used by the California Energy Commission (CEC) to establish cost effective building energy standards (Title 24, Part 6).[1]

2.1 Cost Effectiveness

TRC determined cost effectiveness by assessing the incremental costs of each measure and comparing them to the energy cost savings over the measure life, as specified by CEC. Incremental costs represent the equipment, installation, replacements, and maintenance costs of the proposed measure relative to the 2019 Title 24 Standards minimum requirements. We estimated savings using both time depending valuation (TDV) of energy and Palo Alto utility bill rates:

- **TDV** is a normalized monetary format developed and used by the CEC for comparing electricity and natural gas savings, and it considers the cost of electricity and natural gas consumed during different times of the day and year. The 2019 TDV values are based on long term discounted costs—30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures.
- **Utility bill impacts** are estimated by each calendar month for electricity and natural gas consumption for each prototype using Title 24 compliance simulation software outputs or spreadsheet analysis for measures that cannot be modeled in the software. TRC used the below Palo Alto Utilities rates to estimate bill impacts:[2]
  - Residential: E-1 for electricity and G-1 for gas.
  - Commercial:
    - Small office: E-2 for electricity and G-2 for gas
    - Medium office: E-4 for electricity and G-2 for gas
  - All buildings: EEC-1 Net Energy Metering successor program for solar PV

TRC obtained measure costs through interviews with contractors and distributors who serve the Palo Alto region and reviewed online sources, such as Home Depot and RS Means. We added taxes and contractor markups, as appropriate. Please find detailed costs in *Appendix B: Cost Data*. Measure costs are the same when comparing to either TDV or utility bill savings.

TRC performed a net present value (NPV) calculation over 30 years for residential and 15 years for non-residential prototypes, assuming a 3% discount rate and a 2% energy escalation rate. TRC uses net savings (NPV benefits minus NPV costs) as the cost effectiveness metric. If the net savings metric of a measure is positive, the measure or package is considered cost effective. A measure that has negative energy cost benefits can still be cost effective if the costs to implement the measure are more negative (i.e., material and maintenance cost savings) as compared to the energy benefits.

[1] Architectural Energy Corporation (January 2011) Life-Cycle Cost Methodology. California Energy Commission. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

[2] Attained on July 26, 2018 from https://www.cityofpaloalto.org/gov/depts/utl/.

2.2 Prototypes

TRC estimated the energy impacts of most measures using CBECC-Res 2019.0.9 to simulate the residential prototypes and CBECC-Com 2019.0.2 for the nonresidential prototypes in California climate zone 4 (CZ4).[3] TRC used five prototypes as the basis for determining cost effectiveness, based on a request by the City of Palo Alto:

- 2,100 ft^2 single-family single-story home
- 2,700 ft^2 single-family two-story home
- 6,960 ft^2 low-rise multifamily residential building, with two stories and eight dwelling units
- 5,502 ft^2 one-story small office building
- 53,628 ft^2 three-story medium office building

Prototypes are based on CEC prototypes in the Residential and Nonresidential Alternate Calculation Method Manuals, with equal geometry oriented facing north, east, south, and west.[4] The prototype geometries were developed with both new construction and alterations characteristics, with the new construction prototypes meeting T24 2019 prescriptive requirements and the alterations prototypes using estimated characteristics for buildings constructed prior to an energy code. Please find a baseline characteristics summary in *Appendix A: Prototype Details*. Palo Alto's list of measure action items vary for new construction and alterations, described in detail in *Section 3: Measure Descriptions* below.

The residential prototypes have auto-sized photovoltaic (PV) arrays included, which trigger net metering compensation. It is important to note that this PV auto-sized in the compliance software based on the electrical consumption of a prescriptive mixed-fuel home and electrifying one or more appliances does not necessarily increase the PV size in the model or incur additional cost.

CBECC-Com is not currently capable of simulating solar PV. TRC determined the PV output of a solar array in CZ4 using CBECC-Res and applied the outputs to CBECC-Com hourly results. During periods of over-generation (i.e., electricity export) solar output TDV was reduced by removing the retail rate adder.

[3] More information on CBECC-Res available at: http://www.bwilcox.com/BEES/BEES.html. More information on CBECC-Com available at: http://bees.archenergy.com/software.html

[4] Available at: https://www.energy.ca.gov/title24/2016standards/

3 Measure Descriptions

TRC investigated measures developed through the City's Zero Net Energy Roadmap, Green Building Summit, and Technical Advisory Committee (TAC) meetings. Community members voted on potential measures during the Green Building Summit (results shown in *Appendix D: Green Building Summit Voting Cards*) and the top-ranking measures were further discussed for potential adopting during subsequent TAC meetings. TRC categorized these measures into Electrification, Solar, and Alterations-Only measures. The correlation between the action items and the measures are as follows:

1. Electrification Measures – New construction measures focus on requiring all electric appliances, while the alterations measures focus on enhancing existing homes to become ready to install all-electric appliances.
    a. Residential
        i. New Construction
            1. Require minimum 200A or 400A electric panel (Action 2.1.6)
            2. Require 240V, 30A outlets for gas water heating (Action 2.1.5)
            3. Require all-electric (Action 2.1.1)
                a. Electric range/cooktop
                b. Heat pump clothes dryer
                c. Heat pump space heater
                d. Heat pump water heater
                e. No natural gas piping
        ii. Alterations
            1. Require 200A or 400A electric panel during panel replacement (Action 1.1.8)
            2. Heat pump water heater 240V, 30A outlet with water heater replacement (Action 1.1.4)
            3. Heat pump space heating capability during HVAC replacement (Action 1.1.5). Note that TRC also studied induction stove and heat pump clothes dryer capability at the request of the City.
    b. Nonresidential
        i. New Construction
            1. All-electric: small office only (Action 2.2.3)
                a. Heat pump space heater
                b. Heat pump water heater
                c. No natural gas piping
        ii. Alterations
            1. Heat pump space heating capability on replacement packaged AC less than 15 tons (Action 1.2.5)

2. Solar Measures – New Construction
    a. Residential - Solar ready zone increase from 250 ft^2 to 500 ft^2 for single-family (Action 2.1.3)
    b. Nonresidential
        i. PV panels to achieve Zero Code (no Action associated, added during June TAC meeting)
        ii. Solar ready zone increase from 15% to 50% of roof area (Action 2.2.4)

3. Alteration-Only Measures
    a. Residential: R-30 roof insulation with radiant barrier (Action 1.1.1)
    b. Nonresidential: Require higher efficacy parking lighting (Action 1.2.6)

TRC developed specific measure characteristics, such as appropriate manufacturers and efficiency levels, by requiring that the measure must be readily available in the Palo Alto region and that the measure may not trigger federal pre-emption. Measure costs are based on several factors; please see *Appendix B: Cost Data* for additional details. TRC estimated the net savings for individual measures and as part of packages for relevant building types, described in *Cost Effectiveness Results*.

3.1 Electrification Measures

TRC investigated the implementation of electrification measures and associated infrastructural costs. This includes heat pump space heating, heat pump water heating, and heat pump clothes drying. In general, heat pumps use a refrigeration cycle to absorb heat from one medium and reject heat to another medium. Mediums are typically air or water. A household refrigerator is a common example of an air-to-air heat pump.

The induction stove is the only electrification measure that is not a heat pump technology. Induction stoves operate by inducing an electric current in the cooking vessel (made of iron or stainless steel) for heat generation, as opposed to electric resistance stoves that generate heat directly on the stovetop and conduct to the cooking vessel.

Electric appliances and equipment typically require a larger electrical connection than an equivalent natural gas appliance due to a higher voltage and amperage necessary to operate heat pump and induction equipment. Many buildings may require larger electrical capacity than a comparable building with natural gas appliances.

3.1.1 Electrical Panel

This measure focuses on the panel sizing for an all-electric dwelling unit. Estimates for branch circuit capacity changes are described for each measure later in this section.

TRC found that new construction single-family dwellings in Palo Alto are typically built with 200A panels. TRC also found that an all-electric home can be sufficiently serviced with a 200A panel, based on a calculator available on the City of Palo Alto Utilities website.[5] This calculator is summarized in Figure 4 and depicts how the 2700 ft^2 prototype home loads can translate into an approximate 161A panel capacity when considering all proposed electrification measures. Note that an electric vehicle (EV) power capacity is included in the table based on Palo Alto's current and planned EV-related reach code, though it is outside the scope of this study. The following steps describe how the calculator sizes the minimum panel ampacity:

1. The first 10,000 watts are directly considered for sizing the panel.
2. All wattage exceeding 10,000 watts and not associated with HVAC is sized at 40% and summed with the first 10,000 watts. This procedure accounts for non-coincident electrical loads.
3. The wattage associated with HVAC is summed.
4. The total summed wattage is divided by 240V.

[5] Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/53173

	Description of Load	Volts	Nameplate Amps	Total Watts
Gen Lighting	General lighting & receptacle (2700 sq.ft x 3 watts/sq.ft)	-	-	8,100
	(2) Kitchen circuits	-	-	3,000
	Laundry circuit	120	13	1,500
	Total General Lighting Load	-	-	*12,600*
Appliances	Induction cooktop	240	40	9,600
	Heat pump dryer	240	30	7,200
	Dishwasher	120	13	1,500
	Trash compactor	120	5	600
	Waste disposal	120	20	2,400
	Heat pump water heater	240	20	4,800
	Range hood	120	5	600
	Electric resistance oven	120	17	2,000
	Refrigerator	120	10	1,200
	Microwave	120	15	1,800
	Electric Vehicle supply equipment	240	38	9,000
	Total Appliances	-	-	*40,700*
Ltg + App	Total Gen Lighting + Appliances	-	-	53,300
	First 10,000 watts at 100%	-	-	*10,000*
	Balance (43,300) at 40%	-	-	*17,320*
	Lighting + Appliances	-	-	**27,320**
Other	Heat Pump outdoor unit	240	20	4,800
	Heat pump electric resistance back up	240	20	4,800
	Indoor air handling unit	120	15	1,800
	Total Heating/Cooling at 100%	=		**11,400**
Total Adjusted House Load		=		38,720
Minimum service panel ampacity (total load/240)		=		**161**

Figure 4: Panel Size for the 2700 ft² Single-Family Home

Using the same method, TRC determined that an all-electric multifamily dwelling unit would require a 150A electrical panel. However, TRC found that new construction multifamily dwellings in Palo Alto are typically built with 125A panels.

Nonresidential building electrical loads can be much higher than residential buildings due to higher lighting power density, larger HVAC systems, plug loads, or process loads. Electric panel installations or replacements for nonresidential buildings are typically large enough in both existing buildings and new construction to adequately accommodate all proposed electrification measures. Thus, this measure is only investigated for residential buildings.

- **Relevance:** Residential new construction and alterations.
- **Baseline assumptions:** New panels installed on single family homes are 200A, and new panels installed on multifamily dwellings are 125A.
- **Proposed measure:** According to Figure 4, a 200A panel would provide more than enough capacity for a single-family home (same as baseline). A 150A panel would be required for a multifamily dwelling unit.

- **Cost sources:** Electrical contractor interviews, RSMeans, City of Palo Alto Utilities.

3.1.2 Natural Gas Piping

In an all-electric new construction scenario, natural gas would not be supplied to the site. Eliminating natural gas in new construction would save costs associated with piping distribution within the building and monthly connection charges by the utility.

TRC determined that in either a new construction or redevelopment scenario where the existing connection to the main is iron piping (NC or RD-Iron), the natural gas connection fees are the same. In a redevelopment where the branch to the existing site is iron piping, Palo Alto Utilities requires building owners upgrade the piping to polyethylene, which requires street trenching and equates the redevelopment connection to a new connection. However, Palo Alto Utilities are gradually performing capital improvement to replace mains and branches in the street to polyethylene. If an existing building is on a street that has already had the main and branch converted to polyethylene (RD-PolyE), the connection fee is significantly reduced, and there is no street cut fee.

- **Relevance:** Residential and nonresidential (small office only) new construction**.**
- **Baseline assumptions:**
    - NC or RD-Iron: Branch connection from the main to the building plus street cut fee. Natural gas piping routed to water heater, furnace, clothes dryer, and stove. Indoor piping of steel and corrugated stainless steel tubing (CSST) material. This fee structure applies to both new construction and redevelopment where the existing main has not been upgraded through capital improvement projects.
    - RD-PolyE: Branch connection from the sidewalk to the building. Natural gas piping routed to water heater, furnace, clothes dryer, and stove. Indoor piping of steel and corrugated stainless steel tubing (CSST) material. This fee structure applies only to redevelopment scenarios that have existing mains that were already upgraded to polyethylene. It does not apply to new construction because new construction would require a new main connection.
- **Proposed measure:** No natural gas piping connection.
- **Cost sources:** Plumbing contractor interviews, RSMeans, City Palo Alto Utilities.

3.1.3 Heat Pump Space Heating

TRC assumed a central ducted split heat pump space heater (HPSH) in the residential prototypes and packaged heat pumps in the nonresidential prototypes. The central and packaged heat pump systems are very similar to the baseline systems except they lack a furnace and gas connection—the heat pumps are essentially split air conditioners that operate in reverse to heat the space. TRC assumed one split system installed in each single-family prototype, one in each multifamily dwelling unit, and five packaged heat pumps installed in the small office.

Electrical resistance backup is usually unnecessary with Palo Alto’s mild winters, but some residential contractors have started including them because of customer callbacks on exceptionally cold days. TRC’s analysis includes backup heating to accommodate this scenario, but only in residential alteration scenarios. Residential new construction buildings are well insulated and not in need of the electric resistance backup. Nonresidential packaged heat pumps in CZ4 are typically not provided with backup electric resistance, aside from the strip heater that is used for defrosting.

In relation to Action 1.2.5 requiring heat pump capability on central packaged or split system replacements, TRC determined that heat pump systems smaller than 15 tons have the same electrical requirements, curb adaptor requirements, maintenance, and expected useful lives as packaged gas furnace and air conditioner. Furthermore, light commercial split systems are typically designed to be variable refrigerant flow, an all-electric design. Thus, there are no incremental costs associated for nonresidential alterations to be heat pump capable.

- **Relevance:** Residential and nonresidential (small office only), new construction and alterations
- **Baseline assumptions:**
  - Residential: Central ducted combination furnace and air conditioner, 80% AFUE, 14 SEER, 20-year EUL based on DEER. 240V, 20A circuit.
  - Nonresidential: Packaged single zone air conditioners, 80% AFUE, 14 SEER, 20-year EUL based on DEER. 460V, 50A circuit.
- **Proposed measure:**
  - Residential: Central ducted heat pump, 8.2 HSPF, 14 SEER, 15-year EUL based on DEER. 240V, 20A circuit. For alterations, add extra 240V, 30A circuit for electrical resistance backup.
  - Nonresidential: Packaged heat pumps, 8.0 HSPF, 14 SEER, 15-year EUL based on DEER. 460V, 50A circuit, including electrical resistance defrost (no impact on electrical connection).
- **Cost sources:** Mechanical contractor and designer interviews, National Air Warehouse, EComfort.

3.1.4 Heat Pump Water Heating

Heat pump water heaters (HPWH) have tanks and require an air supply for heat rejection, which can be either ambient or ducted. They can be installed in conditioned or unconditioned spaces, though locating a HPWH in conditioned space will create additional space conditioning loads. The size and shape of the HPWH is comparable to a natural gas storage water heater, and condensate draining is required. HPWHs can produce similar temperatures to natural gas water heaters under typical weather conditions but may occasionally need to switch to an electric resistance mode in cold weather. TRC assumed one water heater in the single story single-family prototype and each multifamily dwelling unit.[6]

Due to lower hot water demand, nonresidential service water heaters are typically less than 20 gallons and electric resistance. However, since City of Palo Alto's green building ordinance requires new construction office buildings to have showers, TRC assumed tanked water heaters would be required. Note that hot water loads associated with showers in nonresidential buildings are not integrated into compliance software, so energy impacts are likely imprecise.

- **Relevance:** Residential and nonresidential, new construction and alterations**.**
- **Baseline assumptions:**
  - Residential: Gas tankless water heater, EF=0.82, 20-year EUL based on DEER. 125V, 20A circuit as per prescriptive T24 requirements. Floor drain required. Flushing required every five years by a service professional.

[6] When a HPWH is selected, the CBECC-Res standard model assumes that a HPWH is in conditioned space. This impacts space conditioning loads, which are also reflected in the standard model.

  - Nonresidential: Gas storage water heater, 50 gallons, EF=0.68, 15-year EUL based on DEER. 120V, 20A circuit. Floor drain required.
- **Proposed measure:**
  - Residential: Heat pump water heater, UEF=2.8, 50 gallons. 15-year EUL based on DEER. 240V, 25A circuit. Located in conditioned space, non-ducted, including condensate drained to a floor drain. No additional maintenance that requires a service professional.
  - Nonresidential: Heat pump water heater, UEF=2.8, 50 gallons. 15-year EUL based on DEER. 240V, 25A circuit. Non-ducted, including condensate drained to a floor drain. No additional maintenance that requires a service professional.
- **Cost sources:** Home Depot, Lowes, EComfort, DEER, contractor interviews.

3.1.5 Heat Pump Clothes Dryer

Heat pump clothes dryers have been available internationally since the 1990s and have recently become available in the United States.[7] TRC considered heat pump clothes dryers instead of electric resistance because they use less energy, though, they require a longer drying time.

- **Relevance:** Residential new construction and alterations.
- **Baseline assumptions:** Natural gas clothes dryer, 13-year EUL based on Consumer Reports. 120V, 20A circuit.
- **Proposed measure:** Heat pump clothes dryer, 13-year EUL based on Consumer Reports. 240V, 30A circuit.
- **Cost sources:** Home Depot, Consumer Reports, manufacturer interviews.

This measure could not be modeled in CBECC-Res software. TRC used EnergyStar® and Pacific Northwest National Laboratory research to estimate energy impacts to CBECC-Res standard appliance energy consumption.[8,9]

3.1.6 Induction Stove

Induction stoves do not save dramatically more energy than electric resistance stoves. However, they do provide a better responsiveness than electric resistance, and they are perceived as being safer than either natural gas or electric resistance stoves. Induction stoves are still paired with electric resistance ovens (when combined are called ranges).

- **Relevance:** Residential new construction and alterations.
- **Baseline assumptions:** Gas range, 15-year EUL based on Consumer Reports. 120V, 15A circuit.

[7] Research into Action. (September 2015). Product Trends and Manufacturer Insights for Residential Laundry, Cooking, and Refrigeration Appliances. CALMAC. Available at: http://www.calmac.org/publications/Product_Trends_Mfr_Insights_Report_Final_2015.09.15.pdf

[8] EnergyStar (Nov 2011) ENERGY STAR Market & Industry Scoping Report Residential Clothes Dryers. Available at: https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

[9] W TeGrotenhuis, A Butterfield, D Caldwell, A Croo. PNNL. (June 2016). Affordable Hybrid Heat Pump Clothes Dryer. Pacific Northwest National Laboratory. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25510.pdf

- **Proposed measure:** Induction range, electrical resistance oven, 13-year EUL based on Consumer Reports. 240V, 50A circuit.
- **Cost sources:** Home Depot, Consumer Reports, manufacturer interviews.

This measure could not be modeled in CBECC-Res software. TRC used Electric Power Research Institute's research to estimate energy impacts to CBECC-Res standard appliance energy consumption.[10]

3.2 Solar Measures

TRC researched a solar-ready measure as well as the installation of solar photovoltaics (PV).

3.2.1 Solar Ready

Palo Alto's proposed ordinance requires increasing the solar ready size and installing conduit to support future solar PV installation. T24 has detailed solar ready requirements for new residential buildings that have not installed solar PV.

- **Relevance:** Single-family residential and nonresidential new construction without installed solar PV. The residential prototypes already include PV as per prescriptive T24 requirements and are thus not required to be solar ready. However, costs are provided in *Appendix B: Cost* Data.
- **Baseline assumptions:**
  - Single-family residential: 250 ft^2 of roof with solar access, reserved circuit breaker.
  - Commercial: 15% of roof with solar access, reserved circuit breaker.
- **Proposed measure:**
  - Single-family residential: 500 ft^2 of roof with solar access, reserved circuit breaker, ¾" conduit installed.
  - Commercial: 50% of roof with solar access, reserved circuit breaker, 1" or 1-1/2" conduit installed (small and medium office, respectively).
- **Cost sources:** RSMeans, solar contractor interviews

3.2.2 Solar PV to Achieve Zero Code

T24 prescriptively requires installation of solar PV on residential new construction, but not nonresidential new construction. TRC sized solar PV for nonresidential new construction according to the Zero Code, which requires generating enough electricity (through a combination of on-site renewables and off-site procurement) to offset both gas and electricity usage.[11] TRC assumed that all renewable energy would be generated on-site through a solar PV installation. This represents the highest potential upfront cost and assumes that off-site procurement would be more economical.

TRC applies savings from the federal income tax credit (ITC), although because it is schedule to be phased out between 2020 and 2022, an average ITC of 16% is used for residential systems and 19% for commercial systems.

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[10] M Sweeney, J Dols, B Fortenbery, F Sharp. Electric Power Research Institute. (2014) Induction Cooking Technology Design and Assessment. ACEEE Summer Study on Energy Efficiency in Buildings. Available at: https://aceee.org/files/proceedings/2014/data/papers/9-702.pdf

[11] For more information visit: https://zero-code.org/

- **Relevance:** Nonresidential new construction.
- **Baseline assumptions:** No solar PV installed.
- **Proposed measure:** Solar PV installed to full on-site electricity and gas usage of building in kBtu. In the small office this represents approximately 47% of the roof area, while the medium office this represents approximately 121% of the roof area.[12]
- **Cost sources:** NREL, LBNL[13,14]

Note that TDV savings for solar PV during time of export are calculated by assuming all TDV components except the retail adjustment.[15]

3.3 Alterations-Only Measures

The City provided a limited set of measures that focus on energy efficiency in alterations and are not related to electrification.

3.3.1 Ceiling Insulation and Radiant Barrier

This measure requires the addition of a radiant barrier and ceiling insulation for roofing permits that require access to the attic. The baseline pre-code prototype assumes R-11 insulation in the attic. Based on feedback from contractors, this insulation would be removed before adding new insulation.

- **Relevance:** Residential alterations.
- **Baseline assumptions:** R-11 ceiling insulation with no radiant barrier.
- **Proposed measure:** Removal of existing R-11 batt and installation of R-30 batt or loose-fill in place. Installation of radiant barrier, 30-year EUL based on CEC LCC methodology.
- **Cost sources:** Insulation contractor interviews, RSMeans, Home Depot, Lowes.

3.3.2 High Efficacy Parking Lighting

TRC investigated increasing the lighting efficacy requirement for all nonresidential parking areas that replace lighting.

- **Relevance:** Nonresidential alterations.
- **Baseline assumptions:** Figure 5 outlines 2019 T24 hardscape lighting requirements. The efficacy range required to meet 2019 T24 is approximately 93 lumens per watt (Lm/W) for lighting zone 2 (LZ2) and LZ3 for asphalt and concrete hardscapes. LZ2 applies to rural areas with low ambient light and LZ3 applies to urban areas with medium ambient light.

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[12] TRC assumed similar costs for solar PV panels that could not fit on the roof. Costs associated with other types of mounting scenarios are not included in this analysis.
[13] F. Ran et al. (September 2016) U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016. National Renewable Energy Laboratory. Available at: https://www.nrel.gov/docs/fy16osti/66532.pdf
[14] Barbose, G. and Darghouth, N. (September 2017) Tracking the Sun 10. Lawrence Berkeley National Laboratory. Available at: http://eta-publications.lbl.gov/sites/default/files/tracking_the_sun_10_report.pdf
[15] Correspondence with Environment, Energy and Economics (E3). August 5th, 2018.

Lighting Zone	Hardscape Material	Area Wattage Allowance (W/ft²)	Linear Wattage Allowance (W/ft)	Initial Wattage Allowance (W)
LZ2	**Asphalt**	0.023	0.17	250
	Concrete	0.025	0.40	250
LZ3	**Asphalt**	0.025	0.25	350
	Concrete	0.030	0.40	350

Figure 5: Baseline Hardscape Lighting Requirements

- **Proposed measure:** Decrease hardscape wattage allowance by 15% to the amounts listed in Figure 6 below. Minimum efficacy to meet this wattage allowance is approximately 106 Lm/W. Fixtures that meet or exceed this efficacy are readily available.

Lighting Zone	Hardscape Material	Area Wattage Allowance (W/ft²)	Linear Wattage Allowance (W/ft)	Initial Wattage Allowance (W)
LZ2	**Asphalt**	0.020	0.14	213
	Concrete	0.021	0.34	213
LZ3	**Asphalt**	0.021	0.21	298
	Concrete	0.026	0.34	298

Figure 6: Proposed Hardscape Lighting Requirements

- **Cost sources:** Lightpolesplus.com, Bulbbasics.com, 1000bulbs.com, Navigant.

4 Cost Effectiveness Results

Cost effectiveness results are presented in this section for residential and nonresidential measures, separately for new construction and alteration measures. Each measure's cost effectiveness is provided within the individual row, while cost effectiveness for the package of measures is presented in the bottom row, when applicable. Because of the impact of PV generation, net metering credits, and monthly minimum charges, individual measure's energy impacts (both TDV and Bill) may not sum to the package. Similarly, the kWh and therm savings, multiplied by the utility rates, will not equate to the NPV bill impacts.

Cost effectiveness is determined over a 15-year or 30-year lifespan (as described in *Methodology*), including first costs, equipment replacements, maintenance, and energy savings. The metric used to determine cost effectiveness is net savings (NPV benefits minus NPV costs). If the net savings of a measure is greater than or equal to zero, the measure or package is cost effective.

Results are sensitive to the assumptions outlined in *Section 3 Measure Descriptions*. Measures that are cost effective by a few hundred dollars over a 30-year timespan may be easily switched to being cost effective (and vice versa) through minor changes in assumptions and/or changes in the policies underlying those assumptions.

Some cells may be grayed out because they are not applicable for one of two reasons. The first reason is that the measure does not impact energy usage, as in the case of infrastructure measures (i.e., electrical panels, branch circuits, or gas piping). The second reason is that CEC compliance software does not attribute TDV savings or penalties associated with the measure, as in the case of heat pump space heating and heat pump water heating. In this case, the standard and proposed design assumes a minimum efficiency heat pump system.

Cells highlighted in green emphasize that measures or packages have positive net savings and are cost effective. Natural gas infrastructure measures, which have positive net cost savings but do not have any inherent energy benefits, are not highlighted in green because they may only be considered in the all-electric package and not individually.

4.1 Residential

Single-family and low-rise multifamily new construction and alterations results are presented below in Figure 7 through Figure 10. Single-family results represent a straight average of the results from the 2,100 ft^2 and 2,700 ft^2 single-family prototypes.

4.1.1 New Construction

TRC analyzed new construction residential buildings for all-electric construction, including electrifying all appliances and eliminating a natural gas connection. We developed packages for two scenarios:

- **Package A (NC or RD-Iron):** Assumes the building is either completely new construction or is a redevelopment where the existing natural gas made is iron piping. In both scenarios, a new connection to the main would be required by the City of Palo Alto Utilities.
- **Package B (RD-PolyE):** Assumes the building is a redevelopment where the existing natural gas main is made of polyethylene piping. In this scenario, a branch upgrade would only be required from the sidewalk to the building.

The TDV Net Savings results in Figure 7 show that the heat pump water heater measure and Package A are cost effective. Heat pump water heaters and both Packages A and B are cost effective using the Bill Net Savings approach, largely due to the significant avoided cost from eliminating a natural gas connection. Package B is not cost effective using the TDV Net Savings approach, suggesting that TDV rate assumptions do not align with Palo Alto Utility rates. Other notes:

- The HPWH-ready outlet is provided as a separate measure to align with the City's action items. This is the only measure that has the branch circuit cost explicitly separated—the induction cooktop, heat pump dryer, and heat pump space heater measures include branch circuit costs along with appliance costs. The heat pump water heater measure life cycle costs represent only those associated with the appliance, not the electrical infrastructure.
- Prescriptively, solar ready will not be required on a home that already has solar PV installed. Thus, solar ready is not included in the package. The cost is $540.

Single-Family New Construction	kWh savings	therms savings	Life Cycle Costs	$TDV savings	$Bill savings	Net TDV Savings	Net Bill Savings
200A Electrical Panel	0	0	$0	$0	$0	$0	$0
HPWH-ready outlet (240V, 25A)	0	0	$181	$0	$0	-$181	-$181
Induction cooktop	-272	15	$1,838	-$922	-$67	-$2,760	-$1,905
Heat pump clothes dryer	-468	30	$817	-$1,131	$109	-$1,947	-$708
Heat pump space heater	-1849	166	$601	$0	-$856	-$601	-$1,456
Heat pump water heater	-987	108	-$356	$0	$1,787	$356	$2,142
No natural gas piping (NC or RD-Iron)	0	0	-$8,772	$0	$0	$8,772	$8,772
No natural gas piping (RD-PolyE)	0	0	-$4,851	$0	$0	$4,851	$4,851
Package A (NC or RD-Iron)	**-3637**	**322**	**-$5,691**	**-$2,052**	**$2,003**	**$3,639**	**$7,694**
Package B (RD-PolyE)	**-3637**	**322**	**-$1,770**	**-$2,052**	**$2,003**	**-$282**	**$3,773**

Figure 7: Single-family New Construction Cost Effectiveness Summary

In the multifamily building, heat pump water heaters prove cost effective using both the TDV and Bill Net Savings approach, despite increasing space heating loads (Figure 8). The multifamily building Packages A and B are cost effective through Bill Net Savings largely due to avoided costs resulting from elimination of natural gas piping. However, because the natural gas connection fees are a smaller portion of the overall costs to build all-electric as compared to the single-family prototypes, neither Packages A or B are cost effective using TDV Net Savings.

Multifamily New construction	kWh savings	therms savings	Life cycle Costs	$TDV savings	$Bill savings	Net Savings (TDV)	Net Savings (Bill)
150A Electrical Panel	0	0	$4,256	$0	$0	-$4,256	-$4,256
HPWH-ready outlet (240 V, 25 A)	0	0	$903	$0	$0	-$903	-$903
Induction cooktop	-1788	96	$13,141	-$5,991	$496	-$19,132	-$12,646
Heat pump clothes dryer	-3017	192	$5,945	-$7,730	$2,710	-$13,675	-$3,234
Heat pump space heater	-2389	160	$3,312	$0	-$321	-$3,312	-$3,633
Heat pump water heater	-4487	440	-$2,846	$0	$13,023	$2,846	$15,869
No natural gas piping (NC or RD-Iron)	0	0	-$25,097	$0	$0	$25,097	$25,097
No natural gas piping (RD-PolyE)	0	0	-$20,269	$0	$0	$20,269	$20,269
Package A (NC or RD-Iron)	**-13192**	**1095**	**-$1,290**	**-$13,721**	**$7,016**	**-$12,431**	**$8,305**
Package B (RD-PolyE)	**-13192**	**1095**	**$3,538**	**-$13,721**	**$7,016**	**-$17,259**	**$3,477**

Figure 8: Multifamily New Construction Cost Effectiveness Summary

4.1.2 Alterations

For alterations in both single-family (Figure 9) and low-rise multifamily buildings (Figure 10) most measures are designed to ensure sufficient capacity for electric appliances. TRC has not packaged the residential alterations measures, as each of these measures would be required at different trigger points (in other words, an outlet capable of serving a heat pump water heater may by triggered by a different permit than a kitchen remodel, which may trigger requiring an outlet capable of serving an induction cooktop). The R-30 ceiling insulation with radiant barrier measure was the only measure with potential energy savings, but the measure does not provide sufficient energy savings to be cost effective.

Single-Family Alterations	kWh savings	therms savings	Life cycle Costs	$TDV savings	$Bill savings	Net Savings (TDV)	Net Savings (Bill)
200A Elec panel with any panel permit	0	0	$0	n/a	n/a	n/a	n/a
Heat pump water heater capable outlet with water heater permit	0	0	$783	n/a	n/a	n/a	n/a
Induction cooktop capable outlet	0	0	$962	n/a	n/a	n/a	n/a
Heat pump clothes dryer capable outlet	0	0	$845	n/a	n/a	n/a	n/a
Heat pump space heater capable outlet with HVAC permit	0	0	$721	n/a	n/a	n/a	n/a
R-30 ceiling insulation with radiant barrier	138	19	$6,508	$2,296	$1,909	-$4,212	-$4,599

Figure 9: Single-Family Alterations Cost Effectiveness Summary

Multifamily Alterations	kWh savings	therms savings	Life cycle Costs	$TDV savings	$Bill savings	Net Savings (TDV)	Net Savings (Bill)
150A Elec panel with any panel permit	0	0	$16,859	n/a	n/a	n/a	n/a
Heat pump water heater capable outlet with water heater permit	0	0	$4,177	n/a	n/a	n/a	n/a
Induction cooktop capable outlet	0	0	$5,129	n/a	n/a	n/a	n/a
Heat pump clothes dryer capable outlet	0	0	$4,508	n/a	n/a	n/a	n/a
Heat pump space heater capable outlet with HVAC permit	0	0	$3,846	n/a	n/a	n/a	n/a
R-30 ceiling insulation with radiant barrier	372	46	$10,785	$6,099	$4,929	-$4,686	-$5,855

Figure 10: Multifamily Alterations Cost Effectiveness Summary

4.2 Nonresidential

Small office and medium office new construction and alterations results are presented below in Figure 11 through Figure 13.

4.2.1 New Construction

TRC analyzed new construction small office buildings for all-electric capability, including electrifying all appliances and eliminating a natural gas connection. Four small office packages were analyzed:

- **Package 1A:** All-electric + solar ready, plus avoided natural gas piping for new construction or an existing building with an iron main.
- **Package 1B:** All-electric + solar ready, plus avoided natural gas piping for an existing building with a polyethylene main.
- **Package 2A:** All-electric + PV, plus avoided natural gas piping for new construction or an existing building with an iron main.
- **Package 2B:** All-electric + PV, plus avoided natural gas piping for an existing building with a polyethylene main.

The PV array size is smaller for Package 2 than the individual PV measure. This is because the Zero Code requires offsetting all energy (in kBtu) within a building, and a mixed-fuel building uses more energy than an all-electric building.

As shown in Figure 11, heat pump space heating, solar PV, and all packages are cost effective in both the TDV Net Savings and Bill Net Savings analysis. Packages are cost effective primarily due to the avoided natural gas connection charges and large savings due to PV generation. The heat pump space heating measure is individually cost effective by a small margin.

Small Office New construction	kWh savings	therms savings	Life-cycle Costs	$TDV savings	$Bill savings	Net Savings (TDV)	Net Savings (Bill)
Heat Pump Space Heating	-1,713	188	-$476	-$377	-$273	$99	$203
Heat Pump Water Heater	-1,079	105	$339	-$974	-$862	-$1,314	-$1,201
Solar Ready	0	0	$984	$0	$0	-$984	-$984
PV to achieve Zero Code	61,998	0	$80,847	$102,844	$144,227	$21,997	$63,380
No natural gas piping installed (NC or RD-Iron)	0	0	-$14,085	$0	$14,381	$14,085	$28,466
No natural gas piping installed (RD-PolyE)	0	0	-$10,164	$0	$14,381	$10,164	$24,545
Package 1A (Solar ready, NC or RD-Iron)	**-2,781**	**292**	**-$13,237**	**-$1,342**	**$14,722**	**$11,896**	**$27,959**
Package 1B (Solar ready, RD-PolyE)	**-2,781**	**292**	**-$9,316**	**-$1,342**	**$14,722**	**$7,975**	**$24,038**
Package 2A (PV, NC or RD-Iron)	**53,468**	**292**	**$59,480**	**$95,392**	**$152,815**	**$35,912**	**$93,335**
Package 2B (PV, RD-PolyE)	**53,468**	**292**	**$63,401**	**$95,392**	**$152,815**	**$31,991**	**$89,414**

Figure 11: Small Office New Construction Cost Effectiveness Summary

All-electric was not analyzed for medium office buildings because of the larger HVAC loads and the limited availability of high capacity heat pump space conditioning systems. The two measures analyzed for medium office buildings are solar PV and solar ready. Figure 12 shows positive NPV TDV Savings and NPV Bill Savings for the PV measure. Because the solar ready measure only is not associated directly with energy benefits, it is not cost effective.

New construction, Medium Office	kWh savings	therms savings	Life-cycle Costs	$TDV savings	$Bill savings	Net Savings (TDV)	Net Savings (Bill)
PV to Achieve Zero Code	523,841	-	$682,753	$860,882	$994,061	$178,129	$311,308
Solar Ready	0	0	$1,970	$0	$0	-$1,970	-$1,970

Figure 12: Medium Office New Construction Cost Effectiveness Summary

4.2.2 Alterations

The following two measures are proposed for nonresidential alterations:

- **Require heat pump capability on all new rooftop packaged HVAC systems or split air conditioning systems under 15 tons:** Ensuring adequate electrical branch circuit capacity for HPSH in small offices is cost effective because the power provided to rooftop air conditioners smaller than 15 tons with gas heating is adequate to support a heat pump packaged system. Split systems for light commercial are typically designed to be variable refrigerant flow. Thus, ensuring heat pump capability carries no incremental cost for either packaged or split systems.
- **Require high efficacy lighting for all nonresidential parking lot lighting luminaire replacements:** TRC collected data on all available arm-mounted parking lot lights from three distributors and determined that 80% of the products collected had efficacy of 106 Lm/W or higher. TRC determined that there is no correlation with higher-efficacy lighting fixtures having higher costs, as depicted in Figure 13, and that a higher efficacy parking lot lighting is available on the market cost effectively.

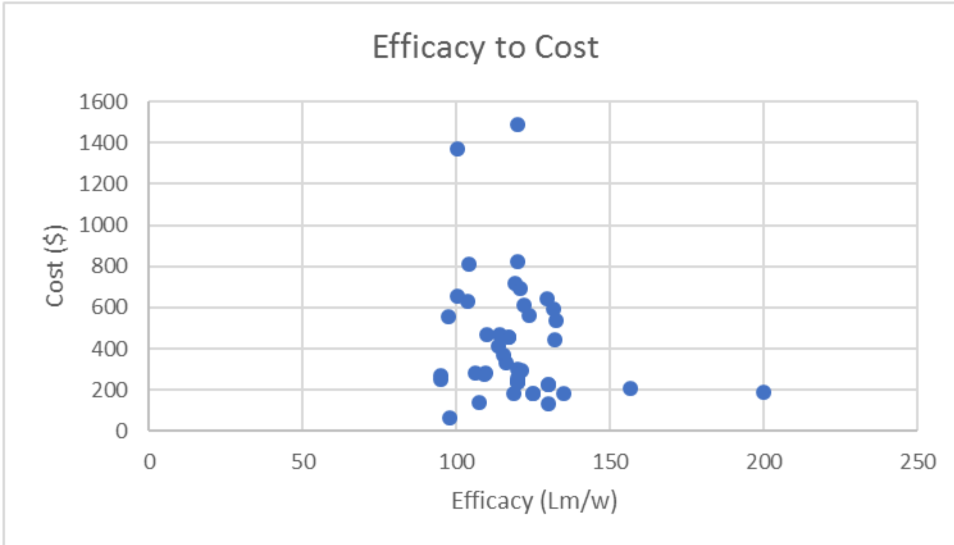

Figure 13: Scatterplot of Fixture Efficacy vs. Cost

The results of this data collection are supported by a recent study conducted by Navigant Consulting.[16] Navigant compared prices of Design Lights Consortium (DLC) Standard and DLC Premium products and concluded that DLC Premium low-output parking had no significant price difference to its DLC Standard equivalent. DLC Premium Mid and High output parking lot lights were on average 12% less expensive than the DLC Standard products.

[16] Navigant Consulting, Inc. (January 2018). California LED Pricing Analysis. CALMAC. Available at: http://calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_FinalES.pdf

5 Conclusions and Recommendations

TRC provides these conclusions and recommendations based on the cost-effectiveness findings and TAC discussions.

5.1 Residential

5.1.1 Electrification

In both single-family and multifamily prototypes, heat pump water heating and all-electric packages are cost effective using Bill Net Savings. Some packages that show Bill Net Savings do not show TDV Net Savings, suggesting that TDV rate assumptions do not align with Palo Alto Utility rates.

Intermediary policies requiring electrification of individual appliances do not save costs associated with a natural gas connection and are mostly not cost effective. Palo Alto could consider electrification policies that do not allow natural gas connection in new construction for low-rise residential. Policies should consider how residents may still desire natural gas appliances, including those not analyzed in these prototypes (such as fireplaces or outdoor grills).

Induction cooktop and heat pump clothes dryers are more expensive than electric resistance alternatives, and electric resistance cooktops and clothes dryers cost equal to or less than comparable quality natural gas products. While proposing electric resistance appliances would bring the life cycle costs down, these products have poorer efficiency which will reduce TDV Savings and Bill Savings and may not improve cost effectiveness.

5.1.2 Solar Ready

TRC does not recommend that Palo Alto require solar ready policies exceeding the State’s for residential new construction. Solar PV is prescriptively required in 2019 T24, and solar ready requirements are excepted when installing solar PV.

5.1.3 Alterations

The alterations measures analyzed are intended to promote future electrification capabilities. Because these measures only have implementation costs and do not have associated energy impacts, they are not cost effective. Because only cost effective measures can be required in local energy ordinances, TRC recommends Palo Alto examine whether the higher electrical capacity requirements can be adopted as electrical code ordinances rather than the building energy efficiency ordinances.

TRC does not recommend requiring R-30 ceiling insulation and a radiant barrier for alterations that require attic access, because the measure is not cost effective. At Palo Alto’s request, TRC can reassess cost effectiveness by revising the measure specification, potentially to a lower insulation value and/or removing the radiant barrier.

5.2 Nonresidential

5.2.1 Electrification

Palo Alto should consider promoting all-electric new construction for small nonresidential buildings. Nonresidential buildings are typically already designed with adequate electrical capacity to serve electric service hot water systems and heat pump space heating systems. Light commercial HVAC is routinely specified as all-electric without incurring substantial costs above that for natural gas systems. Bill impacts for heat pump water heating and space heating equipment are minor, and easily compensated for by the initial and monthly cost savings resulting from avoiding a natural gas connection.

5.2.2 Solar PV and Solar Ready

Procuring and installing enough Solar PV on-site to achieve Zero Code is cost effective given current PV prices and utility rates. Zero Code requires generating enough electricity (through a combination of on-site renewables and off-site procurement) to offset both gas and electricity usage.[17] Off-site procurement of renewable energy may be an even more cost effective option without a high upfront cost. Both options should be available to nonresidential building owners because many multistory nonresidential buildings may not have adequate roof area for a solar PV array that offsets the entire source energy of the building, as in the case of the medium office prototype.

Renewable procurement requirements may be further reduced for Palo Alto nonresidential buildings -- Zero Code uses standard assumptions for carbon intensity of electricity generation, and Palo Alto's renewable electricity supply may affect these standard assumptions. This analysis considers the largest potential renewable generation necessary to comply with Zero Code.

One important consideration before adopting Zero Code are limits to overgeneration. The 2019 T24 requires residential buildings to install solar, but only to offset the annual electricity load. This is to prevent widescale electricity overgeneration resulting from compensating for natural gas consumption. Before adopting solar PV requirements for nonresidential buildings, Palo Alto should consider potential grid harmonization issues resulting from high penetration of commercial-scale renewables, particularly for mixed-fuel buildings.

TRC recommends Palo Alto adopt some form of solar PV requirements for nonresidential new construction. Doing so would negate the need for solar ready requirements, unless Palo Alto examined efficiency, battery, or other tradeoffs for installing solar PV.

5.2.3 Alterations

As mentioned in *Section 4.2.2*, packaged heat pumps less than 15 tons require the same electrical power supply as gas furnace air conditioners. Furthermore, split systems for light commercial are typically designed to be all-electric variable refrigerant flow systems. Thus, ensuring heat pump capability in alterations carries no incremental cost for either packaged or split systems. Because of the market status quo, Palo Alto may not need to require that electrical supply to the building and HVAC systems can serve heat pumps. Doing so may require a set of electrical requirements for various system sizes.

TRC recommends that Palo Alto consider decreasing hardscape wattage allowances by 15% for nonresidential parking lot luminaire replacements, to the amounts listed in Figure 6. Minimum efficacy to meet this wattage allowance is approximately 106 Lm/W. TRC also recommends expanding this policy to all outdoor parking lots with lighting, including retail parking and multifamily.

[17] For more information visit: https://zero-code.org/

Appendix A: Prototype Details

New construction prototypes baseline characteristics are summarized in Figure 14 and Figure 15, and they are based on prescriptive 2019 T24 requirements. The air conditioning and water heating systems represent what would be installed in both new construction and alteration baseline scenarios.

Building Type	One-Story	Two-Story	Low-Rise Multifamily
Dwelling Units	1	2	8
Area (ft^2)	2,100	2,700	6,960
Roof Area (ft^2)	2,540	1,690	3480
# of floors	1	2	2
Window-to-Floor Area Ratio	20%	20%	15%
HVAC System	Central Ducted Split Air Conditioner with Gas Furnace		
HVAC Distribution System	Ducts in Attic	Ducts in Attic	Ducts in Conditioned Space
Thermal Zones	1	1	2
Domestic Water Heating (New Construction)	Natural Gas Tankless Water Heater, 0 Gallon Tank, EF=0.82		8x Natural Gas Tankless Water Heater, 0 Gallon Tank, EF=0.82
Domestic Water Heating (Alteration)	Natural Gas Small Storage, 50 Gallon Tank, EF = 0.525, 40MBH		8x Natural Gas Small Storage, 50 Gallon Tank, EF = 0.525, 40MBH

Figure 14: Residential Baseline Prototypes Summary

Building Type	Medium Office	Small Office
Floor Area (ft2)	53,628	5,502
# of Floors	3	1
Window-to-Floor Area Ratio	13%	11%
HVAC Distribution System	3x Packaged Variable Air Volume with VAV Hot Water Reheat	5x Packaged Single Zone Air Conditioners
Cooling System	Direct Expansion, 9.8 EER, Economizer	Direct Expansion, 13 SEER, No Economizer
Heating System	Boiler, 80% Thermal Efficiency	Furnace, 78% AFUE
Conditioned Thermal Zones	18	5
Domestic Water Heating	Natural Electric Small Storage, EF = 0.95	

Figure 15: Nonresidential Baseline Prototypes Summary

Figure 16 and Figure 17 compare in detail the building characteristics for new construction and alteration scenarios. The average existing building in Palo Alto was built in the early 1960's for all building types, which was before California adopted any building energy efficiency code. TRC simulated alteration prototypes with "pre-code" conditions according to the Residential Compliance Manual Appendix B to estimate the energy impact of measures in alteration scenarios.[18] Generally, we assumed building characteristic that pre-date code without substantial upgrades. While lighting or fenestration upgrades are likely over time, we used pre-code characteristics to represent the highest potential energy usage in the building stock, while the new construction code represent the lowest potential energy usage.

The differences between pre-code and new construction non-residential prototype applies to envelope characteristics and lighting power density (see Figure 17); while for residential prototype, the differences apply to HVAC characteristics as well.

[18] Available at: http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV3.pdf

	Component	Pre-Code	New Construction (2019 T24)
Envelope	Attic Insulation (R-value)	13	38
	Radiant Barrier	No	Yes
	Below Roof Deck Insulation (R-value)	0	19
	Window U-Factor	1.28	0.30
	Window SHGC	0.80	0.23
	Infiltration ACH50	10	5
Lighting	Power Adjustment Multiplier	0.63	0.63
	Fraction Portable	0.22	0.22
HVAC	Duct Location	Attic	Attic
	Duct Leakage	10%	5%
	HERS Verified Duct Sealing	No	No
	Duct Insulation (R-value)	2.1	8.0
	IAQ Fan W/cfm	None	0.25
	Whole House Fan	No	No

Figure 16: Residential Pre-code and New Construction Assumptions

Component	Pre-Code	New Construction (2019 T24)
Roof Insulation (R-Value)	8	29
Roof Solar Reflectance	0.10	0.63
Wall Insulation (R-Value)	0	14
Window U-Factor	1.23	0.36
Window SHGC	0.71	0.25
Window VT	0.60	0.42
Lighting Power Density (W/ft^2)	1.2	0.75

Figure 17: Nonresidential Pre-code and New Construction Assumptions

Appendix B: Cost Data

Electrification Measures

Electrical Panel

TRC determined that the proposed measure of 200A panel is sufficient for an all-electric single-family building and matches the commonly implemented baseline of 200A for both new construction and alterations. The multifamily baseline is 125A and the proposed is 150A.The table below summarizes the incremental measure cost of electric upgrades. Note that the baseline for the HPWH Outlet measure is 125V and the proposed case is 240V.

HPWH Outlet	Single Family - 2100 ft2		Single Family - 2700 ft2		Multifamily	
First Measure Cost	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
Electrical Panel	$2,480	$2,480	$2,480	$2,480	$12,603	$16,859
Incremental Cost	**$0**		**$0**		**$4,256**	

Figure 18: Residential New Construction and Alterations Electric Panel Costs

Natural Gas Piping

The two following tables outline the cost of natural gas piping for new construction projects in residential and nonresidential sectors. There is a table for each redevelopment case, namely depending if the pipe is iron or polyethylene. Permit fees are not included.

Residential: New Construction						
Natural Gas Piping - NC or RD-Iron	**Single-Family: 2100 ft2**		**Single-Family: 2700 ft2**		**Multifamily**	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$9,068	$ -	$8,475	$ -	$25,097	$ -
Natural Gas Plan Review	*$848*		*$848*		*$848*	
Connection Charge to Existing Main	*$4,343*		*$4,343*		*$5,250*	
Meter	*$850*		*$850*		*$6,800*	
Meter Manifold					*$3,703*	
Plumbing Distribution	*$2,027*		*$1,434*		*$7,496*	
Street Cut Fee	*$1,000*		*$1,000*		*$1,000*	
Total Cost (NPV)	**$9,068**	**$ -**	**$8,475**	**$ -**	**$25,097**	**$ -**
Incremental Cost	**-$9,068**		**-$8,475**		**-$25,097**	

Figure 19: Residential New Construction or Redevelopment with Iron Natural Gas Piping Costs

Residential: New Construction						
Natural Gas Piping - RD-PolyE	**Single-Family: 2100 ft2**		**Single-Family: 2700 ft2**		**Multifamily**	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$5,147	$ -	$4,554	$ -	$20,269	$ -
Natural Gas Plan Review	*$848*		*$848*		*$848*	
Existing Main-to-Meter Relocation	*$1,422*		*$1,422*		*$1,422*	
Meter	*$850*		*$850*		*$6,800*	
Meter Manifold					*$3,703*	
Plumbing Distribution	*$2,027*		*$1,434*		*$7,496*	
Street Cut Fee	*$0*		*$0*		*$0*	
Total Cost (NPV)	**$5,147**	**$ -**	**$4,554**	**$ -**	**$20,269**	**$ -**
Incremental Cost	**-$5,147**		**-$4,554**		**-$20,269**	

Figure 20: Residential Redevelopment with Polyethylene Natural Gas Piping Costs

Nonresidential: New Construction		
Natural Gas Piping - NC or RD-Iron	***Small Office***	
Cost Type	**Baseline**	**Proposed**
First Cost	$14,085	$ -
Natural Gas Plan Review	*$2,316*	
Connection Charge to Existing Main	*$4,343*	
Meter	*$1,886*	
Plumbing Distribution	*$4,540*	
Street Cut Fee	*$1,000*	
Total Cost (NPV)	**$14,085**	**$ -**
Incremental Cost	**- $ 14,085**	

Figure 21: Nonresidential New Construction or Redevelopment with Iron Natural Gas Piping Costs

Nonresidential: New Construction		
Natural Gas Piping - RD-PolyE	***Small Office***	
Cost Type	**Baseline**	**Proposed**
First Cost	$10,164	$-
Natural Gas Plan Review	*$2,316*	
Existing Main-to-Meter Relocation	*$1,422*	
Meter	*$1,886*	
Plumbing Distribution	*$4,540*	
Total Cost (NPV)	*$10,164*	$-
Total Cost (NPV)	**$10,164**	**$ -**
Incremental Cost	**- $10,164**	

Figure 22: Nonresidential Redevelopment with Polyethylene Natural Gas Piping Costs

Heat Pump Space Heating

Residential: New Construction						
HP Space Heater	***Single-Family: 2100 ft2***		***Single-Family: 2700 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$2,369	$2,102	$3,052	$2,869	$18,954	$16,816
Package Unit/Heat Pump	*$2,019*	*$2,102*	*$2,702*	*$2,869*	*$16,154*	*$16,816*
Installation (Pad/Flue)	*$350*	*$0*	*$350*	*$0*	*$2,800*	*$0*
Replacement	$1,534	$2,215	$2,053	$3,023	$12,272	$17,722
Maintenance	$0	$0	$0	$0	$0	$0
EUL (years)	20	15	20	15	20	15
Total Cost (NPV)	**$3,903**	**$4,317**	**$5,105**	**$5,892**	**$31,226**	**$34,538**
Incremental Cost	**$414**		**$788**		**$3,312**	

Figure 23: Residential New Construction Heat Pump Space Heating Costs

Nonresidential: New Construction		
HP Space Heater	***Small Office***	
Cost Type	**Baseline**	**Proposed**
First Cost	$5,126	$4,650
Replacement	$ -	$ -
Maintenance	$ -	$ -
EUL (years)	20	16
Total Cost (NPV)	**$5,126**	**$4,650**
Incremental Cost	**- $476**	

Figure 24: Nonresidential New Construction Heat Pump Space Heating Costs

Heat Pump Water Heating

Note that the cost of the HPWH receptacle (outlet) is included in Figure 25 under "Electrical." This amount is provided separately in Figure 7 and Figure 8.

Residential: New Construction						
HP Water Heater	***Single-Family: 2100 ft2***		***Single-Family: 2700 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$2,449	$2,758	$2,494	$2,824	$18,714	$20,730
Water Heater	*$789*	*$1,313*	*$789*	*$1,313*	*$6,315*	*$10,504*
Installation	*$1,017*	*$945*	*$1,017*	*$945*	*$8,136*	*$7,560*
Flue	*$313*	*$0*	*$313*	*$0*	*$2,500*	*$0*
Electrical	*$331*	*$500*	*$375*	*$567*	*$1,763*	*$2,666*
Replacement	$1,372	$2,380	$1,372	$2,380	$10,978	$19,037
Maintenance	$1,502	$ -	$1,502	$ -	$12,017	$ -
EUL (years)	20	15	20	15	20	15
Total Cost (NPV)	**$5,324**	**$5,137**	**$5,368**	**$5,204**	**$41,709**	**$39,766**
Incremental Cost	**-$186**		**-$164**		**-$1,943**	

Figure 25: Residential New Construction Heat Pump Water Heating Costs

Heat Pump Clothes Dryer

Residential - New Construction						
HP Clothes Dryer	***Single-Family: 2100 ft2***		***Single-Family: 2700 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$1,334	$1,807	$1,385	$1,882	$9,664	$12,958
Dryer	*$956*	*$1,245*	*$956*	*$1,245*	*$7,646*	*$9,961*
Electrical	*$378*	*$562*	*$429*	*$637*	*$2,018*	*$2,997*
Replacement	$1,094	$1,425	$1,094	$1,425	$8,752	$11,402
Maintenance	$ -	$ -	$ -	$ -	$ -	$ -
EUL (years)	13	13	13	13	13	13
Total Cost (NPV)	**$2,428**	**$3,232**	**$ 2,479**	**$ 3,307**	**$ 18,416**	**$ 24,361**
Incremental Cost	**$804**		**$829**		**$5,945**	

Figure 26: Residential New Construction Heat Pump Clothes Dryers Costs

Induction Stove

Residential: New Construction						
Induction Range	***Single-Family: 2100 ft2***		***Single-Family: 2700 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$926	$1,998	$952	$2,089	$6,906	$14,176
Range	*$737*	*$1,320*	*$737*	*$1,320*	*$5,897*	*$10,558*
Branch Circuit	*$189*	*$678*	*$214*	*$769*	*$1,009*	*$3,618*
Discounted Replacement	$ 777	$1,511	$777	$1,511	$6,215	$12,086
Maintenance	$ -	$ -	$ -	$ -	$ -	$ -
EUL (years)	15	13	15	13	15	13
Total Cost (NPV)	**$1,703**	**$3,509**	**$1,728**	**$3,599**	**$13,121**	**$26,262**
Incremental Cost	**$ 1,806**		**$ 1,871**		**$13,141**	

Figure 27: Residential New Construction Range Costs

Solar Measures

Solar Ready

Residential - New Construction						
Solar Ready	***Single-family: 2100 ft2***		***Single-family: 2700 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost - Conduit ($8.12/lf)	$ -	$374	$ -	$706	$ -	$666
Incremental Cost	**$374**		**$706**		**$666**	

Figure 28: Residential New Construction Solar Ready Costs

Nonresidential: New Construction				
Solar Ready	***Small Office***		***Medium Office***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$ -	$984	$ -	$1,970
Conduit ($/lf)		*$ 9.84*		*$ 13.13*
Total Cost (NPV)	**$ -**	**$984**	**$ -**	**$1,970**
Incremental Cost	**$984**		**$ 1,970**	

Figure 29: Nonresidential New Construction Solar Ready Costs

Solar PV to Achieve Zero Code

Nonresidential: New Construction				
PV - Zero Code	***Small Office***		***Medium Office***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$-	$66,185	$-	$558,930
System Cost ($2.13/W)		*$82,048*		*$692,889*
Solar Income Tax Credit (19%)		*$(15,863)*		*$(133,959)*
Inverter Replacement	$-	$4,174	$-	$35,251
Maintenance	$-	$10,488	$-	$88,572
Inverter EUL (years)		11		11
Total Cost (NPV)	**$-**	**$80,847**	**$-**	**$682,753**
Incremental Cost	**$80,847**		**$682,753**	

Figure 30: Nonresidential New Construction Solar PV Costs

Alterations-Only Measures

Ceiling Insulation and Radiant Barrier

Residential: Alterations				
R-30 + Radiant Barrier	***Single-Family: 2100 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$ -	$6,508	$ -	$10,785
Insulation Removal		*$1,869*		*$3,097*
Insulation (mat+labor)		*$2,774*		*$4,597*
Radiant Barrier (mat+labor)		*$1,865*		*$3,091*
Replacement	$ -	$ -	$ -	$ -
Maintenance	$ -	$ -	$ -	$ -
EUL (years)	30	30	30	30
Total Cost (NPV)	**$ -**	**$6,508**	**$ -**	**$10,785**
Incremental Cost	**$ 6,508**		**$10,785**	

Figure 31: Residential Alteration R-30 Insulation with a Radiant Barrier Costs

Heat Pump Water Heater Outlet

Residential: Alterations				
HPWH Outlet	***Single-Family: 2100 ft2***		***Multifamily***	
Cost Type	**Baseline**	**Proposed**	**Baseline**	**Proposed**
First Cost	$ -	$783	$ -	$4,177
HPWH 240 V 25 Amp		$500		$2,666
Demolition costs		$283		$1,511
Total Cost (NPV)	**$ -**	**$783**	**$ -**	**$4,177**
Incremental Cost	**$783**		**$4,177**	

Figure 32: Residential Alteration Heat Pump Water Heater Outlet Costs

Appendix C: Carbon Price TDV Adder Results

CBECC-Res compliance software allows users to select TDV values that include potential future carbon prices for residential buildings. These carbon prices (known as MIDRESOLVE and HIGHRESOLVE) reflect the potential for future renewable generation of electricity, and thus improve the TDV results for electrification measures. MIDRESOLVE assumes a medium level estimate of carbon price, while HIGHRESOLVE assumes a more aggressive price. TRC has provided these results below. Despite showing improved net savings, the carbon prices do not shift cost-effectiveness findings in a significant way.

CALGreen MIDRESOLVE		Normal TDV Savings		CALGreen MIDRESOLVE TDV Savings	
New construction - Single-Family	Life Cycle Costs	$ TDV Savings	Net Savings (TDV)	$ TDV Savings	Net Savings (TDV)
200A Electrical Panel	$0	n/a	n/a	n/a	n/a
HPWH-ready outlet	$181	n/a	n/a	n/a	n/a
All-electric: Induction cooktop	$1,838	-$922	-$2,760	-$884	-$2,722
All-electric: Heat pump clothes dryer	$817	-$1,131	-$1,947	-$1,015	-$1,831
All-electric: Heat pump space heater	$601	n/a	n/a	n/a	n/a
All-electric: Heat pump water heater	-$356	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (NC or RD-Iron)	-$8,772	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (RD-PolyE)	-$4,851	n/a	n/a	n/a	n/a
Package A (NC or RD-Iron)	**-$5,691**	**-$2,052**	**$3,639**	**-$1,899**	**$3,792**
Package B (RD-PolyE)	**-$1,770**	**-$2,052**	**-$282**	**-$1,899**	**-$129**

Figure 33: CALGreen MIDRESOLVE TDV for Single-Family New Construction Measures and Packages

CALGreen HIGHRESOLVE		Normal TDV Savings		CALGreen HIGHRESOLVE TDV Savings	
New Construction: Single-Family	**Life Cycle Costs**	**$ TDV Savings**	**Net Savings (TDV)**	**$ TDV Savings**	**Net Savings (TDV)**
200A Electrical Panel	$0	n/a	n/a	n/a	n/a
HPWH-ready outlet	$181	n/a	n/a	n/a	n/a
All-electric: Induction cooktop	$1,838	-$922	-$2,760	-$826	-$2,664
All-electric: Heat pump clothes dryer	$817	-$1,131	-$1,947	-$833	-$1,649
All-electric: Heat pump space heater	$601	n/a	n/a	n/a	n/a
All-electric: Heat pump water heater	-$356	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (NC or RD-Iron)	-$8,772	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (RD-PolyE)	-$4,851	n/a	n/a	n/a	n/a
Package (NC or RD-Iron)	**-$5,691**	**-$2,052**	**$3,639**	**-$1,658**	**$4,033**
Package (RD-PolyE)	**-$1,770**	**-$2,052**	**-$282**	**-$1,658**	**$112**

Figure 34: CALGreen HIGHRESOLVE TDV for Single-Family New Construction Measures and Packages

CALGreen MIDRESOLVE		Normal TDV Savings		CALGreen MIDRESOLVE TDV Savings	
New Construction: Multifamily	**Life Cycle Costs**	**$ TDV Savings**	**Net Savings (TDV)**	**$ TDV Savings**	**Net Savings (TDV)**
200A Electrical Panel	$4,256	n/a	n/a	n/a	n/a
HPWH-ready outlet	$903	n/a	n/a	n/a	n/a
All-electric: Induction cooktop	$13,141	-$5,991	-$19,132	-$5,745	-$18,887
All-electric: Heat pump clothes dryer	$5,945	-$7,730	-$13,675	-$6,998	-$12,943
All-electric: Heat pump space heater	$3,312	n/a	n/a	n/a	n/a
All-electric: Heat pump water heater	-$2,846	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (NC or RD-Iron)	-$25,097	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (RD-PolyE)	-$20,269	n/a	n/a	n/a	n/a
Package (NC or RD-Iron)	**-$1,290**	**-$13,721**	**-$12,431**	**-$12,744**	**-$11,454**
Package (RD-PolyE)	**$3,538**	**-$13,721**	**-$17,259**	**-$12,744**	**-$16,282**

Figure 35: CALGreen MIDRESOLVE TDV for Multifamily New Construction Measures and Packages

CALGreen HIGHRESOLVE		Normal TDV Savings		CALGreen HIGHRESOLVE TDV Savings	
New Construction: Multifamily	**Life Cycle Costs**	**$ TDV Savings**	**Net Savings (TDV)**	**$ TDV Savings**	**Net Savings (TDV)**
200A Electrical Panel	$4,256	n/a	n/a	n/a	n/a
HPWH-ready outlet	$903	n/a	n/a	n/a	n/a
All-electric: Induction cooktop	$13,141	-$5,991	-$19,132	-$5,366	-$18,508
All-electric: Heat pump clothes dryer	$5,945	-$7,730	-$13,675	-$5,847	-$11,792
All-electric: Heat pump space heater	$3,312	n/a	n/a	n/a	n/a
All-electric: Heat pump water heater	-$2,846	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (NC or RD-Iron)	-$25,097	n/a	n/a	n/a	n/a
All-electric: No natural gas piping (RD-PolyE)	-$20,269	n/a	n/a	n/a	n/a
Package (NC or RD-Iron)	**-$1,290**	**-$13,721**	**-$12,431**	**-$11,214**	**-$9,924**
Package (RD-PolyE)	**$3,538**	**-$13,721**	**-$17,259**	**-$11,214**	**-$14,752**

Figure 36: CALGreen HIGHRESOLVE TDV for Multifamily New Construction and Packages

Appendix D: Green Building Summit Voting Cards

The City of Palo Alto staff distributed the following action item list to community members during the Green Building Summit held in February 2018. Community members were asked to vote for their top-ranking measures, which are tallied in the *Vote* column. The community's top ranking measures (shown in *Section 3: Measure Descriptions*) were further discussed during June and July TAC meetings. During these meetings TRC received guidance on how to interpret measures for cost effectiveness analysis.

Residential New Construction

Action	VOTE
Action 2.1.1: Require all-electric (found to be cost effective) with exceptions, potentially based on minimum size threshold	19
Action 2.1.2: Require EDR = 0 for all new residential construction [1] or potentially based on minimum size threshold	9
Action 2.1.3: Require solar ready zone to installed solar for ALL new single-family *(continued from current reach code)*	7
Action 2.1.4: Smart California Roofs: Require 75% of roof to be occupiable, solar, or vegetated.	1
Action 2.1.5: Require 240V, 30A outlet within 3 feet from new gas or propane water heaters with emergency shutoff within sight of water heater	29
Action 2.1.6: Palo Alto Utilities: Require minimum 200/400A service for all new residential.	30

Commercial New Construction

Action	VOTE
Action 2.2.1: Require annual energy benchmarking (ENERGY STAR reporting) for new commercial construction exceeding 10,000 square feet [1]	20
Action 2.2.2: Require roof insulation weighted average u-value 0.090 for metal buildings and 0.070 for wood-framed	8
Action 2.2.2: Require wall insulation weighted average u-value of opaque walls of 0.0105 for metal buildings, 0.140 for metal framed, and 0.100 for wood-framed.	8
Action 2.2.3: Require all-electric for new small office buildings (found to be cost effective)	29
Action 2.2.4: Increase solar ready zone to 50% of roof area, with exceptions for green or occupiable roofs	17

Residential Existing Buildings

Note that many of the *Triggers* listed below may have changed based on recent TAC discussions.

Action	Trigger	VOTE
Action 1.1.1: Require R-30 roof insulation with radiant barrier when attic is accessed for roof replacement	Roof Permit	4
Action 1.1.2: Require wall insulation in walls exposed during construction to be R-19 minimum	Renovation or Addition	1
Action 1.1.3: Require R-22 below floor insulation in crawlspaces when crawlspace is accessed or floor is replaced	Renovation of Addition	2
Action 1.1.4: Require 240V, 30A outlet within 3 feet from new gas or propane water heaters with emergency shutoff within sight of water heater under certain conditions, e.g. when pulling solar PV or EV permit, when alteration > 1,000 sq. ft, etc.	Water Heater Permit	29
Action 1.1.5: Require and incent heat pump capability for all new or replaced air conditioners	HVAC Permit	22
Action 1.1.6: Require roof insulation weighted average u-value 0.090 for metal buildings and 0.070 for wood-framed when attic is accessed for roof replacement or HVAC replacement	Renovation or Addition	1
Action 1.1.7: Require minimum of (2) zones for all replacements of central heating systems with COP below 1.0	HVAC Permit	3
Action 1.1.8: Require minimum 200/400A service for any electrical panel upgrades	Electrical Permit	25

Commercial Existing Buildings

Action	Trigger	VOTE
Action 1.2.1: Require heat recovery chiller study in the event of chiller replacement over 200 Tons	HVAC Permit	10
Action 1.2.2: Require solar thermal study in the event of boiler replacement at hospitals, hotels, and large restaurants	HVAC permit	16
Action 1.2.3: Require R-25 roof insulation with radiant barrier when attic is accessed for roof replacement	Roof Permit	7
Action 1.2.4: Require wall insulation in walls exposed during construction to be R-19 minimum	Building Permit	7
Action 1.2.5: Require heat pump capability on all new rooftop packaged HVAC systems or split air conditioning systems under 15 tons	HVAC Permit	22
Action 1.2.6: Require LED lighting for all parking lot lighting luminaire replacements	Lighting Permit	15
Action 1.2.7: Require LED signage upgrade for all retail signs when a major interior renovation occurs	Renovation Permit	12