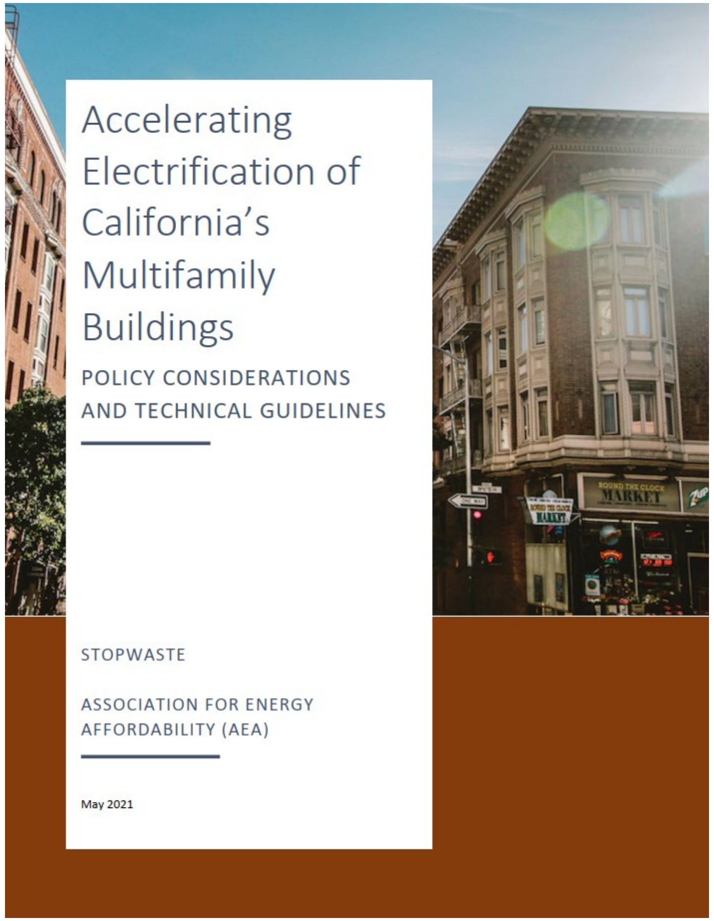


Accelerating Electrification of California's Multifamily Buildings

POLICY CONSIDERATIONS AND TECHNICAL GUIDELINES

STOPWASTE

ASSOCIATION FOR ENERGY AFFORDABILITY (AEA)

May 2021

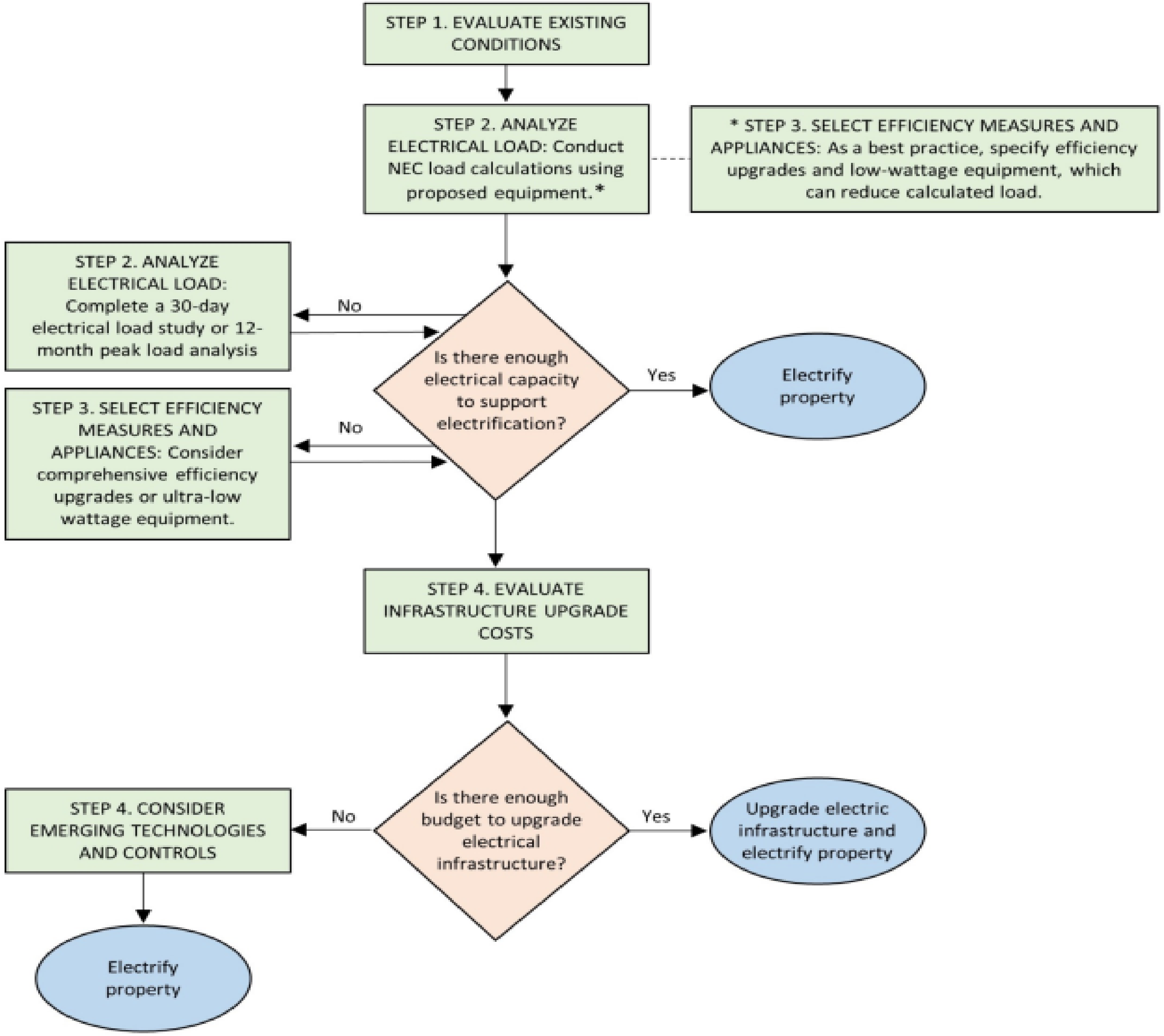
Accelerating Electrification of CA's Multifamily Buildings

Technical Guidelines

June 8, 2022

Part 2 – Technical Considerations for the Electrification of Existing MF Bldgs

- Electricity fundamentals
- Cost-Efficient Electrification Overview (Decision Tree)
- 4 step process



STEP 1. EVALUATE EXISTING CONDITIONS

STEP 2. ANALYZE ELECTRICAL LOAD: Conduct NEC load calculations using proposed equipment.*

* STEP 3. SELECT EFFICIENCY MEASURES AND APPLIANCES: As a best practice, specify efficiency upgrades and low-wattage equipment, which can reduce calculated load.

STEP 2. ANALYZE ELECTRICAL LOAD: Complete a 30-day electrical load study or 12-month peak load analysis

STEP 3. SELECT EFFICIENCY MEASURES AND APPLIANCES: Consider comprehensive efficiency upgrades or ultra-low wattage equipment.

Is there enough electrical capacity to support electrification?

Electrify property

STEP 4. EVALUATE INFRASTRUCTURE UPGRADE COSTS

Is there enough budget to upgrade electrical infrastructure?

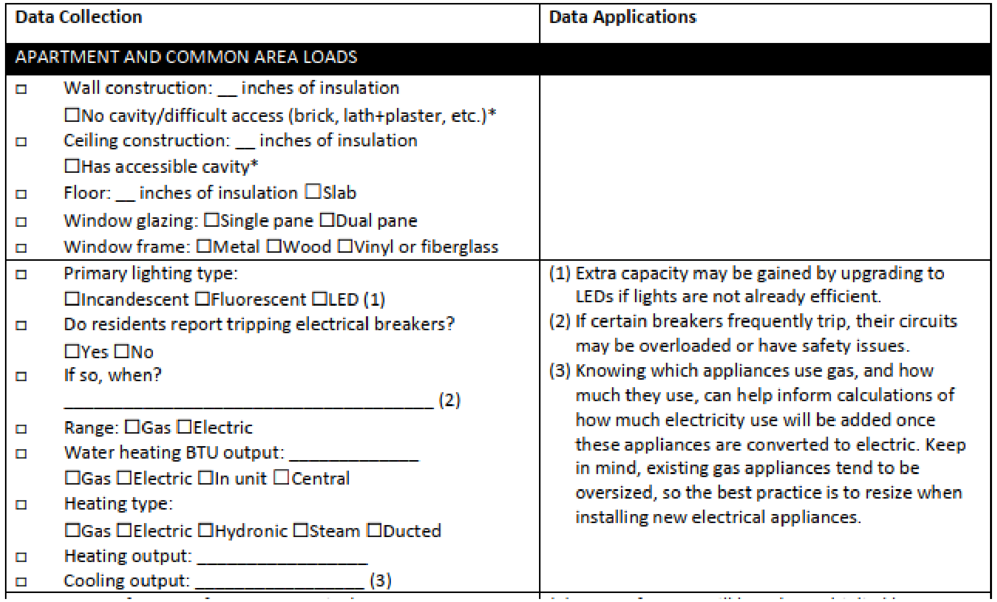
Upgrade electric infrastructure and electrify property

STEP 4. CONSIDER EMERGING TECHNOLOGIES AND CONTROLS

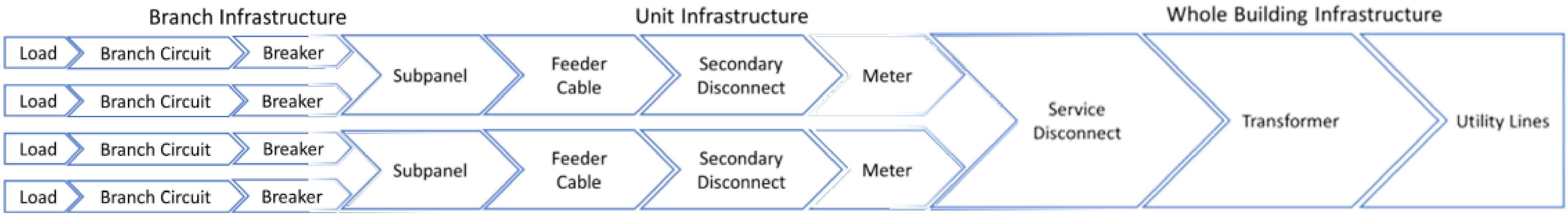
Electrify property

Step 1 – Evaluate Existing Conditions

- Typical existing infrastructure (80/20 rule)
- Planned modernization
- Data collection, usable 3pg form:
  - Main panel and subpanel capacities
  - Equipment specifications
  - Wiring types
- Identifying elect. infrastructure



Data Collection	Data Applications
APARTMENT AND COMMON AREA LOADS	
☐ Wall construction: __ inches of insulation ☐No cavity/difficult access (brick, lath+plaster, etc.)* ☐ Ceiling construction: __ inches of insulation ☐Has accessible cavity* ☐ Floor: __ inches of insulation ☐Slab ☐ Window glazing: ☐Single pane ☐Dual pane ☐ Window frame: ☐Metal ☐Wood ☐Vinyl or fiberglass	
☐ Primary lighting type: ☐Incandescent ☐Fluorescent ☐LED (1) ☐ Do residents report tripping electrical breakers? ☐Yes ☐No ☐ If so, when? ___________________________________ (2) ☐ Range: ☐Gas ☐Electric ☐ Water heating BTU output: ____________ ☐Gas ☐Electric ☐In unit ☐Central ☐ Heating type: ☐Gas ☐Electric ☐Hydronic ☐Steam ☐Ducted ☐ Heating output: ________________ ☐ Cooling output: ________________ (3)	(1) Extra capacity may be gained by upgrading to LEDs if lights are not already efficient. (2) If certain breakers frequently trip, their circuits may be overloaded or have safety issues. (3) Knowing which appliances use gas, and how much they use, can help inform calculations of how much electricity use will be added once these appliances are converted to electric. Keep in mind, existing gas appliances tend to be oversized, so the best practice is to resize when installing new electrical appliances.



Branch Infrastructure

Unit Infrastructure

Whole Building Infrastructure

Load → Branch Circuit → Breaker

Load → Branch Circuit → Breaker

→ Subpanel → Feeder Cable → Secondary Disconnect → Meter

Load → Branch Circuit → Breaker

Load → Branch Circuit → Breaker

→ Subpanel → Feeder Cable → Secondary Disconnect → Meter

→ Service Disconnect → Transformer → Utility Lines

Figure 8. Electrical Infrastructure Sequence

Helpful “real-world” photos throughout

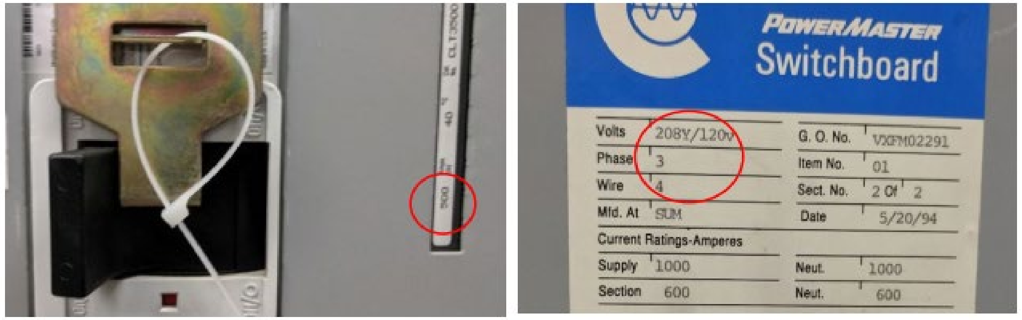


Figure 20. Service Disconnect and Switchboard of a Large Multifamily Building

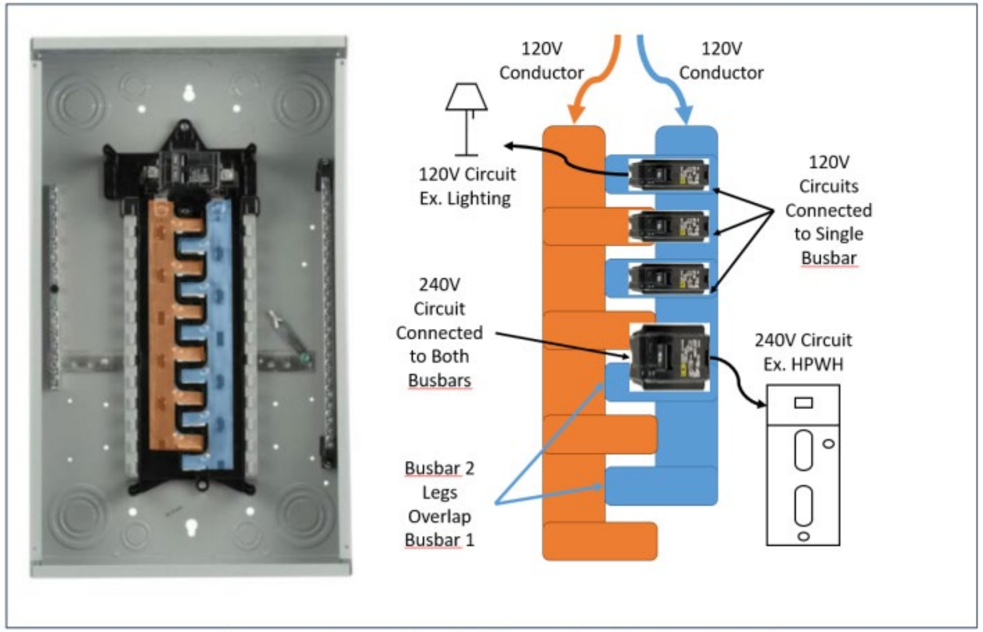


Figure 14. Photograph and Diagram of Inside of a Subpanel

(Square D, 2020) (Square D, 2020) (Saltzman) (Murray, 2020)

Figure 23. Pole-Mounted Transformer

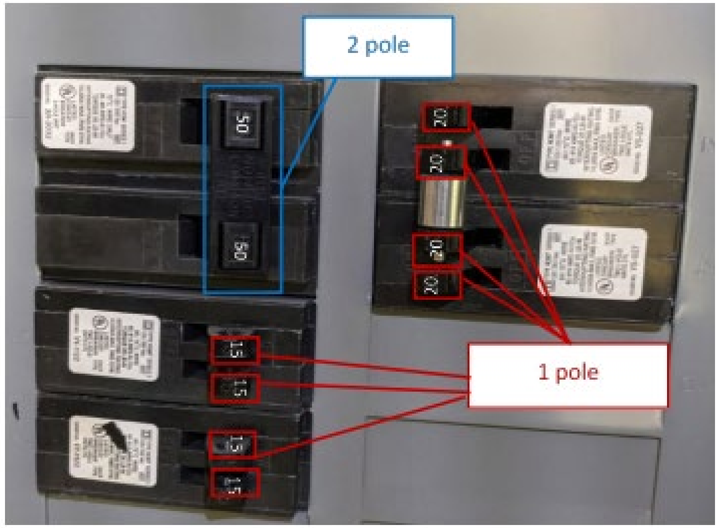


Figure 11. Panel Showing Single- and Dual-Pole Breakers

Step 2 – Analyze Electrical Load

- NEC deemed electrical load calculation, 2 examples fully detailed
- NEC electrical load monitoring study
- References in works cited and appendix

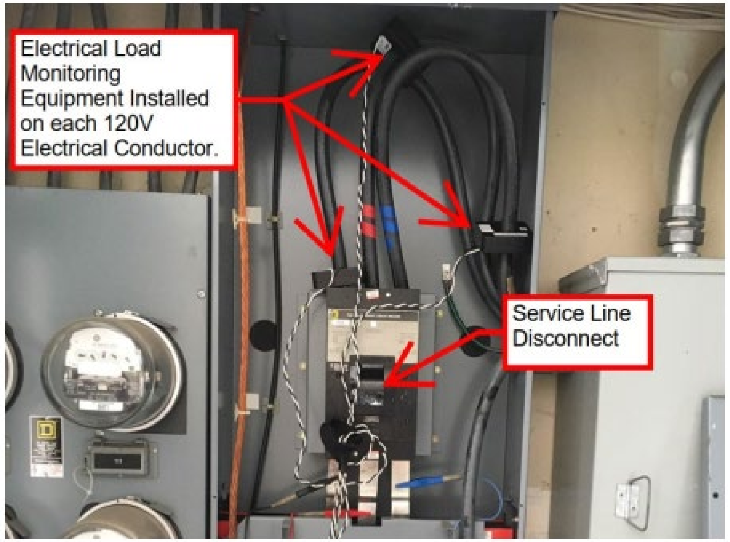
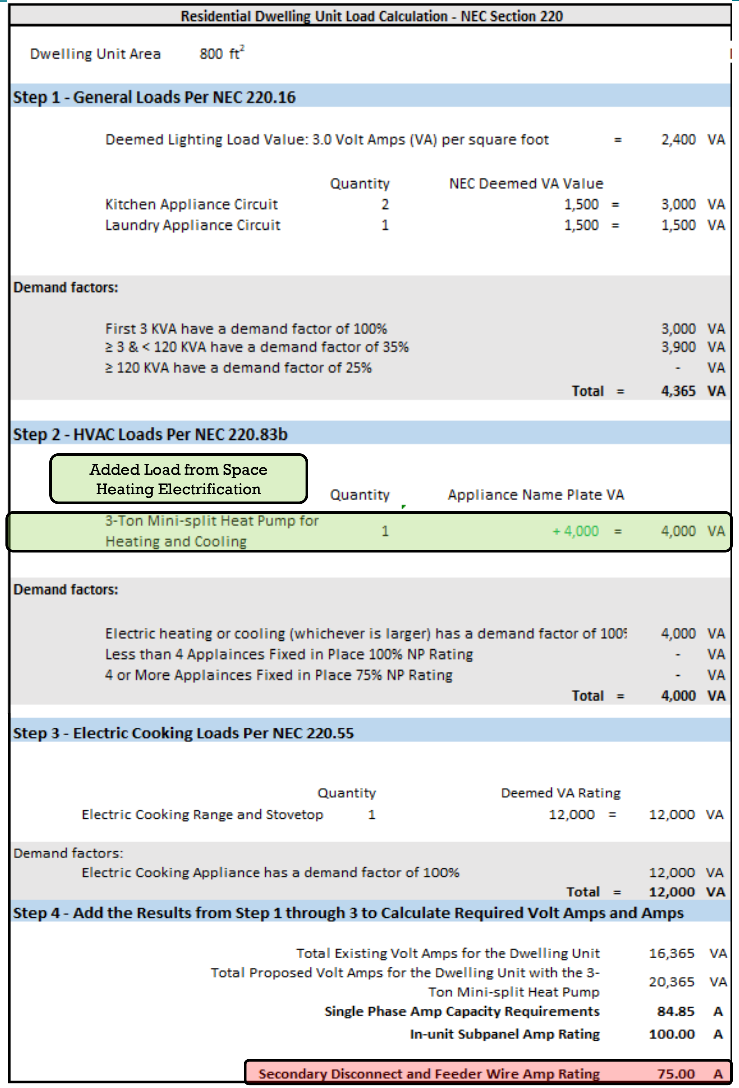


Figure 26. Load Monitoring Equipment



Residential Dwelling Unit Load Calculation - NEC Section 220					
Dwelling Unit Area	800 ft^2				
Step 1 - General Loads Per NEC 220.16					
Deemed Lighting Load Value: 3.0 Volt Amps (VA) per square foot			=	2,400	VA
	Quantity	NEC Deemed VA Value			
Kitchen Appliance Circuit	2	1,500	=	3,000	VA
Laundry Appliance Circuit	1	1,500	=	1,500	VA
Demand factors:					
First 3 KVA have a demand factor of 100%				3,000	VA
≥ 3 & < 120 KVA have a demand factor of 35%				3,900	VA
≥ 120 KVA have a demand factor of 25%				-	VA
		Total	**=**	**4,365**	**VA**
Step 2 - HVAC Loads Per NEC 220.83b					
Added Load from Space Heating Electrification	Quantity	Appliance Name Plate VA			
3-Ton Mini-split Heat Pump for Heating and Cooling	1	+ 4,000	=	4,000	VA
Demand factors:					
Electric heating or cooling (whichever is larger) has a demand factor of 100				4,000	VA
Less than 4 Applainces Fixed in Place 100% NP Rating				-	VA
4 or More Applainces Fixed in Place 75% NP Rating				-	VA
		Total	**=**	**4,000**	**VA**
Step 3 - Electric Cooking Loads Per NEC 220.55					
	Quantity	Deemed VA Rating			
Electric Cooking Range and Stovetop	1	12,000	=	12,000	VA
Demand factors:					
Electric Cooking Appliance has a demand factor of 100%				12,000	VA
		Total	**=**	**12,000**	**VA**
Step 4 - Add the Results from Step 1 through 3 to Calculate Required Volt Amps and Amps					
Total Existing Volt Amps for the Dwelling Unit				16,365	VA
Total Proposed Volt Amps for the Dwelling Unit with the 3-Ton Mini-split Heat Pump				20,365	VA
Single Phase Amp Capacity Requirements				**84.85**	**A**
In-unit Subpanel Amp Rating				**100.00**	**A**
Secondary Disconnect and Feeder Wire Amp Rating				**75.00**	**A**

Notes for Example A

Step 1: General Loads are required by the NEC. These are intended to serve small plug-in appliances throughout the dwelling unit.

Demand factors: For each load type, demand factors are applied to help simulate the coincidence that all loads will be on at the same time. Different load types have different demand factors deemed by the NEC.

Step 2: HVAC Loads have different demand factors and must be calculated separately from general loads. For all NEC load calculations, the calculation must represent the final conditions. In this example, the 3-ton heat pump replaces the existing furnace during electrification.

Step 3: Electric Cooking also has different demand factors and must be calculated separately from HVAC Loads and General Loads.

Step 4: Sum all loads after demand factors have been applied to determine the total volt amps for the dwelling unit. Divide this number by the volt ratings of the panel/secondary disconnect to determine required amps. In this example, it is being divided by single phase 240V.

Step 3 – Select Efficiency Measures and Appliances

- HVAC efficiency and equipment
- Domestic Hot Water systems
- Lighting, cooking, appliances + misc. equipment
- Includes system-specific considerations: climate, electrical requirements, equipment selection, and efficiency opps.

Existing 3 Ton Split AC + 3 Ton Natural Gas Fueled Furnace

Proposed 2 Ton Mini-split Inverter Driven Heat Pump with Indoor Air Handler

Smaller proposed heat pumps can be installed when envelope efficiency measures are in the scope of work

	Existing	**Proposed**	**Capacity & Infrastructure Savings with Smaller Proposed Heat Pump**
Cooling Efficiency (SEER)	13.0	18.0	-
Heating Efficiency	80%	285%	-
Cooling Capacity (Btu/hr)	36,000	28,000	-
Heating Capacity (Btu/hr)	32,000	24,000	-
Watts (VA)	5,610	1,910	+ 3,700
Breaker Size	• 240V 30 Amp Breaker (Outdoor Unit) • 120V 15 Amp Breaker (Indoor Unit)	240V 20 Amp	+ 120V 25 Amp

Figure 30. 1.5 to 3 Ton Split AC Replaced with Heat Pump with Efficiency Measures Applied

Images and data: (Goodman, 2020) (Goodman, 2020) (Mitsubishi Electric, 2020)

HVAC

- HVAC Efficiency and Equipment
- Design Considerations
  - Envelope Penetrations (Packaged Systems)
  - Location of Outdoor Compressor (Split Systems)
  - Refrigerant Line sets (Split Systems)
  - Cold Ambient Performance
  - Defrost Cycle

DHW

- Domestic Hot Water Efficiency and Product Selection
- Residential & Commercial HPWH Considerations
    - Electrical Requirements
    - Equipment Location
    - Cold Ambient Temperature Performance

Lighting, cooking, appliances and misc. equipment

- Efficiency Opportunities
  - Lighting
  - Cooking
  - Laundry
  - Misc. - Fan Efficiency and Pumps
- Electrification Opportunities
  - Cooking
  - Laundry
  - Pool/Spa Heaters

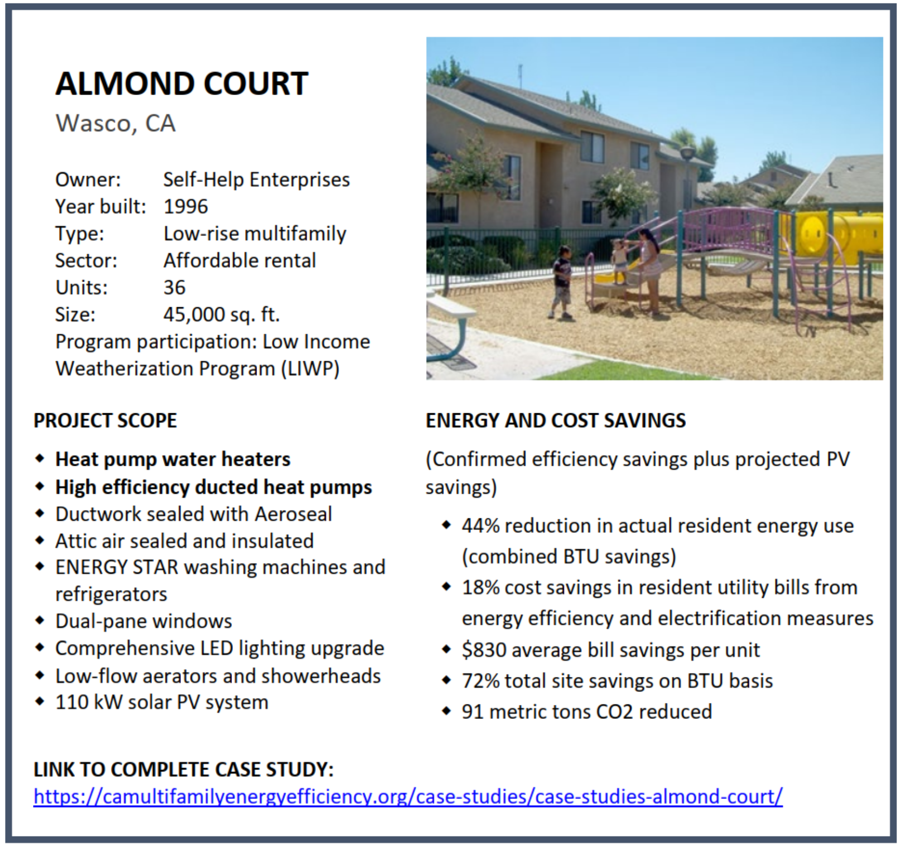
Existing Residential Washing Machine and Electric Resistance Clothes Dryer

Proposed Residential Condensing Dryer/Washer Combination

	Existing	**Proposed**	**Capacity & Infrastructure Savings**
Total Watts	5,700	1,200	+ 4,500
Breaker	• 240V 30 Amp (Dryer) • 120V 15 Amp* (Washing Machine)	120V 15 Amp*	+ 1 Single Pole Breaker Slot

**These efficiency measures are typically not reflected in NEC calcs due to deemed electrical loads*

Case Studies



ALMOND COURT

Wasco, CA

Owner: Self-Help Enterprises
Year built: 1996
Type: Low-rise multifamily
Sector: Affordable rental
Units: 36
Size: 45,000 sq. ft.
Program participation: Low Income Weatherization Program (LIWP)

PROJECT SCOPE

- **Heat pump water heaters**
- **High efficiency ducted heat pumps**
- Ductwork sealed with Aeroseal
- Attic air sealed and insulated
- ENERGY STAR washing machines and refrigerators
- Dual-pane windows
- Comprehensive LED lighting upgrade
- Low-flow aerators and showerheads
- 110 kW solar PV system

ENERGY AND COST SAVINGS

(Confirmed efficiency savings plus projected PV savings)

- 44% reduction in actual resident energy use (combined BTU savings)
- 18% cost savings in resident utility bills from energy efficiency and electrification measures
- $830 average bill savings per unit
- 72% total site savings on BTU basis
- 91 metric tons CO2 reduced

LINK TO COMPLETE CASE STUDY:
https://camultifamilyenergyefficiency.org/case-studies/case-studies-almond-court/

Figure 1. Almond Court Case Study

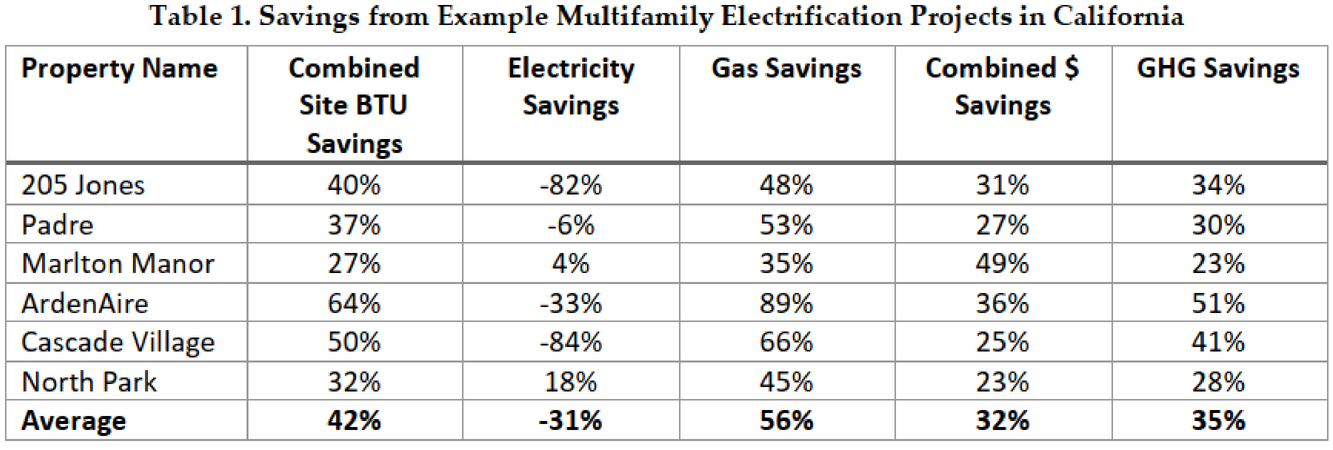


Table 1. Savings from Example Multifamily Electrification Projects in California

Property Name	Combined Site BTU Savings	Electricity Savings	Gas Savings	Combined $ Savings	GHG Savings
205 Jones	40%	-82%	48%	31%	34%
Padre	37%	-6%	53%	27%	30%
Marlton Manor	27%	4%	35%	49%	23%
ArdenAire	64%	-33%	89%	36%	51%
Cascade Village	50%	-84%	66%	25%	41%
North Park	32%	18%	45%	23%	28%
Average	**42%**	**-31%**	**56%**	**32%**	**35%**

Step 4 – Evaluate Upgrade Cost and Consider Emerging Alternatives

- Infrastructure upgrade costs
- Emerging alternatives to upgrading electrical infrastructure, current and future use cases
    - Smart panels and splitters
    - EV dynamic load management

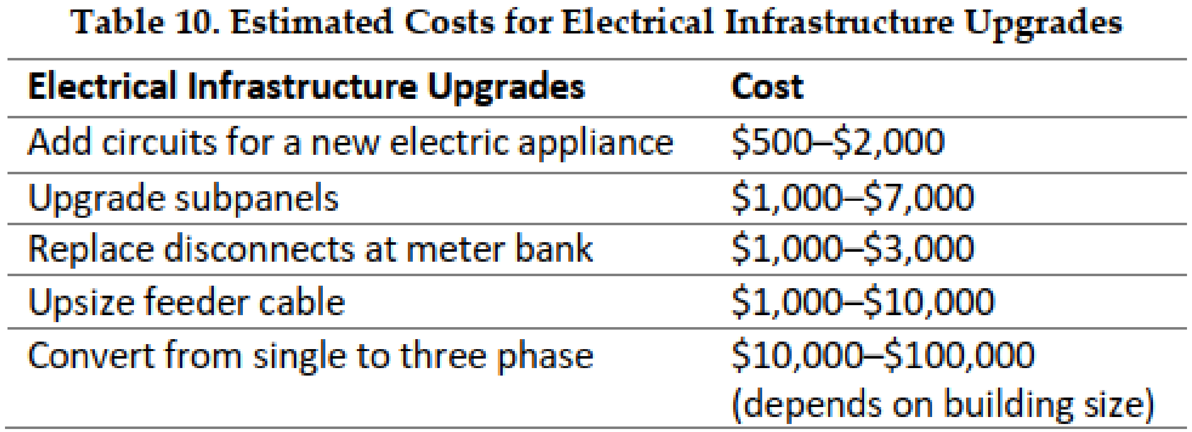


Table 10. Estimated Costs for Electrical Infrastructure Upgrades

Electrical Infrastructure Upgrades	Cost
Add circuits for a new electric appliance	\$500–\$2,000
Upgrade subpanels	\$1,000–\$7,000
Replace disconnects at meter bank	\$1,000–\$3,000
Upsize feeder cable	\$1,000–\$10,000
Convert from single to three phase	\$10,000–\$100,000 (depends on building size)

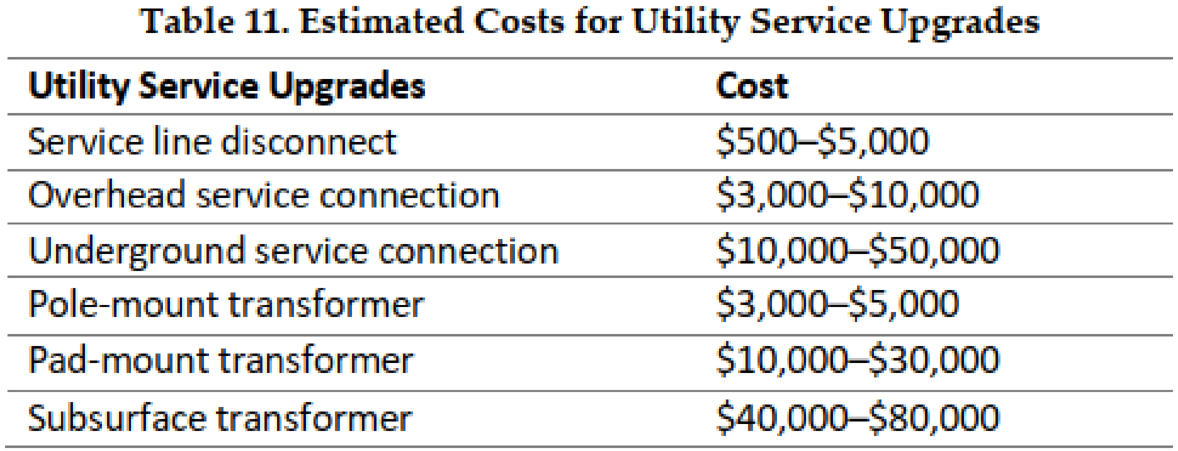
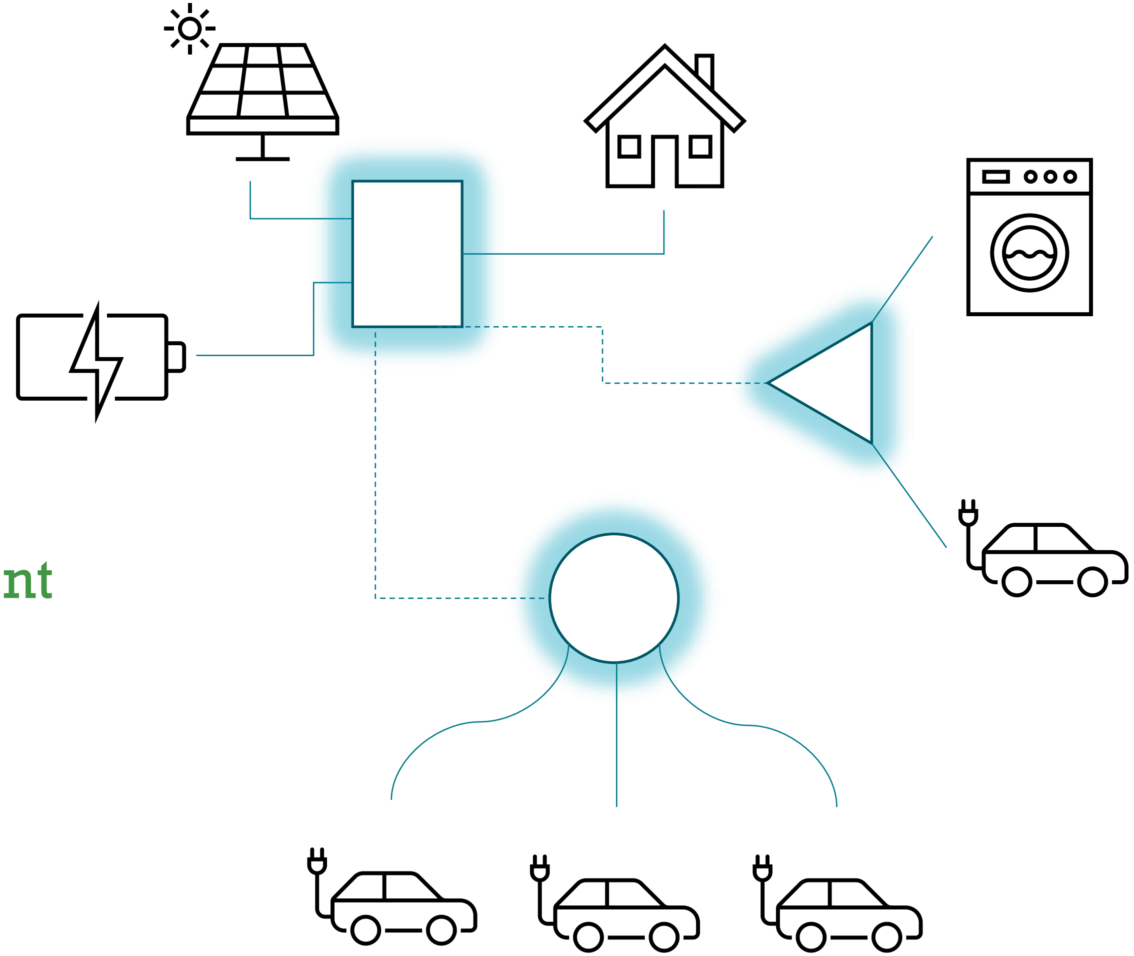


Table 11. Estimated Costs for Utility Service Upgrades

Utility Service Upgrades	Cost
Service line disconnect	\$500–\$5,000
Overhead service connection	\$3,000–\$10,000
Underground service connection	\$10,000–\$50,000
Pole-mount transformer	\$3,000–\$5,000
Pad-mount transformer	\$10,000–\$30,000
Subsurface transformer	\$40,000–\$80,000

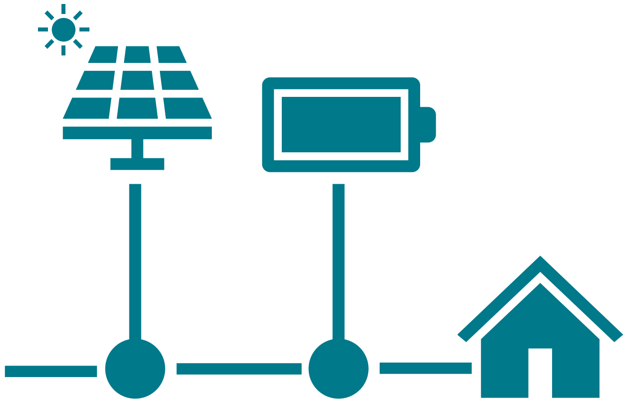
Emerging Alternatives

- Smart Panels
  - Future use cases
  - Battery control
  - Load shifting
- Smart Splitters
  - Future use cases
- EV dynamic load management
- Dialogue with local code enforcement



Solar PV

- Impact of solar PV on electrification
  - Tie in with electrical infrastructure upgrades
  - Types of infrastructure connections
  - Metering types
- Resilience*
  - Load shifting
  - Power outage/shutoff
  - NZE use potential
  - Hedge against utility rate escalation



Resilience benefits of PV and batteries are mentioned in Part 1. However, resilience strategies and benefits expand well beyond those addressed in this report.

Appendix A – Product Guides

- Retrofit equipment product guide
  - HPWHs
  - Mini-splits
  - Packaged terminal HPs
- Emerging alternatives product guide
  - Smart panels
  - Smart splitters
  - EV load management

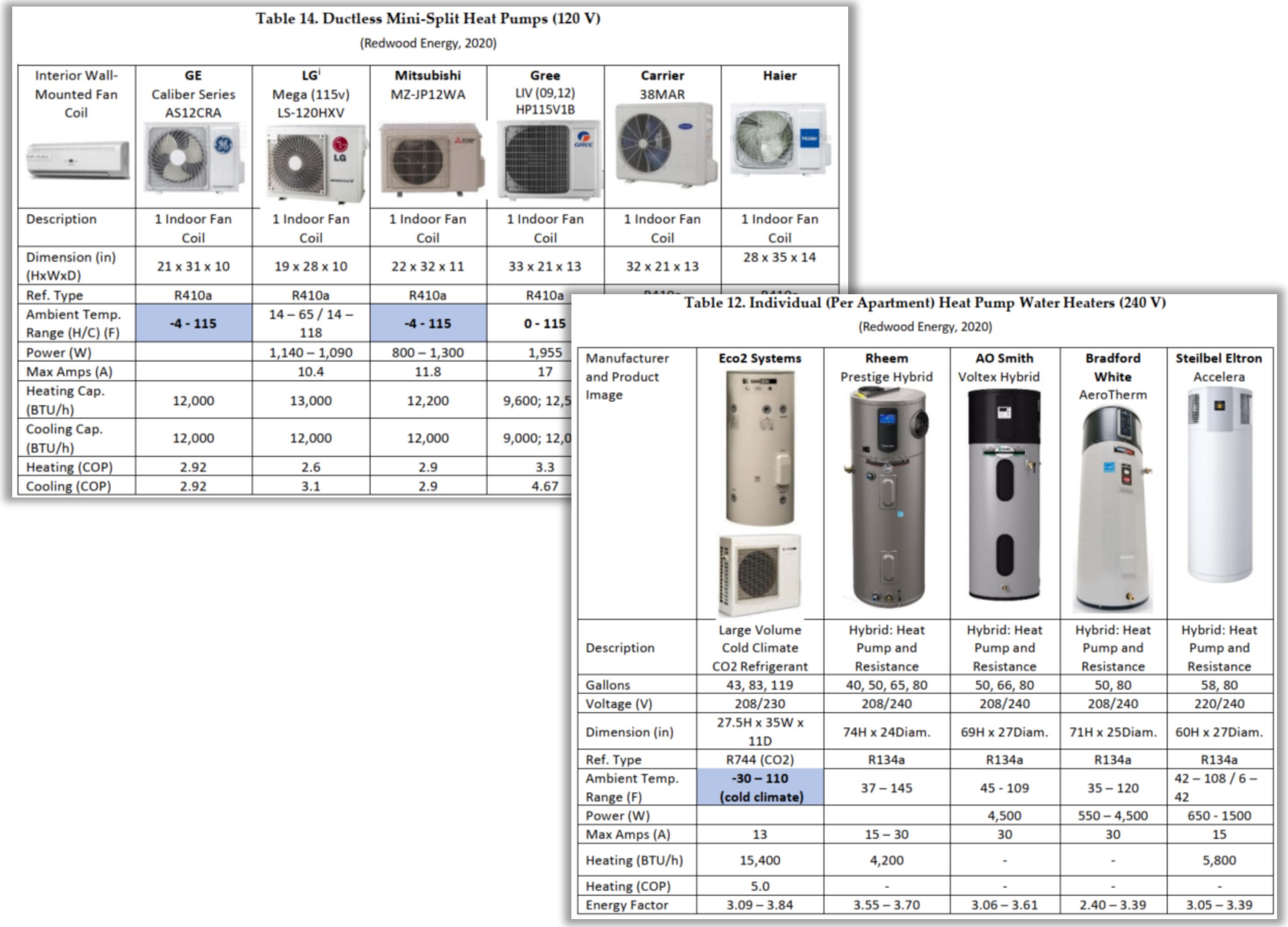


Table 14. Ductless Mini-Split Heat Pumps (120 V)

(Redwood Energy, 2020)

Interior Wall-Mounted Fan Coil	**GE** Caliber Series AS12CRA	**LG**[i] Mega (115v) LS-120HXV	**Mitsubishi** MZ-JP12WA	**Gree** LIV (09,12) HP115V1B	**Carrier** 38MAR	**Haier**
Description	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil
Dimension (in) (HxWxD)	21 x 31 x 10	19 x 28 x 10	22 x 32 x 11	33 x 21 x 13	32 x 21 x 13	28 x 35 x 14
Ref. Type	R410a	R410a	R410a	R410a		
Ambient Temp. Range (H/C) (F)	**-4 - 115**	14 – 65 / 14 – 118	**-4 - 115**	**0 - 115**		
Power (W)		1,140 – 1,090	800 – 1,300	1,955		
Max Amps (A)		10.4	11.8	17		
Heating Cap. (BTU/h)	12,000	13,000	12,200	9,600; 12,5		
Cooling Cap. (BTU/h)	12,000	12,000	12,000	9,000; 12,0		
Heating (COP)	2.92	2.6	2.9	3.3		
Cooling (COP)	2.92	3.1	2.9	4.67		

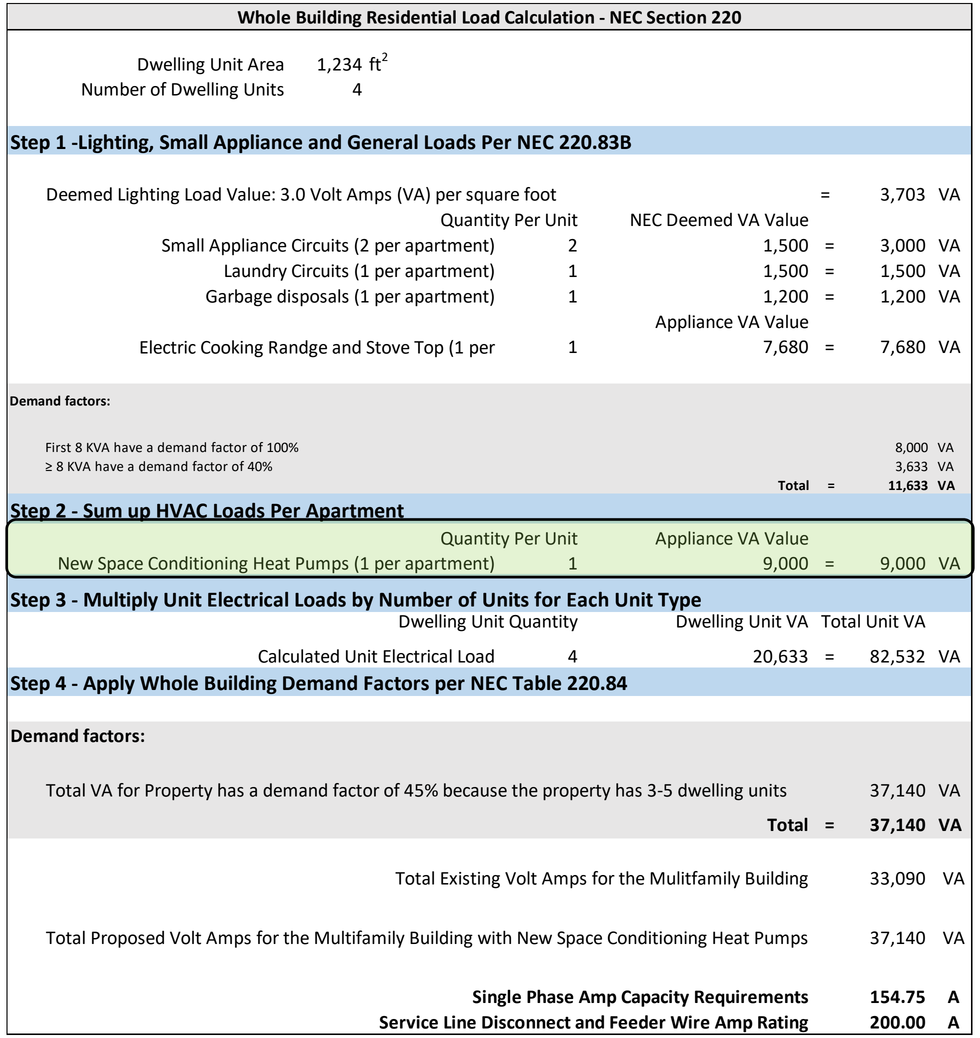
Table 12. Individual (Per Apartment) Heat Pump Water Heaters (240 V)

(Redwood Energy, 2020)

Manufacturer and Product Image	**Eco2 Systems**	**Rheem** Prestige Hybrid	**AO Smith** Voltex Hybrid	**Bradford White** AeroTherm	**Steilbel Eltron** Accelera
Description	Large Volume Cold Climate CO2 Refrigerant	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance
Gallons	43, 83, 119	40, 50, 65, 80	50, 66, 80	50, 80	58, 80
Voltage (V)	208/230	208/240	208/240	208/240	220/240
Dimension (in)	27.5H x 35W x 11D	74H x 24Diam.	69H x 27Diam.	71H x 25Diam.	60H x 27Diam.
Ref. Type	R744 (CO2)	R134a	R134a	R134a	R134a
Ambient Temp. Range (F)	**-30 – 110 (cold climate)**	37 – 145	45 - 109	35 – 120	42 – 108 / 6 – 42
Power (W)			4,500	550 – 4,500	650 - 1500
Max Amps (A)	13	15 – 30	30	30	15
Heating (BTU/h)	15,400	4,200	-	-	5,800
Heating (COP)	5.0	-	-	-	-
Energy Factor	3.09 – 3.84	3.55 – 3.70	3.06 – 3.61	2.40 – 3.39	3.05 – 3.39

Appendix B – NEC Deemed Load Calculations

- Step-by-step calculation process overview
- Load calc references
- Example dwelling unit load calc worksheet
- Example calcs: laundry room and whole building



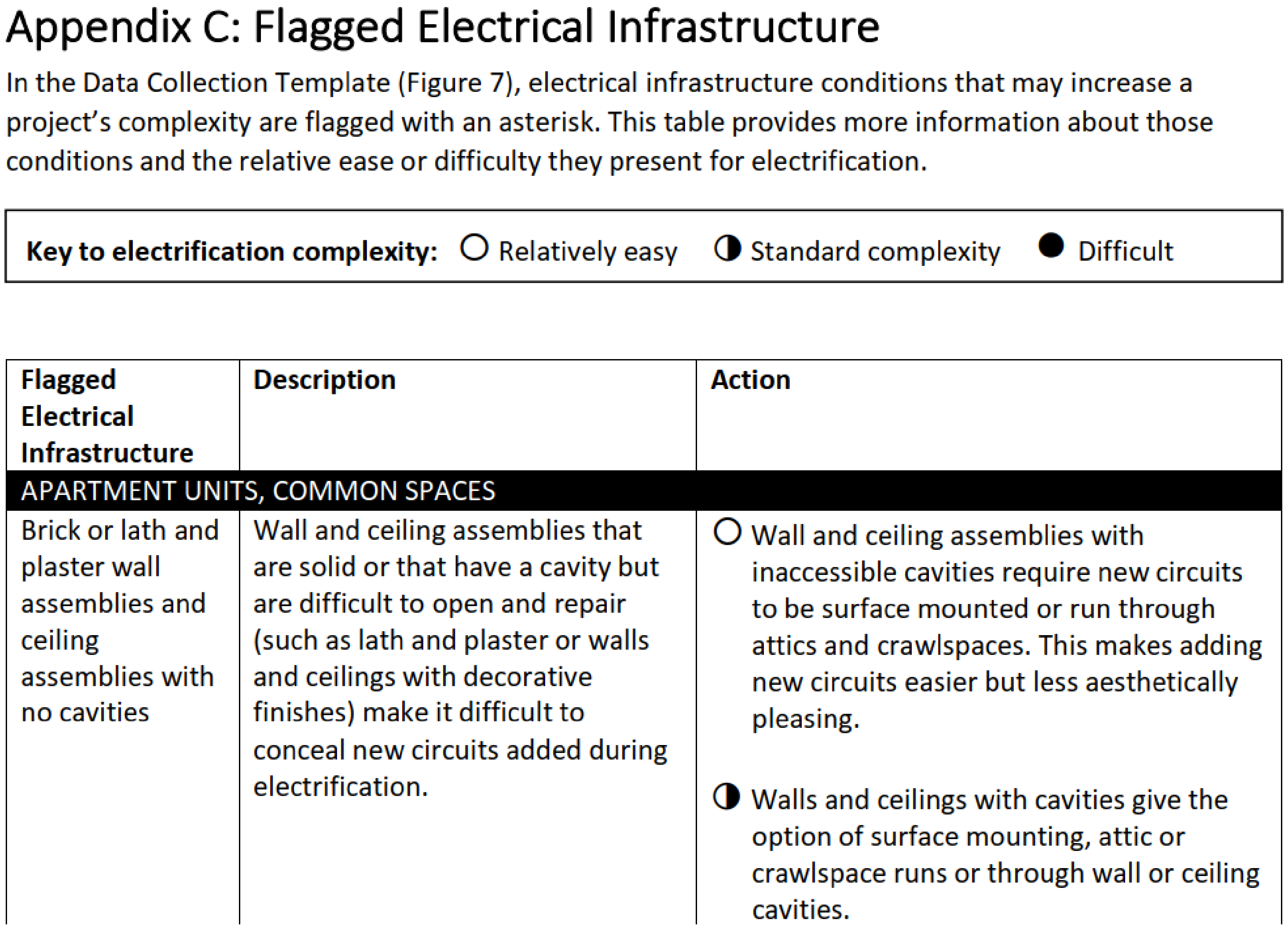
Whole Building Residential Load Calculation - NEC Section 220

Dwelling Unit Area	1,234 ft^2				
Number of Dwelling Units	4				
Step 1 -Lighting, Small Appliance and General Loads Per NEC 220.83B					
Deemed Lighting Load Value: 3.0 Volt Amps (VA) per square foot			=	3,703	VA
	Quantity Per Unit	NEC Deemed VA Value			
Small Appliance Circuits (2 per apartment)	2	1,500	=	3,000	VA
Laundry Circuits (1 per apartment)	1	1,500	=	1,500	VA
Garbage disposals (1 per apartment)	1	1,200	=	1,200	VA
		Appliance VA Value			
Electric Cooking Randge and Stove Top (1 per	1	7,680	=	7,680	VA
Demand factors:					
First 8 KVA have a demand factor of 100%				8,000	VA
≥ 8 KVA have a demand factor of 40%				3,633	VA
		Total	**=**	**11,633**	**VA**
Step 2 - Sum up HVAC Loads Per Apartment					
	Quantity Per Unit	Appliance VA Value			
New Space Conditioning Heat Pumps (1 per apartment)	1	9,000	=	9,000	VA
Step 3 - Multiply Unit Electrical Loads by Number of Units for Each Unit Type					
	Dwelling Unit Quantity	Dwelling Unit VA		Total Unit VA	
Calculated Unit Electrical Load	4	20,633	=	82,532	VA
Step 4 - Apply Whole Building Demand Factors per NEC Table 220.84					
Demand factors:					
Total VA for Property has a demand factor of 45% because the property has 3-5 dwelling units				37,140	VA
		Total	**=**	**37,140**	**VA**
Total Existing Volt Amps for the Mulitfamily Building				33,090	VA
Total Proposed Volt Amps for the Multifamily Building with New Space Conditioning Heat Pumps				37,140	VA
Single Phase Amp Capacity Requirements				**154.75**	**A**
Service Line Disconnect and Feeder Wire Amp Rating				**200.00**	**A**

Load Added During Electrification

Appendix C – Flagged Electrical Infrastructure

- Existing building conditions that directly impact electrification
- Explanation of each condition and why it matters
- Actions to address



Appendix C: Flagged Electrical Infrastructure

In the Data Collection Template (Figure 7), electrical infrastructure conditions that may increase a project's complexity are flagged with an asterisk. This table provides more information about those conditions and the relative ease or difficulty they present for electrification.

Key to electrification complexity: ○ Relatively easy ◑ Standard complexity ● Difficult

Flagged Electrical Infrastructure	Description	Action
APARTMENT UNITS, COMMON SPACES		
Brick or lath and plaster wall assemblies and ceiling assemblies with no cavities	Wall and ceiling assemblies that are solid or that have a cavity but are difficult to open and repair (such as lath and plaster or walls and ceilings with decorative finishes) make it difficult to conceal new circuits added during electrification.	○ Wall and ceiling assemblies with inaccessible cavities require new circuits to be surface mounted or run through attics and crawlspaces. This makes adding new circuits easier but less aesthetically pleasing. ◑ Walls and ceilings with cavities give the option of surface mounting, attic or crawlspace runs or through wall or ceiling cavities.

Thank you!

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510-256-5890

Report available here:

https://www.stopwaste.org/accelerating-electrification-of-california%E2%80%99s-multifamily-buildings