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U.S. DEPARTMENT OF ENERGY

Low-Power Electrification, the NEC and Building Energy Codes

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LBNL Residential Building Systems

2024-04-18

DOE Codes Webinar: The Intersection of Energy Codes and Electrical Codes on the Road to Decarbonization

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Energy (*use over time*) vs. Power (*instantaneous demand*)

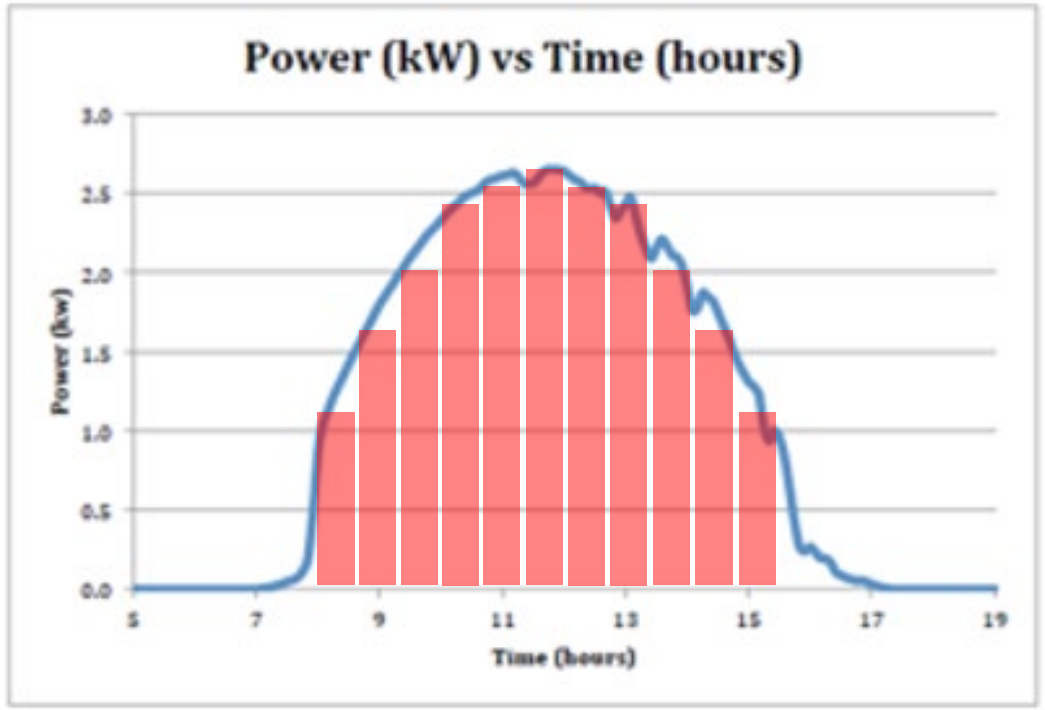


Figure 1. The power (in kW) produced by a solar panel installation at Bryn Mawr College [1] on January 27, 2013.

Building Energy Codes

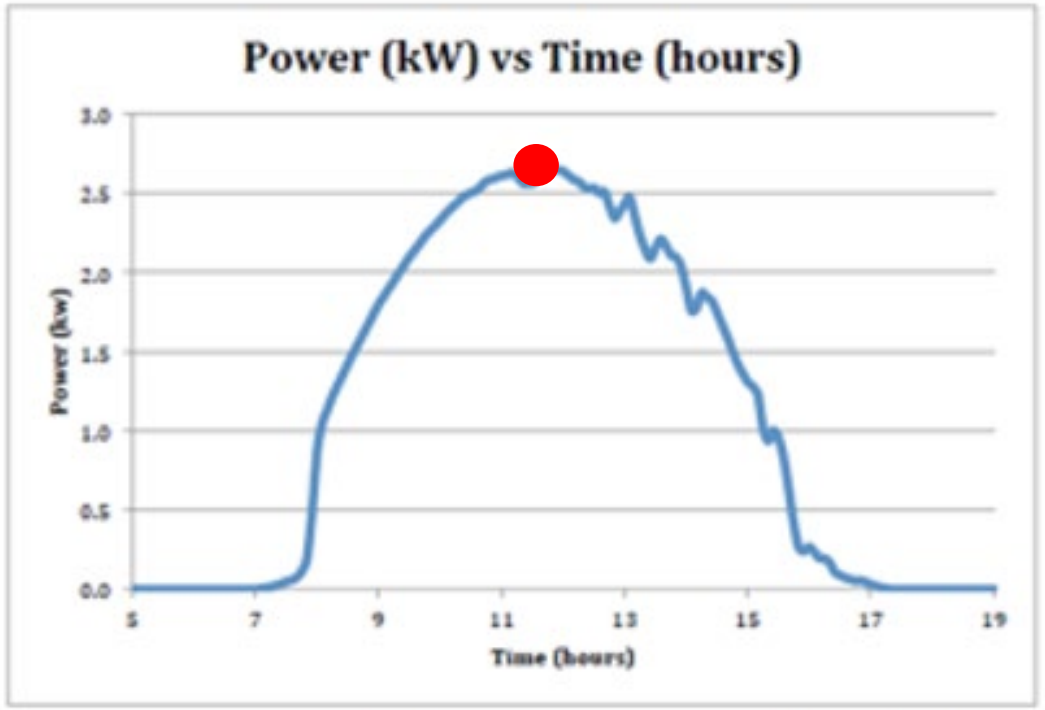


Figure 1. The power (in kW) produced by a solar panel installation at Bryn Mawr College [1] on January 27, 2013.

National Electrical Code

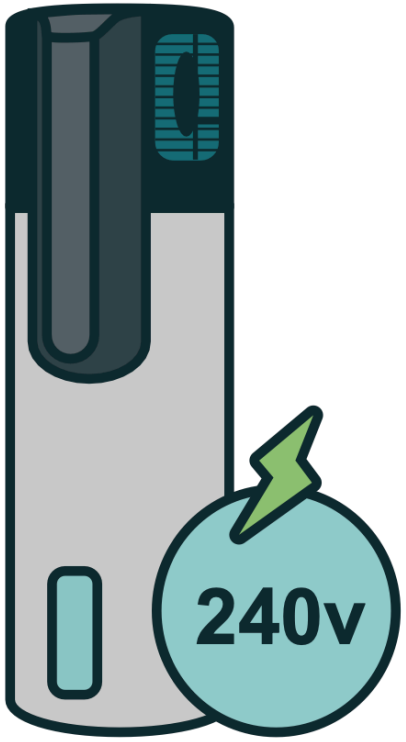
Energy Efficiency vs. Power Efficiency

Electric Resistance Water Heater

~3,500 kWh per year

4.5-5.5 kW

Energy and Power Inefficient

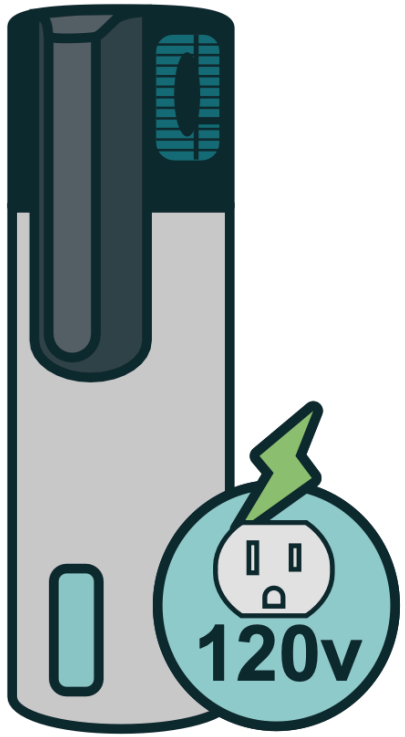


240V Heat Pump Water Heater

~1,000 kWh per year

4.5 kW

Energy Efficient, Power Inefficient



120V Heat Pump Water Heater

~1,000 kWh per year

1 kW

Energy and Power Efficient

Why Power Efficiency in Existing Dwellings?

- Massive electrification of US housing
- Majority existing dwellings
- ~1/3 with 100A service and limited breaker slots
- Upsizing panels and service wires is expensive and time consuming
  - >$100 billion for all 100A service panels
- Context: Flexible utility rates, PV, storage, demand response, controls.

Type	Machines (Millions)
Fossil space heating	69
Fossil water heating	63
Clothes Drying	19
Cooking	95
Vehicles	275
Breaker boxes	100
Vehicle chargers	275
Rooftop solar	55
Home battery storage	29
Total Fossil	**980**
Elect. Resist. space heating	29
Elect. Resist. water heating	54
Total Fossil + Elect. Resist.	**1,063**

Table 6: Adding up all the machines.

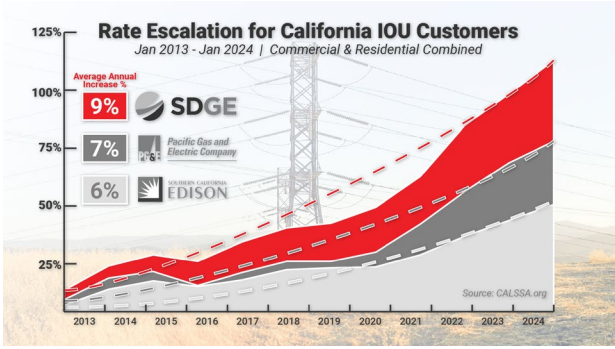
Source: *https://www.rewiringamerica.org/policy/one-billion-machines*

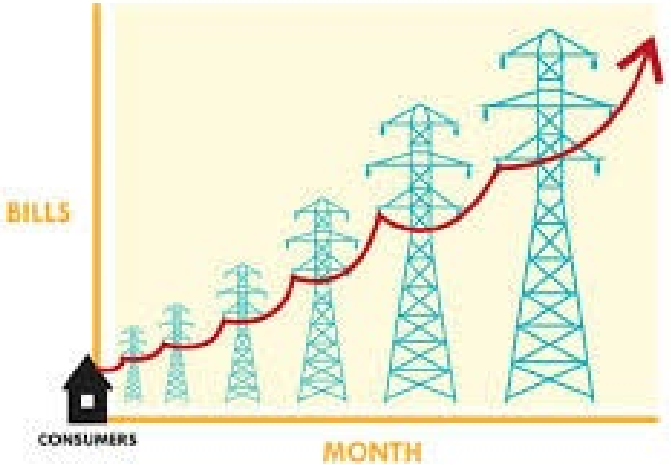
Why Power Efficiency in New Construction?

- Every new load added to the grid can contribute to need for:
  - Utility distribution infrastructure upgrades
  - New power generation facilities
  - Utility staff time for load studies and infrastructure upgrades

- Direct impacts:
  - Infrastructure upgrade costs passed onto homeowners or developers
  - Time-delays for utility interconnection
  - Interconnection denials

- Indirect impacts:
  - Limits ability of other households to electrify
  - Increases utility rates for all ratepayers



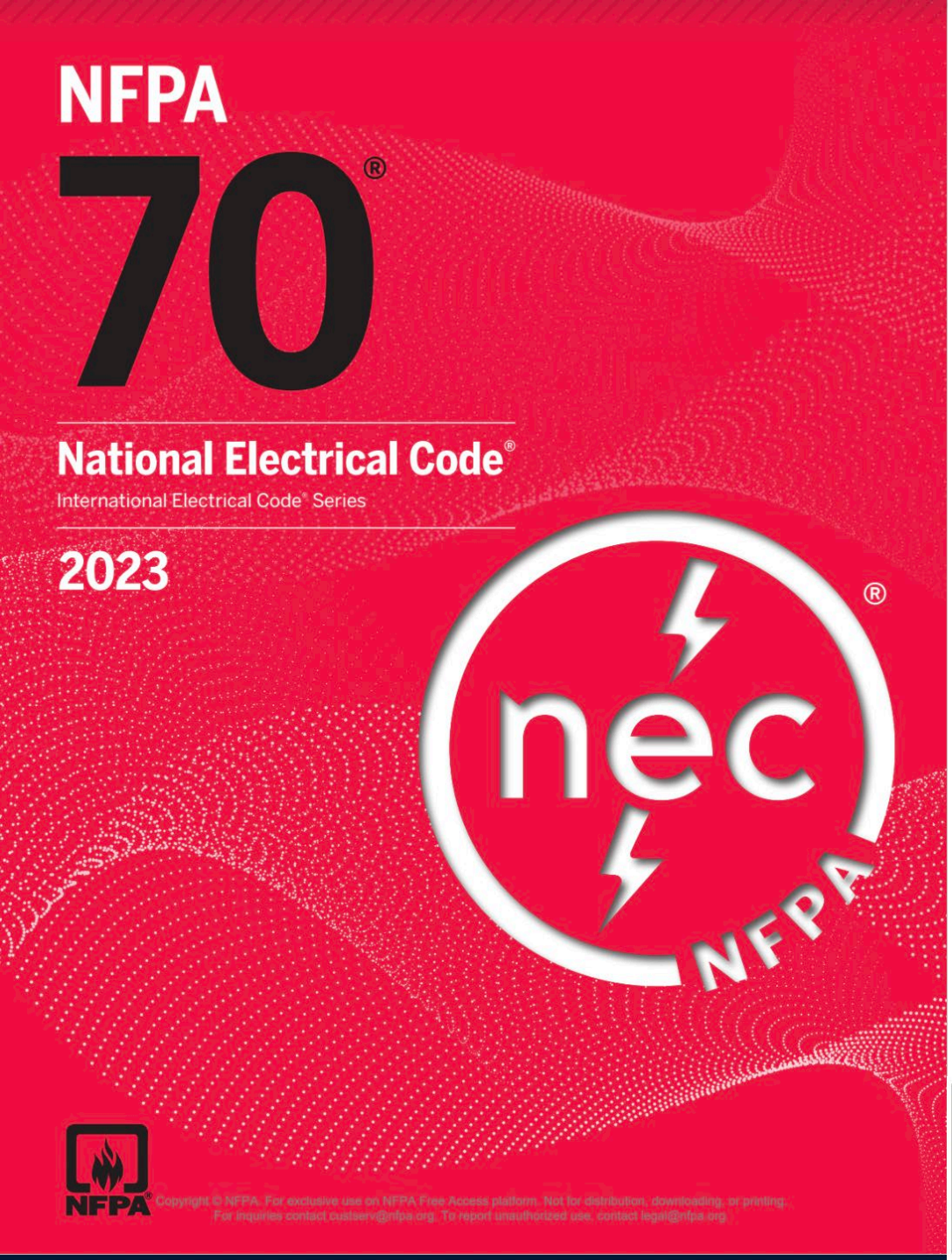


Strategies to Use Today for Low-Power Electrification

1. Pick high efficiency equipment (Heat Pump HSPF > 10)
2. Pick power efficient versions of heat, water heater, dryer, cooking
   - E.g., heat pumps without backup resistance, low amp heat pump water heaters with big tanks
3. Avoid oversizing (heat pump 2- to 3-tons for most homes, low-power level 2 EVSE)
4. Pick multifunction devices (e.g., combo washer/dryer, range)
5. Consider circuit sharing devices (e.g., alternate dryer & EV charger)
6. Consider circuit pausing devices (e.g., pauses EVSE charger or heat pump water heater)
7. Decrease your loads (e.g., improved envelope, use ductless equipment, efficient fixtures)

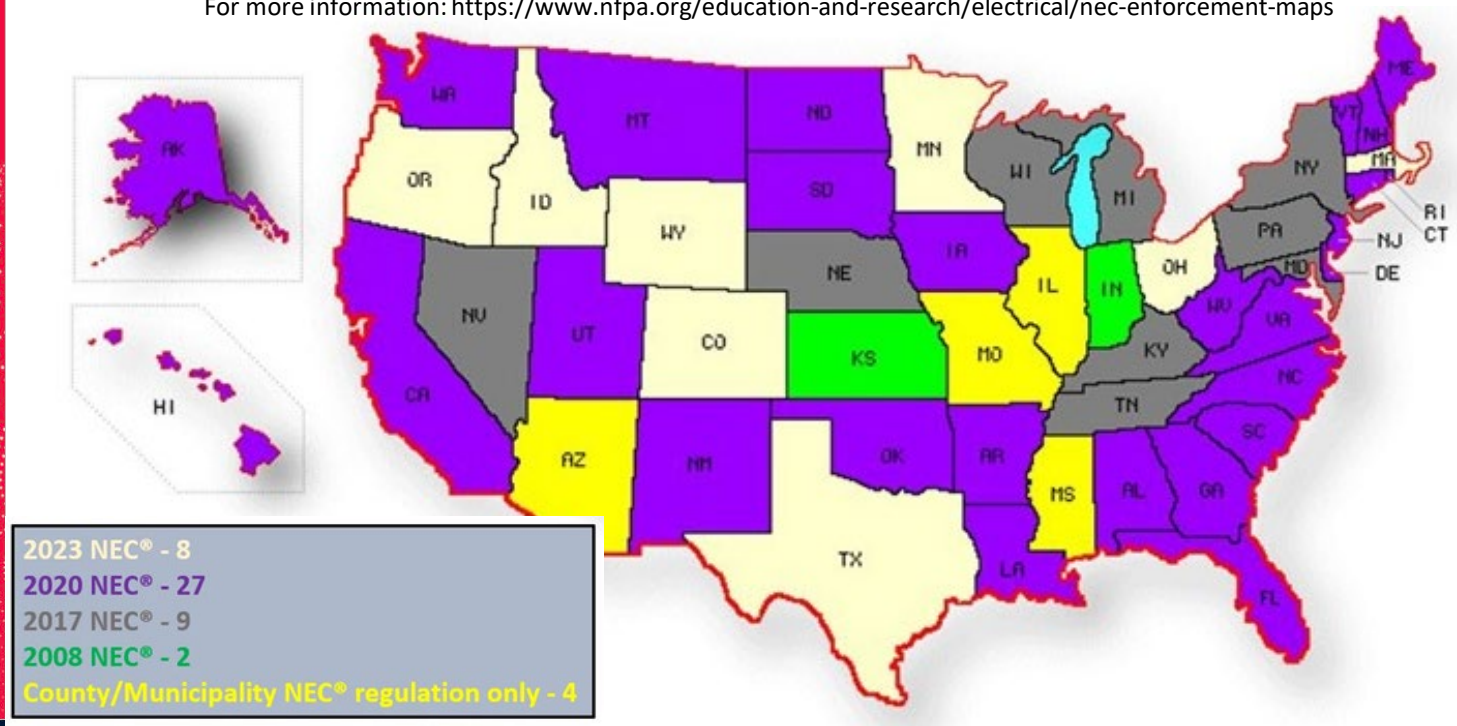
Building Energy Codes vs. Electrical Codes

- Building Energy Codes
  - What loads you must install, their efficiency, etc.
  - Electrification, pre-wiring and sizing mandates
- National Electrical Code
  - How you must safely install and size infrastructure for those loads
  - Circuit requirements, load calculations, conductor and overcurrent sizing, labeling, etc.
- National Electrical Safety Code
  - Addresses grid distribution infrastructure
  - Like the “NEC” for the grid



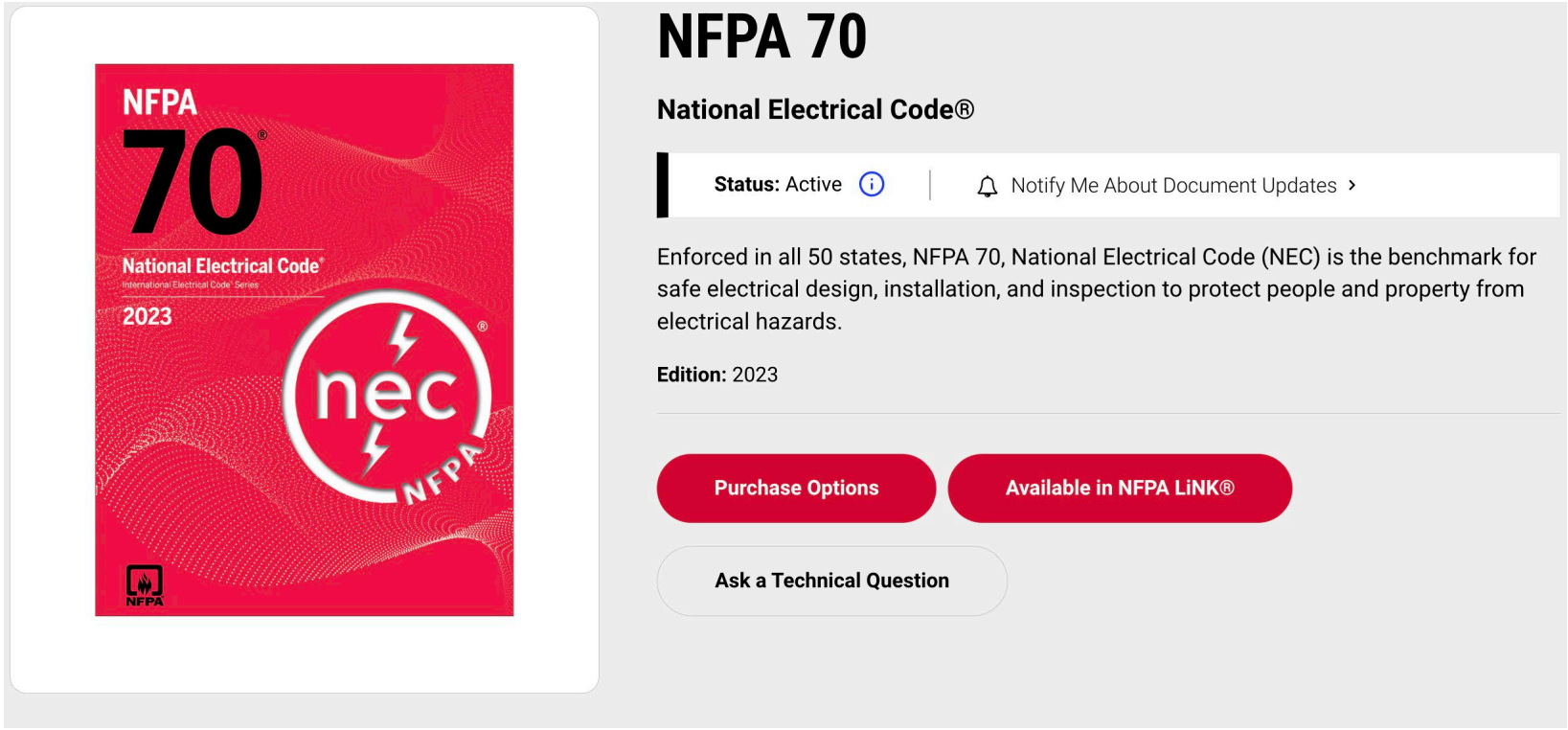
- **National Fire Protection Association (NFPA)** standard addressing electrical hazards and fire safety
- **NOT** a decarbonization or efficiency code
- Adopted and enforced by local jurisdictions, most often at the state-level, sometimes at county or municipal levels

For more information: https://www.nfpa.org/education-and-research/electrical/nec-enforcement-maps



Accessing the NEC for Free Online

- Visit: https://www.nfpa.org/en/codes-and-standards/nfpa-70-standard-development/70



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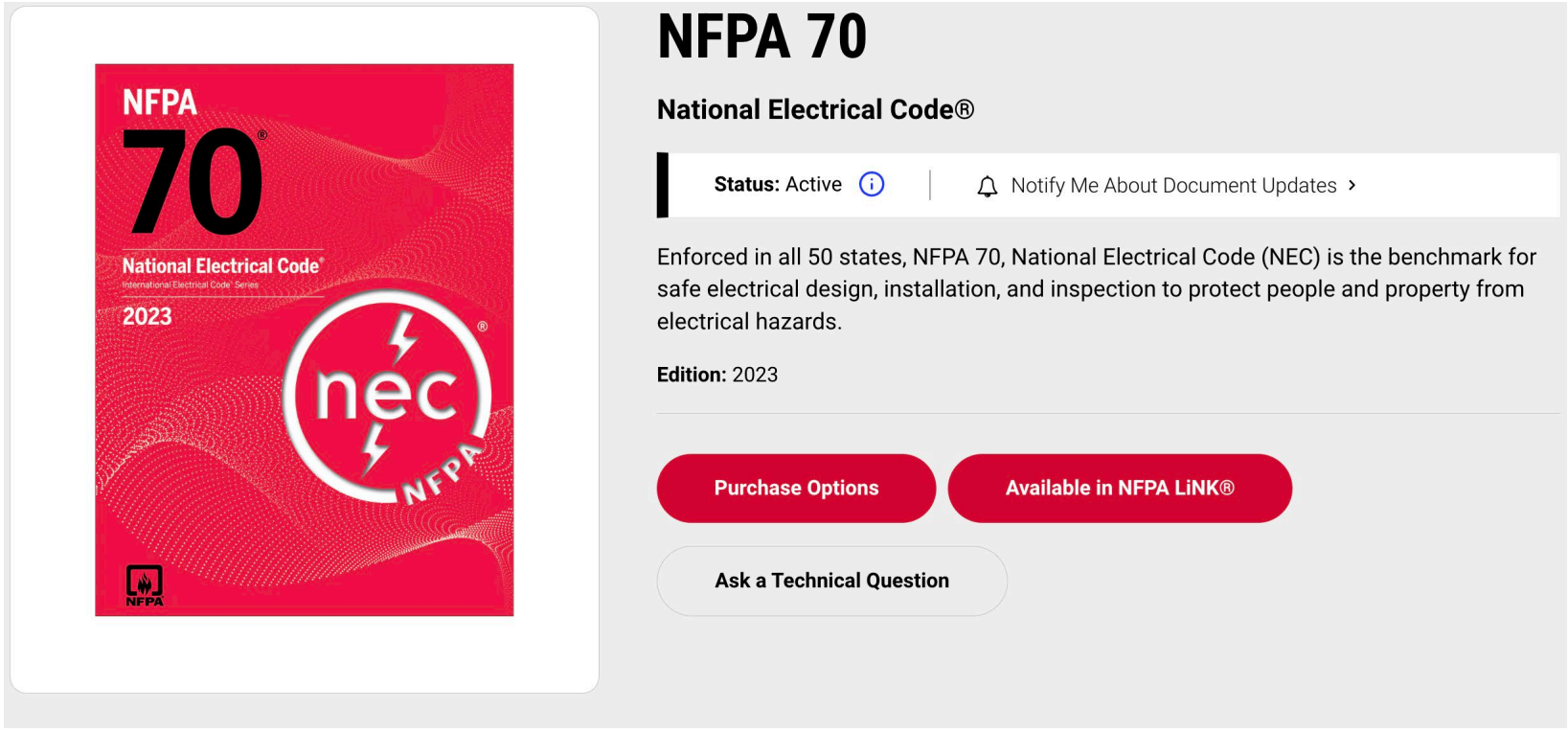


NEC Sections Relevant to Building Energy Codes

- Load Calculations (Section 220)
- Electric Vehicle Power Transfer System (625)
- Solar Photovoltaic (PV) Systems (690)
- Interconnected Electric Power Production Sources (705)
- Energy Storage Systems (706)
- Energy Management Systems (750)

NEC Sections Relevant to Building Energy Codes

- Load Calculations (Section 220) ← **Today's focus**
- Electric Vehicle Power Transfer System (625)
- Solar Photovoltaic (PV) Systems (690)
- Interconnected Electric Power Production Sources (705)
- Energy Storage Systems (706)
- Energy Management Systems (750)

Important Changes 2023 vs. 2020 NEC

- New Electric Vehicle Supply Equipment (EVSE) (220.57) provision for load calculations
  - Must use larger of 7.2 kW and nameplate rating.

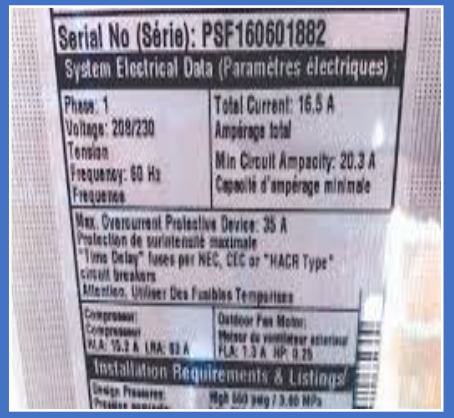
- New Energy Management System (EMS) (220.70) provision for load calculations
  - EMS current set point can be used in load calculations, limited to 80% of panel rating

- Revision of Metering Data method (220.87)
  - Homes with PV systems or demand response can use this method when at least one-year of data is available

- Revision of EVSE Rating (625.42) provision allowing ratings:
  a) Based on use of EMS
  b) Based on EVSE with adjustable settings.

- Revision of Energy Management System (EMS) (750) section:
  - Added listing requirement (750.60) (UL 916?)
  - Added details around current setpoints, labeling requirements, malfunction behavior, and protection from end-user tampering (750.30)

Load Calculations in Dwellings



220.83 Existing Dwelling Units

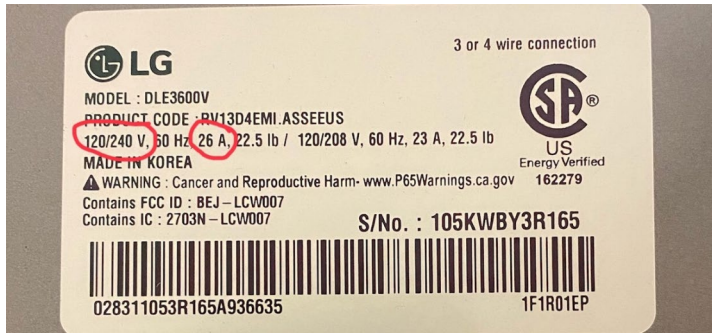
- Asset rating
- Estimates load based on nameplate ratings of installed appliances
  - *No New HVAC: 100% of first 8,000 w + 40% of remaining loads (including hvac)*
  - *New HVAC: 100% of first 8,000 w + 40% of remaining loads + max(heating, cooling)*
- Gives larger existing load but allows more new load
- Best option when adding lots of new loads and/or cannot use metering data
- Requires inspection of home and recording of nameplate values
- Similar sections for new dwellings (220.82) and multifamily dwellings (220.84)

220.87 Determining Existing Loads

- Operational rating
- Estimates load based on metering data plus 25% safety factor
- New loads add at 100% of their nameplate rating
- Gives smaller existing load but allows less new load
- Best option when adding one or two loads, or adding loads over time
- Automated and scalable using smart meter infrastructure

Load Calculation with 220.87

100 A 24 kW → 100 amps X 240 V = **24,000 W Rating**

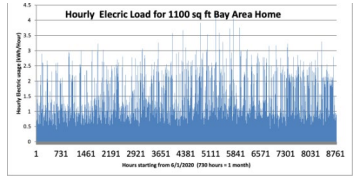


Remaining space available for full nameplates of new equipment:

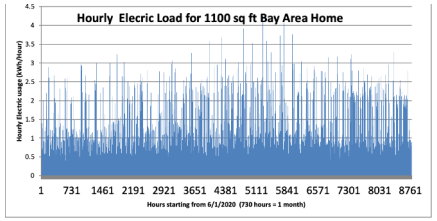
19,000 Nameplate Watts

24,000 W – 5,000 W → 19 kW

4,000 W peak usage measured →



4,000 W peak usage X 1.25 = **5,000 W occupied**



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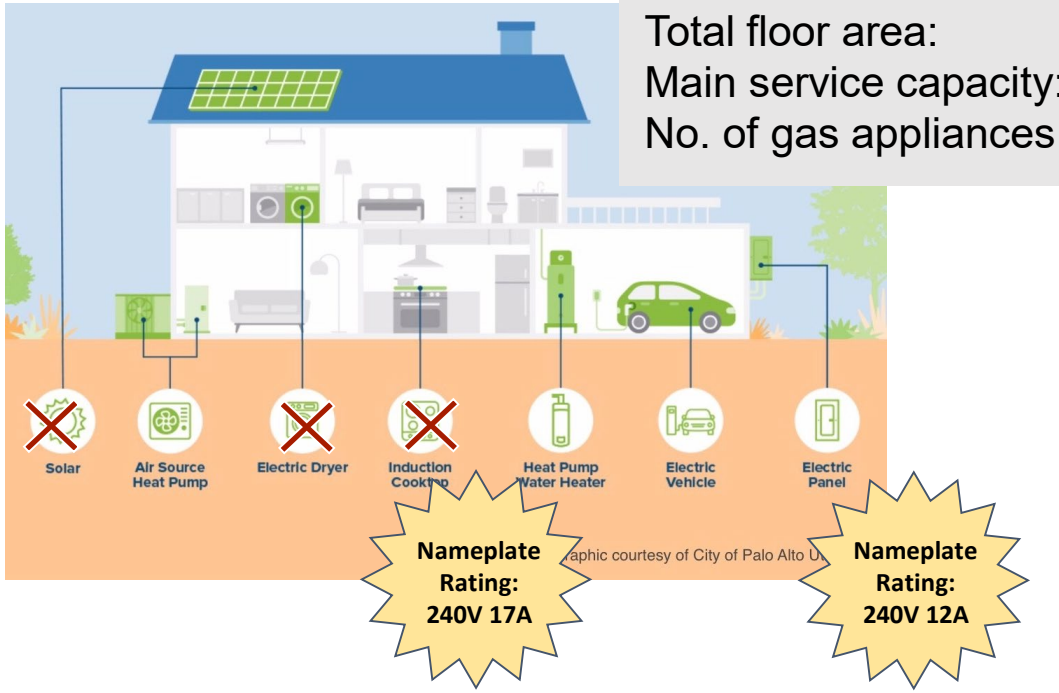
Credit: Tom Kabat

Load Calculation with 220.83

Adding Electric HVAC, Heat Pump Water Heaters

In this example, we use NEC code sections **220.83 (B)**

Home B
Total floor area: 2,000 sq ft
Main service capacity: 100 amps
No. of gas appliances: 2



Load Type	Amps	Volts	Watts
Kitchen Circuit	12.5	x 120	= 1500
Kitchen Circuit	12.5	x 120	= 1500
Laundry Circuit	12.5	x 120	= 1500
Refrigerator	10	x 120	= 1200
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 6000
First 8,000 watts @ 1.0 coincidence factor			= 8,000
Remaining 5,500 watts @ 0.4 coinc. Factor			= 2,200
HVAC 4,080 watts @ 1.0 coincidence factor			= 4,080
HPWH 2,880 watts @ 0.4 coincidence factor			= 1,152
		Total	**= 15,432**

Amperage = 15,432 with 240V = 65 amps

Credit: Tom Kabat

What New Loads Matter Most?

- **EVSE**: 3 - 12 kW
- **Resistance Heating**: 5 - 20 kW
- **Cooking**: 6 - 13 kW
- **HVAC Heat Pumps**: 3 - 10 kW
- **Clothes Drying**: 4 - 6 kW
- **Water heaters**: 4.5 kW

Working to Make the 2026 NEC Friendly to Home Decarbonization

Two DOE lab teams (**LBNL** and **NREL**) are investigating panel upgrades in the US housing stock, and working with an industry coalition formed under **Build-It Green**'s POWER group (led by Jenny Low and Hannah Bruegmann)

What Did We Do and What Are Our Goals?

- What did we do?
  - Reviewed Section 220 for barriers/challenges to existing dwelling electrification
  - Analyzed metering data to understand dwelling power demand
  - Submitted 17 PIs to NFPA addressing load calculations in Section 220
  - Participated in Task Group 4, attended CMP meetings in Jan 2024

- Our Goals
  - Clear and safe load calculations that support home electrification
  - Assumptions based on actual performance in dwellings based on metered data
  - Accurate, scalable electrical load calculations using nation’s smart meters
  - Apply results to other sections throughout 220, as appropriate

What Data Did We Use?

- **Whole dwelling 15- and 60-minute maximum demand data**
  - 11,750 existing US dwellings
  - 2.7 years per dwelling
  - 32,000 dwelling-years of data

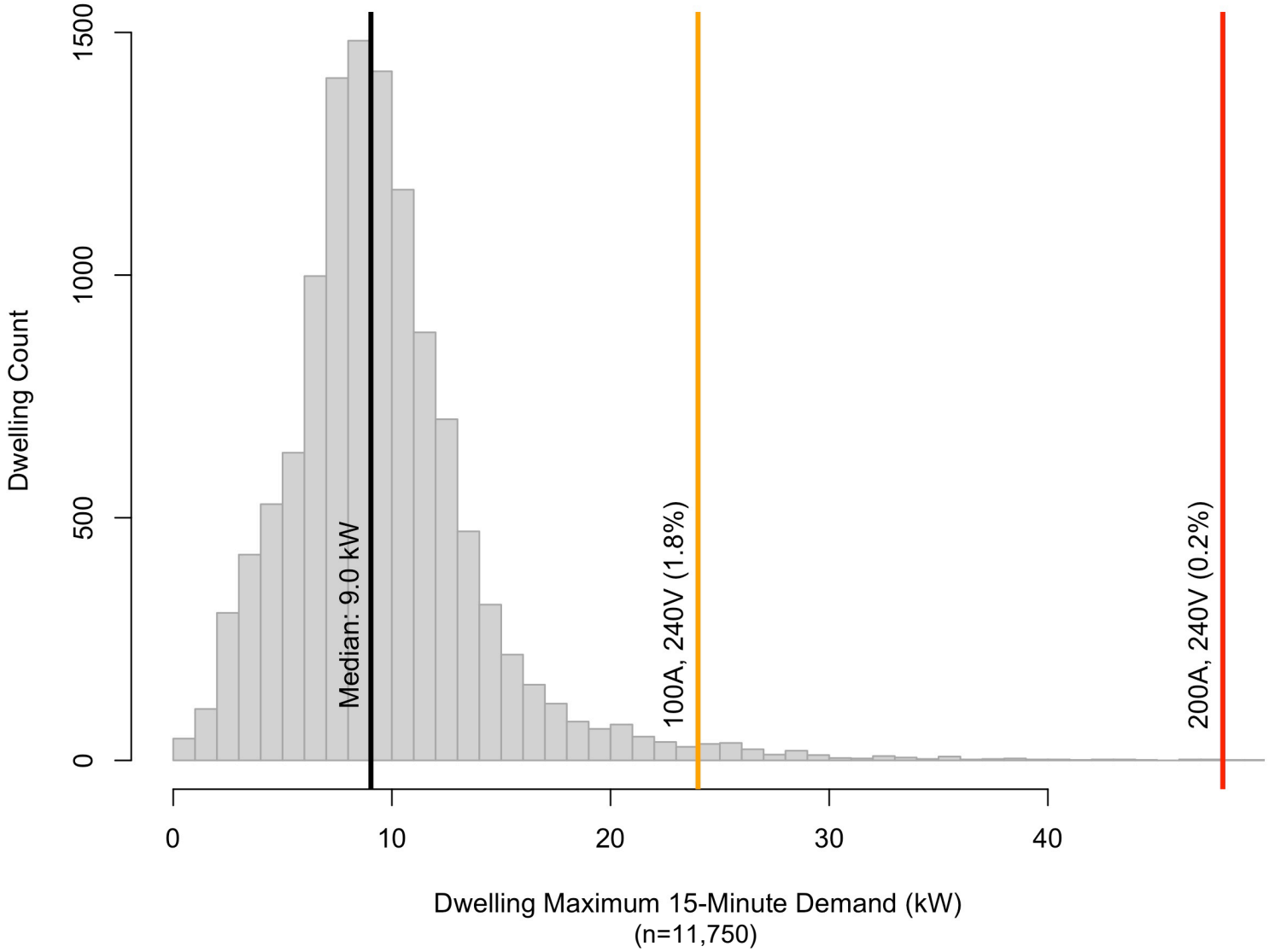
- **End-use sub-metering 15-minute data**
  - 957 existing US dwellings
  - 9,490 branch circuits
  - 3.5 years per dwelling
  - 3,376 dwelling-years of data

- **Lighting audit data**
  - 2,053 existing US dwellings

- States include: **TX**, CA, NY, CO, OR, WA, ID, MT, **VT**
- Housing types: **Single-family**, multi-family and manufactured

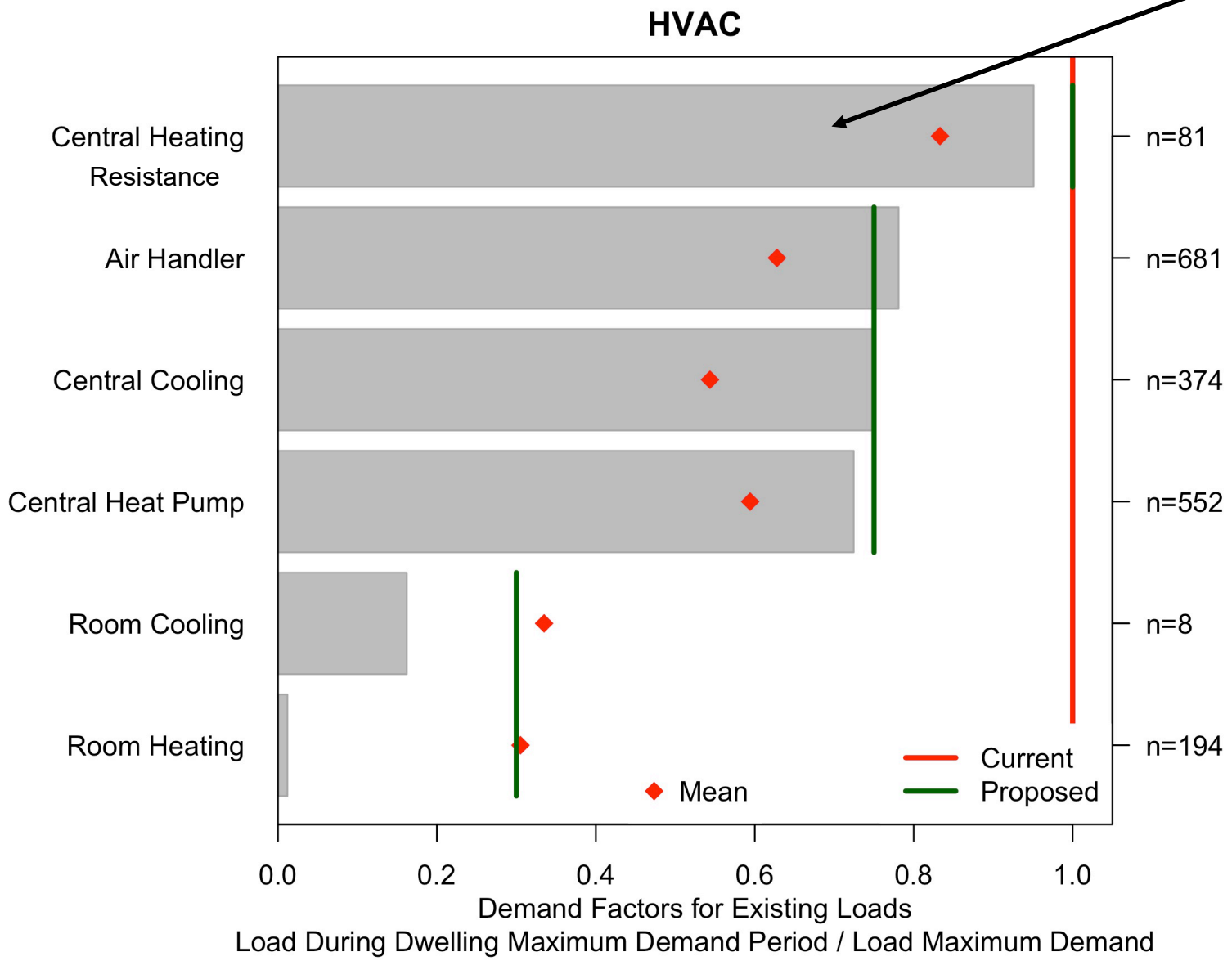
High-Level Learnings for Services and Feeders

- Most dwellings have LOTS of capacity for new loads
- New loads add at <100%
- Lots of load diversity (40-50%), increases with more connected loads
- Never do more than four loads operate at or near 100% together
- Appliance maximum power draw < nameplate ratings

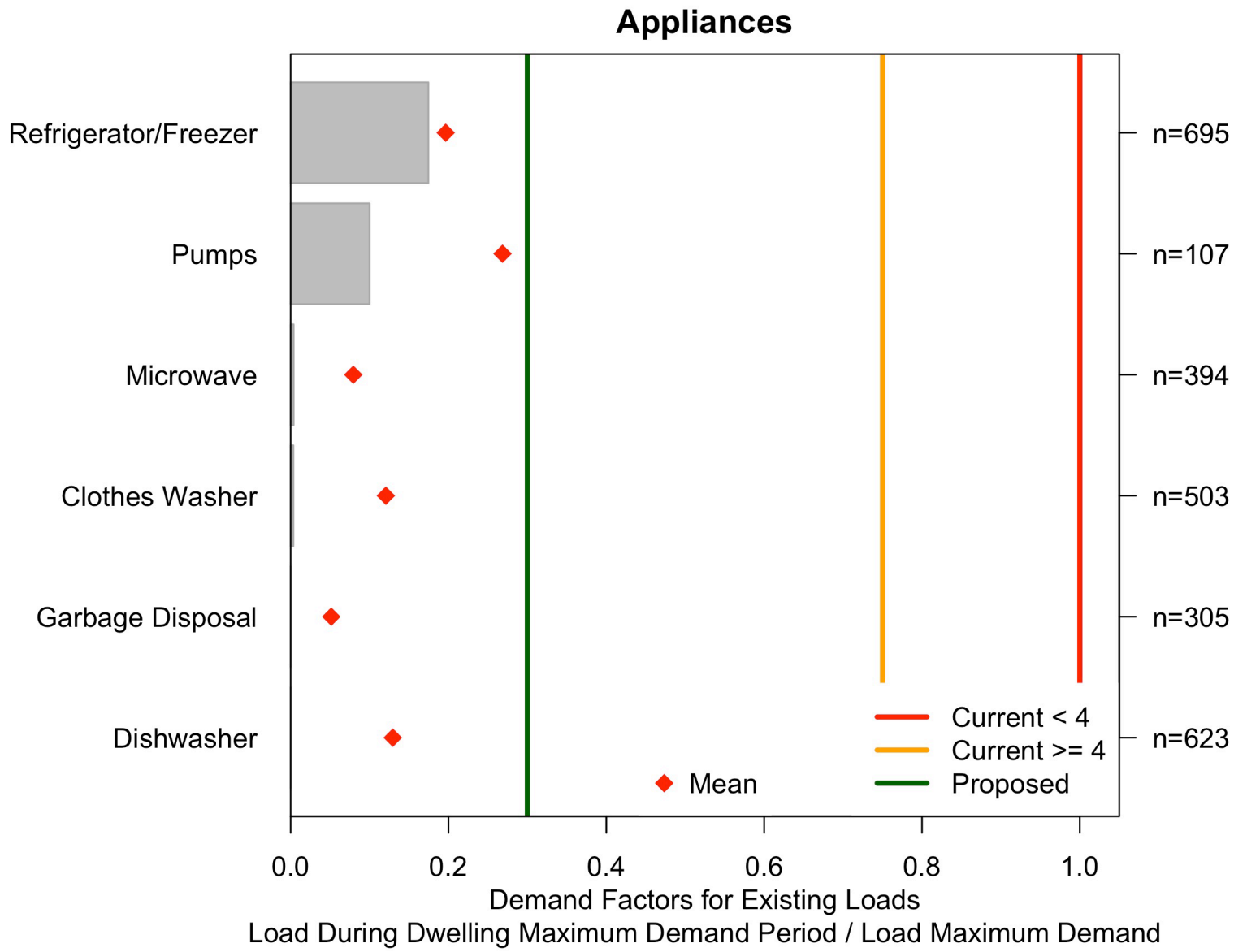


HVAC Loads –220.51, 220.82

Grey bars = median

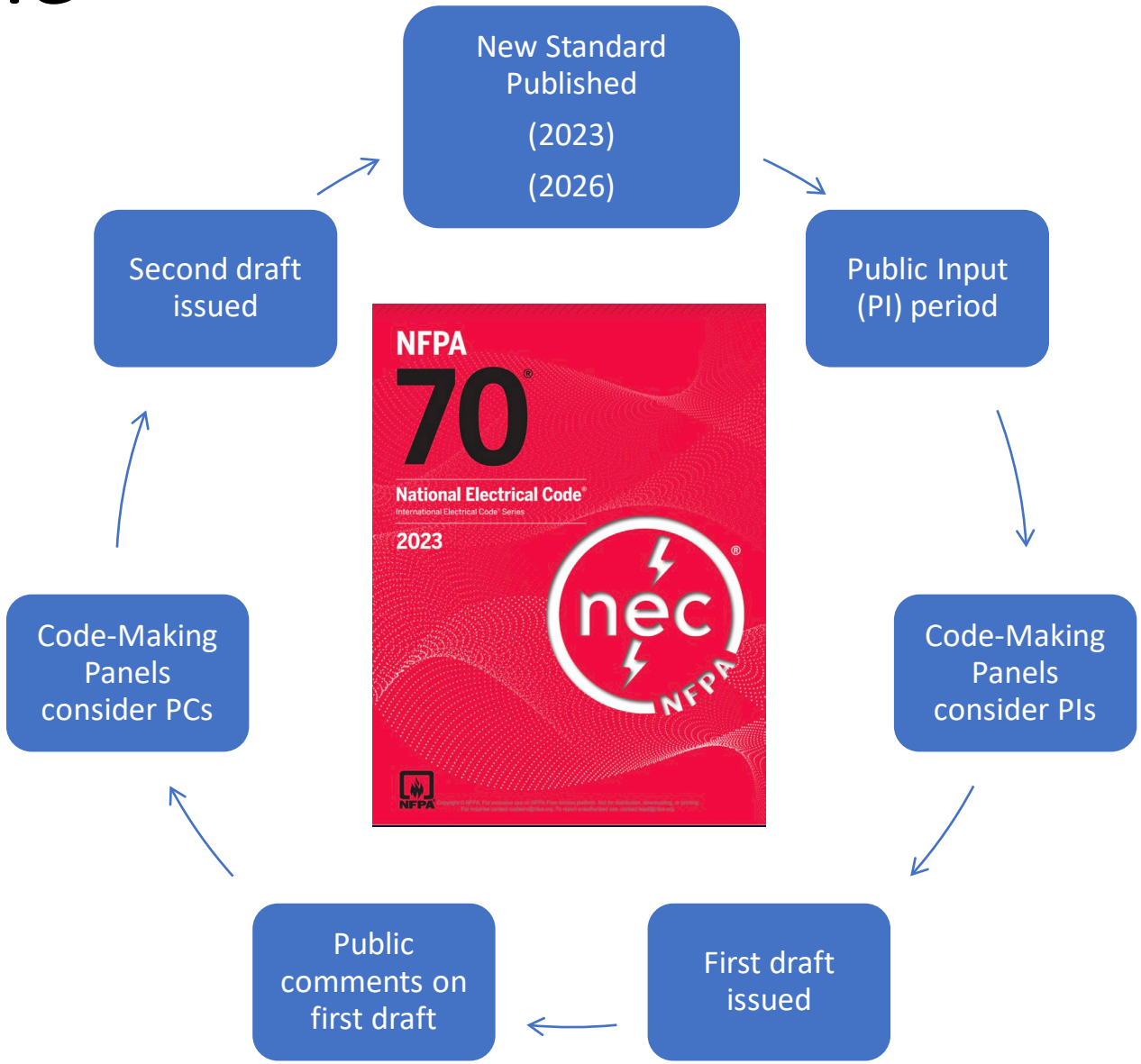


Appliance Loads – 220.53



NEC Revision Cycle

- Revised on a 3-year cycle
- Current edition: 2023
- Next edition: 2026
- Adopted on different timelines across the US



Changes We Proposed for the 2026 NEC

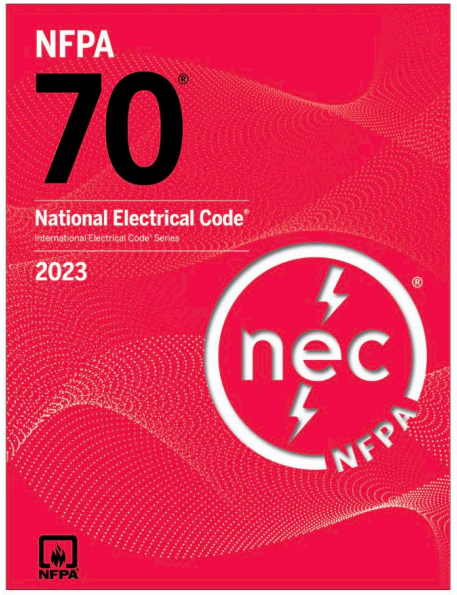
- Changes likely in the pipeline. NOT yet finalized or approved.
  - Reduction in general lights and general receptacles loads, from 3 w/ft^2 to 2 w/ft^2
  - Reduction in baseline kVA for loads in new dwelling units, from 10 kVA to 8 kVA (220.82)
  - Remove differential treatment of new HVAC vs. other new loads in existing dwellings (220.83)
  - Explicit treatment of EVSE in new, existing and multifamily dwelling load calculations (220.82 - 220.84)
  - “Power Control Systems” provide overload protection. New concept to supplement EMS provisions.
  - Expanding ability to take credit for load controls in NEC load calculations
- Changes we are still fighting for. We NEED your help.
  - Re-write of metering data method (220.87) to allow deduction of loads being removed, use of demand factors, and clarification around metering, data interval, time frequency and dwellings with PV.
  - Reduced demand factors for heat pump technologies throughout section 220
  - Allowance to use nameplate ratings for low-power appliances (e.g., clothes dryers, EVSE)

How To Get Involved

Event	***Date***	***Complete***
Public Inputs (PIs) to 2023 NEC	Summer 23’	X
Task groups review/process PIs	Fall 23’	X
Code-making panel meetings, draft 1	January 24’	X
Final, online 1st draft voting. ⅔ majority required for First Revision	Spring 24’	
First draft 2026 NEC issued publicly	**July 10th, 24’**	
END of Public Comment (PCs) period for First Draft	**Aug 28th, 24’**	
Task groups review/process PCs	Sept 24’	
Code-making panel meetings, draft 2	Oct 24’	
Final, online 2nd draft voting. ⅔ majority required for Revision	Winter 25’	
Second draft 2026 NEC issued publicly	March 21, 25’	

Submitting Public Comments on Draft 1

Visit: https://www.nfpa.org/en/codes-and-standards/nfpa-70-standard-development/70



NFPA 70

National Electrical Code®

Status: Active | Notify Me About Document Updates ›

Enforced in all 50 states, NFPA 70, National Electrical Code (NEC) is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards.

Edition: 2023

Purchase Options | **Available in NFPA LiNK®**

Ask a Technical Question

Current & Prior Editions | **Next Edition** | Technical Committee

Next Edition: 2026 | **Revision Cycle:** Annual 2025 NEC

View Public Input Online

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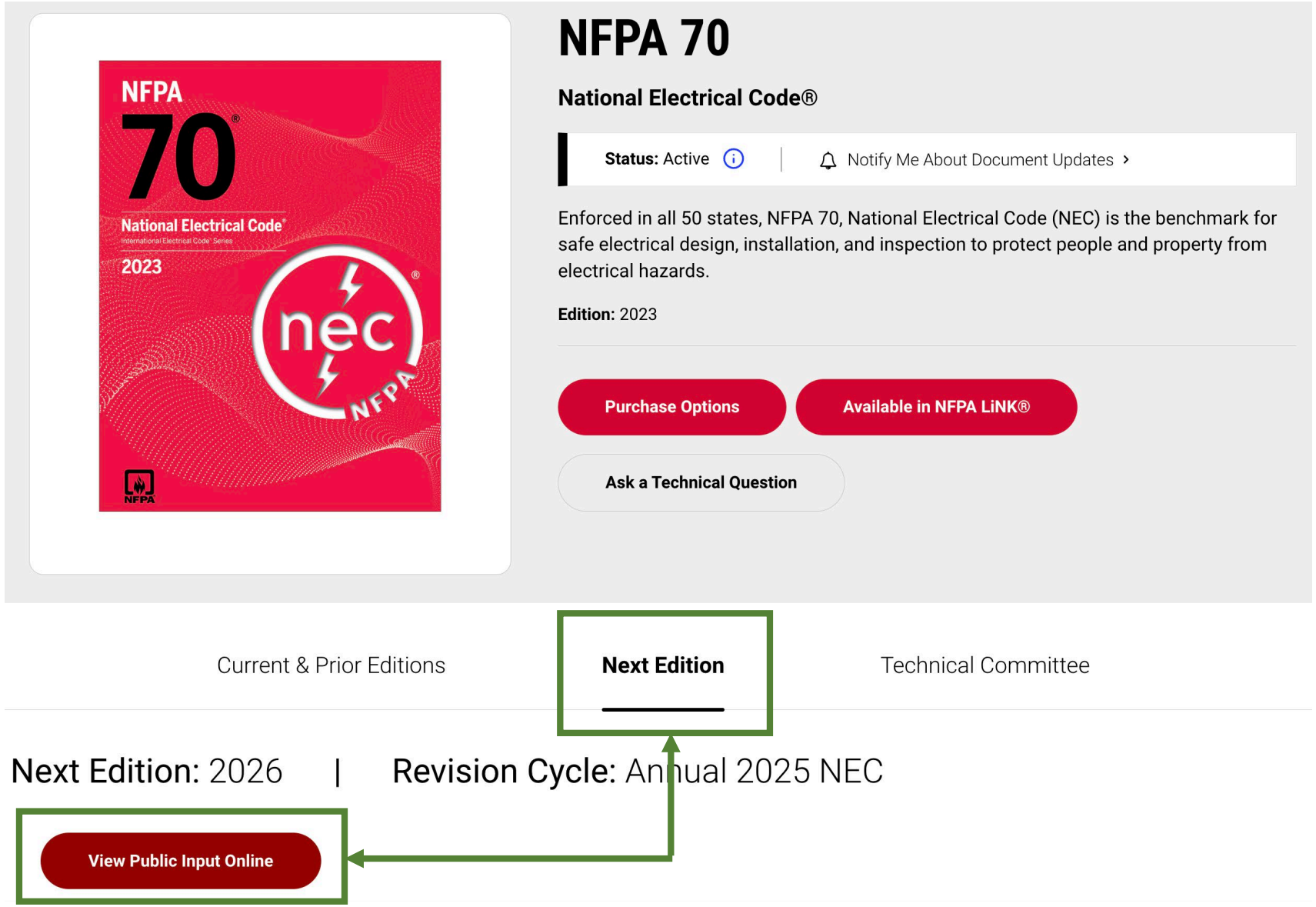


What’s Not In the NEC Yet

- Battery-integrated appliances
- Digital load control (e.g., CTA 2045, smart appliances)
- DC microgrids
- Back feeding power from end-use appliances with batteries
- Required EVSE circuit(s)
- Vehicle-to-Everything

Ways the Energy Code Might Encourage Power-Efficient Electrification

- Large wires, small loads
- Support installation of low-power appliances
- Credit use of load controls
- Envelope solutions that limit HVAC loads and eliminate provision of backup strip heat
- Ban instant electric water heaters
- Require EVSE configured with load control capability
- Consider trade-offs of wiring for 240v electric vs. 120v electric loads
- Encourage use of smart panels and/or smart breakers for future energy management
- Encourage use of equipment with remote control capability for demand response

Other Resources for Power-Efficiency

Redwood Energy Pocket Guides and Watt Diet Calculator

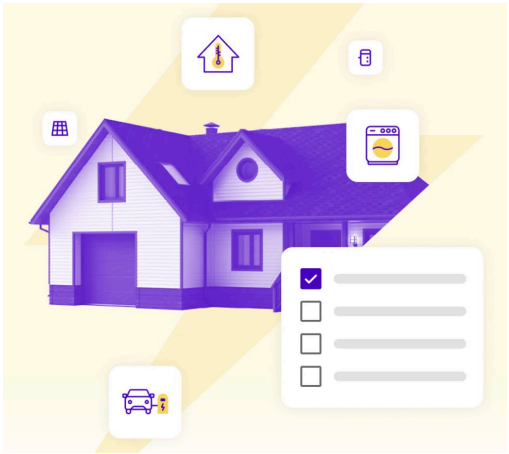
https://www.redwoodenergy.net/research

https://www.redwoodenergy.net/watt-diet-calculator

Rewiring America planning tools

https://homes.rewiringamerica.org/projects/electrical-panel-homeowner

https://homes.rewiringamerica.org/personal-electrification-planner



CalNext Study of Load Control Solutions

https://www.veic.org/Media/Default/Reports/ET22SWE0057%20Market%20Study%20of%20Electric%20Infrastructure%20Upgrade%20Alternatives%20for%20Electrification.pdf

Thanks!

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