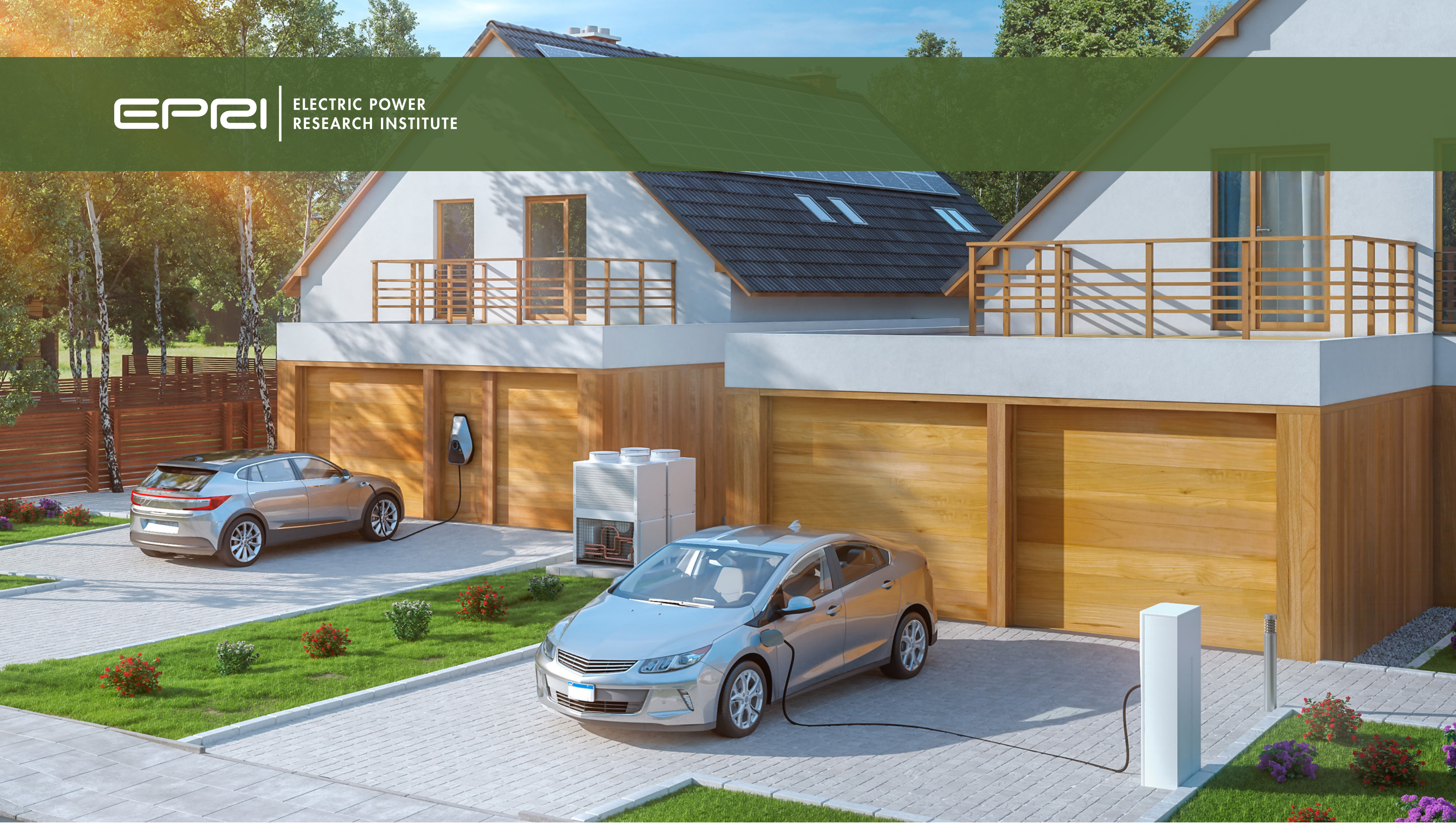


Quick Insight: Electrification Considerations for Premise Service Sizing in Residential Applications

RESEARCH QUESTION

Recent and accelerated adoption of electric end-use technologies in residential premises, such as electric vehicles and heat pumps for space conditioning, are resulting in questions about the adequacy of existing electrical service size to accommodate expansion. This brief is intended to explain the process by which such determinations are made and to provide general knowledge and guidance for those involved in electrification efforts.

BACKGROUND

The National Electric Code (NEC)—NFPA 70[1] is the governing code for U.S. electrical installations, downstream of the service point, or point of common coupling (PCC). The service point is typically considered the tie, just upstream of the meter, from utility owned lines to the customer owned electrical system. The NEC is adopted state-wide in 47 states and locally by municipalities in the other three. It is revised and updated every three years with the most recent being the 2020 edition. At the time of this document, 29 states have adopted the 2017 edition, while the others continue use of the 2008, 2011 or 2014 editions.[2] The calculations in this document are based on the 2020 NEC.

The adopting authority (*authority having jurisdiction-AHJ*) is the enforcer of the code. Enforcement is typically through a system of state or municipality authorized inspectors working through a permitting office. Ultimate application and interpre-

---

1 https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70

2 https://www.nfpa.org/NEC/NEC-adoption-and-use/NEC-adoption-maps

tation of the NEC is performed by the individual AHJs. As an example, the state of Tennessee has adopted the 2017 NEC and maintains a system of inspectors that work through local permitting offices, often located at local utility customer service centers. Individual incorporated cities in Tennessee may choose to act as their own AHJ and supersede the state level operation. Larger cities, like Nashville and Knoxville, operate this way. In either case, it is up to the AHJ to interpret and enforce the NEC as they determine to be necessary.

Licensed electricians, electrical contractors, and in some cases unlicensed homeowners are allowed to obtain electrical permits, perform electrical installations and alterations on a premise, and receive inspection documenting compliance with the NEC. This documented compliance is typically a requirement for utility connection in new construction or for re-connection after renovations. It may also be a requirement for occupancy in coordination with other municipal building code policy.

POTENTIAL ISSUES

When designing new or expanded premise electrical installations, it is the responsibility of the permit receiver, usually the electrician, to apply the NEC and to properly size service, feeder and branch circuit wiring and circuit protection. Though not sanctioned by the AHJ (and possibly in violation of local building code requirements or law), some expansion type electrical work—like the addition of a car charging circuit at a house—is done without obtaining an electrical permit and thus is done without the proper state or municipality authorization. In such cases there is risk taken by the installer, and they must take care to follow the guidance of the NEC of their own accord. Also, the homeowner could be at risk if a fire occurs, and run the risk that an insurance company may refuse to pay if uninspected work is found to be the cause of the fire.

METHODS FOR DETERMINING PROPER SIZING

The NEC details methods for determining service, feeder and branch circuit sizing in Article 220. The remainder of this brief focuses on methods for determining required service and feeder sizes for various residential situations of expanded electrical appliances, like electric vehicle chargers (EVSEs) and heat pumps for premises where they didn't exist prior.

Both Electric Vehicle Supply Equipment (EVSE) and Heating, Ventilation and Air Conditioning (HVAC) systems are required to be on individual branch circuits[3], sized in accordance with the nameplate current draw of the equipment, per Article 625 and 440 respectively.

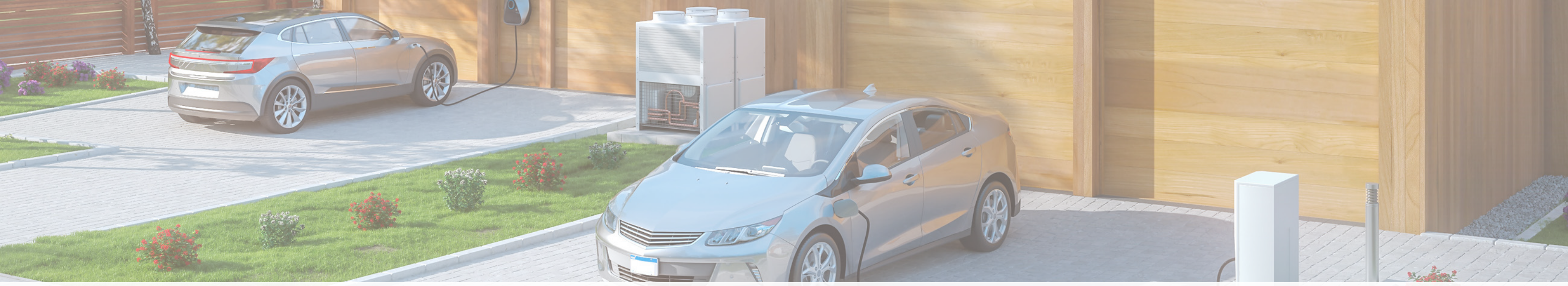
Per Article 220, *Branch-Circuit, Feeder and Service Load Calculations*, there are effectively two approaches to determining the required electrical capacity for a premise: a general method defined in Part III and an optional method defined in Part IV. This calculated capacity in turn defines the required amperage, conductor sizing and circuit overload protection for feeders and service entrance equipment. The optional method may be used for dwelling units fed by a single 120/240 or 120/208 supply. It can be simpler, depending on specific circumstances, and so it is often the chosen method for residences.

The general method stipulates that feeders and service equipment must be sized to accommodate the sum of all branch circuit currents being fed, after applying any applicable demand factors for multiple appliances. Demand factors reduce the effective draw of an appliance class if multiple units are present on one feeder or service.

As an example, a single service may feed individual 100 Amp feeder panels for 20 units of an apartment building. If each of the apartment units contains an electric range rated at 10 kW, then there is a derating demand factor applied to these appliances when calculating the main service (equal to 35% of the nameplate rating of the ranges for this case). This accounts for the reduced coincident use of all 20 appliances. Individual feeder panels for apartments are not subject to the demand factor, since there is only one of each appliance on an individual feeder.

The optional method defines a prescribed procedure for calculating service (or feeder) load based roughly on the following:

[3] *See NFPA 70 Article 100 for term definitions*



1. Sum the expected loads
   - 3 VA per square foot of floor space for general lighting and plug loads (including potential future finished space)
   - 1500 VA for each kitchen and/or small appliance circuit (*minimum 2*[4])
   - 1500 VA for each 120 Volt laundry circuit
   - The nameplate rating for all fixed or single-circuit appliances (e.g. water heater, range, cooktop, dryer)
2. Take 100% of the first 10,000 VA plus 40% of the remainder[5]
3. Calculate the HVAC load
   - A prescribed calculation for the HVAC equipment (effectively nameplate rating for central air conditioning and single-source heating equipment, plus a de-rated value for supplemental electric resistance heat working in combination with a heat pump)[6]
4. Add the two load portions together to find the total design load

Feeder/service conductors and circuit breakers should be sized to accommodate 100% of the non-continuous load plus 125% of the continuous load.[7] Continuous loads are those expected to remain on for periods of three hours or longer. The NEC does not explicitly define which loads are continuous, rather it is left to the wisdom of the electrician or electrical designer and to the ultimate discretion of the inspector and the AHJ. There is discussion in the industry about whether appliances such as water heaters are continuous or non-continuous. In ordinary use they don't run for three hours but could in special circumstances (i.e. someone is filling a hot tub or swimming pool; a faucet is left on accidentally for days, etc.). When there is a question, the deference is typically toward treating appliances as continuous use. For such cases, Article 427 may be applied, which treats vessel heating equipment as continuous load.

When considering the capacity of a residential electrical system to accommodate new loads, the installing electrician should complete a new load calculation that incorporates the anticipated new loads. From an efficient electrification standpoint, three of the most likely new loads are heating, water heating (both via heat pumps) and electric vehicle chargers (EVSEs).

Within the NEC, there are provisions for calculating expanded electrical capacity of existing residences. It follows a similar procedure to above, but applies a 100% weighting to the HVAC load, 100% to the first 8,000 VA of other loads, and 40% to the remainder.[8]

However, the more conservative approach[9] used in the remainder of this document is to apply a 100% weighting to the HVAC load, 100% to the first 10,000 VA of other loads, and 40% to the remainder.

- When adding a heat pump to an existing residence, the load calculation should be undertaken by the electrical designer or installer to ensure that the main service to the residence, and/or any sub-fed panel is adequately sized for the expansion.
- Heat pumps are often accompanied by 2nd stage electric resistance heat of varying sizes from ~3kW through 20kW. It is important that the full new load is understood and accounted for by the designer/installer.
- A homeowner may want to confirm that the electrical portion of a new heat pump installation is permitted and inspected to ensure that proper load sizing was undertaken by the installer.

EXAMPLE CALCULATIONS

Addition of a Heat Pump

- 2500 sq.ft. residence with electric water heat, clothes dryer; gas range and gas heat, no air conditioning.

---

[4] *2020NEC, Article 210.11(C)(1)*

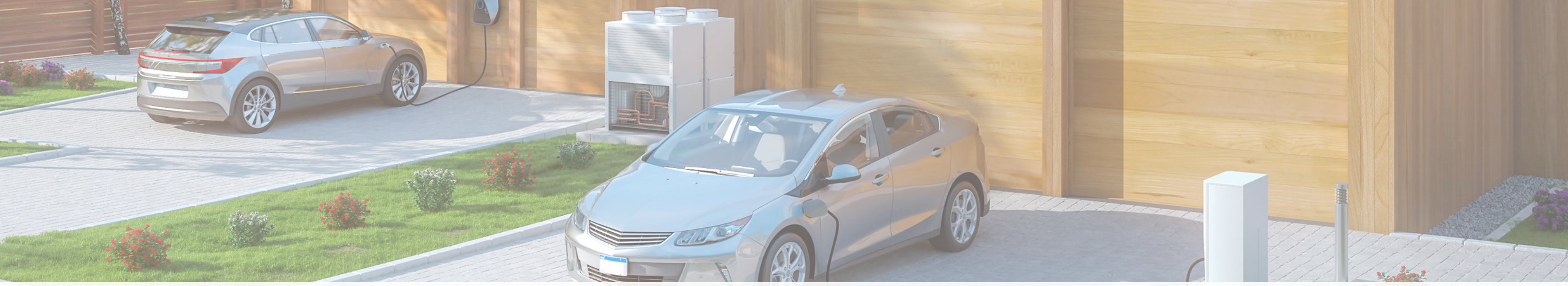
[5] *2020NEC, Article 220.82(B)*

[6] *2020NEC, Article 220.82(C), the largest of (1) – (6)*

[7] *NEC2020, Article 230.42(A)(1)*

[8] *NEC2020, Article 220.83(A) & (B)*

[9] *NEC2020, Article 220.82*



- 240Volt service with 100 Amp Main Circuit Breaker

Can the service accommodate a switch to a 2.5-ton electric heat pump with 10kW of 2nd stage electric resistance heat?

Calculate the existing load based on the **optional method** (*sum the following*):

- 2 x kitchen and/or small appliance circuits -> 2 x 1500 VA = 3000 VA
- 1 x laundry circuit = 1500 VA
- 2500 sq.ft. x 3 VA/sq.ft. = 7500 VA (general lighting and plug loads)
- Nameplate rating of water heater = 4500 VA x 1.25 (continuous) = 5625 VA[10]
- Nameplate rating of dryer 5100 VA
- Sum = 22,725 VA (Existing Load)
- Service load then equals: 100% x 10,000 VA + 40% x (22,725-10,000) VA = 15,090 VA
- Current = 15,090 VA ÷ 240 Volts = 63 Amps (which is acceptable for a 100 Amp service)

If a heat pump with electric second stage heat is added, it's load is calculated as 100 percent of the nameplate rating of the heat pump, plus 65% of the rating of the electric 2nd stage heat.[11]

- 2.5-ton HP 5500 VA
- 2nd stage heat 9600 VA
- New load -> 100% x 5500 + 65% x 9600 VA = 11,740 VA
- Adding existing loads and new load:
  Existing Load: 22,725 VA
  New Load: 11,740 VA
  Total New Load: 34,465 VA
- New Service load: 100% x 10,000 VA + 40% x (34,465 VA – 10,000 VA) = 19,786 VA

[10] *NEC2020, Table 220.3 Article 427.4*

[11] *NEC2020, Article 220.82(C)(3)*

- New Service Load Current: 19,786 VA ÷ 240 V = 82 Amps

Service panels may or may not be continuously rated. For example, a service panel continuously rated for 100A will have a 125A main circuit break. If the breaker is only 100A, then the maximum service load current can only be 80A.

For the above example, the main breaker is 100A, therefore the maximum service load current is 80A, since the new service load current calculates to 82 Amps, the new load addition exceeds the existing service capacity. The logical upgrade would be to a 200 Amp service.

What if the heat pump was a high capacity, low temperature model, capable of carrying the full heating load of the home without need for 2nd stage electric heat?

In this case, there would not be an additional 9600 VA (x 65%) load from electric heat, and the new HP load would only be 5500 VA. The total new service design current now becomes 72 Amps. Since the new service design current is less than the maximum service load current of 80A for the 100A main breaker, the existing 100 Amp service could accommodate this expansion.

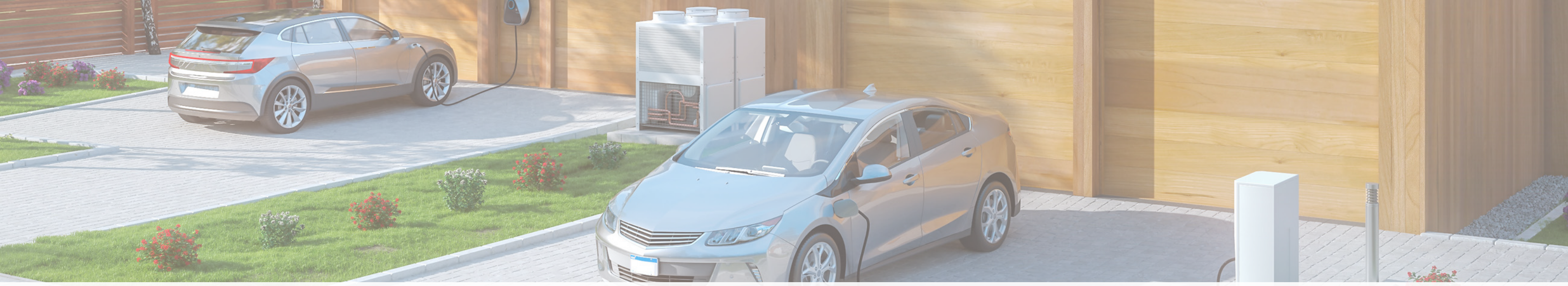
Addition of an EVSE

Below is a similar example with a proposed addition of a 6.7 kW Level-2 EVSE charger.

Calculate the existing load based on the **optional method** (*sum the following*):

- 2 x kitchen and/or small appliance circuits -> 2 x 1500 VA = 3000 VA
- 1 x laundry circuit = 1500 VA
- 2500 sq.ft. x 3 VA/sq.ft. = 7500 VA (general lighting and plug loads)
- Nameplate rating of water heater = 4500 VA x 1.25 (continuous) = 5625 VA[12]
- Nameplate rating of dryer 5100 VA
- Sum = 22,725 VA (Existing Load)

[12] *NEC2020, Table 220.3 Article 427.4*



- Service load then equals: 100% x 10,000 VA + 40% x (22,725-10,000) VA = 15,090 VA
- Current = 15,090 VA ÷ 240 Volts = 63 Amps
- The new Level 2 EVSE has a nameplate rating of 6700 VA, which would add to the existing load with the 40% derating factor, since it is a general (non-HVAC) load.
- The new load sum equals: 22,725 VA + 6700 VA = 29,425 VA
- New service load equals: 100% x 10,000 + 40% x (29,425-10000) = 17,770 VA
- New current = 17,770 VA ÷ 240 Volts = 74 Amps

Since the 100 Amp service can handle 80 Amps of continuous load, it can accommodate addition of the new EVSE.

Additional example load calculations are available in Informative Annex D of the 2017 edition NEC.

POTENTIAL NEC UPDATES

HVAC equipment is called out specifically and is treated as its own class of load with specific methods of load calculation.

However, the NEC does not explicitly call out EVSE as a unique device type in the load calculation section, therefore it is treated as a general load as an appliance that is fastened in place, much the same as a water heater. In future editions of the NEC, it is possible that EVSE equipment could be called out separately, with prescribed approaches for load calculation.

Consultation with a local electrical code official is advisable when questions arise regarding premise service sizing and electrical expansion.

ACKNOWLEDGMENT

Special thanks to David Shepherd, Electrical Inspector, SR, Plans Review and Building Inspections, dshepherd@knoxvilletn.gov for his review of this document.

EPRI RESOURCES

Ashley Kelley-Cox, Project Operations Coordinator
Project Set 170D: Technology Transfer Lead
865.218.8146, akcox@epri.com

TECHNICAL CONTACTS

Ron Domitrovic, Program 170 Manager
865.218.8061, rdomitrovic@epri.com

John Halliwell, Program 18 Senior Technical Executive
865.218.8149, jhalliwell@epri.com

Carl Miller, Program 1 Principal Technical Leader
865.218.8027, cemiller@epri.com

End-Use Energy Efficiency and Demand Response, Electric Transportation, and Power Quality

3002017638 December 2019

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA • 800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com