Commute & Multifamily EV Charging Level Needs Analysis:

Level 1 or Power-Managed Level 2 Charging at 1.65 kW Meets the Daily Needs of 94+% of Drivers

Executive Summary

The study, 'Commute & Multifamily EV Charging Level Needs Analysis', analyzes the charging levels required for residents in multifamily buildings. By understanding the charging needs required by multifamily residents, charging solutions can be designed to be more cost-efficient and to provide charging to as many residents as possible.

The study uses the Census Bureau's ACS dataset for Public Use Microdata Areas (PUMA) for San Mateo County, Santa Clara County, and Fresno County, which reports an individual's dwelling type and self-reported commutes, representing real commute patterns of the entire population, including individuals with low, average, and high commute distances. The study analyzes groups of 3-5 vehicles with mixed commute patterns sharing 6.6 kW (standard 40A circuit) of charging capacity via a power-managed Level 2 charging system. [1] A vehicle efficiency of 3.5 kWh per mile is assumed for all scenarios.

The key takeaways are summarized below as average across the three countries studied:

Power Mgmt. Level, Vehicles per Level 2, 40A of Power	Percent of drivers' commutes satisfied	Charging Level
3 vehicles	98.8%	2.2 kW, 77-92 miles of range per night
4 vehicles	94.1%	1.65 kw, 58-69 miles of range per night)
5 vehicles	73.5%	1.32 kW, 46-55 miles of range per night

The results suggest that providing a minimum of 1.65 kW per car will satisfy nearly all commute needs. The 5.9% of individuals whose needs are not met are those with the longest commutes. While the study tested various locations, commute patterns will vary.

Implications for Charging Infrastructure Deployment

As the results show, a 1.65 kW charging solution will cover nearly all commute needs. Power managed Level 2 or Level 1, which can provide up to 1.9 kW at 16A, are technological charging solutions that fit this minimum power delivery requirement at the lowest cost compared to a traditional 32A Level 2 station powered by a single 40A circuit. A traditional Level 2 port may cost between $8,000 to $12,000 installed whereas a power managed Level 2 port may cost as low as $3,600 and a Level 1 outlet costs even less, around $1,800[2]. Utilizing these technologies also allows sites to install more chargers than otherwise would be possible through energy management.

A non-powered managed Level 2 station is significantly overpowered for drivers' commuting needs and is nearly 3x-5x the cost of power-managed Level 2 or Level 1 outlet solutions. When approaching charging infrastructure deployment, organizations should leverage power-managed Level 2 and Level 1 to minimize installation costs and increase charging access to help support the adoption of electric vehicles and accelerate rapid transportation decarbonization.

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[1] For an overview of how power management works, please visit https://www.peninsulacleanenergy.com/wp-content/uploads/2021/06/Overview-of-L1-and-ALMS-Strategy.pptx

[2] https://www.peninsulacleanenergy.com/wp-content/uploads/2021/02/PCE_MinL1L2_CostAnalysisCPUC_011220.xlsx

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Multifamily Power Sharing Analysis

Determining the Appropriate Level of Power Sharing for EV Charging in Multifamily Properties

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With growing commitments to zero emission vehicles by both governments and major automakers, expanded access to electric vehicle charging is clearly needed. The California Energy Commission's impressive body of work for AB2127 infrastructure assessments most recently showed that nearly one million chargers are needed by 2030 to support 5 million zero emission vehicles.[1] Others, such as Szinai et al (2020), illustrate that the use of smart charging infrastructure has the potential to avoid billions of dollars annually in electric system costs.[2]

There is now widespread recognition that multifamily residents face higher barriers to EV adoption. This is in large part due to the absence of charging infrastructure and difficulty of deploying such infrastructure. The difficulty lies in part in the landlord-tenant split incentive, wherein the benefit of a landlord's investment in charging infrastructure accrues primarily to the tenant in the form of convenient charging and lower vehicle fueling costs. There are payment mechanisms to balance the scales on such investment, though in our experience considerable education of all parties is needed to plan and implement such projects.

Compounding this generally more difficult case of multifamily charging is the problem of limited electrical capacity. Multifamily properties, particularly older properties, often have little spare electrical capacity to dedicate to new EV charging. Upgrading the electrical service and main distribution panel is a costly proposition, easily adding tens of thousands of dollars to the total project cost. Many are now recognizing load management as a way to provide more charging access within the existing electrical service constraint.[3]

The value of load management in multifamily becomes clear when one considers the diversity of charging needs among households. Given pervasive range anxiety, we assume all drivers desire to have their vehicle fully charged when they leave their home. Yet commuters across households travel different distances and arrive home at different times. Figures 1 and 2 illustrate the distribution of energy needs and estimated arrival times using a small sample (n=32) of real multifamily household commute data for Santa Clara County, CA from the Census Bureau's American Community Survey (ACS). The varying times that they will plug in and the differing daily charge requirements shows that it is neither necessary nor prudent to provision power capacity for EV charging as if all drivers simultaneously charge at full power. This is especially true if one considers potentially cascading incremental costs from panelboards to transformers and up through the electric system.

Figure 1. Daily charging energy requirement of different drivers living in multifamily properties (Santa Clara Co.)

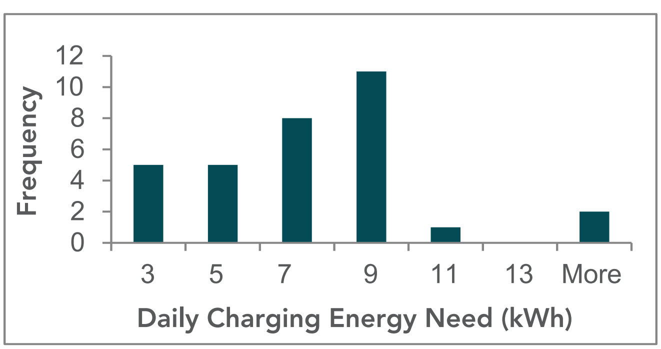
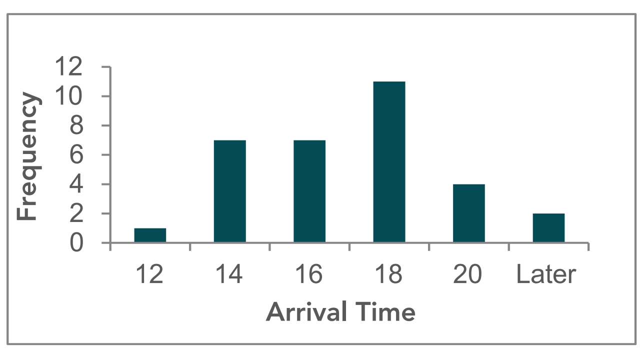


Figure 2. Estimated arrival time to home for different drivers living in multifamily properties (Santa Clara Co.)



1 California Energy Commission (2021), "Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment (Staff Report)".
2 Szinai, Julia K. et al, "Reduced grid operating costs and renewable energy curtailment with electric vehicle charge management." Energy Policy 136.
3 Load management, referred to as automated load management systems within the National Electrical Code (2017) article 625.42, allows multiple networked EV chargers to share a limited power capacity. For example, when one charger is active, it may use the full power capacity and when several are active, they could equally share that same capacity.

In our role providing technical assistance to multifamily properties, it is relatively easy to recognize the opportunity afforded by load management but more difficult to specify exactly how one should utilize load management when planning a project. For one, we must select hardware and software that is up to the task. We have completed requests for qualifications and found many vendors supporting load management. After careful review, however, we have also encountered some responses representing the ability to provide load management but lacking safeguards that we believe are necessary to comply with the intent of NEC 625.42. It is possible that a new test certification will address the ambiguity that exists today, but until that happens, care is required.

Perhaps the biggest question we have faced when recommending load management is, "How much power sharing is appropriate?" If we recommend too few chargers for a given capacity, then we are not maximizing charging access. If we recommend too many, then we will have unhappy drivers who cannot meet their daily charging needs. This question required a rigorous answer, and we turned to the best source of multifamily driving data that we could find to provide that answer.

The Census Bureau's ACS data for Public Use Microdata Areas (PUMA) are the highest spatial resolution for which individual household data is provided.[4] The 2019 ACS PUMA 1-year data files provides both identification of dwelling type and commuting behaviors. Specifically, the housing record data file field "BLD" indicates the number of units in the structure in which the respondent lives and several fields shown in Table 1 from the person records data file are useful for estimating commuting time, distance and energy.[5]

Table 1. 2019 ACS PUMA data fields from person records used to estimate commute time and energy

Field	Definition	Use
JWMNP	Travel time to work	Average commute speed of 30mph used to convert to daily distance traveled and 3.5mi/kWh used to estimate daily energy requirement[6]
WKHP	Usual hours worked per week	These times used together with the travel time to work to estimate the home arrival time
JWAP	Time of arrival at work	

To address our question of how much power sharing is appropriate, we framed our hypothesis that if we were to assign groups of n drivers to share a given electrical capacity, 80 percent or more groups represented by the PUMA data would be satisfied. Here, "satisfied" means the entire group of drivers has its charging needs met overnight, which we approximated as within 12 hours. We selected 6.6 kW as the amount of electrical capacity to share, as this is a typical amount available to utilize for EV charging on a 40A circuit on 120/208V service that is often found in multifamily properties with the 125% continuous load factor required by NEC. We started with groups of n=3 drivers and then increased n until our hypothesis no longer held true.

[4] US Census Bureau (2021), "Understanding and Using the American Community Survey Public Use Microdata Sample Files"
[5] US Census Bureau (2019), "2018 ACS PUMS Data Dictionary"
[6] 30mph is an estimate average speed of travel derived from the average vehicle trip duration and length for the West census region from the 2017 National Household Travel Survey, and 3.5mi/kWh represents approximately the first quartile of rated vehicle efficiency for EVs on the market

Our analysis encompassed three geographic areas: San Mateo and Santa Clara Counties where we provide technical assistance today, and also Fresno County for a lower population density point of comparison. We analyzed each county separately and each county spans several PUMAs which were each analyzed separately. The key steps in each batch of analysis were:

1. Filter the people data records to contain only those with commute data
2. Join the housing data to the remaining records and filter for only those living in structures with five or more dwelling units
3. Calculate the commute energy needs and home arrival times for each driver
4. Create all possible combinations of the resulting drivers and calculate the total charging time for the group using a first-in, first-out charging prioritization

Even after filtering significantly reduced the number of eligible records, the number of possibly combinations becomes quite large, following the formula, $C_k^n = \frac{n!}{k!(n-k)!}$, here k is the total sample of qualified drivers available from the ACS and n, as previously noted, is the size of the power management group. We programmed the analysis in Python 3.9 and each batch of analysis took several hours to run.

The results of our analysis are summarized in the table immediately below, with additional detail shown on the following page. What we see across each county is that nearly all groups are satisfied when 3 chargers share 6.6 kW, and a high percentage of groups remain satisfied at 4 chargers per 6.6 kW. However, the situation begins to change dramatically at 5 chargers per 6.6 kW, with 26.5 percent of groups overall not meeting their daily charging requirements. From this analysis, we conclude that 4 chargers per 6.6 kW is generally an appropriate recommendation.

Table 2. Three-county summary of percent of groups not satisfied when power sharing is at group size n=x

Group Size	Fresno	San Mateo	Santa Clara	Total
n=3	0.4	1.3	1.2	1.2
n=4	1.3	8.4	5.5	5.9
n=5	3.7	30.7	20.2	26.5

While we believe this work significantly advances the industry's thinking on load management in multifamily scenarios, there are some limitations worth mentioning. First, we chose several fixed points for our analysis, such as the 3.5 mi/kWh vehicle efficiency and 6.6 kW circuit. Changing vehicle efficiency should be monitored to determine whether the results remain applicable. We have also assumed than any multifamily household grouping of drivers is possible, but in reality we recognize the tendency of households to cluster by factors such as socio economic status, and to the extent such factors correlate with commute patterns, it may skew group of drivers' needs. Some form of correction factor is needed to address such effects. Finally, we acknowledge a tradeoff between the infrastructure cost savings of load management and the reduced flexibility to shift the charging load when doing so could be advantageous to increase use of low cost, low emission renewable energy. These considerations merit further study, and in the meantime program designers may prefer to generally recommend 3 chargers per 6.6 kW circuit and reserve 4 chargers per circuit for circumstance where doing so produces a decided infrastructure cost advantage.

Table 3. Fresno County PUMAs percent of groups not satisfied at when power sharing is at group size n=x

	1901	1902	1903	1904	1905	1906	1907	Total
n=3	6.0	0.4	0.0	1.2	0.2	0.0	0.0	0.4
n=4	21.4	1.4	0.3	3.1	2.0	0.0	4.1	1.3
n=5	50.0	3.8	1.7	7.5	8.3	0.1	17.8	3.7

Table 4. San Mateo County PUMAs percent of groups not satisfied at when power sharing is at group size n=x

	8101	8102	8103	8104	8105	8106	Total
n=3	2.9	0.4	3.3	1.2	0.7	0.0	1.3
n=4	13.9	6.7	20.5	9.8	4.8	0.1	8.4
n=5	33.2	25.5	49.9	27.3	15.7	1.7	30.7

Table 5. Santa Clara County PUMAs percent of groups not satisfied at when power sharing is at group size n=x

	8501	8502	8503	8504	8505	8506	8507	8508	8509	8510	8511	8512	8513	8514	Total
n=3	1.5	0.7	0.8	3.9	3.3	2.0	0.3	1.7	1.4	2.7	3.3	2.1	0.1	3.0	1.2
n=4	5.6	3.0	4.7	15.1	11.0	11.4	3.7	5.1	8.7	10.7	12.0	14.2	4.6	7.9	5.5
n=5	15.3	6.3	14.1	37.0	24.0	30.3	15.6	14.6	39.0	18.8	29.9	38.6	23.6	19.3	20.2