Alternative and Renewable Fuel and Vehicle Technology Program

FINAL PROJECT REPORT

Overcoming Barriers to Electric Vehicle Charging in Multi-unit Dwellings: A South Bay Case Study

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Prepared by: UCLA Luskin Center for Innovation and the South Bay Cities Council of Governments

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Prepared by:

Primary Author(s):
Alex Turek
George M. DeShazo

UCLA Luskin Center for Innovation
3323 Public Affairs Building
Los Angeles, CA 90095
310-267-5435

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Prepared for:

California Energy Commission

Sharon Purewal
Agreement Manager

John Butler
Office Manager
Zero-Emission Vehicle & Infrastructure Office

John Kato
Deputy Director
Fuels and Transportation Division

Robert P. Oglesby
Executive Director

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVT Program). The statute, subsequently amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), authorizes the California Energy Commission (Energy Commission) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. The Energy Commission has an annual program budget of about $100 million and provides financial support for projects which:

- Develop and improve alternative and renewable low-carbon fuels.
- Enhance alternative and renewable fuels for existing and developing engine technologies.
- Produce alternative and renewable low-carbon fuels in California.
- Decrease, on a full-fuel-cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability.
- Expand fuel infrastructure, fueling stations, and equipment.
- Improve light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets.
- Expand infrastructure connected with existing fleets, public transit, and transportation corridors.
- Establish workforce training programs, conduct public education and promotion, and create technology centers.

The Energy Commission issued solicitation Program Opportunity Notice (PON)-14-603 to provide funding opportunities under the ARFVT Program for Zero Emission Vehicle (ZEV) Readiness. This first-come, first-served grant solicitation was an offer to fund projects that support new and existing planning efforts for plug-in electric vehicles (PEVs) and fuel cell electric vehicles (FCEVs). To be eligible for funding under PON-14-603, the projects must also be consistent with the Energy Commission's *ARFVT Investment Plan,* which is updated annually. In response to PON-14-603, the UCLA Luskin Center for Innovation submitted application 4, which was proposed for funding in the Energy Commission's Notice of Proposed Awards on January 16, 2015; the agreement was executed as ARV-14-035 on March 19, 2015. This report represents Part 2 of 3 of the Agreement Number ARV-14-305.

ABSTRACT

Governor Jerry Brown signed an executive order calling for 1.5 million zero emission vehicles (ZEV) on California's roads by 2025. To achieve this ambitious goal, significant barriers must be overcome to expand and accelerate plug-in electric vehicle (PEV) adoption including the need to build out the necessary refueling infrastructure. To point, residents of multi-unit dwellings (MUDs) such as apartments and condominums are unlikely to have access to home charging (electric vehicle supply equipment or EVSE).

The purpose of this report is to explore barriers to PEV adoption for residents of MUDs within the South Bay subregion of Los Angeles County, and then identify MUDs within the study area that may exhibit high latent PEV demand and low-cost EVSE installation for the purpose of targeted outreach. Researchers analyzed Los Angeles County Office of the Assessor tax parcel data to understand the MUD portfolio of the South Bay, as well as IHS Automotive new car registration data to identify census tracts in the South Bay that have exhibited high PEV demand to date. Researchers also visited 27 MUD sites within the South Bay and reviewed 19 EVSE installation cost estimates to evaluate how installation costs vary across MUD sites.

The results confirm the cost of EVSE installation in MUDs is variable from site to site and often high. Level 1 charging and group investments for EVSE installations may provide MUD residents access to home charging at lower costs. Policy tools such as targeted outreach to promote the PEV, PEV rebates, and PEV-ready new construction codes are likely required to ease the MUD related barriers to PEV adoption.

Keywords: Plug-in electric vehicle, PEV, multi-unit dwelling, MUD, PEV charging, EVSE, South Bay, California Energy Commission, demand, installation costs

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EXECUTIVE SUMMARY

In 2012, Governor Jerry Brown signed an executive order creating a goal of 1.5 million zero-emission vehicles (ZEVs) on California's roadways by 2025. To achieve this ambitious goal, a number of adoption barriers must be overcome. In the Governor's 2013 ZEV Action Plan, the first challenge presented is the need to build out the necessary refueling infrastructure. Electric vehicles require an entirely new refuel behavior and set of equipment. Instead of refueling at gas stations, most plug-in electric vehicle (PEV) owners refuel when they are at home overnight using Level 1 or Level 2 charging (electric vehicle service equipment or EVSE).

While this is generally a straightforward proposition for single-family homeowners, residents of apartments and condominiums, also known as multi-unit dwellings (MUDs), face a number of obstacles to installing EVSE at home. Foremost is the variable and often high cost of EVSE installation. Additionally, the renter or owner exhibits a low to non-existent investment motivation: renters are unlikely to invest in a piece of immobile equipment that they may move away from in the future; and owners do not yet see home PEV charging as an amenity by which to increase property value and attract tenants.

This report explores MUD related barriers to greater PEV adoption, using the South Bay subregion of Los Angeles County as a case study. This report also seeks to support the prioritization of policy tools and targeting of outreach for MUDs that exhibit relatively high latent PEV demand and a low cost of EVSE installation.

To understand the MUD portfolio of the South Bay subregion and identify MUD parcels that are likely to exhibit latent PEV demand, the UCLA Luskin Center for Innovation analyzed land use data from the Los Angeles County Office of the Assessor and new car registration data from IHS Automotive. Additionally, researchers visited 27 MUD sites across the South Bay with a qualified electrician and reviewed 19 EVSE installation cost estimates to evaluate the cost of providing home charging to MUD residents and identify potential low-cost home charging solutions.

The UCLA Luskin Center finds that while the cost of EVSE installation at MUD sites is indeed variable and often high, low-cost solutions may exist and policy tools can target those low-cost solutions. The key results of our findings include:

The South Bay is a leader in PEV adoption despite a significant number of MUD households: The South Bay subregion is home to 5,657 PEV drivers and 144,132 MUD households including 33,785 MUDs in disadvantaged communities. MUD related barriers are likely serving as a significant constraint to PEV adoption in the subregion. Strategic programs and policies, however, can help to effectively expand PEV adoption and home charging access to MUD residents in places like the South Bay.

EVSE installation costs are variable and often high: Level 2 EVSE installation costs ranged between $1,800 and $17,800 and averaged $5,400. To contrast, single-family EVSE installations average $1,500.

The cost of EVSE installation is positively correlated to the distance between the relevant electric panel and the PEV parking spot: Of the six projects evaluated requiring a conduit run of 100 feet or greater, construction or engineering activities such as coring, trenching, and/or the x-raying of concrete was required, greatly increasing the cost of installation.

Detached parking layouts are likely to incur high EVSE installation costs: With the parking area separated from the main MUD structure, there is a high probability of needing to trench or perform some other construction activity to run wiring and conduit from the panel to the PEV parking spot.

Level 1 charging may be a feasible home charging solution for MUD residents: Most MUD parking areas in the South Bay (78%) have access to a 110/120-volt outlet. To perform Level 1 charging, the property owner and/or electrician will need to assess the electrical capacity of the relevant panel.

Investing in multiple EVSEs per deployment greatly reduces the per driver cost of installation: The high variable costs of EVSE installation and the group parking environments of some MUD parking layouts provides an opportunity for multiple charger investments to reduce per driver costs.

Governments, state agencies, and other relevant stakeholders should use these findings and others to design policies and programs moving forward. Interested stakeholders should also use this report to gain a better understanding of MUD related barriers to PEV adoption and how they can be overcome.

CHAPTER 1:
Introduction

With the transportation sector representing the largest source of California's greenhouse gas (GHG) emissions, the state is making a concerted effort to promote the adoption of advanced clean vehicles. The transition to more fuel-efficient and zero-emission vehicles (ZEVs) is critical to achieving the state's ambitious climate goals and air quality requirements. In 2012, Governor Jerry Brown signed an executive order setting a target of 1.5 million ZEVs on California's roads by 2025.

To achieve the goals laid out by the Governor's executive order, a number of adoption barriers must be overcome. The first challenge addressed in the Governor's 2013 ZEV Action Plan is the need to build out the necessary refueling infrastructure including in apartment buildings and condominiums, also known as multi-unit dwellings (MUDs). ZEVs, and specifically plug-in electric vehicles (PEVs), require an entirely new refuel behavior and set of equipment. In place of a 15-minute detour to a gas station, most PEV owners refuel overnight when they are at home. While this is generally a straightforward proposition for single-family homeowners, MUD residents face a number of obstacles to installing home charging (electric vehicle service equipment or "EVSE"). Foremost is the variable and often high cost of EVSE installation at a MUD site. Additionally, the renter or owner exhibits a low to non-existent investment motivation: renters are likely not to invest in a piece of immobile equipment that they may move away from in the future; and owners do not yet see home PEV charging as an amenity by which to increase property value and attract tenants.

Purpose of the Report

The goal of this report is to explore MUD related barriers to greater PEV adoption within the South Bay subregion, as well as to prioritize policy tools and target outreach for MUD sites that exhibit relatively high latent PEV demand and a low cost of EVSE installation. This report represents the final report for Task 2 of 3 for Agreement Number ARV-14-035.

The South Bay subregion of Los Angeles County is a leader in the adoption of PEVs with 5,657 total registrations.[1] Yet it is likely that the full adoption potential of the subregion is constrained by its mix of residential land uses, specifically the significant number of MUDs. MUDs account for 144,132 total households across 15 South Bay cities and 46% of the residential land use mix.[2] As such, the subregion provides a quality study area to evaluate MUD related barriers to PEV

[1] IHS Automotive New Vehicle Registration Data. Accessed February, 2016.

[2] Los Angeles County Office of the Assessor Secured Basic File Abstract. Accessed October, 2015.

adoption, as well as to implement future policies or programs aiming to overcome this barrier. The report is organized as follows:

Chapter 2 provides an overview of the MUD portfolio in the South Bay. Researchers analyzed the Los Angeles County Office of the Assessor's Secured Basic File Abstract to identify MUD characteristics that may influence PEV demand such as size, per unit value, vintage, and ownership type. We present the most common MUD parking layouts of the South Bay because they influence the distance from a MUD's electric panel to the PEV parking location; one of the strongest determinants of EVSE installation costs. This chapter concludes with a review of the South Bay's 33,785 MUD households located within disadvantaged communities. These may be appropriate targets for investments from Greenhouse Gas Reduction Fund revenues.

Chapter 3 identifies MUDs in the South Bay that may exhibit high latent PEV demand. Using the results of Chapter 2 and IHS Automotives's new vehicle registration data, researchers identified census tracts with a 50% or more MUD residential land use mix, as well as high PEV adoption rates. Moreover, our PEV demand analysis provides parcel level information: we calculated a propensity to purchase score using the historical adoption rate of PEVs in each census tract, as well as the PEV adoption rate of individuals living in households of a certain value. Those MUD parcels that result in a higher propensity to purchase score should be targets for future outreach efforts or other policy interventions.

Chapter 4 presents the costs associated with Level 1 and Level 2 EVSE installation at MUD sites in the South Bay. Using empirical evidence from visiting MUD sites and obtaining installation cost estimates from a qualified electrician, this chapter investigates how installation costs vary based on the electrical and structural configuration of the MUD building, and highlights potential low-cost installation solutions.

Chapter 5 offers policy tools that help alleviate the MUD related barriers to PEV adoption. Potential policy solutions include designing rebates to reduce the cost of EVSE installation, implementing PEV ready new construction codes, siting public charge programs to benefit MUD residents and prioritizing outreach and education to increase PEV adoption.

Intended Audience

This report is intended for a wide audience of decision makers and advocates seeking to advance PEV adoption in MUDs and specifically, those in the South Bay. Those that may find the report most useful include regional, subregional, and municipal planners; state agencies; utility representatives; MUD property owners; members of homeowner associations; as well as PEV and potential PEV drivers.

Regional, subregional, and municipal planners should use this report to facilitate PEV adoption where latent demand is greatest and installation solutions are needed. By outlining the subregion's MUD portfolio, this report empowers planners to strategically conduct targeted outreach and prioritize MUD sites for policy interventions.

State agencies should use this report to understand the MUD related barriers to PEV adoption and consider policy tools, such as rebates, that reduce the cost of installing EVSE at MUD sites.

Utility representatives should use this report to identify and plan for where PEV demand and related electrical load may grow most rapidly in the subregion. Southern California Edison (SCE), the predominant electric utility in the South Bay, recently received approval for Phase 1 of their Charge Ready program to install charging infrastructure at long dwell-time sites, including MUDs, where PEV drivers will be parked for at least four hours. SCE should use this report to help identify census tracts and specific parcels to prioritize outreach for this and other PEV programs.

Property managers and members of homeowner associations (HOAs) should use this report to understand the elements of their building's electrical systems and to better predict the cost of installing PEV home charging options.

PEV and prospective PEV drivers should use this report to better understand the challenges and costs of installing PEV charging infrastructure at home.

1.1 Methodology

The guiding objective of UCLA Luskin Center researchers was to prioritize outreach by 1) understanding the MUD portfolio of the South Bay, 2) identifying high latent demand for residents of MUDs in the South Bay, and 3) identifying MUD types with a low cost of EVSE installation. The MUD parcels that exhibited high latent demand and low-cost installation opportunities represents the low-hanging fruit for outreach or other policy interventions. The following presents the methodology conducted to achieve the goals of the research.

1) Understating the multi-unit dwelling portfolio of the South Bay

Researchers analyzed Los Angeles County Office of Assessor Secured Basic File Abstract data across a number of parcel specific variables. Most importantly, the data provided researchers the assessor identification number, number of units, the land and improvement value ("total value"), year built ("vintage"), and ownership type (i.e. rental or condominium). Researchers assessed the spatial distribution of South Bay MUDs using geographic information systems (GIS).

To estimate the most frequently observed MUD parking layouts, researchers conducted a random sample of 900 MUD parcels across six different South Bay cities including El Segundo, Hermosa Beach, Inglewood, Manhattan Beach, Ranchos Palos Verdes, Torrance covering all four city groupings (i.e. Beach Cities, Inland Cities, Hybrid Cities, and Peninsula Cities). For each city, researchers randomly selected 30 parcels for each size category (duplex/triplex, 4- to 9-unit, 10- to 19-unit, 20- to 49-unit, more than 50 units; 150 total parcels for each city's random sample) and recorded the parking layout and year built.

Researchers scaled up the random, observed sample results of parking layouts based on the city's vintage distribution. For example, if during the random sampling exercise of Manhattan

Beach's 4- to 9-unit MUD size category, 9 of 30 observations were built prior to 1970 and 3 of the 9 (or 33%) had a dingbat with door parking layout, then 33% of all of Manhattan Beach's 4- to 9-unit MUDs built prior to 1970 were assumed to have the dingbat with door parking layout.

2) Estimating plug-in electric vehicle demand for multi-unit dwelling residents

To identify high latent PEV demand, researchers used census tract PEV registration data from IHS Automotive, census tract socioeconomic data from the United States Census Bureau and parcel level data from the Los Angeles County Office of the Assessor. PEV registration data includes monthly registration data from December 2010 to January 2016 for all battery electric vehicle and plug-in hybrid electric vehicle make and models. Researchers mapped the PEV registrations across the South Bay and overlaid the MUD spatial distribution making an assumption thatMUD residents living in census tracts with high PEV adoption should also have high PEV demand.

Researchers then constructed a PEV propensity-to-purchase model to assign a score to specific MUD parcels based on historical purchasing trends in each census tract for different income levels and home values. First, researchers forecasted the number of PEV purchases per census tract based on that census tract's number of purchases from the previous year. Researchers then downloaded survey data from the California Clean Vehicle Rebate Program (CVRP) and computed the proportion of PEV purchases in each income group (<$24,999; $25,000-$49,999; $50,000-$74,999; $75,000-$99,999; greater than $100,000). Finally, researchers downloaded data on income by home value for each census tract and used this to estimate the probability of someone with a certain income level living in a home with a given value. From these three variables – the forecasted PEV purchases per census tract, the number of PEV purchases per income group, and the percentage of income group living in households of certain values, researchers calculated a probability of PEV purchase for each MUD parcel based on that MUD's per unit value.

3) Identifying multi-unit dwelling types with low-cost EVSE installation

With the South Bay Cities Council of Governments, researchers released a Request for Information for qualified electricians in Los Angeles County with experience installing EVSE in MUDs. Researchers requested 30 MUD site visits to assess Level 1 and Level 2 charge readiness, and to estimate the cost of installing a single Level 2 EVSE unit, as well as EVSE installation for 25% and 50% of parking spots per each site visited.

With the selected electrician, researchers visited 27 of 30 MUD sites across the South Bay. Researchers were not able to visit three sites because property owners were unable to be found or were not interested in participating in the study. Additionally, researchers were unable to attain property owner and/or utility permission to determine the service being provided to the MUD. The result is not knowing whether or not MUDs receive enough power from the utility to provide Level 2 charging for one or more vehicles. Due to this limitation, the electrician partner was hesitant to provide cost estimates for EVSE installation for more than 19 sites.

CHAPTER 2:

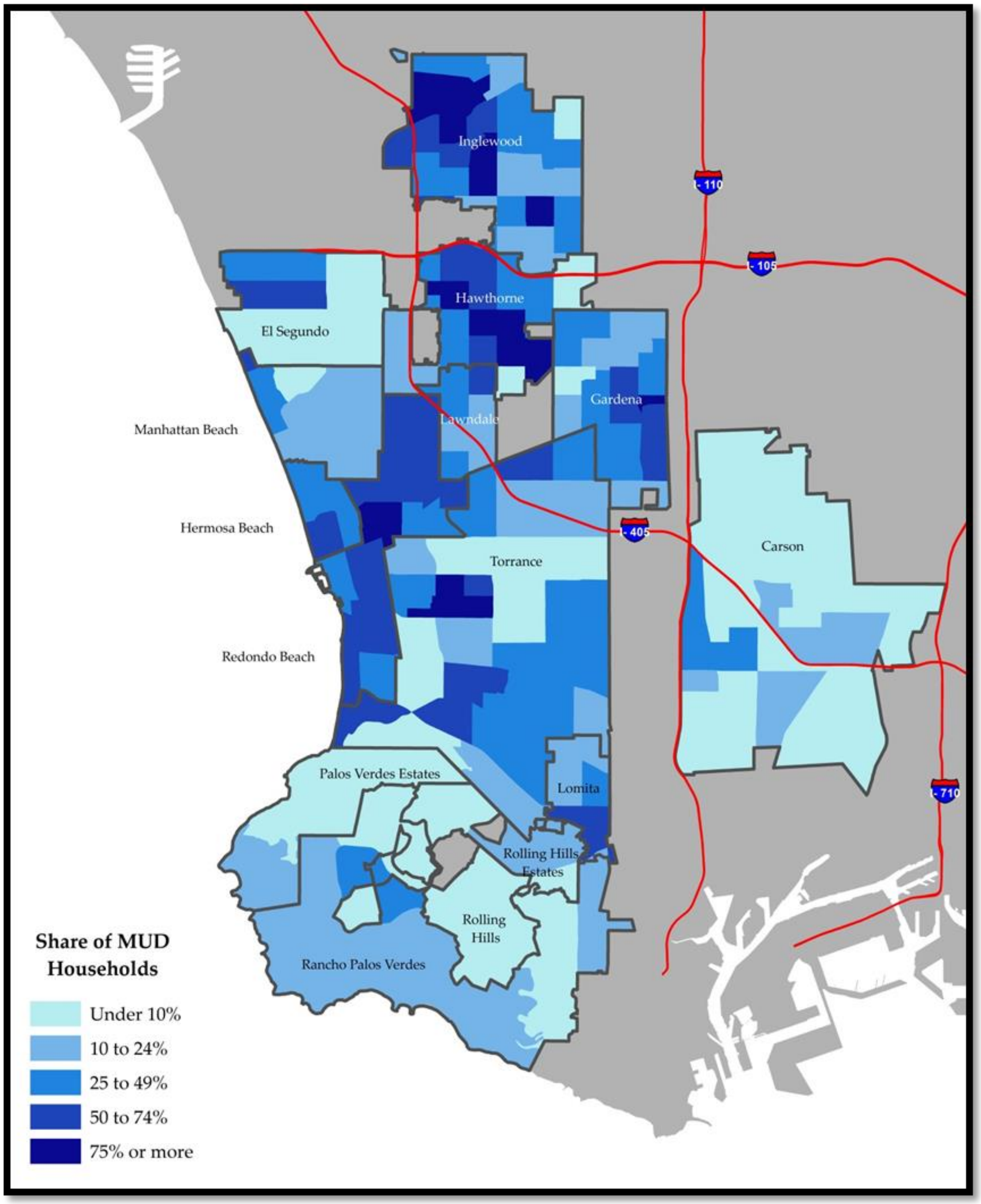
The Multi-unit Dwellings of the South Bay Subregion

The South Bay is home to nearly 150,000 MUD households, making up 46% of the subregion's residential land use. Although the South Bay is driving PEV adoption for Southern California, this land use mix may very well be constraining the full potential of the area's PEV uptake. The MUDs present a series of hurdles to installing charging infrastructure (electric vehicle supply equipment or EVSE) at home - the preferred refueling choice for early adopters of PEVs - including the variable and often high costs of installation.

The following chapter provides an overview of the South Bay's MUD portfolio, including MUD characteristics that can influence the cost of EVSE installation and the investment motivation such as size (i.e. number of units), per unit value, vintage, ownership type, parking layout and locational attributes such as those MUDs located in disadvantaged communities. Subregional and city planners and other interested parties can review this chapter to understand the MUD composition of the subregion at large and where the MUD might most significantly be constraining PEV adoption.

Two-thirds (66.4%) of the South Bay's MUD households can be found in four cities: Hawthorne, Inglewood, Redondo Beach and Torrance. Figure 1 shows the MUD's share of residential land use per census tract and a high MUD density in the northern Inland Cities such as Inglewood and Hawthorne, as well as along the coast in the Beach Cities as seen with Redondo Beach.

Figure 1. Share of MUD Households across the South Bay Cities



Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 1. MUD Household Count and Share for the South Bay Cities

City	MUD Household Count	% MUD
Hermosa Beach	6,476	46%
Manhattan Beach	5,072	22%
Redondo Beach	20,778	57%
Carson	6,136	23%
Gardena	11,017	48%
Hawthorne	23,033	68%
Inglewood	25,618	60%
Lawndale	7,516	53%
Lomita	4,429	47%
Palos Verdes Estates	352	7%
Rachos Palos Verdes	2,831	17%
Rolling Hills	0	0%
Rolling Hills Estates	106	3%
El Segundo	4,518	57%
Torrance	26,250	42%
Total	**144,132**	**46%**

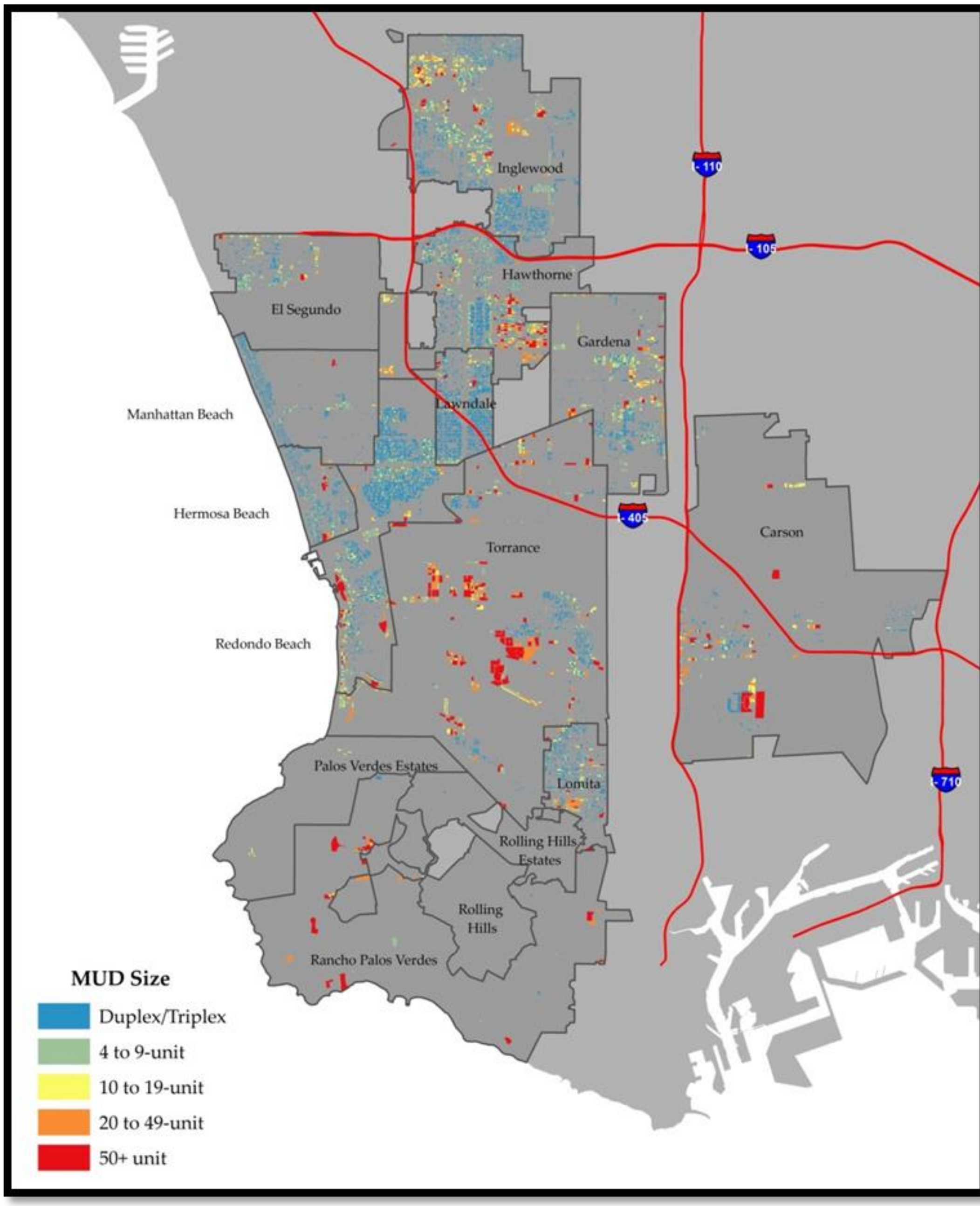
Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

In total, MUDs in 69 of the subregion's 141 census tracts make up 50% or more of the residential land use. In 21 census tracts, MUD density is very high (75% or more of residential land use). Sixteen of the very high MUD density census tracts are in the Inland Cities, with six tracts classified as disadvantaged communities. Alternatively, the Peninsula Cities are made up mostly of single-family households. Only Rancho Palos Verdes has more than 500 MUD households.

2.1 Size

MUDs can range in size from two to over 100 units. Figure 2 presents MUD sizes and their spatial distribution per city.

Figure 2. MUD Sizes across the South Bay Cities



Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 2. MUD Sizes for the South Bay Cities

City	Duplex/Triplex	4 to 9-unit	10 to 19-unit	20 to 49-unit	50+ unit	Total
Hermosa Beach	2,961	1,756	514	291	954	**6,476**
Manhattan Beach	3,303	1,063	338	160	208	**5,072**
Redondo Beach	7,081	6,193	2,204	2,331	2,969	**20,778**
Carson	964	693	762	1,258	2,459	**6,136**
Gardena	2,017	4,072	2,034	1,911	983	**11,017**
Hawthorne	3,856	5,781	2,780	6,219	4,397	**23,033**
Inglewood	5,773	8,960	4,781	3,738	2,366	**25,618**
Lawndale	4,273	1,330	734	697	482	**7,516**
Lomita	1,291	961	609	1,029	539	**4,429**
Palos Verdes Estates	19	133	155	45	0	**352**
Rancho Palos Verdes	18	73	70	524	2,146	**2,831**
Redondo Beach	7,081	6,193	2,204	2,331	2,969	**20,778**
Rolling Hills Estates	2	0	18	86	0	**106**
El Segundo	834	2,141	709	646	188	**4,518**
Torrance	2,624	3,741	2,898	6,541	10,446	**26,250**
Total	**35,016**	**36,897**	**18,606**	**25,476**	**28,137**	**144,132**

Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

The South Bay subregion is home to a large number of duplexes and triplexes (two and three units, respectively). For the Beach Cities, these are the most common size of MUD. For example, duplexes and triplexes in Manhattan Beach are 65% of its MUD households.

For the Inland Cities, MUD size is more evenly distributed. Gardena and Inglewood have a majority of medium-sized MUDs (4 to 19-units), while Carson and Hawthorne have higher occurrences of large MUDs (20+ units). Lawndale is similar to the Beach Cities; the majority of its MUDs are duplexes and triplexes.

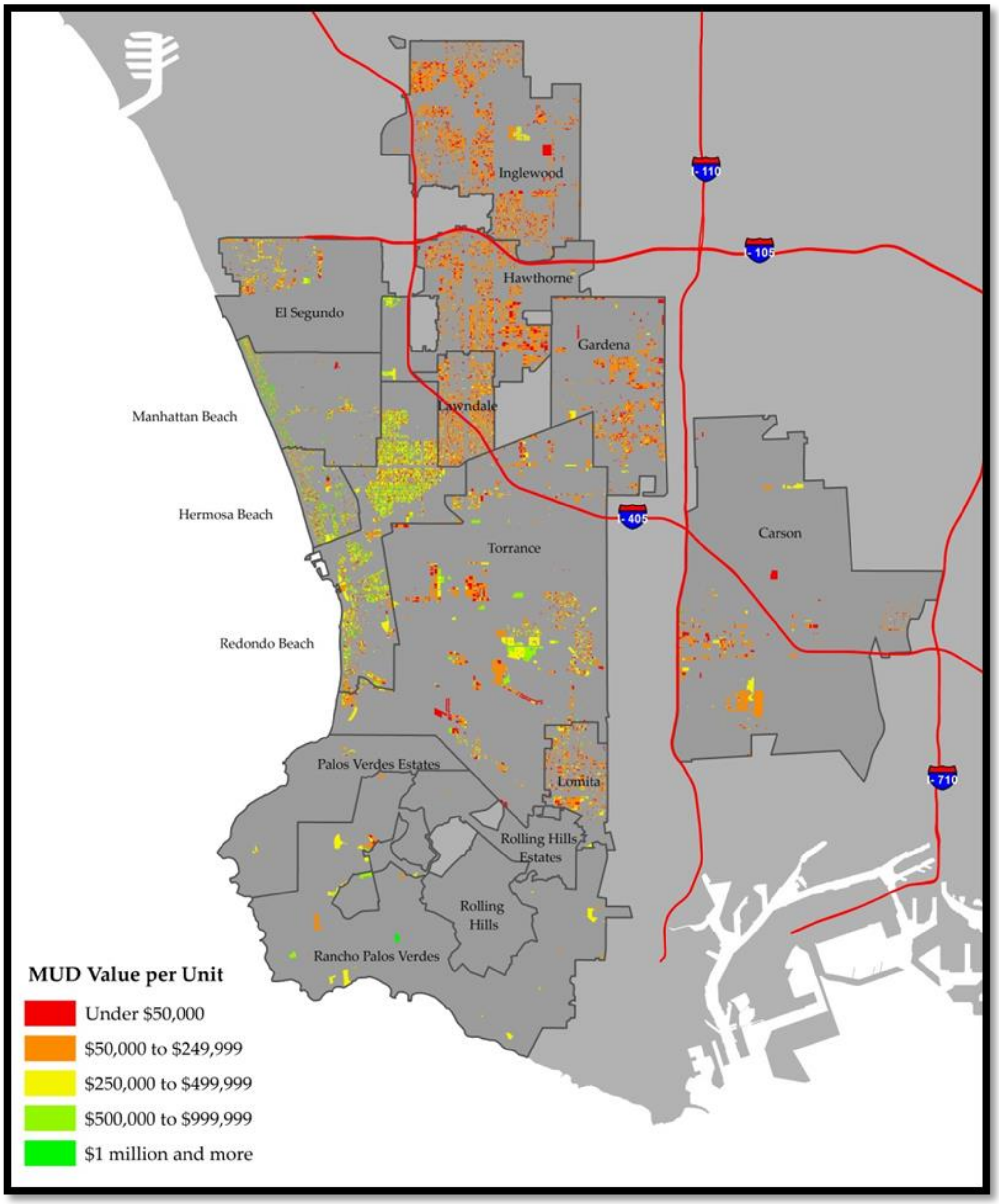
Torrance is home to a significant share of the subregion's 50+ unit MUDs.

2.2 Per Unit Value

Early PEV sales indicate that higher-income households are purchasing PEVs at higher rates than middle- and low-income households.[3] High-income households tend to purchase new vehicles at faster rates in general and also have more disposable income to spend on new technologies such as PEVs. High-income earners can also afford to live in higher value homes, making the MUD value per unit an indicator of latent PEV demand. This provides the basis for the propensity to purchase measure discussed in Chapter 3. Figure 3 and Table 3 present the spatial distribution and total number of MUD households by value per unit for each South Bay city.

[3] DeShazo, J.R., Samuel Krumholz, Tamara L. Sheldon et al. UCLA Luskin Center for Innovation. 2015.*Learning from California's Early Plug-in Electric Vehicle Market Growth and Policy Experiments: 2010-2015*.

Figure 3. MUD per Unit Value across the South Bay Cities



Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 3. MUD per Unit Value for the South Bay Cities

City	Under $50,000	$50,000 to $249,999	$250,000 to $499,999	$500,000 to $999,999	$1 million and more
Hermosa Beach	763	2,267	1,964	1,040	442
Manhattan Beach	445	1,865	1,066	983	713
Redondo Beach	1,724	7,493	6,997	4,355	209
Carson	1,523	3,996	613	2	2
Gardena	2,435	7,983	573	26	0
Hawthorne	6,223	15,837	649	324	0
Inglewood	6,156	19,047	415	0	0
Lawndale	1,075	5,701	726	14	0
Lomita	805	2,883	734	7	0
Palos Verdes Estates	8	145	183	13	3
Rancho Palos Verdes	116	1,051	1,580	76	8
Rolling Hills Estates	0	2	42	62	0
El Segundo	670	2,587	1,017	244	0
Torrance	6,646	13,278	4,836	1,489	1
Total	**28,589**	**84,135**	**21,395**	**8,635**	**1,378**

Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

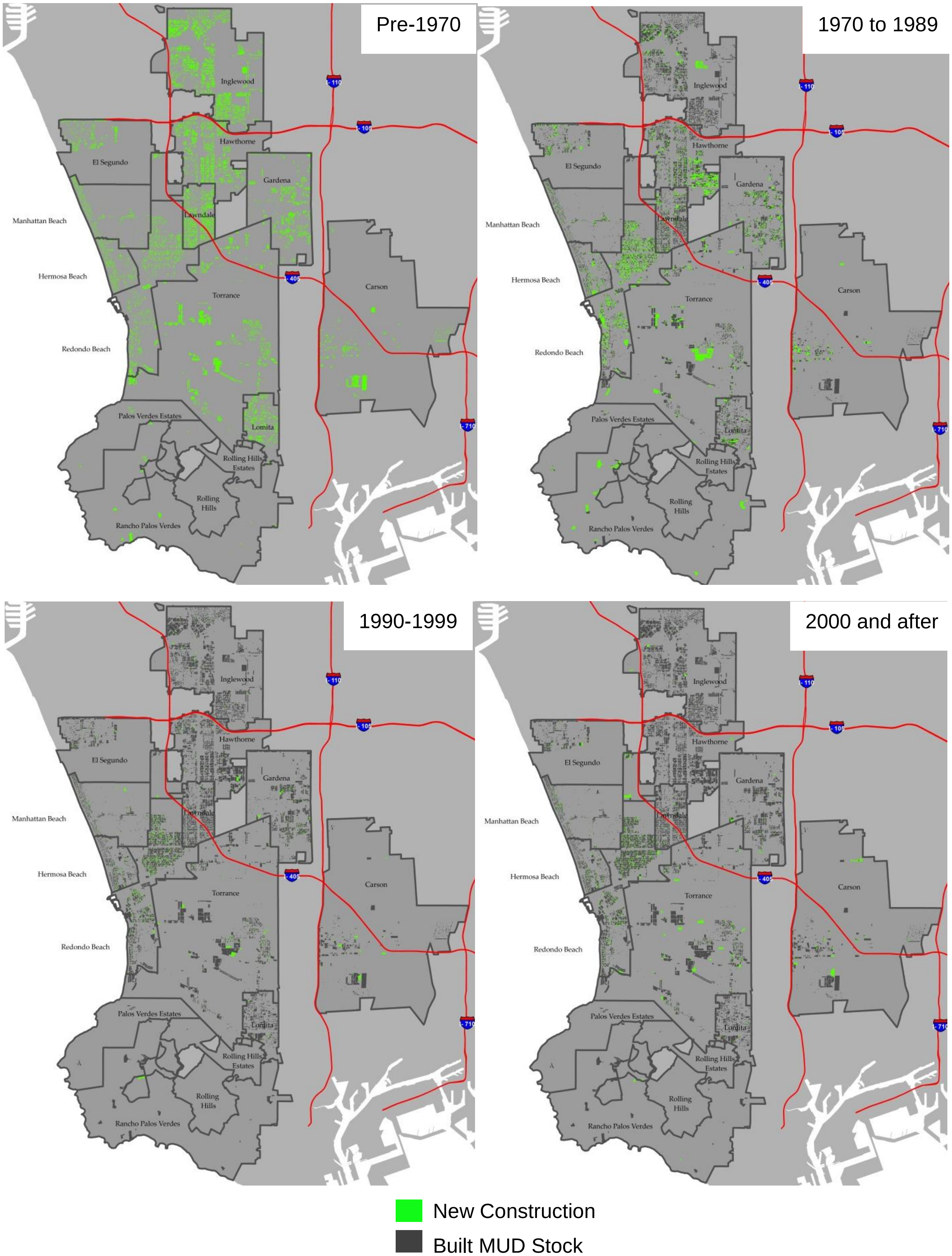
The value of property, including MUDs, in the South Bay is generally higher closer to the Pacific Coast. Indeed, 90% of MUDs valued at $500,000 per unit or greater are located within the Beach Cities. Alternatively, for the Inland Cities (except Lomita), 90% or more of MUD households are valued at less than $249,999 per unit.

2.3 Vintage

More recently constructed MUDs may provide advantages when installing EVSE on site for two reasons. First, the electrical service being provided by the utility to the MUD is more likely to have sufficient capacity for supporting PEV charging, avoiding the need for potentially costly service upgrades like installing a new service wire or transformer. Second, if panel upgrades such as new circuit breakers are required to provide sufficient capacity for PEV charging, replacement materials may be easier to find and less expensive.

The MUD stock in the South Bay subregion can be described as older with over 61% of MUD households (88,108) built before 1970. Only 10% or 12,465 MUD households were built in or after the year 2000. Figure 4 and Table 4 present the MUD construction trends in the South Bay over time as well as the MUD vintage of each South Bay city’s building stock.

Figure 4. MUD Construction over Time across the South Bay Cities



Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 4. MUD Vintage for the South Bay Cities

City	Pre-1970	1970 to 1989	1990 to 1999	2000 and later
Hermosa Beach	3,633	2,209	274	360
Manhattan Beach	3,245	815	601	411
Redondo Beach	8,647	8,966	1,310	1,855
Carson	3,285	1,491	754	606
Gardena	6,923	3,210	608	276
Hawthorne	11,271	10,757	528	477
Inglewood	21,051	3,553	470	544
Lawndale	5,149	1,946	263	158
Lomita	3,311	1,006	47	65
Palos Verdes Estates	226	118	0	8
Rancho Palos Verdes	941	1,852	0	38
Rolling Hills Estates	2	0	44	60
El Segundo	2,760	1,416	172	170
Torrance	17,664	6,220	837	1,529
Total	**88,108**	**43,559**	**5,908**	**6,557**

Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Inglewood has the majority of MUDs (21,051 or 82%) built before 1970; Rolling Hills Estates has the least (2). Redondo Beach is home to the most number of MUDs (1,855 or 28%) built in the South Bay in or after the year 2000, however the majority of its MUDs (17,613) were also built before 1989. The cities with the second, third, and fourth highest number of newer MUDs are Torrance (1,529), Carson (606) and Inglewood (544), respectively.

2.4 Ownership Types

MUD ownership influences a residence's motivation to invest in home charging. MUDs include both apartment buildings and condominiums. Apartment buildings are generally owned by an individual or company that rents out the units to individual tenants. The building owner is responsible for all common spaces such as lighting for the building's lobby. Any structural changes to the building will be paid for by the owner who will make investment decisions based on increasing the value of the units and charging higher rents. Condominiums are owned by the resident with non-unit decisions, such managing common areas, often made by a home owner association (HOA) governing board.

For renters, the invetsment motivation is weak or non-existent because they are unlikely to invest a significant sum of money in an immobile piece of equipment that they may move from in the future. Moreover, apartment owners and management groups may not view EVSE as an amenity by which to attract tenants. Alternatively, condominium owners are likely to view the

EVSE as a property improvement positively affecting the potential resale value of their unit, although a significant installation may require approval by the HOA governing board.

MUD ownership will also determine who is responsible for common area management including overseeing the 110/120-volt outlets that may be accessible in the parking area. In an apartment building setting, these outlets, which can provide Level 1 charging if there is sufficient electrical capacity, are often connected to the house panel. The house panel controls the electrical supply for all shared appliances and common areas such as laundry machines and pool pumps. Renters should seek approval from the property owner to consume electricity when the parking area electrical outlets are connected to the house panel (see Chapter 4 for more information about the electrical configuration of MUDs).

Table 5. MUD Apartment Building Share for the South Bay Cities

City	Duplex/Triplex	4 to 9-unit	10 to 19-unit	20 to 49-unit	50+ unit	Total
Hermosa Beach	77%	80%	86%	32%	68%	**75%**
Manhattan Beach	79%	76%	76%	82%	100%	**79%**
Redondo Beach	36%	77%	63%	63%	45%	**55%**
Carson	100%	76%	22%	44%	48%	**55%**
Gardena	97%	91%	70%	70%	62%	**82%**
Hawthorne	98%	95%	84%	90%	97%	**93%**
Inglewood	99%	96%	88%	66%	79%	**89%**
Lawndale	98%	87%	77%	87%	34%	**89%**
Lomita	98%	86%	93%	58%	63%	**81%**
Palos Verdes Estates	58%	71%	50%	53%	-	**59%**
Rancho Palos Verdes	72%	89%	50%	35%	53%	**51%**
Rolling Hills Estates	100%	-	0%	0%	-	**2%**
El Segundo	98%	90%	71%	73%	0%	**83%**
Torrance	84%	89%	75%	73%	69%	**75%**
Total	**81%**	**89%**	**76%**	**72%**	**67%**	**78%**

Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

The MUD stock of the South Bay consists of 78% apartment buildings with the highest concentration in the Inland Cities. The Beach Cities and Peninsula Cities have a far greater incidence of condominiums. Redondo Beach's significant duplex and triplex supply (7,081) is 64% condominium. Table 5 provides the percent of apartment building ownership across the MUD size categories for each South Bay city.

2.5 Parking Layouts

In Southern California and the South Bay, the private vehicle has played a significant role in shaping land use patterns and the built environment, as well as MUD architectural designs. The latter tends to change over time and location depending on construction trends and sociodemographic changes. These changes can influence unit size, the availability of on-site amenities such as laundry services, and the parking layout of the property.

The parking layout is of particular importance to PEV ownership and EVSE installation. Indeed, one of the most significant drivers of EVSE installation costs is the distance from the electrical panel to the PEV charging spot and a MUD's parking layout will greatly influence this length of distance. The parking layout may also determine whether a PEV driver will have access to an electrical outlet for Level 1 charging. And finally, some parking layouts such as shared garages may provide opportunities for sharing the installation costs for multiple EVSE or the deployment of new technologies such as energy management systems (EMS) which allow for the strategic charging of multiple PEVs by optimally balancing each vehicle's state of charge with available electrical capacity. The impact of parking layout on MUD EVSE installation costs is discussed at length in Chapter 4.

The nine most common MUD parking layouts of the South Bay are the 1) dingbat with door, 2) dingbat without door, 3) detached parking with door, 4) detached parking without door, 5) podium garage, 6) subterranean garage 7) parking lot, and 8) driveway only. As described in Table 6, the "dingbat" design was the most frequently observed MUD parking layout by far; it accounts for the parking design for over half of the South Bay MUD households.

Common MUD Parking Layouts of the South Bay:

1) Dingbat with door

Photo Credit: UCLA Luskin Center

- Enclosed individual garage partitioned by walls
- Equipped with private garage door
- Often located directly below driver's housing unit
- At or below grade
- High probability of electrical outlet access

2) Dingbat without door

Photo Credit: UCLA Luskin Center

- Open or partitioned parking spots
- Not equipped with private garage door
- Located below housing units
- At or below grade
- Medium probability of electrical outlet access

3) Detached parking with door

Photo Credit: UCLA Luskin Center

- Enclosed individual garage partitioned by walls
- Equipped with private garage door
- Detached from main MUD structure
- At grade
- Medium to high probability of electrical outlet access

4) Detached parking without door

- Open parking structure often partitioned by walls
- Not equipped with private garage door
- Detached from main MUD structure
- At grade
- Low to medium probability of electrical outlet access

Photo Credit: UCLA Luskin Center

5) Podium garage

Photo Credit: UCLA Luskin Center

- Enclosed shared garage
- Not equipped with private garage door
- Located below housing units
- Below grade
- Medium to high probability of electrical outlet access

6) Subterranean garage

Photo Credit: UCLA Luskin Center

- Enclosed shared garage
- Not equipped with private garage door
- Located below housing units
- At grade
- Medium to high probability of electrical outlet access

7) Parking lot

- Open parking lot not partitioned by walls
- Not equipped with private garage door
- Located adjacent to main MUD structure
- At grade
- Zero to low probability of electrical outlet access

8) Driveway only

- Open parking spot or spots not partitioned by walls
- Not equipped with private garage door
- Located adjacent to main MUD structure
- At grade
- Zero to low probability of electrical outlet access

Table 6. MUD Apartment Building Share for the South Bay Cities

City	Dingbat with door	Dingbat without door	Detached parking with door	Detached parking without door	Podium garage	Sub-terannean garage	Parking lot	Driveway only
Hermosa Beach	4,105	254	415	0	554	492	64	592
Manhattan Beach	3,462	209	231	80	166	250	14	661
Redondo Beach	12,769	813	1,461	488	1,843	1,791	198	1,416
Carson	2,277	574	263	459	1,123	933	275	231
Gardena	4,143	2,503	665	1,118	852	670	468	597
Hawthorne	7,654	4,071	1,359	2,665	2,979	2,289	787	1,230
Inglewood	9,049	3,501	2,200	4,804	1,662	1,282	1,113	2,007
Lawndale	3,393	928	1,065	422	393	305	86	923
Lomita	1,479	658	381	621	397	303	250	338
Palos Verdes Estates	151	0	0	0	104	97	0	0
Rancho Palos Verdes	1,176	22	0	0	904	729	0	0
Rolling Hills Estates	46	0	0	0	31	28	0	0
El Segundo	2,996	393	222	0	358	286	68	195
Torrance	13,579	939	647	0	5,198	4,456	819	612
Total	**66,280**	**14,865**	**8,909**	**10,658**	**16,564**	**13,912**	**4,141**	**8,803**

To identify the most common parking layout at MUDs in the South Bay, we conducted a random sampling exercise that considered 900 South Bay MUD parcels. The most common parking layout in subregion is the dingbat with door, accounting for nearly 46% of MUD households. For the Beach Cities, the dingbat with door share increased to 63% and for the Inland Cities, the share reduced to 36%.

Inland cities are estimated to provide significantly more detached parking layouts than the other city groupings, comprising 20% of household's parking access compared to 8% for the Beach Cities, 3% for Torrance and El Segundo, and 0% for the Peninsula Cities. In Chapter 4, we discuss how detached parking layouts are likely to result in high EVSE installation costs.

Shared garages make up a large share of MUDs in Torrance, El Segundo and the Peninsula Cities when compared to the Beach and Inland Cities. These parking layouts may lend themselves to group investments of EVSE equipment or the deployment of new technologies such as energy management systems.

2.6 Presence in Disadvantaged Communities

The South Bay includes 49 census tracts that are classified as disadvantaged communities by the California Office of Environmental Health Hazard Assessment's CalEnviroScreen 2.0 screening tool. Disadvantaged communities are defined using a series of environmental, health and socioeconomic criterion with the purpose of identifying areas disproportionately burdened by and vulnerable to multiple sources of pollution.[4] The distinction is an important one with Senate Bill 535 allocating 25% of Greenhouse Gas Reduction Funds to projects that provide a benefit to disadvantaged communities, and a minimum of 10% of the funds for projects located directly within these predefined communities.[5] In fiscal year 2014-15, the Greenhouse Gas Reduction Fund (GGRF) received $1.49 billion from Cap-and-Trade revenue, an amount that is expected to increase in subsequent years.[6] Table 7 and Figure 5 provide an overview of the MUD households in the South Bay's disadvantaged communities.

Table 7. MUD Counts in Disadvantaged Communities per South Bay City

City	Duplex/Triplex	4 to 9-unit	10 to 19-unit	20 to 49-unit	50+ unit	Total
Carson	550	424	94	434	1,125	**2,627**
Gardena	1,095	2,680	845	860	402	**5,882**
Hawthorne	1,888	3,180	978	1,668	1,266	**8,980**
Inglewood	2,343	3,117	2,422	1,320	941	**10,143**
Lawndale	3,473	881	424	529	166	**5,473**
Torrance	153	231	25	129	142	**680**
Total	**9,502**	**10,513**	**4,788**	**4,940**	**4,042**	**33,785**

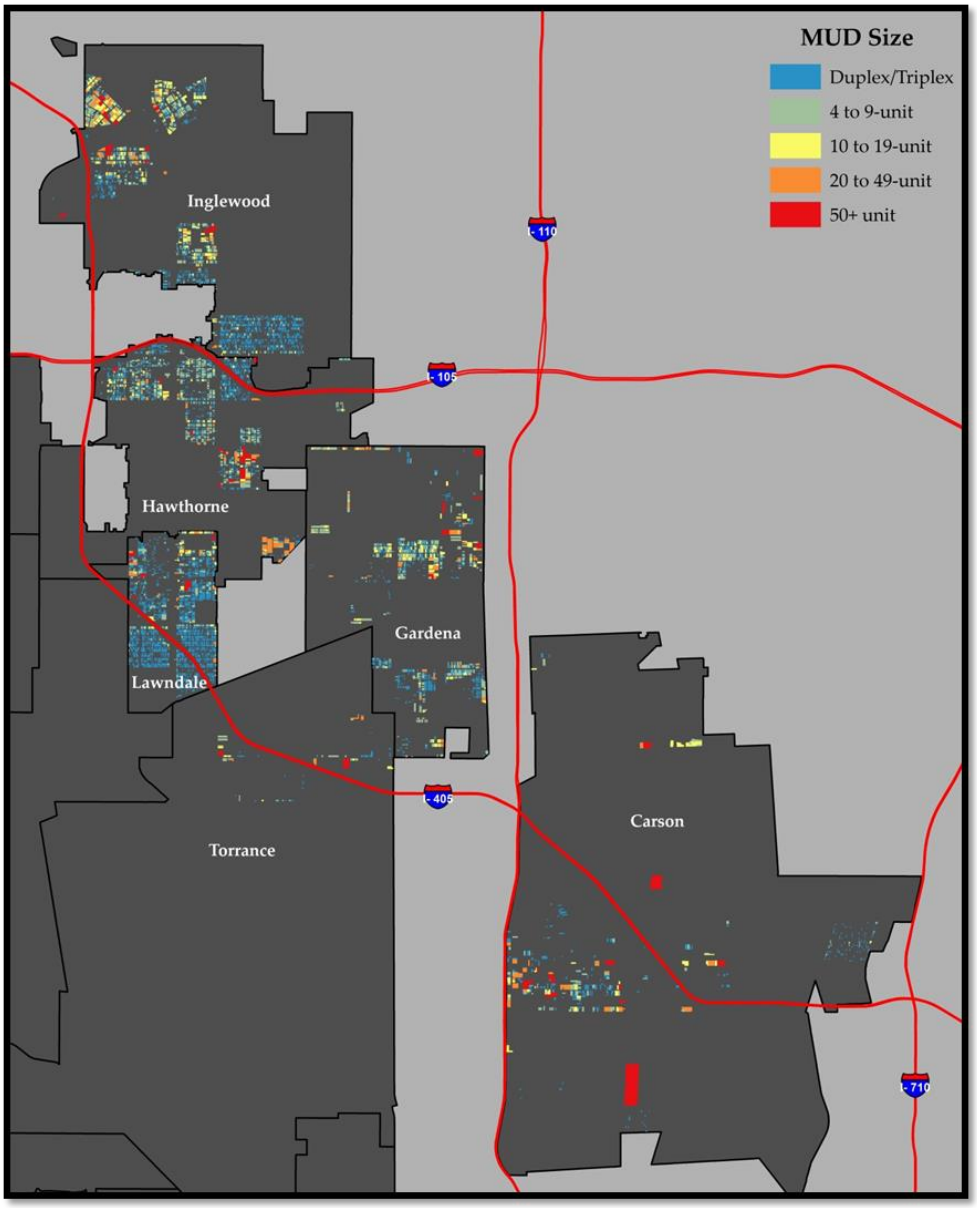
Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

[4] California Office of Environmental Health Hazard Assessment. http://oehha.ca.gov/ej/ces2.html

[5] Text of Chapter 830, Statutes of 2012 (SB 535, de Leon), Section 39713. http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0501-0550/sb_535_bill_20120930_chaptered.

[6] Rabin, Jeffrey, Colleen Callahan, and J.R. DeShazo. UCLA Luskin Center for Innovation. 2015. *Guide to Greenhouse Gas Reduction Fund Program Designs, Expenditures and Benefits*.

Figure 5. MUD Sizes in the South Bay's Disadvantaged Communities



Source: Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Inglewood and Hawthorne account for 56% of MUD households in disadvantaged communities in the South Bay with 10,143 and 8,980 households, respectively. Most of the MUDs within disadvantaged communities are smaller, with duplexes and triplexes making up 28% of households and 4 to 9-unit MUDs making up 31%.

These households may be the target of future investment including from one of the largest recipients of GGRF - the Low Carbon Transportation program - with the purpose of accelerating the transition to zero-emission or near-zero emission passenger cars, transit vehicles and freight transportation. GGRF investments are already being channeled to programs looking to expand PEV adoption to low- and moderate-income households. An example is the California Air Resources Board's Enhanced Fleet Modernization (EFMP) Plus-Up Pilot Program, which provides significant financial assistance to low income households in the Greater Los Angeles area and the San Joaquin Valley who scrap their old gross-polluting car and replace it with a more fuel-efficient vehicle. When purchasing a PEV, low-income participants can receive $9,500 to buy or lease a new plug-in hybrid electric vehicle plus a $1,500 Clean Vehicle Rebate Program (CVRP) rebate for a total of $11,000 of assistance. For a new battery electric vehicle, the rebate is $9,500 plus the $2,500 CVRP rebate for a total of $12,000. To qualify, the resident must live in a zip code that includes a disadvantaged community census tract.[7]

Additionally, Southern California Edison's Charge Ready program - which aims to install up to 1,500 charging stations at parking sites where dwell times exceed four hours or longer-term parking sites including MUDs - will target at least 10% of its deployment within disadvantaged communities.

[7] California Air Resources Board. Making the Cleanest Cars Affordable. http://www.arb.ca.gov/newsrel/efmp_plus_up.pdf.

CHAPTER 3:

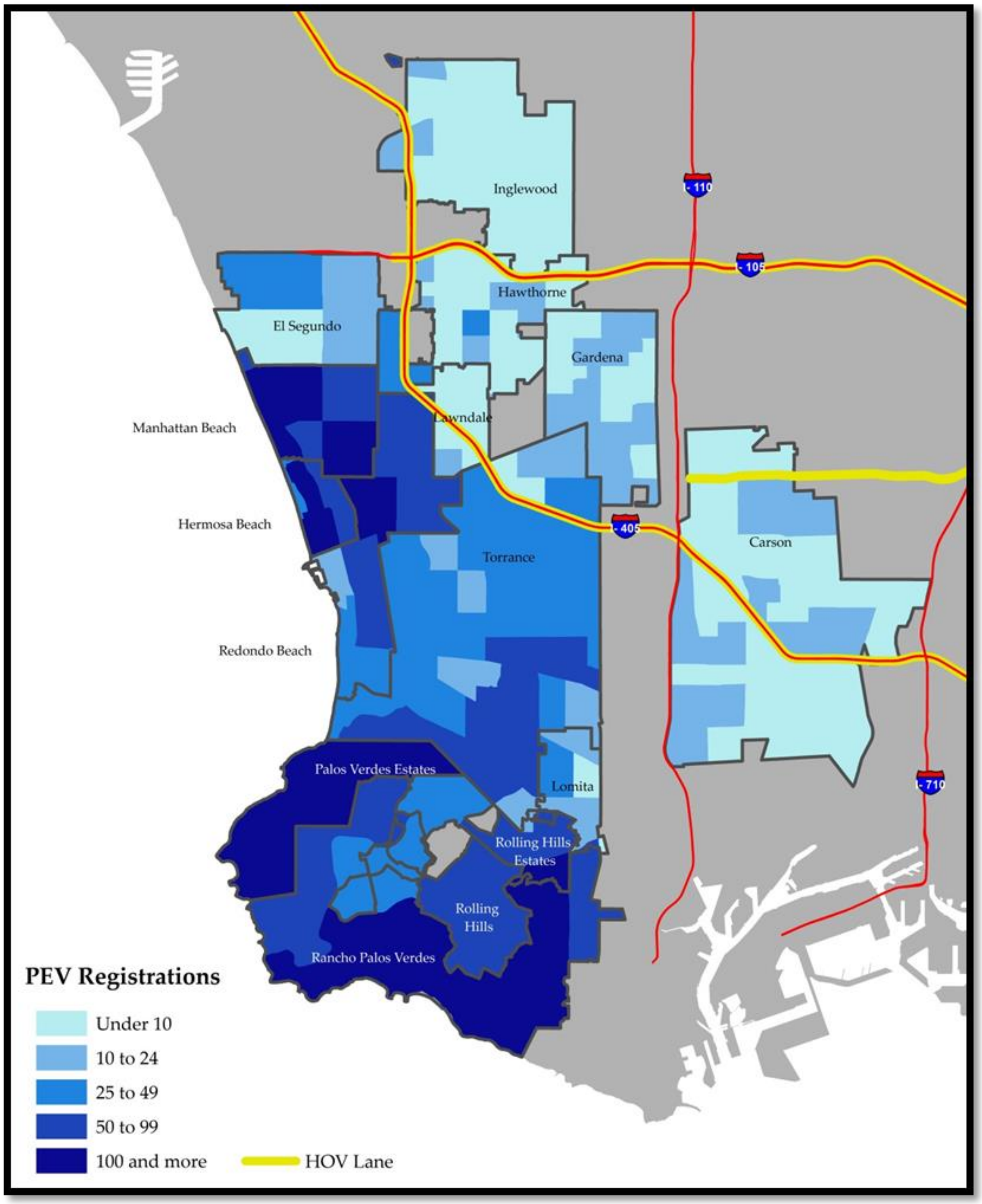
Plug-in Electric Vehicle Demand in the South Bay

The South Bay is a leader in the adoption of plug-in electric vehicles (PEVs) in Southern California. By the end of 2015, the subregion was home to 22 census tracts in the top fifth percentile for PEV registrations across Los Angeles County, with three census tracts in the top 10 for PEV adoption. In total, the subregion is home to 5,657 PEV drivers.

This chapter provides an overview of where PEV demand in the South Bay subregion is the greatest and where this demand is greatest among multi-unit dwellings (MUD) residents. The latter is calculated using a propensity to purchase score which estimates PEV demand as a function of historical PEV adoption trends as well as income level and MUD per unit value. Subregional and municipal governments and other interested stakeholders should use this chapter to prioritize neighborhood outreach or organize other planning efforts (see Chapter 5 for more detail on outreach strategies).

Consistent with statewide trends, early PEV drivers tend to be higher income households. As such, the Beach Cities, the Peninsula Cities and the City of Torrance are responsible for 78% of PEV registrations. Figure 6 and Table 8 provide a PEV registration overview for each South Bay city.

Figure 6. PEV Registrations across the South Bay Cities



Source: IHS Automotive, California Department of Transportation

Table 8. PEV Adoption for the South Bay Cities

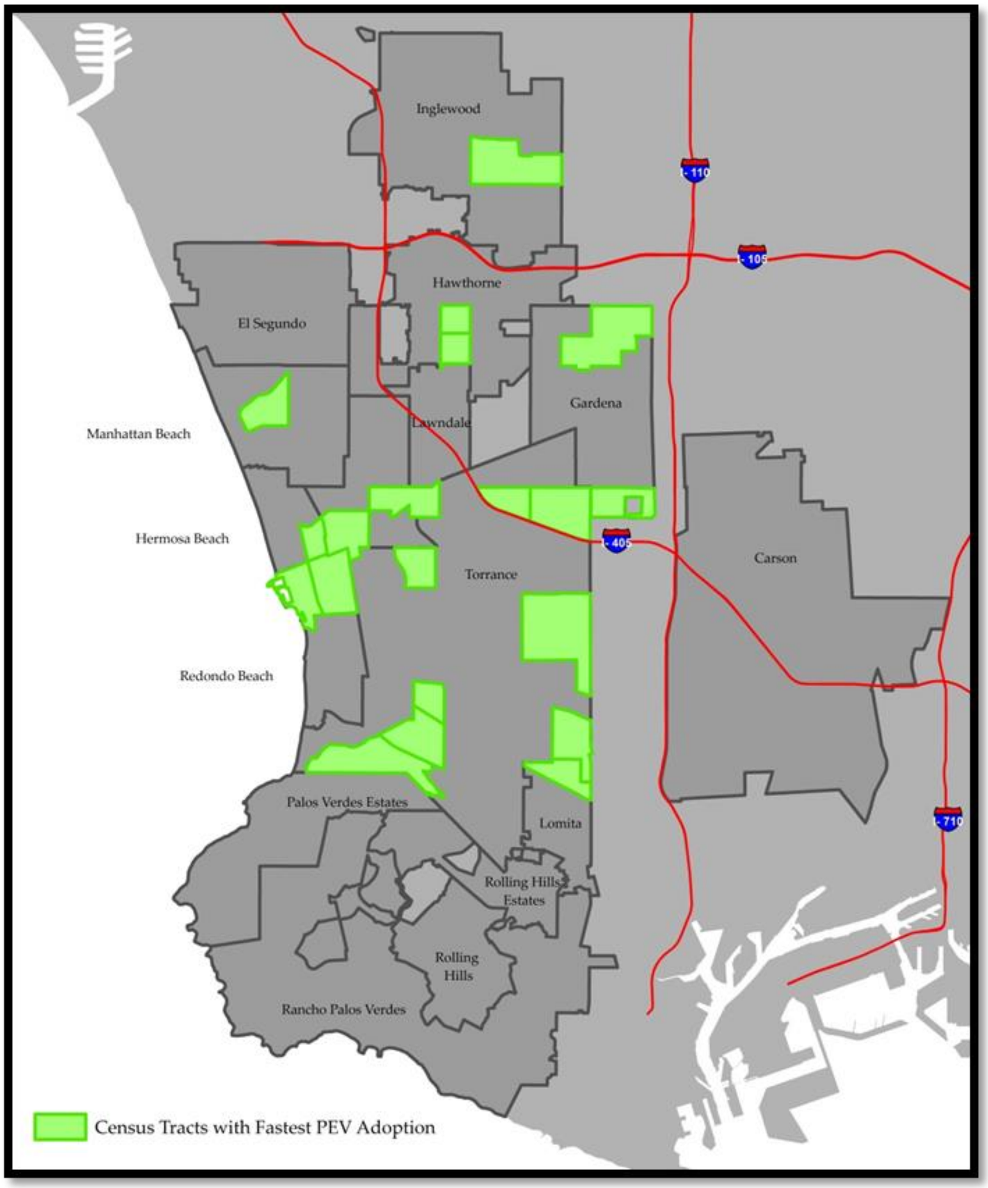
City	PEV Registrations	PEVs per 100 Residents	2015 Growth Rate	% Battery Electric Vehicle	Number of Publically Available Chargers
Hermosa Beach	420	21.5	42%	45%	7
Manhattan Beach	1,081	30.8	45%	47%	9
Redondo Beach	69	1.7	38%	39%	13
Carson	193	2.1	36%	36%	14
Gardena	128	2.2	44%	49%	2
Hawthorne	186	2.2	62%	41%	20
Inglewood	110	1.0	64%	42%	1
Lawndale	53	1.6	39%	38%	1
Lomita	74	3.7	40%	32%	0
Palos Verdes Estates	388	28.9	40%	42%	0
Rancho Palos Verdes	877	13.1	45%	42%	6
Rolling Hills	168	90.3	31%	50%	0
Rolling Hills Estates	678	84.0	38%	47%	2
El Segundo	152	9.1	52%	49%	31
Torrance	1,080	7.4	40%	38%	24
Total	**5,657**	**7.6**	**43%**	**42%**	**130**

Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract File, U.S. Department of Energy Alternative Fuels Data Center

As more moderate-income households begin to view the PEV as a viable transportation option,[8] adoption will spread beyond the higher-income census tracts. Figure 7 presents evidence that this is occurring in the South Bay, with some of the largest percentage PEV registration growth of 2015 taking place in census tracts within the Inland Cities of Gardena, Hawthorne, Inglewood and Lomita.

[8] In 2012, PEV drivers with income levels below $100,000 made up 18% of PEV purchases. In 2015, this same group has made up over 25% of new PEV purchases (California Center for Sustainable Energy. 2014. *California Plug-in Electric Vehicle Driver Survey* Results.).

Figure 7. Census Tracts with Fastest PEV Registration Rates

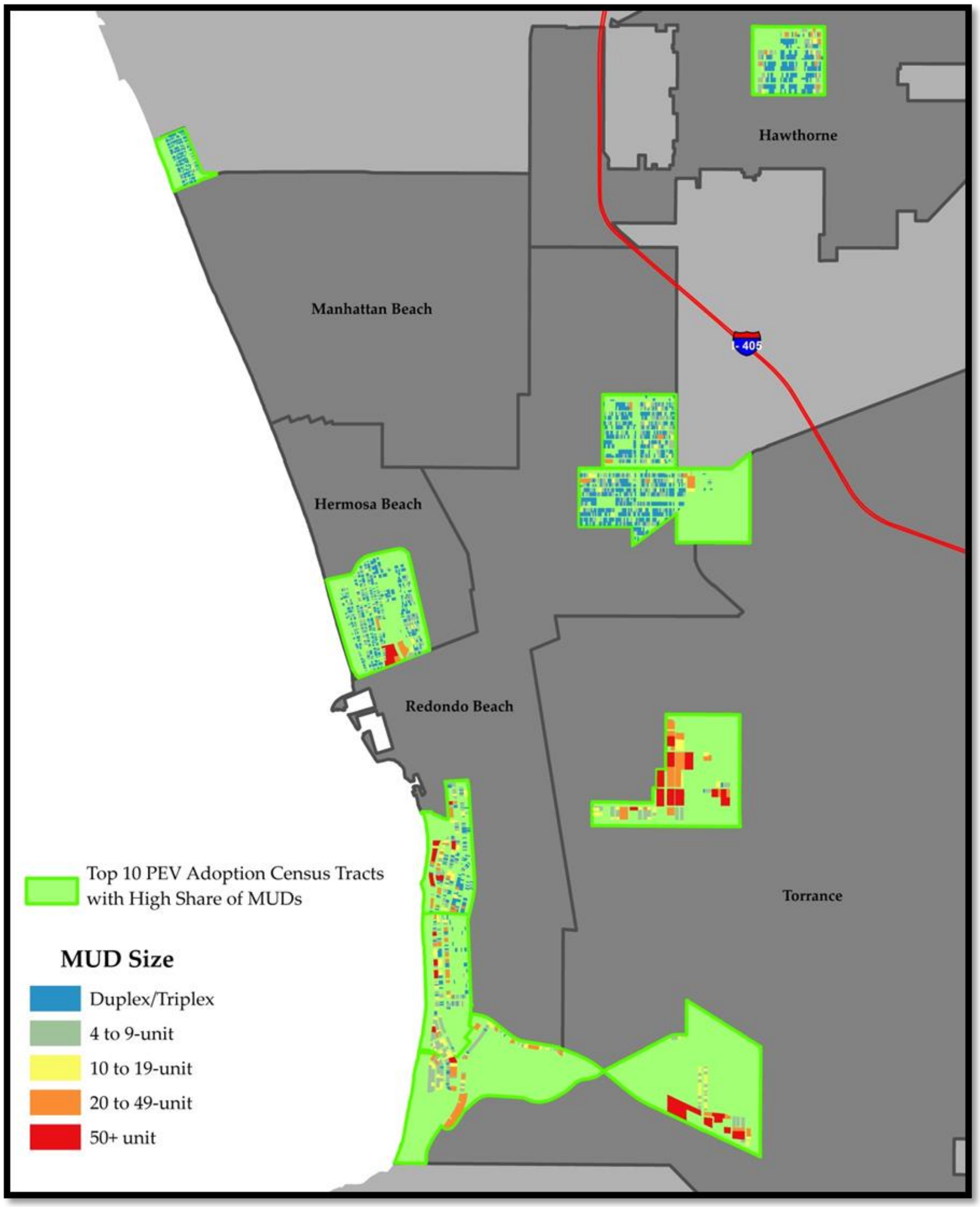


Source: IHS Automotive

3.1 High PEV Demand in High MUD Census Tracts

Census tracts with high PEV adoption and a high share of MUDs may be areas with high latent PEV demand. If MUD residents here do not have access to home charging, it is likely that the MUD is serving as a constraint to these census tracts' full PEV adoption potential. Figure 8 and Table 9 provide the 10 highest PEV registration census tracts with at least a 50% MUD residential land use mix. Neighborhood level outreach to increase PEV adoption may be most effective within these 10 census tracts.

Figure 8. Census Tracts with High PEV Adoption and High MUD Share



Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 9. Census Tracts with High PEV Adoption and High MUD Share

Census Tract	City	PEV Registrations	Percent MUD	Total MUD Households
6037621104	Hermosa Beach	133	64%	2,439
6037620601	Redondo Beach	66	59%	1,460
6037620201	Manhattan Beach	53	74%	794
6037651304	Torrance	58	55%	1,459
6037620521	Redondo Beach	54	50%	858
6037602403	Hawthorne	54	77%	1,387
6037621324	Redondo Beach	53	77%	1,774
6037650602	Torrance	39	77%	2,392
6037621326	Redondo Beach	39	80%	1,607
6037651222	Torrance	39	60%	1,493

Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

The Manhattan Beach and Hermosa Beach census tracts (6037620201 and 6037621104, respectively) show a high percentage of duplexes and triplexes, and outreach here should incorporate this MUD size. The Torrance census tracts (6037650602 and 6037651222) consist mostly of large and very large MUDs (20 to 49-unit and 50+ unit, respectively). There may be opportunities for multiple tenants to invest in the installation of EVSE and reduce per resident costs (see Chapter 4 for more detail about this cost reduction strategy).

3.2 Demand within Multi-unit Dwelling Parcels

To identify and prioritize high latent PEV demand within MUD households, we calculated a propensity to purchase score for each MUD parcel in the South Bay. The score accounts for the historical adoption rate of PEVs in each census tract, as well as the PEV adoption rate of individuals living in households of a certain value.

Considering that a large share of PEVs are purchased by high-income individuals who are likely to live in high-value homes, the propensity to purchase score model allocates a greater score to high-value homes.

When totaling propensity to purchase scores across cities or census tracts, the results provide an estimate of aggregate PEV demand for MUD residents. As seen in Table 10, duplexes and triplexes are generally higher-value properties and are thus estimated to show the greatest demand for PEVs. The Beach Cities account for over 70% of the PEV demand for MUD residents, a result of the high PEV adoption rates and the large number of high-value MUDs including duplexes and triplexes. Redondo Beach has the highest cumulative propensity to purchase score for each MUD size category, particularly for medium and large MUDs (4+ units). After the Beach Cities, Hawthorne and Torrance have the fourth and fifth highest cumulative propensity to purchase scores respectively. The Peninsula Cities account for the lowest scores, due to the low number of MUD households.

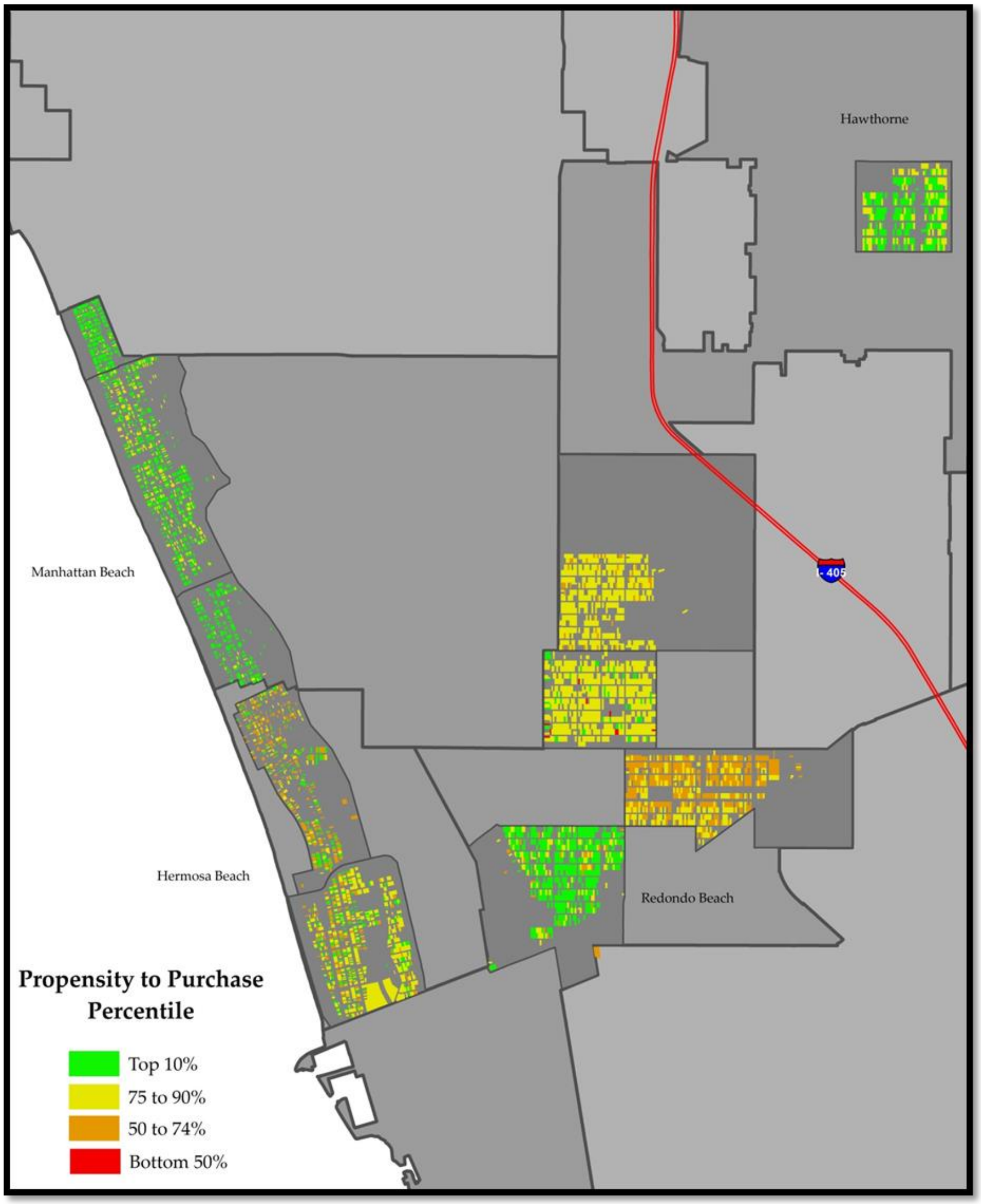
Table 10. Census Tracts with High PEV Adoption and High MUD Share

	Cumulative Propensity to Purchase Scores			
City	**Duplex/Triplex**	**4 to 9-unit**	**10 units or more**	**Total**
Hermosa Beach	17.34	3.82	0.66	21.82
Manhattan Beach	29.36	3.31	0.52	33.18
Redondo Beach	35.53	9.71	2.04	47.28
Carson	0.74	0.21	0.26	1.21
Gardena	1.29	1.03	0.39	2.7
Hawthorne	6.66	2.69	1.17	10.51
Inglewood	2.86	2.02	0.48	5.35
Lawndale	3.89	0.53	0.13	4.55
Lomita	1.47	0.39	0.21	2.08
Palos Verdes Estates	0.09	0.31	0.19	0.58
Rancho Palos Verdes	0.07	0.12	0.33	0.52
Rolling Hills Estates	0.02	0	0.03	0.05
El Segundo	2.18	2.09	0.43	4.69
Torrance	5.48	2.62	1.96	10.07
Total	**106.96**	**28.84**	**8.81**	**144.60**

Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Figure 9 and Table 11 present the top 10 cumulative propensity to purchase score census tracts. Parcels with scores in the top 10 percentile across all MUDs in the subregion are highlighted in bright green. As expected, census tracts from the Beach Cities top the list with a single Hawthorne census tract as the only non-Beach. Again, these census tracts likely represent quality starting points for neighborhood level outreach.

Figure 9. Census Tracts with Highest Cumulative Propensity to Purchase Score



Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 11. Census Tracts with Highest Cumulative Propensity to Purchase Score

Census Tract	City	Cumulative Propensity to Purchase Score	PEV Registrations	Total MUD Households
6037620305	Manhattan Beach	13.03	203	1,249
6037621104	Hermosa Beach	8.78	133	2,439
6037620702	Redondo Beach	8.73	128	411
6037620904	Manhattan Beach	7.83	109	224
6037620201	Manhattan Beach	7.74	53	794
6037620522	Redondo Beach	7.4	69	842
6037621004	Hermosa Beach	5.8	115	951
6037602403	Hawthorne	5.42	54	1,387
6037620601	Redondo Beach	5.04	66	1,460
6037620501	Redondo Beach	5.04	83	515

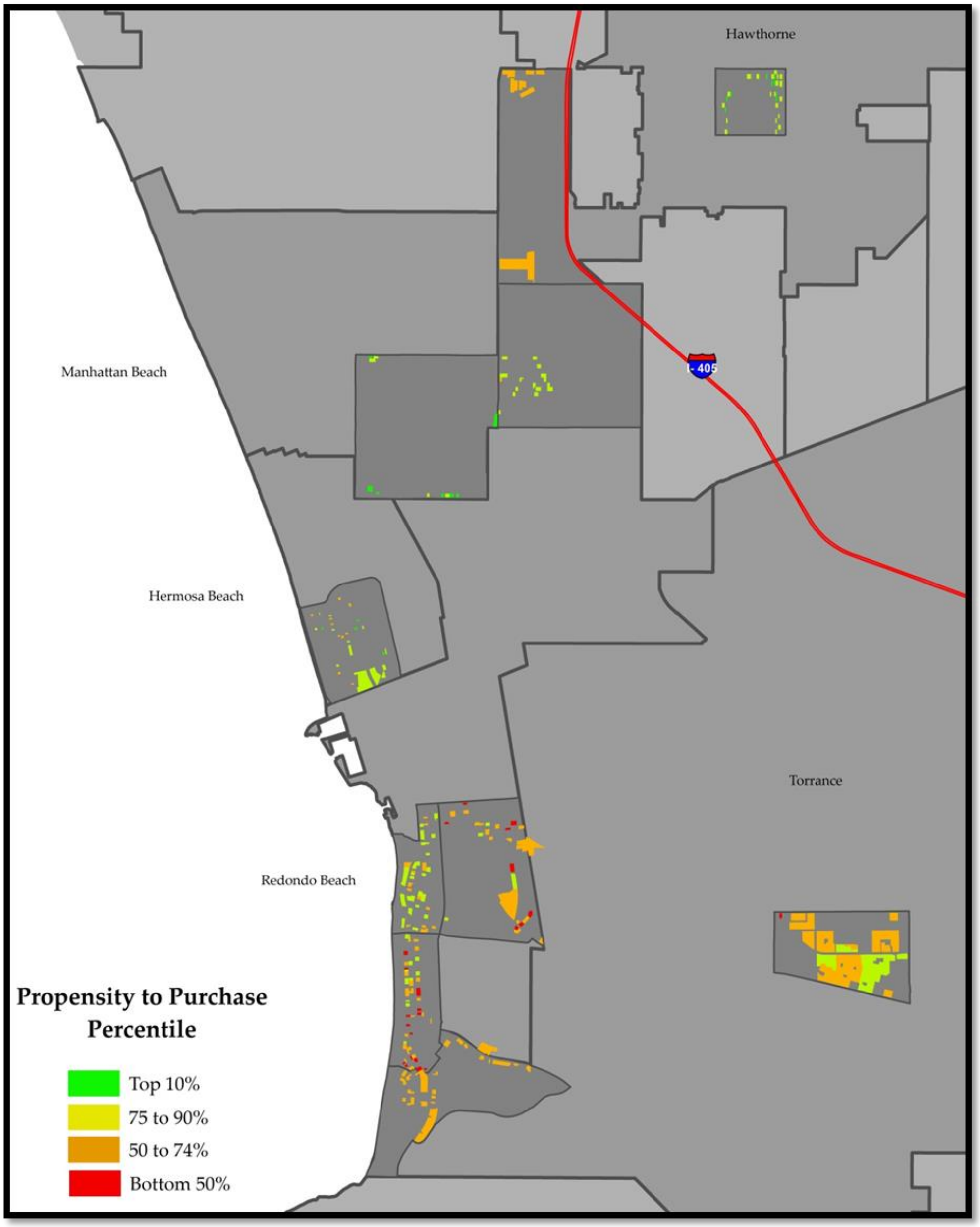
Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

3.2.1 Demand at Large Multi-unit Dwellings

There may be significant advantages to installing multiple EVSE and sharing installation costs among PEV drivers. Additionally, Southern California Edison's (SCE) Charge Ready program requires a minimum of 10 EVSEs per site.[9] As such, Figure 10 and Table 12 present the census tracts with the highest cumulative propensity to purchase scores for MUDs of 10 units or more. These census tracts may serve as quality candidates for neighborhood level outreach programs to increase PEV adoption among residents of larger MUDs, as well as promote the potential cost savings to group investing in EVSE installation.

[9] A minimum of 5 EVSE in disadvantaged communities.

Figure 10. Census Tracts with Highest Cumulative Propensity to Purchase Score for MUDs with 10 or more Units



Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

Table 12. Census Tracts with Highest Cumulative Propensity to Purchase Score for MUDs with 10 or more Units

Census Tract	City	Cumulative Propensity to Purchase Score for MUDs with 10+ units	PEV Registrations	Total MUD Parcels with 10 or more units	Total MUD Households with 10 or more units
6037602403	Hawthorne	0.49	49	35	654
6037621324	Redondo Beach	0.43	46	45	1,420
6037650800	Torrance	0.32	67	38	2,247
6037621326	Redondo Beach	0.28	36	51	1,198
6037621104	Hermosa Beach	0.28	121	30	886
6037620800	Manhattan Beach	0.2	182	11	190
6037621301	Redondo Beach	0.2	79	33	1,098
6037602302	Hawthorne	0.2	33	30	598
6037620501	Redondo Beach	0.18	76	14	270
6037651304	Torrance	0.17	51	35	792

Source: IHS Automotive, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

CHAPTER 4:

The Cost of Charging Infrastructure Installation in Multi-unit Dwellings, a Barrier to Plug-in Electric Vehicle Adoption

As owners of a new transportation technology, plug-in electric vehicle (PEV) drivers are changing the way they refuel their vehicles. In place of a 15-minute detour to a gas station, most PEV owners refuel when they are at home and plugged-in throughout the night. To charge PEVs at home overnight, drivers generally choose a Level 1 or 2 charger. The decision is based on charging preference, recharging needs and cost of installation. Level 2 chargers refuel PEVs at a much faster rate than Level 1 but are likely to require greater installation costs. In many instances, Level 1 charging does not involve any installation costs.

Level 1 charging requires a 110/120-volt outlet, the standard 3-prong plug that is available in many parking layouts. It requires 15 amps of continuous load to charge between four and six miles per hour. Seventy-eight percent of PEV drivers average 15 to 45 miles of driving per day, which can be satisfied with 3 to 8 hours of Level 1 charging.[10]

Level 2 charging requires a 208/240-volt outlet and charges PEVs at a much faster rate: 3.3 kW (30 amps) to 19.2 kW (100 amps). Most vehicles currently on the market are only capable of using 30 amps for 3.3 or 6.6 kW charging with a charge rate between 8 and 24 miles per hour. Level 2 charging is the more popular choice for early adopters of PEVs.[11]

The important tradeoff to consider when selecting charge levels in an MUD environment is the electric load each requires. The Level 1 load is minimal, similar to a microwave. Level 2 charging is likely to produce a significant new load for the property. In both instances, a homeowner or renter should seek the expertise of an electrician to estimate the electrical capacity of the property and to determine if the additional load can be supported.

For single-family homeowners, home charging is generally an easily available amenity. They tend to have sufficient electrical capacity to support overnight charging and the installation of the charging equipment (electric vehicle supply equipment or EVSE) is a predictable cost and a straightforward process.

The same cannot be said for PEV home-charging at MUDs. Foremost, the cost of installing EVSE in a MUD parking environment varies greatly from site to site and can quickly become cost prohibitive. Costs can arise at two stages of installation:

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[10] California Center for Sustainable Energy. 2014. *California Plug-in Electric Vehicle Driver Survey* Results.

[11] 64% of respondents have installed a Level 2 charger at home (California Center for Sustainable Energy. 2014. *California Plug-in Electric Vehicle Driver Survey* Results.)

1. **Investing in sufficient electrical capacity to support the additional load of PEV charging.**
   Electrical upgrades, at either the panel or utility service level, can quickly increase installation costs depending on the electrical configuration of the property and the utility that serves it. For example, a new panel with sufficient electrical capacity can cost over $1,000 for materials and labor and a new transformer at the utility service level can cost upwards of $7,000.
2. **Connecting the EVSE to the building's electrical system.**
   To provide electricity to the EVSE, wiring is run through conduit from an electrical panel to the PEV parking spot. Costs can become significant as the distance between the two increases and varies depending on the property's structural configuration and parking layout. For example, all MUD sites where the PEV parking spot was 100 feet or greater from the relevant electrical panel required construction and/or engineer activities to safely run the wiring and conduit. Such activities alone can cost $4,000 or more and significantly increase total EVSE installation costs.

This chapter presents the findings made when visiting MUD sites with a qualified electrician throughout the South Bay and reviewing the resulting installation cost estimates including the electrical configuration of MUDs, the panel and service upgrades that may need to be performed to provide home charging, the costs associated with EVSE installation at MUDs and how these might vary across different parking layouts, and potential opportunities and solutions for low-cost Level 1 and Level 2 installation.

The cost barrier to home charging for MUD residents was repeatedly validated during this exercise; cost estimates ranged from $1,800 to $17,800 and averaged $5,400. Even more, our electrician partner estimated that all 27 sites visited required at least some panel upgrades for Level 2 charging, with only one site electrically ready for EVSE installation (Case Study 1, Section 4.5.1).

Although barriers to home charging at MUDs were decisively confirmed, some potential cost-reduction strategies emerged. This includes Level 1 charging as a viable option for home charging, particularly in dingbat parking layouts, and the opportunity to share EVSE installation costs across multiple PEV drivers. Additionally, some parking layouts and electrical configurations may offer potentially lower-cost Level 2 charging infrastructure installations. These findings are shared in Section 4.6 and will inform the policy recommendations outlined in Chapter 5.

4.1 Overview of Electrical Service at Multi-unit Dwellings

MUDs have a distinct electrical configuration that makes the prospect of home charging challenging. MUDs receive power from utilities' distribution networks at a single service point that leads to the property's electric meter which is on the side of the structure or within an electrical box (or electrical room). Electrical service is supplied through either an overhead service drop or an underground service connection. An overhead drop often comes from a utility pole to the roof of the property and down to the meter section or to the electric box. Underground service connections come from a pull section or pull box – an underground compartment that serves as the main termination point for the utility feed. The connection is then run up to the MUD's electric box. Alternatively, an underground service connection can run down a utility pole, be tunneled underground, and then resurfaced at the property's electric box.

Two examples of overhead service drops providing electricity to the MUD's electric box

Inside the electric box is the property's meter section which includes the house and unit meters as well as the main breakers (pictured). Each residential unit has its own meter and main breaker. Power is distributed from the meter section to a panel located in each unit, or the **unit panel**, where circuit breakers safely manage each unit's electric load. The house meter(s) and main breaker(s) distribute power to a **house panel(s)** which then provides electricity to common areas and general electrical loads such as parking outlets, laundry machines, pool pumps, electric water heaters and more. The house panel can be located in the electric box or in another common space.

A grouping of house and unit meters (i.e. the meter section) and their main breakers inside an electric box.

4.2 Electrical Upgrade Options and Estimated Costs

When installing Level 2 chargers, an electrical upgrade will likely be required. Level 1 EVSE may also necessitate additional capacity through an electrical upgrade. The upgrade can occur in two ways within an MUD's electrical configuration: 1) adding capacity to the unit or house panel, and/or 2) upgrading electric service capacity to the MUD from the utility.

The cost of upgrading a MUD's electrical system varies based on a host of factors, including the age of the building and its electrical equipment and the utility servicing the MUD. For the South Bay, the MUD housing stock can be described as older and often times has insufficient panel capacity for significant new loads. The subregion is almost exclusively served by Southern California Edison (SCE), a utility whose codes and standards influence the costs of service upgrades.

The following section reviews observations made when visiting 27 MUD sites across the South Bay with a qualified electrician and the 19 cost estimates that resulted. Additional utility-specific information was attained by reviewing the SCE Electric Service Requirements and other SCE Guidelines.

4.2.1 Adding Electrical Capacity at the Panel Level

For **Level 1 charging**, a dedicated 20-amp breaker rated for continuous use is required. In many instances, 110/120-volt outlets are available in the parking area and receive electricity from a 15- or 20-amp breaker on the house panel. The amount of available capacity often depends on the other loads tied to that panel, such as electricity needed for common areas. A confluence of loads on the same house panel may trip the main breaker – a safety response that shuts down service to all loads sharing the panel.

To assess the feasibility of Level 1 charging, the resident, property manager or owner and an electrician should review the annual peak load of the house panel to determine if there is available capacity. This information is often available from your electric utility at the request of the person named on the bill.

To support **Level 2 charging**, a dedicated 40-amp circuit is required. If there is sufficient capacity and breaker space on the panel, then additional breakers can simply be added to the panel to create the necessary dedicated circuits. When there is insufficient capacity or space on the electrical panel for a dedicated circuit, an electrician must create additional capacity in one of the following ways: upgrade to a new panel, reconfigure the current panel to provide more breaker space, add a sub-panel for the EVSE unit, or add a separate panel from the existing service.

1) **Upgrade to a new panel**

   A panel upgrade replaces the existing panel (e.g. 50-amp) with one that has additional breaker space or with a new panel of greater capacity (e.g. 100-amp).

2) **Reconfigure the current panel to provide more breaker space**

   Electricians may be able to creatively reconfigure the breakers on the existing panel to free up space for additional breakers. For example, a tandem circuit breaker allows for two circuits to be installed in one circuit breaker space.

3) **Add a sub-panel for the EVSE unit**
Electricians may also install a sub-panel. This is often done by replacing multiple breakers with a tandem circuit breaker and running a wire from it to the new sub-panel. The result is a sub-panel with space for multiple breakers including a dedicated one for Level 2 charging.

4) **Add a separate panel from the existing service**
An electrician may add a separate panel with a dedicated service for PEV charging. This requires a newly installed panel to connect to the current service drop or connection (sometimes called "tapping into" or "tapping off"). The resident and property manager or owner and an electrician should work with their local utility to ensure they follow all electrical service guidelines.

4.2.2 Cost of Adding Electrical Capacity at the Panel Level

In total, 78% of sites visited had access to 110/120-volt outlets in the parking environment. Depending on the parking layout, outlets were either scattered randomly throughout the parking environment or were available at each individual parking spot. Of these sites, 96% of the 110/120-volt outlets were connected to a 15- or 20-amp circuit on the house panel. Without permission to review the annual peak load, it is uncertain whether there is sufficient capacity on the house panel to facilitate Level 1 charging.[12]

For Level 2 charging, 93% of the sites visited were estimated to have insufficient panel capacity or breaker space. At these sites, additional capacity would need to be added through a panel upgrade, a reconfiguration of panel breakers, the installation of a sub-panel, or the installation of a new dedicated panel that is connected to the existing service. Adding capacity at the panel level may cost:

1) $1,000 or more for a panel upgrade with new breakers,
2) $60 to $500 to reconfigure a panel's breakers depending on its type, size and age,
3) $500 to $2,000 to install a sub-panel depending on distance between panel and sub-panel and the number and type of breakers, or
4) $1,000 or more to install a new dedicated panel and to connect to exiting service depending on the space available for the panel and the distance between the new panel and the service connection.

Before a new panel (whether upgraded, sub-, or dedicated) is installed, a SCE representative will visit the site to review the installation and provide electrical code instructions. If the current panel is not up to the utility's current Electrical Service Requirement standards or there is no

[12] a request to the property managers and utility is pending

space for an additional panel, the installer may be required to move the entire meter section, resulting in an additional cost. For example, SCE requires flat ground below meters and three feet of clear working space in front of it so that staff can easily and safely access and read meters. If these standards are not followed, any electrical upgrade that requires SCE approval will require bringing the property up to code. This may include installing a concrete foundation beneath the meter box or moving the meter box in its entirety. Bringing the electric service up to current standards can represent an additional cost and a qualified electrician with experience within the utility territory should review the EVSE installation plan.

4.2.3 Upgrading Electric Utility Service to Multi-unit Dwellings

When considering adding capacity at the panel level, the customer must contact the utility to determine whether there is enough power being provided to the property to support the added load of EVSE charging. If there is insufficient power, tenants or owners must apply for a utility service upgrade. A service upgrade can include service line upgrades such as replacing the service wire that is feeding the MUD, as well as distribution line upgrades such as replacing or upgrading the transformer.

4.2.4 Cost of Upgrading Electric Utility Service to Multi-unit Dwellings

Adding capacity at the panel level may require upgrading the MUD's utility service. Service upgrades may be more likely when the MUD is located at the end of the utility's electrical lines served by a substation or in urban areas where building density has already maximized the electric service capacity.[13] To accommodate additional capacity, the utility may need to perform service line and/or distribution line upgrades.

For these types of upgrades, SCE is "responsible for the cost of the service connector, connectors, support poles, and metering."[14] These costs are covered by a residential allowance and any amount in excess of the allowance is billed to the customer. The customer is "responsible for any trenching, conduit, substructures, or protective structures required for the upgrade. These costs are not covered by the allowance."[15]

Within SCE territory, if the service capacity from an overhead drop increases to over 200 amps, the customer is responsible for burying the overhead feed underground.[16] This will likely require significant construction activities including trenching and the demolition of concrete and may lead to a cost-prohibitive project. Medium-sized MUDs (10-19 units) receiving electricity from an overhead drop may be at or above the 200-amp threshold and thus be subject to this rule and associated costs.

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[13] California Department of Housing and Community Development. 2013. *Electric Vehicle Ready Homes*.

[14] San Diego Gas and Electric. 2014. *Joint IOU Electric Vehicle Load Research Report.*

[15] San Diego Gas and Electric. 2014. *Joint IOU Electric Vehicle Load Research Report.*

[16] Phone Interview with Southern California Edison (November 28, 2015).

Out of 9,300 on-site residential service assessments for PEV charger installations completed before November 2014, SCE required service upgrades only 26 times (0.3%).[17] The service upgrade costs ranged from $274 to $33,499, with service line upgrades averaging $2,055 and distribution line upgrades averaging $7,165.[18] It is important to note that these include a significant share of single-family households that are more likely to have sufficient capacity available. SCE also needed 9 service upgrades for commercial installations which may be more reflective of medium- and large-sized MUDs. In the event that a service upgrade is required, the applicant shall be granted an allowance of $3,402 per residential dwelling unit.[19]

4.3 Connecting Charging Infrastructure to the Building's Electrical System

Once there is sufficient power for PEV charging, the next set of installation costs is from providing electricity to the EVSE itself. This requires an electrician to run wires and conduit from the panel to the PEV charge point. If the panel is proximate to the EVSE location, the installation process can be straightforward. As the length between the panel and the EVSE site is extended, additional costs can arise from materials, labor and construction activities such as trenching through concrete or asphalt. In MUDs where parking areas represent a significant structural feature (e.g. subterranean garages), EVSE installation may require engineering tests such as x-raying concrete to ensure structural integrity.

Soft costs include permitting and inspection fees, tool rentals for construction or engineering activities, taxes on the materials purchased and contractor profit. Labor is often the most significant cost component of project installation and can vary depending on the contractor's experience, complexity of job and whether the contractor is member of a trade union. The cost of tool rentals will be related to the materials and type of labor required and will vary greatly from project to project. Taxes on materials varies by state and profit varies by the company contracted for labor.

Permitting, inspection requirements and associated fees vary by city and by county. The installation of EVSE and any corresponding electrical upgrade will likely require engineering drawings which must be reviewed by the responsible agency such as a Department of Building and Safety. Requirements for engineering drawings can vary and may require electrical load studies of the property.

4.3.1 Cost of Connecting Charging Infrastructure to the Building's Electrical System

Once there is sufficient electrical capacity to perform PEV charging, a contractor needs to run conduit and wire from the relevant panel to the PEV parking spot, overcoming any physical

[17] San Diego Gas and Electric. 2014. *Joint IOU Electric Vehicle Load Research Report.*

[18] San Diego Gas and Electric. 2014. *Joint IOU Electric Vehicle Load Research Report.*

[19] Southern California Edison Tariff Books. Rule 15.

barriers that might arise. The cost of connecting charging infrastructure to the building's electrical system varies from site to site. The strongest predictor of costs is the distance between the panel with the EVSE-dedicated circuit and the PEV parking spot.

For the 27 MUDs visited, we found that the cost of installing Level 2 EVSE at MUD sites is variable and often high, ranging from $1,800 to $17,800, and averaging $5,400. To contrast, Level 2 installation costs for single-family residences average $1,500.[20]

The most significant component of installation costs is labor, at times accounting for over half of the total project cost. Table 13 provides share of costs per category for the 19 installation estimates.

Table 13. Average Category Costs across EVSE Installation Estimates

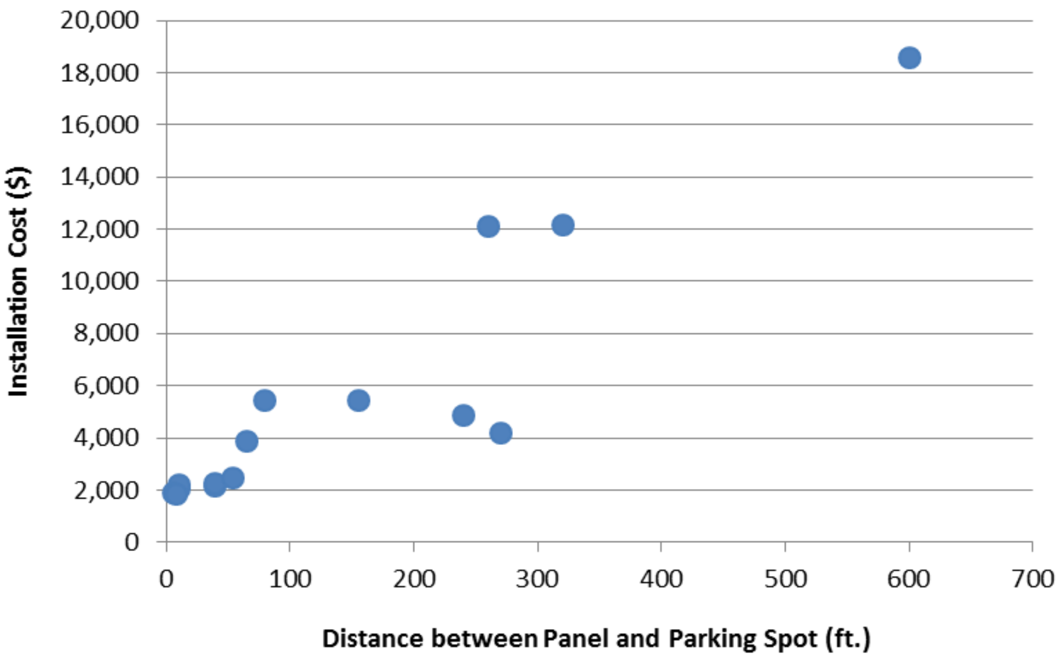
Cost Category	Average Share of Total Installation Costs	Range
Material	33%	28% - 40%
Labor	46%	41% - 56%
Tools, Permits and Fees	7%	3% - 10%
Other	13%	12% - 20%

Source: On Target Electric, for study purposes only

The further the distance between the EVSE and the PEV dedicated circuit, the greater the installation costs. Figure 11 confirms this correlation.

[20] Electric Power Research Institute. 2013. *Electric Vehicle Supply Equipment Installed Cost Analysis.*

Figure 11. Estimated Total Installation Costs and Distance between Panel and EVSE



Source: On Target Electric, for study purposes only

EVSE installations that traverse long distances not only require greater lengths of conduit and wiring, but also increase the likelihood of requiring significant construction and engineering activities. For each of the six MUD sites visited that required a wiring and conduit run of 100 feet or greater, additional construction and engineering work would be needed. Table 14 presents the construction and engineering requirements for the six MUD sites with 100 feet or more between the relevant panel and the PEV parking spot.

Table 14. Construction and Engineering Activities Impact on Overall Estimated Costs

MUD Site	Construction/Engineering Type	Material and Labor Construction/Engineering Costs[21]	Share of Total Material and Labor Costs
1	Drilling foundation Demolition, rework and patching	$180	5%
2	Drilling foundation Demolition, rework and patching	$238	8%
3	Rework of gutter Demolition, rework and patching	$920	22%
4	Coring X-ray Engineering plans	$2,655	40%
5	Rental equipment lift Demolition, rework and patching Engineering plans	$3,071	22%
6	Coring X-ray Demolition, rework and patching	$4,600	48%

Source: On Target Electric, for study purposes only

4.4 Opportunities to Reduce Charging Infrastructure Installation Costs

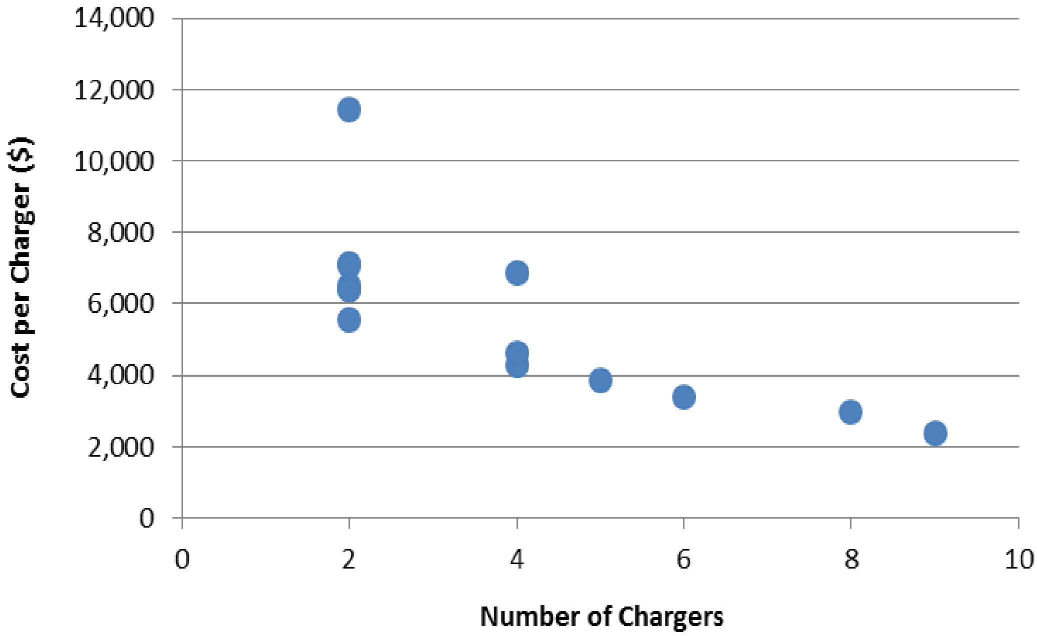
Strategies can be deployed to help reduce the cost of EVSE installations at MUD sites. As multi-unit dwellers reside on the same property and often share parking environments, dividing the installation costs among multiple PEV drivers can be practical and greatly reduce the per driver cost. If group purchasing is unavailable, a PEV driver may rely on Level 1 charging to avoid installation costs altogether. This section reviews these two cost saving strategies.

4.4.1 Cost Advantages to Group Investing in Level 2 Charging Infrastructure

Economies of scale can be realized when EVSE installation costs are shared between multiple MUD residences. Figure 12 shows the decreasing cost per EVSE as additional EVSE are installed. When considering EVSE installation, an owner or renter should survey neighbor units to gauge interest in PEV ownership and to potentially share the costs associated with EVSE installation.

[21] Does not include material tax or profit; assumes $60 per hour prevailing wage for labor

Figure 12. Cost Reductions Achieved due to Multiple EVSE Installations



Source: On Target Electric, for study purposes only

Technological solutions can support group investments in EVSE installation. For example, energy saving technologies such as energy management systems (EMS) can be installed to optimize multiple PEV charges. The management of energy in response to vehicles' state of charge and a building's available electrical capacity can delay the need for costly electrical upgrades.

4.4.2 Accessing Level 1 Charging to Avoid Electrical Upgrades

MUD parking environments with access to 110/120-volt outlets may represent quality candidates for Level 1 EVSE charging. This will ultimately be determined by the PEV driver's available charge time and daily commute, as well as the electrical configuration tied to the parking area outlet. The availability of Level 1 charging can avoid the high installation costs often reuired for Level 2 charging.

Seventy-eight percent of MUD sites visited had access to a 110/120-volt outlet in their parking areas and 96% of these were tied to the house panel. The resident, property manager or owner and an electrician should review the annual peak load of the house panel to determine if there is available capacity considering other loads tied to the panel, such as laundry machines, pool pumps, etc. This information is often available from your utility at the request of the person named on the electric bill.

If the house panel does not have sufficient capacity to supply the additional PEV load, strategic energy efficiency measures may be deployed to reduce the overall load of the house panel. This can include efficient lighting, or energy efficient replacements for a property's electric water heater, washer/dryer, or pool pump. Electric utilities offer a number of rebates and incentives to improve efficiency.

4.5 EVSE Installation Case Studies from the South Bay Region

When reviewing the EVSE installation cost estimates for the sites visited, multiple factors influenced the cost of installation. The following presents three Level 2 charger installation case studies to highlight these cost factors and provide insight into how they resulted in a high or low cost of installation.

4.5.1 Case Study 1: Low-cost Re-working of Panel for a 4-unit Dingbat with Door

Case Study 1 presents the estimated costs of installing Level 2 EVSE at a 4-unit MUD with a dingbat with door parking layout. The site's electrical box is located on the northern side of the building and shares a wall with the parking garages. The house panel has a 30-amp circuit breaker (as shown by red box in Figure 13) that leads to an existing sub-panel in the garage which shares the wall with the electric box.

Figure 13. House Panel and Garage Sub-panel for Case Study 1

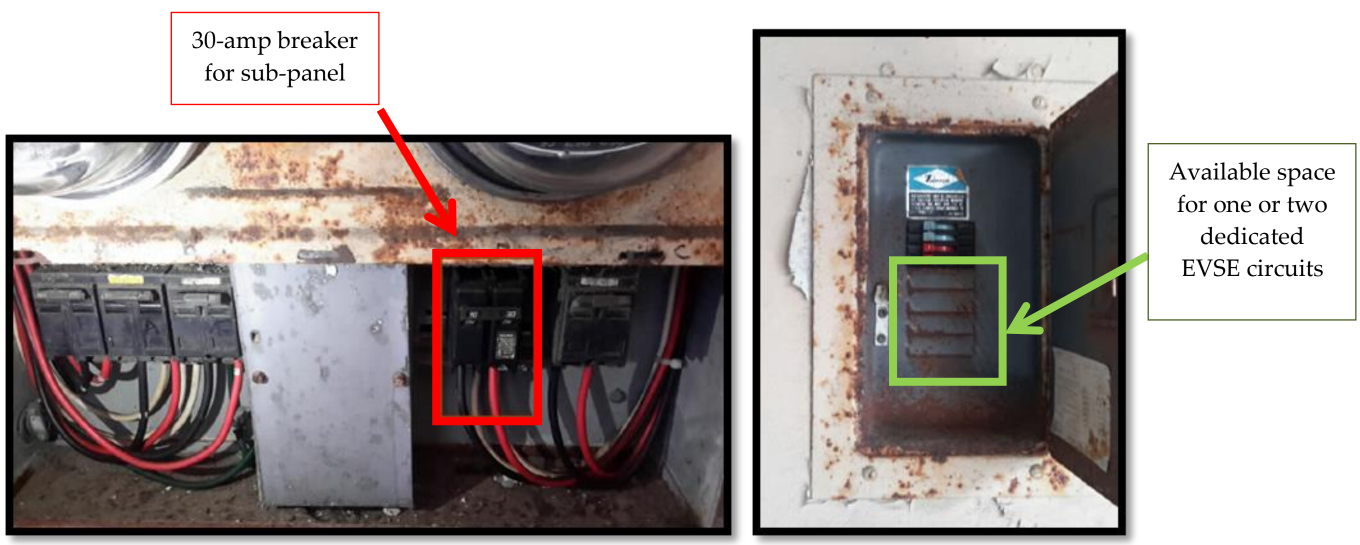


Photo Credit: On Target Electric

The electrician anticipated an easy re-working of the panel by upsizing the existing 30-amp breaker to 50 amps, and then pulling the cover from the sub-panel to add one or two dedicated 40-amp breakers (at the site of the green box in Figure 13) for one or two Level 2 EVSEs. The preexisting equipment and necessary electrical configuration resulted in an estimated installation cost of less than $2,000 for two EVSEs.

4.5.2 Case Study 2: High-cost Coring of Parking Deck for a 42-unit MUD with Subterranean Garage

Case Study 2 presents the estimated costs of installing Level 2 EVSE at a 42-unit MUD with a subterranean garage. The site's electrical room (seen in Figure 14) is located on a different level than the parking garage and receives power from the utility through an underground service connection. To run wire and conduit from a newly installed dedicated panel to the EVSE installation site, a contractor will need to x-ray the subterranean parking deck that needs to be cored through to ensure foundational integrity.

Figure 14. Electrical Room and Conduit for Case Study 2

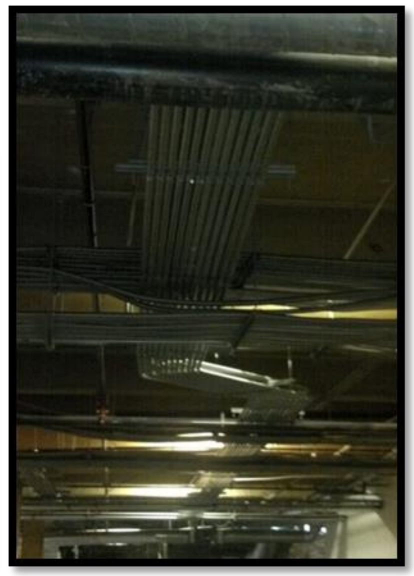


Photo Credit: On Target Electric

In total, the construction and engineering requirements for this job represented 48% of the material and labor costs with a total cost estimate of well over $10,000.

4.5.3 Case Study 3: High-cost Trenching for a 4-unit MUD with a Detached Parking Garage with Door

The final case study presents a cost estimate for a Level 2 EVSE installation at a 4-unit MUD with a detached parking garage with door. The garage is set on the back of the property line and does not share any walls with the main MUD structure. The MUD receives electricity through an overhead drop at the front of the building (indicated by green circle in Figure 15), where a separate dedicated panel would need to connect.

Figure 15. Electrical Service Drop and Detached Parking Layout for Case Study 3

Photo Credit: Google Earth, On Target Electric

The distance from the service drop to the detached garage is about 120 feet. The wire and conduit needs to be surface-mounted along the length of the MUD structure and trenched below the concrete driveway at the back of the main MUD structure. A subcontractor would need to trench beneath the concrete driveway which requires the demolition and hauling away of concrete, the trenching itself, and the pouring of new concrete over the buried wire and conduit. This exercise alone is estimated to cost thousands of dollars and the project, in total, over $20,000.

4.6 Evaluating Charging Potential in the South Bay

Although the ability for a PEV driver and MUD resident to charge at home varies from site to site, some parking layouts in the South Bay can provide greater access to 110/120-volt outlets and Level 1 charging, as well as lower cost installation solutions for Level 2 charging. For example, parking layouts such as the dingbat with door and higher-value detached parking garages with door are likely to have access to a private 110/120-volt outlet. And while the detached parking garage may be a quality candidate for Level 1 charging, it may not be for Level 2 charging due to the strong probability of trenching below asphalt or concrete during installation. The following section presents the Level 1 and Level 2 charging potential for different MUD parking layouts based on our observations from visiting MUD sites throughout the South Bay.

4.6.1 Level 1 Charging Opportunities

For Level 1 charging, PEV drivers need access to a 110/120-volt outlet and sufficient electrical capacity on the house or unit panel. Many driver's travel needs can be satisfied by an overnight Level 1 charge, making this a possible strategy to recharge PEVs under the MUD's current electrical configuration and avoid the need to install Level 2 charging. The resident, property manager or owner and an electrician should review the annual peak load of the house or unit panel to determine if there is available capacity. This section outlines the opportunities for Level 1 charging at the nine most common MUD parking layouts of the South Bay: dingbat with and without door, detached parking with and without door, podium garage, subterranean garage, parking lot and driveway only.

Dingbat with door

It is likely that a significant share of MUDs in the South Bay that have a dingbat with door parking layout will have access to a 110/120-volt outlet in their parking garage. The likelihood is particularly high if the door is automatic, as it shows some electricity is already being fed to the garage. At each dingbat with door parking site visit, a PEV driver would have private access to Level 1 charging.

It is extremely likely that the outlet is connected to the house panel. This represents an opportunity but also a potential issue. If there are no significant loads such as a laundry machine or pool pump on a medium- or large-amp rated panel (50-100 amps), it may have the capacity to support Level 1 charging. In these cases, PEV drivers and the property owner or management group should keep track of an increasing number of PEVs and other loads that may use the house panel.[22] If more than one PEV charges simultaneously throughout the night, electrical issues such as tripping the main breaker can occur.

For condominiums, garage outlets may be connected to individual unit panels. This represents an even greater opportunity for Level 1 charging as the condo owner will have greater access to information on their electricity use and be able to control circuit loads that share their unit panel. For example, they can choose not to wash clothes while charging their PEV.

Dingbat without door

MUDs that have a dingbat without door parking layout will also likely have 110/120-volt outlets, although these may be scattered across the parking environment. One lower-value dingbat without door (under $50,000 per unit) did not have access to any outlet.

These outlets are almost always connected to the house panel so again, consideration to capacity and shared loads should be made. In scenarios where tenants have assigned parking, swapping spots may allow PEV owners to access the outlet.

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[22] At one site, researchers heard anecdotal evidence of PEV charging tripping the house panel's main breaker. The 9-unit MUD's house panel was rated at 50 amps which fed the garage outlets, shared space lighting, and a sub-panel for a washer and dryer machine and an electric water heater.

Detached parking garage with door

For MUDs that have detached garages with doors, it may be less likely to find an outlet in each individual garage, although MUDs of a higher value and/or newer vintage are more likely. If the door can be opened automatically, there is also a higher likelihood of access to an outlet. One lower-value detached garage with door (under $50,000 per unit) did not have access to 110/120-volt outlets, and was used only for storage.

Detached parking without door

MUDs that have detached parking without doors may be the least likely to have access to a 110/120-volt outlet. Four out of six detached garages visited did not have an outlet in the parking area. If outlets are available, they may be scattered. When parking is assigned, residents may need to swap parking spots to gain access to Level 1 charging.

Subterranean garage and podium garage

MUDs that have subterranean or podium garages and are likely to have similar access to 110/120-volt outlets. Every subterranean garage and podium garage visited did have at least one outlet available. They may be scattered throughout the shared parking environments so in assigned parking scenarios, parking spots may need to be swapped.

Driveway only

MUDs that have driveways only are unlikely to have access to a 110/120-volt outlet. There may be an opportunity for Level 1 charging if there is an outlet on the outside wall of the MUD that faces the driveway.

Parking lot

MUDs that have parking lots are unlikely to have access to an electrical outlet.

4.6.2 Level 2 Charging Opportunities

Level 2 charging requires a dedicated 40-amp circuit breaker and wiring and conduit from the dedicated breaker to the EVSE unit. The distance between the breaker and EVSE unit may be influenced by the parking layout of the MUD; the further this distance, the more likely installation costs will rise. The following section presents the nine common parking and electrical layouts found in the South Bay MUDs including those that may offer less expensive Level 2 EVSE installation opportunities.

Dingbat with door

Some MUDs with the dingbat with door parking layout have access to the unit panel if the garage is below or in front of the unit (which is often the case), reducing the length of distance between the panel and parking spot. Although the distance between the two may be minimal, the wiring and conduit may need to be cored through unit walls and/or the floor.

We observed one dingbat with door condominium where the unit panel was inside the garage. This left very little distance between the panel and potential EVSE location, and is likely to result in a low cost EVSE installation.

Without access to the unit panel, the EVSE will need to be connected to the house panel or a separate dedicated panel. The distance from the EVSE to the panel will vary greatly from site to site, and parking spot to parking spot. Although there may be some distance between the dingbat garage and the panel, the two are usually at the same grade and may not require any subterranean coring through foundation or trenching through asphalt or concrete. The most frequent construction activity will be coring through the garage wall.

Dingbat without door

MUDs that have the dingbat without door parking layout offer a similar Level 2 EVSE installation assessment to dingbat with door, although coring through a wall may not be needed. The conduit and wiring can often be surface-mounted along the length of the parking site

Detached parking garage with door and without door

MUDs with detached parking garages with and without doors both present a host of problems for installing Level 2 charging. Case Study 3 in Section 4.5.3 provided a common installation story for these parking layouts. Because parking is usually separated from the MUD structure and the house and unit panels by concrete or asphalt, running wiring and conduit from the panel to the EVSE is likely to require a construction activity such as trenching.

Subterranean garage

MUDs with subterranean parking garages may present Level 2 EVSE installation issues when the building's electrical box is on the ground floor. This is because the wiring and conduit may need to traverse through building material and/or Earth. Large subterranean garages may also have multiple levels of parking and thus may require coring through concrete decks. These difficult conduit pathways may require foundational tests such as the x-raying of concrete as well as using heavy machinery and hiring skilled labor.

When the electrical box is located within the parking garage and there is space available, connecting to the existing service may be present a lower-cost installation opportunity.

Podium garage

MUDs with podium parking garages are likely to have its electrical box on the same level as the parking area. Therefore, the risk of coring through structure or ground may not be as prevalent when compared to subterranean garages. For small and medium-sized podium garage MUDs (4- to 20-units) that are served through an overhead feed, the electrical box may be mounted on the outside of a wall that is shared with the parking garage. With the distance between panel and parking spot reduced, this structural configuration may lend itself to a lower-cost installation.

Podium and subterranean garages may also provide an opportunity to deploy cost reduction strategies discussed in Section 4.4.1. Group investments of EVSE may be more practical in shared garage environments as the EVSE units can be chained along the wall. Likewise, technologies such as energy management systems can more easily be installed and accessed by multiple PEVs.

CHAPTER 5:

Policy Tools to Overcome the Multi-unit Dwelling Barrier to PEV Adoption

To achieve the ambitious zero-emission vehicle (ZEV) adoption goals of the State of California, and to ensure equitable distribution of the benefits of ZEVs, residents of multi-unit dwellings (MUDs) must have the option to charge their plug-in electric vehicles (PEVs) at home. This is particularly true for a South Bay subregion which has 144,132 MUD households. As reviewed in Chapter 4, the cost of EVSE installation at MUD sites is variable and often high. Moreover, renters and property owners show a low- to non-existent motivation to invest in charging infrastructure at their residence or property. To this end, regional, subregional and municipal governments, as well as state agencies, air quality management districts, and utilities (hereafter "other administrative entities") will likely need to deploy policy tools to overcome MUD related barriers to PEV adoption.

Policy solutions aimed at expanding access to PEV home charging for MUD residents can be approached in two distinct ways: 1) reduce the cost of installing PEV charging at MUDs and/or 2) motivate property owners or homeowner associations to invest in PEV home charging. Governments and other administrative entities may opt for a top-down policy intervention to help ease the cost barrier to MUD PEV home charging. This can include: 1) providing rebates designed to reduce the cost of EVSE installation at MUD sites; 2) establishing new building requirements and codes to ensure PEV readiness; 3) offering public charging programs to be provided and potentially administered by local government entities; and finally, 4) finding synergies in outreach to maximize participation with complementary programs such as Southern California Edison's Charge Ready program or the California Air Resources Board's Plus-up Program.

The second strategy requires generating enough PEV demand from apartment renters or condominium owners that property owners or homeowner associations (HOA) view home charging as an amenity by which to increase their property value and attract renters or owners – similar to on-site laundry services. This effectively shifts the investment motivation from the renter to the property owner or from the condo-owner to the HOA. Outreach and education that promotes the financial and environmental benefits of PEVs and the installation of EVSE at MUDs can help overcome the uncertainty of transitioning to a new technology. The following chapter reviews these potential policy solutions to overcome MUD related barriers to PEV adoption.

5.1 Designing Rebates to Reduce the Cost of EVSE Installation

Policymakers design public incentives with the aim of inducing consumers to adopt innovative technologies. Such incentives may include price subsidies, rebates, tax credits, sales tax exemptions, and subsidized financing. Rebates are currently provided to Californians to increase the adoption of PEVs. The Clean Vehicle Rebate Program (CVRP) offers PEV buyers $1,500 for a plug-in electric hybrid (PHEV) or a $2,500 rebate for a battery electric vehicle (BEV) after purchase. Sixty-five percent of PEV drivers found the CVRP to be extremely or very important to their purchase decision.[23] The state, local municipalities, and other administrative entities can also provide free or subsidized Level 2 chargers. Sixty percent of early PEV adopters found a rebate to be extremely or very important to their decision to install a Level 2 charger.[24] Due to the variable and often high cost for installing EVSE at MUD sites, a specific rebate may prove to be an effective policy tool to ease the cost barrier and expand PEV access.

Using the cost estimates and the MUD parking type estimates for the South Bay, the weighted average of EVSE installation for South Bay MUDs is estimated to be $4,468.[25] To retrofit 10% of current MUD parcels,[26] a rebate that fully covers the estimated weighted average cost of installation would cost a total of $4,305,000.

To increase the cost-effectiveness of this substantial rebate, and to maximize the adoption of PEVs at MUDs, we recommend requiring multiple PEV drivers per single MUD to qualify. As reviewed in Section 4.4.1, the high variable costs for EVSE installations provides an opportunity to share costs across multiple residences.

The range of incomes found in the South Bay may lend itself to offer tiered rebates based on consumer income levels. These types of progressive rebates have been found to be more cost effective, have lower total policy costs, and result in greater allocative equity.[27] We recommend tiering the rebate level based on household income or locational attributes such as MUDs within a disadvantaged community.

Alternative rebates may also prove to be effective and at lower total policy cost. For example, a rebate can be designed to incentivize Level 1 PEV charging in MUDs in the South Bay – a charging strategy we view as feasible for many drivers and one that is likely already available at a significant number of sites. At 27 site visits across the South Bay, 78% of MUDs provided a

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[23] California Center for Sustainable Energy. 2014. *California Plug-in Electric Vehicle Driver Survey* Results.

[24] California Center for Sustainable Energy. 2014. *California Plug-in Electric Vehicle Driver Survey* Results.

[25] This removes two high outliers (>$10,000) and should be viewed as lower-cost installations or low-hanging fruit properties.

[26] excludes duplexes and triplexes (963 total parcels of 4+ units)

[27] DeShazo, J.R., Samuel Krumholz, Tamara L. Sheldon et al. UCLA Luskin Center for Innovation. 2015.*Learning from California's Early Plug-in Electric Vehicle Market Growth and Policy Experiments: 2010-2015*.

110/120-volt outlet in the parking area. With access to an outlet, the driver would only need to ensure that the outlet is connected to a panel that has sufficient electrical capacity for Level 1 charging. For a lower cost and potentially highly effective rebate design, we recommend a program that partners with utilities[28] and covers the cost for local electricians to review the electrical capacity of the panel and to conduct an overall assessment of charging readiness.

5.2 Implementing PEV Ready New Construction Codes

Local jurisdictions may set guidelines for remodels and new MUD construction that require developers to provide Level 1 or 2 charging readiness. Many new building code examples exist throughout California that can serve as models for the cities of South Bay. Local jurisdictions should implement the 2013 California Green Building Standards, which in relation to PEVs in MUDs state that "at least 3 percent of the total parking spaces, but not less than one, shall be capable of supporting future electric vehicle service equipment (EVSE)."[29]

Even more, jurisdictions can follow the lead of cities such as Los Angeles whose Green Building Code (Chapter IX, Article 9, of the Los Angeles Municipal Code) mandates newly constructed "high-rise" residential (i.e. multi-level MUDs) to be Level 2 charging-station ready and requires "208/240 Volt 40 Amp outlets equal to 5 percent of the total number of parking spaces, with the outlets located in the parking area." Jurisdictions may also propose PEV readiness mandates for remodels in addition to new construction.

Unfortunately, much of the South Bay's residential land use is built out. If new construction codes were adopted by the South Bay cities, it would take 43 years at current construction rates[30] for 10% of MUDs to be capable of providing PEV charging access. The City of **Torrance** has built the greatest number of MUD parcels since 2000 followed by **Redondo Beach**. We recommend these cities create and implement PEV ready new construction codes as quickly as possible.

5.3 Siting Public Charge Programs to Provide Charging for MUD Residents

Local governments can also provide alternative public charging sites in locations such as city-owned parking lots. Strategic siting of Level 2 or DC Fast Chargers near clusters of MUDs may provide an option for multi-unit dwellers who cannot charge at home. A charging program may need to be administered by a local government to organize and coordinate charge times, etc.

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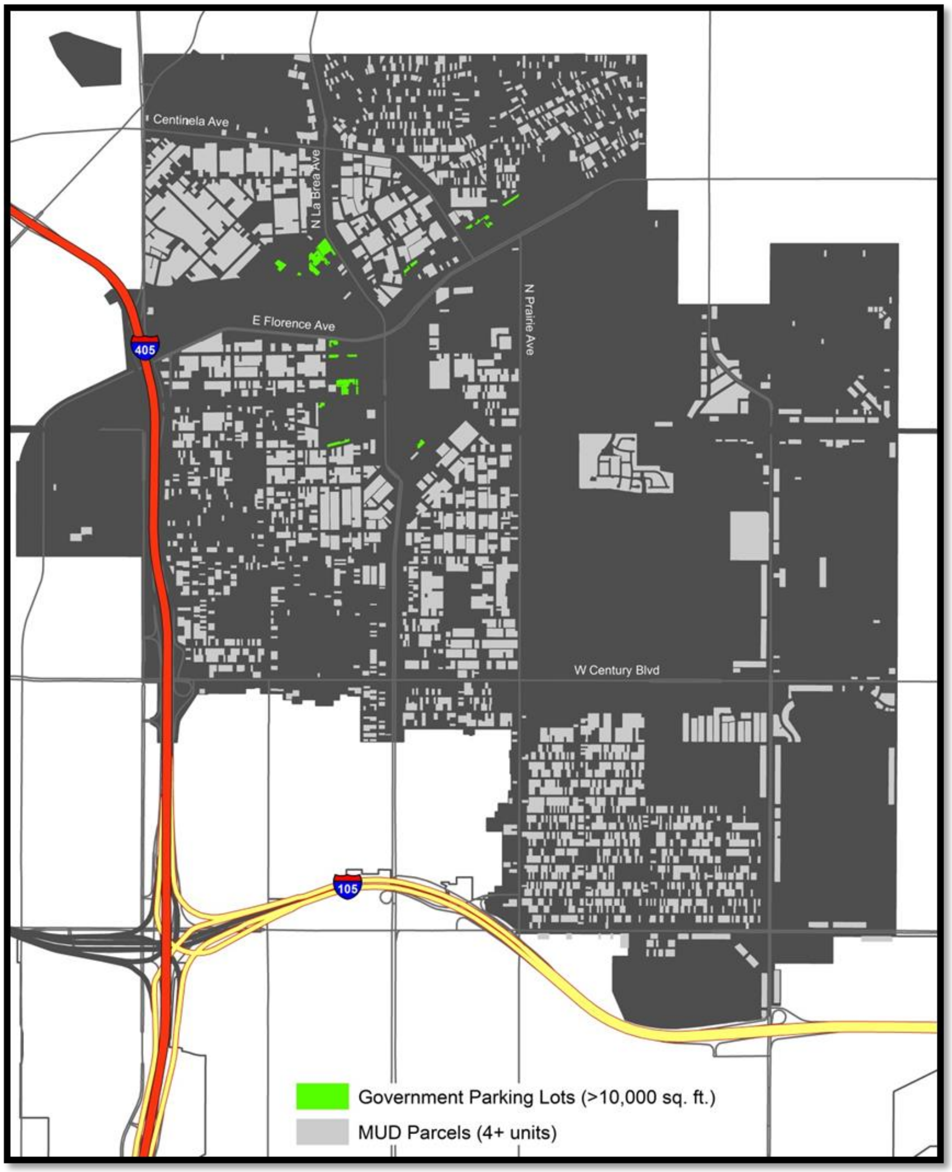
[28] a utility's primary role can be to be responsive to annual peak load requests per site

[29] California Department of Housing and Community Development. 2013. *Electric Vehicle Ready Homes*.

[30] 220 MUD parcels (includes only 4+ unit MUDs) constructed between 1998 and 2008, the final full year of data.

Figure 16 provides an example of city-owned parking lots in **Inglewood** that may be candidates to host a charging program for MUD residents.

Figure 16. City of Inglewood Owned Parking Lots adjacent to MUD Clusters



Source: Los Angeles County GIS Data Portal, Los Angeles County Office of the Assessor Secured Basic Abstract FIle

6.4 Outreach and Education to Drive PEV Ownership and Shift EVSE Investment Motivation to MUD Owners

The PEV remains a relatively new technology. Substantial sales of the battery electric vehicle (BEV) started only in 2010, and most believe we are still in the very early stages of PEV adoption.[31] As with many new technologies, consumers have been hesitant to switch out their internal combustion engine (ICE) for a PEV. Some of this hesitation can be rooted in the comfort level drivers have with the ICE and/or the uncertainty, real or perceived, of new technologies, like range anxiety – the fear of running out of battery mid-trip. ICEs have been the dominant form of private transportation for over a century. Its refueling infrastructure is robust and easily accessible.

Outreach and education can help address this hesitation and introduce potential PEV drivers to the new technology by promoting its environmental and financial benefits as well as answering common questions and concerns. From an EVSE in MUD perspective, the goal with outreach and education is to drive demand for home charging among MUD residents, and shift the investment motivation from the renter to the property owner, who may be motivated to attract tenants by providing new amenities. With strong PEV adoption rates in the South Bay, as well as large number of high-value MUDs (10,013 MUD households valued over $500,000 per unit), the subregion may help lead this shift in investment motivation.

Outreach and education can include direct mailing initiatives, advertising, hosting workshops, and e-newsletters. Local governments and/or Southern California Edison (SCE) should focus neighborhood-level outreach on the census tracts, identified in Chapter 3, that are high-quality candidates due their high number of MUDs and estimated latent PEV demand. The outreach and education materials should focus on a series of topics including:

- **New technology education** including available makes and models and associated lifespan, range, and maintenance requirements; purchase or lease costs and associated rebates; charging technologies such as Level 1 and Level 2 charging including a time of recharge tool (with Level 1 highlighted as a feasible charging choice); and location of public chargers.
- **Environmental and financial benefits** including emissions avoided and fuel savings
- **Charging in MUDs,** including instruction on how to evaluate panel electrical capacity for Level 1 (20-amp circuit with available panel capacity), Level 2 charging (40-amp circuit with available panel capacity), and how to identify cost drivers for EVSE installation (as reviewed in Chapter 4).
  - For Level 1 charging, instruction on how to verify available electrical capacity on the house or unit panel by reviewing shared loads such as laundry machines,

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[31] DeShazo, J.R., Samuel Krumholz, Tamara L. Sheldon et al. UCLA Luskin Center for Innovation. 2015.*Learning from California's Early Plug-in Electric Vehicle Market Growth and Policy Experiments: 2010-2015*.

pool pump, etc., as well as the annual peak load from the utility bill.
    - For Level 2 charging, instruction on how to evaluate installation cost drivers including the distance from the electrical box or relevant electrical panel to the PEV parking spot.
        - Insight into the cost advantages of group purchases for Level 2 charging installation including recommendations to survey other tenants' interest in PEV ownership.
- **Renters' rights** including information about California law SB 880 (Corbett), which makes it illegal to impose any condition that "effectively prohibits or unreasonably restricts" installation of charging in an owner's designated parking space and AB 2565 (Muratsuchi), which requires a lessor of a dwelling to approve a request to install EVSE at a designated parking spot if the installation "complies with the lessor's procedural approval process for modification of the property."
- **South Bay specific benefits** including the cost and time savings that come from access to high-occupancy vehicle (HOV) lanes, a benefit that has had a significant impact on PEV sales.[32]
- **Specialized and culturally sensitive outreach and education** including Spanish language materials and income-adjusted rebate information, such as with the Enhanced Fleet Modernization Program (EFMP) Plus-up Program (see below), for the disadvantaged communities of the South Bay.

Increasing adoption among low- and moderate-income households within disadvantaged communities is a particular challenge but important to achieve the environmental equity goals of California. Low- and moderate-income households are less likely to purchase new vehicles and many reside in MUDs without access to home charging.

California is expected to commit $20 million from the Greenhouse Gas Reduction Fund (GGRF) to be administered by the California Air Resources Board (ARB) through the Enhanced Fleet Modernization Program (EFMP) Plus-up Project in fiscal year 2015-16.[33] The program provides low-income households up to $12,000 for the purchase or lease of a battery electric vehicle (BEV).[34] To qualify, the household must reside in a zip code that includes a disadvantaged community census tract. With the EFMP Plus-up Program and the Charge Ready program, ARB and SCE are providing complementary incentives – one for the PEV itself and the other for

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32 DeShazo, J.R., Samuel Krumholz, Tamara L. Sheldon et al. UCLA Luskin Center for Innovation. 2015.*Learning from California's Early Plug-in Electric Vehicle Market Growth and Policy Experiments: 2010-2015*.

33 Rabin, Jeffrey, Colleen Callahan, and J.R. DeShazo. UCLA Luskin Center for Innovation. 2015. *Guide to Greenhouse Gas Reduction Fund Program Designs, Expenditures and Benefits*.

34 Includes the $2,500 Clean Vehicle Rebate Program (CVRP) rebate.

access to home charging - to a population far less likely to invest in new vehicle technologies and its charging equipment.

We recommend ARB, the South Coast Air Quality Management District (who will administer outreach efforts in the South Bay subregion), and SCE to optimize outreach effectiveness by conducting joint efforts within disadvantaged communities. Events such as "ride and drives" can be held with representatives from both programs to showcase the PEV, as well as the significant amount of savings that can be realized when participating in both programs. Additional mailing campaigns and workshops where both programs and the potential savings are promoted are also encouraged. Section 2.6 in Chapter 2 presents the disadvantaged census tracts with MUDs in the South Bay. Event staff and outreach materials should be conscious of language and cultural barriers and adjust accordingly.