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Addressing Challenges to Electric Vehicle Charging in Multifamily Residential Buildings

June 2011

David Peterson

Addressing Challenges to Electric Vehicle Charging in Multifamily Residential Buildings

About the Study

The aim of this study is to provide an overview of the challenges and opportunities for charging electric vehicles in multifamily residential buildings. The study draws on case studies from Southern California, and most of the analysis is applied to the City of Los Angeles. The author is a second year UCLA Department of Urban Planning graduate student who completed the project as part of his capstone requirement.

About the Author

David Peterson is a 2011 graduate of the UCLA Luskin School of Public Affairs master's degree program in Urban Planning.

Acknowledgements

I would like to thank J.R. DeShazo (Luskin Center for Innovation), Donald Shoup (Department of Urban Planning), and Juan Matute (Luskin Center for Innovation) for their advice and support.

I would also like to thank the following people for sharing their insights about electric vehicles, charging stations, and how to put them together in a multifamily residential building: Maureen Bekins (Southern California Edison), Len Fein (Clipper Creek), Dirk Foster (211 Spalding), Chuck Fredericks (The Azzura), Laura Page (Coulomb), Joel Pointon (San Diego Gas & Electric), Sarah Potts (Clinton Climate Initiative), Cortney Seeple (Towbes Group), Paul Scott (Plug-In America), Peter Suterko (Los Angeles Department of Water and Power), Lim S. Szeto (Southern California Edison), Russell Vare (Nissan), and Osama Younan (Los Angeles Department of Building and Safety).

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For More Information

For more information on this study and the UCLA Luskin Center's Electric Vehicle research contact David Peterson (davidpeterson@ucla.edu or 650-477-4883)

Electronic copies

An electronic copy of the report is available at http://luskin.ucla.edu/ev .

Cover photo

The front cover photo was provided courtesy of AeroVironment, Inc. (www.avinc.com).

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1.1 Introduction

Electric vehicle charging in multifamily residences (i.e. apartments and condominiums) may be one of the primary obstacles to expanding the electric vehicle market in large urban centers around the world.[1] Electric vehicle supply equipment (EVSE), or electric vehicle (EV) charging stations, are installed with relative ease in single family residences, whether with attached or detached garages. An insufficient number of parking spaces, constrained electrical room capacity, expensive installation costs, and multiple EV charging station users are examples of some of the issues facing multifamily residential buildings. Since much of the world's urban population lives in some form of multi-unit residential building, EV owners in these buildings will want to find inexpensive and reliable ways to charge their EVs.[2]

In Tokyo, where practically the entire city lives in multifamily dwellings, some real estate developers have decided to circumvent these thorny issues by building new apartments equipped with EV charging stations.[3] This approach works for new construction, but does not address EV charging station installations in existing buildings. In December 2010, the City of Los Angeles adopted a Green Building Code, mandating that all new single family and multifamily construction be equipped with the necessary electrical infrastructure and designated parking spaces (only for new high-rise residential construction) to accommodate electric vehicles. However, the Green Building Code does not address the existing housing stock that will need to be modified to accommodate electric vehicles. Property managers and homeowner association (HOA) boards (the governing bodies of most condos) are uncertain how to respond to tenant requests for installing EV charging stations. One anonymous property manager stated the following:

> *Bottom line, given a level-headed board of directors and a good management firm, I don't see any issues with owners being able to have an electric vehicle parked on common grounds with a charging station attached to it,* ***as long as the owner is willing to pay for the costs to do so.***[4]

Certainly there wouldn't be a problem from the building management's perspective if the user paid for all of the costs, but in some cases installing an EV charging station in a multifamily building can be cost prohibitive for a single user. Installation costs can range anywhere from $2,000 for a low-cost multifamily installation, to $10,000 for an apartment building requiring trenching to install a

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[1] http://www.youtube.com/user/pluginamerica?feature=mhum#p/u/0/79ShT3YUVVA. Accessed February 2011.

[2] http://www.npr.org/2011/05/16/136282258/automakers-try-to-convince-chinese-to-drive-green. Accessed May 2011.

[3] Schmitt, Bertel, "EVs Encounter Condo Conundrum," The Truth About Cars, January 13, 2011.

[4] Zipp, Yvonne, "Getting Away from Gas," New England Condominium, March 15, 2011. (Bolding is my emphasis).

new conduit, a new circuit, and electric meter. In one case, an electrician assessed an EV charging station installation to be $35,000.[5]

1.2 Level 1 & 2 EV Charging Stations are Preferred for Residential Charging

Charging stations come in a variety of shapes and sizes, from a Level 2 charging station that can replenish a battery in several hours, to a DC Fast Charging station that can fill up a battery in a fraction of an hour. Only charging stations that meet the requirements of vehicles used for urban or regional travel are discussed herein. These include charging stations applicable to models like the Nissan Leaf and Chevrolet Volt. Of the three voltage levels, Levels 1 (110/120 Volts) and 2 (220/240 Volts) are best suited for residential applications given current commercially available technology. DC Fast Charging (480 Volts) may be a viable future means of charging, but it is currently cost-prohibitive for most residential applications (approximately $40,000-$50,000) and goes beyond the charging needs of most city drivers.[6,7] Los Angeles commuters travel an average distance of 19 miles, one way, and depending on how much additional travel is tacked on to that number, most EV drivers should be able to replenish their batteries on a nightly or bi-nightly basis.[8] EV charging frequency is a function of the distance driven, electricity prices, driving style, load, and external conditions (e.g. wind resistance), in addition to the vehicle's body and battery characteristics. Table 1 shows battery charging times for the Nissan Leaf and Chevrolet Volt.

Table 1. Charging Times for Different Vehicle Battery Capacities and Voltage

Vehicle Model	Battery Capacity	Hours to Fully Charge Battery from Empty	
		Level 1 (110/120 V)	Level 2 (220/240 V)
Nissan Leaf (1)	24 kWh	20	7
Chevrolet Volt (2)	16 kWh	10	4

Sources:

(1) http://www.nissanusa.com/leaf-electric-car/faq/view/97#/leaf-electric-car/faq/view/97

(2) http://www.chevrolet.com/volt/#technology

Drivers who are depleting the battery on a daily basis need to charge nightly. But if drivers deplete 1/3 of the battery per day, they may only want to charge every two or three days. Also, drivers charging at work and at businesses that offer EV charging, may not be required to charge as frequently. The combination of all of these factors influences the decision of whether or not to invest in a Level 1 or Level 2 charging station. A Level 1 charging station might be more suitable for vehicles with smaller battery sizes similar to the Chevrolet Volt's battery, but a Level 2 charging

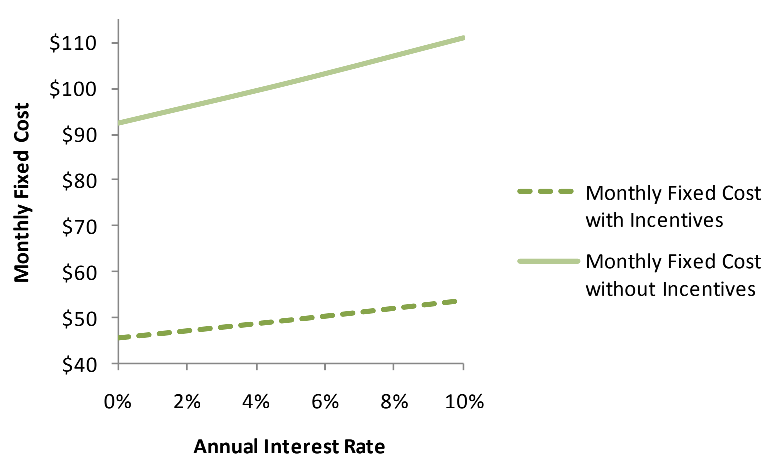
[5] Interview with Peter Suterko, LADWP, March 2011.
[6] Taylor, Dean. "The Differences and Similarities between Plug-In Hybrid EVs and Battery EVs," EVS24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium, Norway, May 13-16, 2009.
[7] http://cta.ornl.gov/TRBenergy/trb_documents/2010/Santini%20Session%20538.pdf. Accessed May 2011.
[8] http://www.calapa.org/attachments/files/1305/The_Longest_Mile.pdf. Accessed May 2011.

station is typically more suitable for larger batteries, like the one in the Nissan Leaf, which can substantially reduce charging times.[9]

1.3 Cost is the Primary Barrier

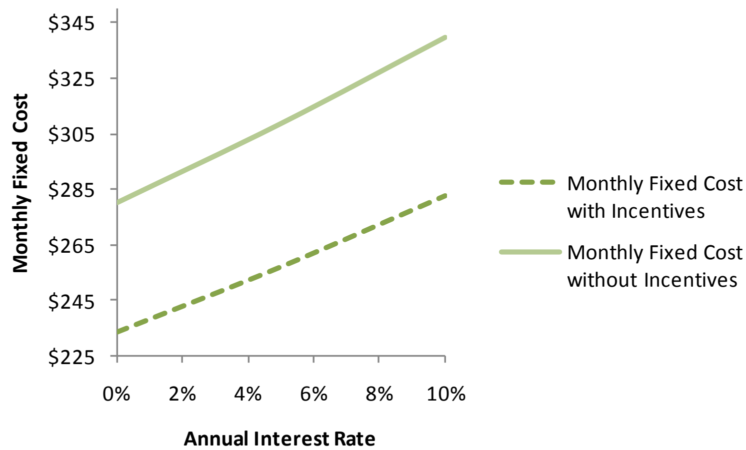
The primary barrier to EV charging station installations is their cost. HOAs, building managers and building owners are opposed to installations because most are unwilling to pay for the upfront capital costs, and if they are, they anticipate the charging station will be underutilized. If the building's management invests in a charging station, they may or may not want to earn a profit on their investment. For example, as a non-profit, an HOA will likely want to break-even, but a building managed by a real estate investment trust (REIT) might want a profit. Figure 1 and Figure 2 show how break-even monthly fixed costs vary with interest rates for low cost ($3,600) and high cost ($11,600) installations, assuming a 7-year loan term, with and without financial incentives. The 7-year term is arbitrary, and was chosen to illustrate the cost scenarios, and a longer term would reduce monthly debt service, and therefore monthly fixed costs. The fixed cost includes the price of a Level 2 charging station ($1,500), a city permit ($100), and low ($2,000) or high ($10,000) installation costs.

Figure 1. Monthly Fixed Cost for a Low Cost Installation ($3,600)



9 http://www.socalev.org/plugin/charging.htm. Accessed April 2011.

Figure 2. Monthly Fixed Cost for a High Cost Installation ($11,600)



Charging station users will also need to pay for the electricity consumed to charge their EVs. Using Los Angeles Department of Water and Power (LADWP) time-of-use (TOU) rates, and including the LADWP EV charging discount, average monthly electricity costs are roughly $30 for seven-hour bi-nightly charging and $75 per month for seven-hour nightly charging, assuming a 24kWh battery and a Level 2 charging station. Total monthly costs, including electricity and fixed costs could range from slightly more than $75 to more than $400 per month. Apartment owners and managers could pass on the costs in the form of charges to users, but because of the transient nature of renters, and the small number of EV owners currently living, or wanting to live, in apartments, this would be difficult.

1.4 EV Charging Station Cost Drivers

The main capital cost drivers are the charging stations, electrical upgrades and the EV parking space. A residential Level 2 charging station typically costs between $1,000 and $2,000 and government incentives can cover the cost in many instances. For example, The City of Los Angeles has a $2,000 rebate program for residential Level 2 charging stations. Electrical upgrades may be necessary and the cost is directly related to the location of the parking space where the EV will be charging. Electrical upgrades external to the building might include a transformer upgrade if the EV's power needs exceed the transformer's capacity (NB: transformer capacity is usually 10 to 15 percent of peak building demand). Internal upgrades could include adding a new circuit, adding a new electricity meter, and conduit installation for the 220/240 Volt line connecting the charging station to the electrical panel. These costs could be as low as a few hundred dollars and can escalate to several thousand.

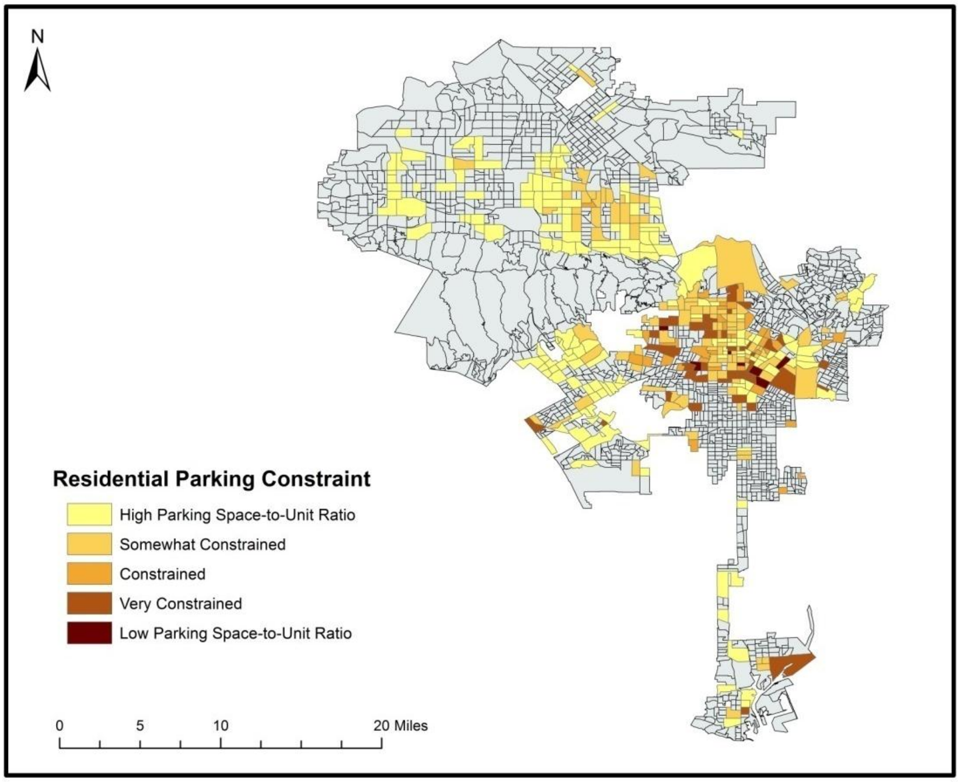
Parking access considerations are a crucial determinant of charging station installation costs. Installations are typically less expensive for parking spaces located a short distance from the electrical panel, and more expensive for parking spaces located farther away. Running a line from the electrical panel to the charging station can be the most difficult step in assuring power delivery to an EV. The crux of the problem lies in whether or not there is an existing conduit from the panel to the parking space. Even if the parking space is three levels below ground, and the electrical panel is located at ground-level, there shouldn't be a problem running a line if a conduit exists. However, if a conduit does not exist, the farther away the charger is from the panel, the more creative, and the more expensive, the solutions become.

1.5 Proposed Solutions

Residents and building management must find creative ways to arrive at the lowest cost solution possible. Building management should facilitate parking space agreements and transactions among residents. Individuals can come to mutually agreed upon arrangements in order to secure a low-cost EV parking space. Additionally, building management could devise management tools uniquely tailored to residents' needs, in order to avoid costly installations. Internal negotiations should be the first step in any EV charging station investment.

For residents of multifamily buildings who must park on the street or in off-street parking lots, the barrier to EV access is less about cost, and more about ensuring reliable access to a an EV charging station. Residents in these situations, and owners and managers of buildings with limited on-site parking availability, must look to low-cost alternatives. Figure 3 displays potential parking constraints for multifamily buildings in the City of Los Angeles by U.S. Census tract. Each tract contains a minimum of 50 percent multifamily buildings, and is weighted by the period within which the building was built (for all residential building types), which I use as a proxy for the parking space-to-residential unit ratio required for new construction in practice at the time.

Figure 3. City of Los Angeles Multifamily Residential Parking Constraint Index



Sources: Whittemore, 2010; U.S. Census American Community Survey, 2009.

Utilizing public and private parking lots for night-time EV charging can address the charging needs of drivers living within close proximity to a public or private lot. However, in cases where such lots are unavailable, installing curbside charging infrastructure could be an option. Publicly accessible charging stations present a revenue opportunity for both types of lot owner, and serve the needs of residents without access to private charging stations.

Expanding the electric vehicle market has become the focus of public policy with both the President of the United States and the Mayor of Los Angeles having expressed their desires to see EVs become a viable long-term transportation alternative. In his 2011 State of the Union Address, President Obama established a goal of "putting one million electric vehicles on the road by 2015," and since the 2009 Climate Summit for Mayors in Copenhagen, Los Angeles Mayor Villaraigosa has been committed to eliminating obstacles to EV adoption in Los Angeles to the furthest extent possible. [10,11] Given this political support, the City of Los Angeles could require the installation of charging stations in multifamily buildings whenever a property (either the building, or units within the building) is sold. From 2002 to 2010, approximately 3,000 multifamily real estate transactions took place per year. This kind of policy would encourage HOA's, building managers, building owners and tenants to find low-cost EV charging solutions.

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[10] "One Million Electric Vehicles by 2015," U.S. Department of Energy, February 2011
[11] http://mayor.lacity.org/PressRoom/PressReleases/LACITYP_007622

The difficulties associated with installing EV charging stations in multifamily residences are not unique to Los Angeles, but are faced by almost every building owner, manager or tenant living in one the world's urban centers. As the world's population continues to grow and urbanize, adopting viable alternatives to petroleum-based transportation is central to ensuring motorized mobility in an increasingly natural resource-constrained world.[12] Electric vehicles offer one such alternative, and enabling their adoption in multifamily buildings increases their potential effectiveness by appealing to a broader user base.

[12] Sperling, Daniel, and Deborah Gordon. "Two Billion Cars," Oxford University Press, 2009.

2. Introduction

Electric vehicle charging in multifamily residences (i.e. apartments and condominiums) may be one of the primary obstacles to expanding the electric vehicle market in large urban centers around the world.[13] Electric vehicle supply equipment (EVSE), or electric vehicle (EV) charging stations, are installed with relative ease in single family residences, whether with attached or detached garages. An insufficient number of parking spaces, constrained electrical room capacity, expensive installation costs, and multiple EV charging station users are examples of some of the issues facing multifamily residential buildings. Since much of the world's urban population lives in some form of multi-unit residential building, EV owners in these buildings will want to find inexpensive and reliable ways to charge their EVs.[14]

In Tokyo, where practically the entire city lives in multifamily dwellings, some real estate developers have decided to circumvent these thorny issues by building new apartments equipped with EV charging stations.[15] This approach works for new construction, but does not address EV charging station installations in existing buildings. In December 2010, the City of Los Angeles adopted a Green Building Code, mandating that all new single family and multifamily construction be equipped with the necessary electrical infrastructure and designated parking spaces (only in new high-rise residential construction) to accommodate electric vehicles. However, the Green Building Code does not address the existing housing stock that will need to be modified to accommodate electric vehicles. Property managers and homeowner association (HOA) boards (the governing bodies of most condos) are uncertain how to respond to tenant requests for installing EV charging stations. One anonymous property manager stated the following:

> *Bottom line, given a level-headed board of directors and a good management firm, I don't see any issues with owners being able to have an electric vehicle parked on common grounds with a charging station attached to it,* ***as long as the owner is willing to pay for the costs to do so.***[16]

Certainly there wouldn't be a problem from the building management's perspective if the user paid for all of the costs, but in some cases installing an EV charging station in a multifamily building can be cost prohibitive for a single user. Installation costs can range anywhere from $2,000 for a low-cost multifamily installation, to $10,000 for an apartment building requiring trenching to install a new conduit, a new circuit, and electric meter. In one case, an electrician assessed an EV charging station installation to be $35,000.[17]

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[13] http://www.youtube.com/user/pluginamerica?feature=mhum#p/u/0/79ShT3YUVVA. Accessed February 2011.
[14] http://www.npr.org/2011/05/16/136282258/automakers-try-to-convince-chinese-to-drive-green. Accessed May 2011.
[15] Schmitt, Bertel, "EVs Encounter Condo Conundrum," The Truth About Cars, January 13, 2011.
[16] Zipp, Yvonne, "Getting Away from Gas," New England Condominium, March 15, 2011. (Bolding is my emphasis)
[17] Interview with Peter Suterko, LADWP, March 2011

Expanding the electric vehicle market has become the focus of public policy with both the President of the United States and the Mayor of Los Angeles having expressed their desires to see EVs become a viable long-term transportation alternative. In his 2011 State of the Union Address, President Obama established a goal of "putting one million electric vehicles on the road by 2015."[18] The primary reasons for this policy push are threefold: (1) reducing reliance on petroleum as an energy source for vehicles; (2) environmental stewardship; (3) and creating jobs and improving economic growth through the emergence of EV and EV charging station innovation, design, engineering, manufacturing, and related services. Since the 2009 Climate Summit for Mayors in Copenhagen, Los Angeles Mayor Villaraigosa has been committed to eliminating obstacles to EV adoption in Los Angeles to the furthest extent possible.[19] In May 2011, the Mayor and U.S. Secretary of Energy Chu, celebrated the success of federal EV programs in Los Angeles.[20]

In a similar vein, this report aims to analyze the issues surrounding charging station installations in Los Angeles, and its intended use is as a tool to help clarify charging station issues for anyone living in, managing, or working with charging station installations in multifamily residential dwellings. Section 3 defines EV charging stations, discusses the different types currently available, and mentions some alternative means of recharging. Section 4 discusses the parking, electrical infrastructure, and cost issues with installing and operating charging stations in apartments and condos, followed by specific discussions and case studies on the issues facing existing buildings and new construction. Section 5 puts forward some new ways of thinking about resolving EV charging station installation difficulties in Los Angeles, and the report concludes with some final thoughts on the future of electrical vehicles in Los Angeles in Section 6.

3. *Electric Vehicle Charging Stations*

Electric vehicle charging stations, otherwise commonly referred to as Electric Vehicle Supply Equipment (EVSE), come in a variety of shapes and sizes, from a Level 2 charging station that can replenish a battery in several hours, to a DC Fast Charging station that can fill up a battery in a fraction of an hour. Since this report is focused on vehicles used for urban or regional travel, only charging stations that meet the requirements for these kinds of vehicles will be discussed. For example, these would be the types of charging stations applicable to models like the Nissan Leaf and Chevrolet Volt.

3.1 EV Charging Station Typology

Charging stations are marketed at three levels of power delivery. Level 1 delivers 110/120 Volts at 15 or 20 Amps, and is the same as plugging the EV into a common electrical wall socket. At this low voltage level, the charger is typically installed on the vehicle and the electricity delivered with the now standard, SAE J1772 Electric Vehicle Conductive Charge Coupler (Figure 4).

[18] "One Million Electric Vehicles by 2015," U.S. Department of Energy, February 2011
[19] http://mayor.lacity.org/PressRoom/PressReleases/LACITYP_007622. Accessed November 2010.
[20] http://www.energy.gov/news/10331.htm. Accessed June 2011.

Figure 4. SAE J1772

Source: http://tennesseevalleyenergy.com/services-tve.html

Level 2 charging delivers 220/240 Volts at 40 Amps, and can charge a battery at a much faster rate than Level 1. There are two types of Level 2 charge, conductive and inductive. Conductive chargers require metal-to-metal contact, whereas inductive chargers do not require it. Most Level 2 charging stations being installed today are conductive, such as AeroVironment's pedestal mounted charging dock (Figure 5).

Figure 5. Conductive Charging Station (AeroVironment's Pedestal Mounted Charging Dock)

Source: http://www.avinc.com/media_gallery/images/ev_charging/

For inductive charging, electricity is transferred through the magnetic field generated by the on-board vehicle receptor coming into a close range with the power delivery source installed in the parking space (Figure 6).

Figure 6. Inductive Charging (A model from Plugless Power)

Source: http://www.wired.com/autopia/2011/03/google-installs-a-wireless-ev-charging-station/

DC Fast Charging delivers 480 Volts and does not require an onboard charger. DC Fast Charging is intended for "fast" or "quick" charging that can replenish a vehicle's batteries in a matter of minutes. DC Fast Charging is more apt for publicly available charging or commercial installations, but is not well-suited to residential needs, in single family or multifamily residences.

Figure 7. DC Fast Charger from Coulomb Technologies

Source: http://www.coulombtech.com/blog/tag/level-3-fast-charging/

Of the three levels, Levels 1 and 2 are best suited for residential applications given current commercially available technology. DC Fast Chargers may be a viable future means of charging, but they are currently cost-prohibitive for most residential applications (approximately $40,000-

$50,000) and go beyond the charging needs of most city drivers.[21,22] Los Angeles commuters travel an average distance of 19 miles, one way, and depending on how much additional travel is tacked on to that number, EV drivers may, or may not, need to charge every day.[23] EV charging frequency is a function of the distance driven, electricity prices, driving style, load, and external conditions (e.g. wind resistance), in addition to the vehicle's body and battery characteristics. Table 2 shows charging times for the Nissan Leaf and the Chevrolet Volt for Level 1 and Level 2 charging.

Table 2. Charging Times for Different Battery Capacities and Voltage

Vehicle Model	Battery Capacity	Hours to Fully Charge Battery from Empty	
		Level 1 (110/120 V)	Level 2 (220/240 V)
Nissan Leaf (1)	24 kWh	20	7
Chevrolet Volt (2)	16 kWh	10	4

Sources:

(1) http://www.nissanusa.com/leaf-electric-car/faq/view/97#/leaf-electric-car/faq/view/97

(2) http://www.chevrolet.com/volt/#technology

The Chevrolet Volt has a relatively small battery capacity (16 kWh), and requires less time to fully charge from empty, whereas the Nissan Leaf's larger battery (24 kWh) requires a longer charge time. Drivers depleting the battery on a daily basis need to charge nightly. But if drivers deplete 1/3 of the battery per day, they may only want to charge every two or three days. Also, if drivers are charging at work and at commercial locations offering EV charging, then they may not be required to charge as frequently. The combination of all of these factors influences the decision of whether or not to invest in a Level 1 or Level 2 charging station. A Level 1 charging station might be more suitable for vehicles with smaller batteries, and a Level 2 charging station is typically more suitable for EVs with larger battery capacities, which can substantially reduce charging times.[24]

3.2 Charging Stations and Financial Incentives

There are federal and local financial incentives that apply to Los Angeles residents and businesses. The Federal Alternative Fuel Infrastructure Tax Credit is, "available for the cost of alternative fueling equipment placed into service after December 31, 2005," and covers up to 30% for equipment placed into service in 2011, up to $30,000.[25] The tax credit differentiates between "service station owners" and "consumers", stating that consumers who purchase refueling equipment are only eligible for a maximum tax credit of $1,000, while service station owners who install equipment at

[21] Taylor, Dean. "The Differences and Similarities between Plug-In Hybrid EVs and Battery EVs," EVS24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium, Norway, May 13-16, 2009.
[22] http://cta.ornl.gov/TRBenergy/trb_documents/2010/Santini%20Session%20538.pdf. *Accessed May 2011.*
[23] http://www.calapa.org/attachments/files/1305/The_Longest_Mile.pdf. *Accessed May 2011.*
[24] http://www.socalev.org/plugin/charging.htm. *Accessed May 2011.*
[25] http://www.afdc.energy.gov/afdc/laws/law/US/351. *Accessed May 2011.*

multiple sites are allowed to use the credit at each location. Electricity qualifies as an alternative fuel. The credit expires December 31, 2011.

The U.S. Department of Energy (DOE) has established two EV charging station incentive programs through Coulomb Technologies and ECOtality. The programs offer charging stations "at no cost to individuals or entities," provided they are publicly accessible and located in "high use" areas. Individuals can qualify for free residential charging stations if they own an electric vehicle, but they must pay for installation costs in most instances. Coulomb's project, ChargePoint America, and ECOtality's project, the EV Project, operate in overlapping, and in some cases, separate geographic markets.[26] Both ChargePoint America and the EV Project are operational in Los Angeles.

As of Spring 2011, the State of California and regional governments in the Los Angeles metropolitan area do not have any incentive programs for charging station installations, and the only incentive program complementing federal efforts is the City of Los Angeles' rebate program. The program covers up to $2,000 in costs for purchasing and installing a charging station.[27] Applicants are required to purchase or lease an EV, purchase a Level 2 charger, and install a time-of-use meter at their home. The rebate makes clear that this offer applies to EV drivers in single family and multifamily residences. The program expires June 30, 2013.

3.3 Alternatives to Charging Stations

Battery swapping is an alternative to conductive and inductive charging, and is currently being championed by Better Place. Better Place's battery swap program is being introduced in several countries and cities, most notably in Israel, where a country-wide system of battery swapping stations has been installed, and will be ready to launch in late 2011.[28] For its Israeli launch, Better Place has partnered with Nissan-Renault to produce the Fluence Z.E., a sedan compatible with the battery swapping station, in addition to Level 1, 2, and DC Fast Charging stations.[29]

[26] http://www.afdc.energy.gov/afdc/laws/law/CA/8631; http://www.afdc.energy.gov/afdc/laws/law/CA/8621; http://www.chargepointamerica.com/; http://www.theevproject.com/index.php; Accessed May 2011.
[27] http://www.ladwp.com/ladwp/cms/ladwp002056.jsp; Accessed June 2011.
[28] http://www.betterplace.com/the-company-pressroom-pressreleases-detail/index/id/Better%20Place%20introduces%20the%20first%20mass%20market. Accessed June 2011.
[29] http://www.renault.com/en/vehicules/renault/pages/fluence-ze.aspx. Accessed June 2011.

Figure 8. Better Place Battery Swap Station

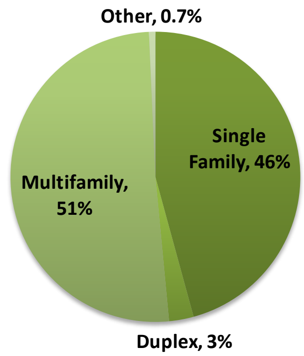
Source: http://www.fastcompany.com/1698338/better-place-bringing-switchable-battery-electric-taxi-program-to-the-bay-area

4. EV Charging Stations and Multifamily Residential Buildings

Approximately half of Los Angeles' residents live in a multifamily dwelling, which could pose significant barriers to widespread EV adoption. Estimates for 2009 show that approximately 51 percent of Los Angeles' housing stock was composed of multifamily residences, 46 percent was single family residences, three percent was duplexes, and less than 1 percent was RV's, motor homes, and other forms of shelter.[30] Installing charging stations in single family residences is rarely a problem because the parking space is private. Owners of the parking space have exclusive rights to park there, and can prevent others from using the space. This facilitates making changes to the parking space, such as adding charging stations, since no other users will be affected by its installation. Additionally, most parking spaces for single family homes are driveways that are at-grade, or slightly below ground level, which makes supplying the garage or driveway with the necessary electrical upgrades fairly simple and relatively inexpensive.

[30] U.S .Census American Community Survey, 2009.

Figure 9. City of Los Angeles Housing Stock, 2009 (U.S. Census Tracts)



Source: U.S. Census American Community Survey, 2009.

Parking in multifamily dwellings is legally and physically more complex, complicating charging station installations, and thus presenting a potential barrier to EV adoption. Unlike most single family homes where an exclusive private parking space is required, this is rarely the case in Los Angeles, where old buildings without any private parking availability mix with new luxury high rise apartments with several levels of underground parking. Accompanying the parking supply issue, are the legal and regulatory hurdles, and sometimes high costs, associated with installing charging stations and the related electrical infrastructure.

Section 4.1 documents the physical infrastructure challenges of installing charging stations as it applies to parking supply and electrical infrastructure. Sections 4.2 and 4.3 place existing buildings and new construction under the microscope for a fine grain look at the enabling and constraining factors involved with charging station installations, with both sections delving into the details of specific case studies.

4.1 Infrastructure

Parking supply and electrical capacity are the primary non-financial factors affecting whether or not charging stations can be installed from an infrastructure perspective. Los Angeles' housing stock may not be as old as many European or U.S. East Coast cities, but a significant portion of the housing stock dates from periods when personal-use light-duty vehicles were not as widespread as they are today, and thus developers didn't build parking in multifamily dwellings. However, as adoption of light-duty vehicles increased, city building and zoning codes changed to accommodate this growth and incorporated parking spaces into its building requirements. Similarly, electricity requirements have changed substantially over the years, moving from periods where household electricity consumption was minimal, to a period when nearly all household appliances are powered by electricity. Therefore, both parking supply and electrical capacity will vary greatly from building to building.

The analysis would be remiss without a discussion about infrastructure costs, and a simple financial model provides some insight in section 4.1.3.

4.1.1 Parking

City of Los Angeles parking requirements have changed substantially over the years, resulting in a great disparity between buildings' parking supply. Whittemore (2010) has documented the changes in the city's parking requirements from the 1930s to the present (Table 3). What can be gleaned from the table is an increasing intensity of parking as a residential development requirement, starting with at least 1 space per unit for buildings over 20 units in the 1930s, to a more refined range of 1 to 2 spaces depending on the number of rooms in the unit, which dates from 1965 and is still implemented today.

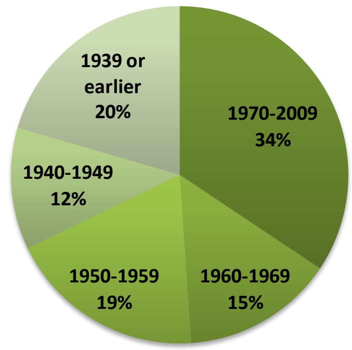
Table 3. History of Los Angeles Residential Parking Requirements

Year	Regulation
1930s	At least 1 space per unit for buildings over 20 units
1934	1 garage space for all units in any multifamily building on the same lot
1948	R3 zone, 1 space per unit
1948	R4 zone, 4 spaces for every 5 units
1948	R5 zone, 2 spaces for every 3 units
1958	1:1 parking:unit ratio, citywide
1958	1.25:1 ratio on lots where more than 6 units exceeded 3 rooms
1965	1 space per unit of one or two habitable rooms
1965	1.5 spaces per any unit of 3 habitable rooms
1965	2 spaces for any unit over three rooms
1970	Kitchen as a habitable room to be factored into parking requirements

Source:Whittemore, 2010

Making a conjecture about the parking supply for a given unit of analysis based on the table above, and combining the age of Los Angeles' housing stock in 2009, could provide some indication about parking supply. Figure 10 displays the age of Los Angeles' housing stock by dividing it into five categories.

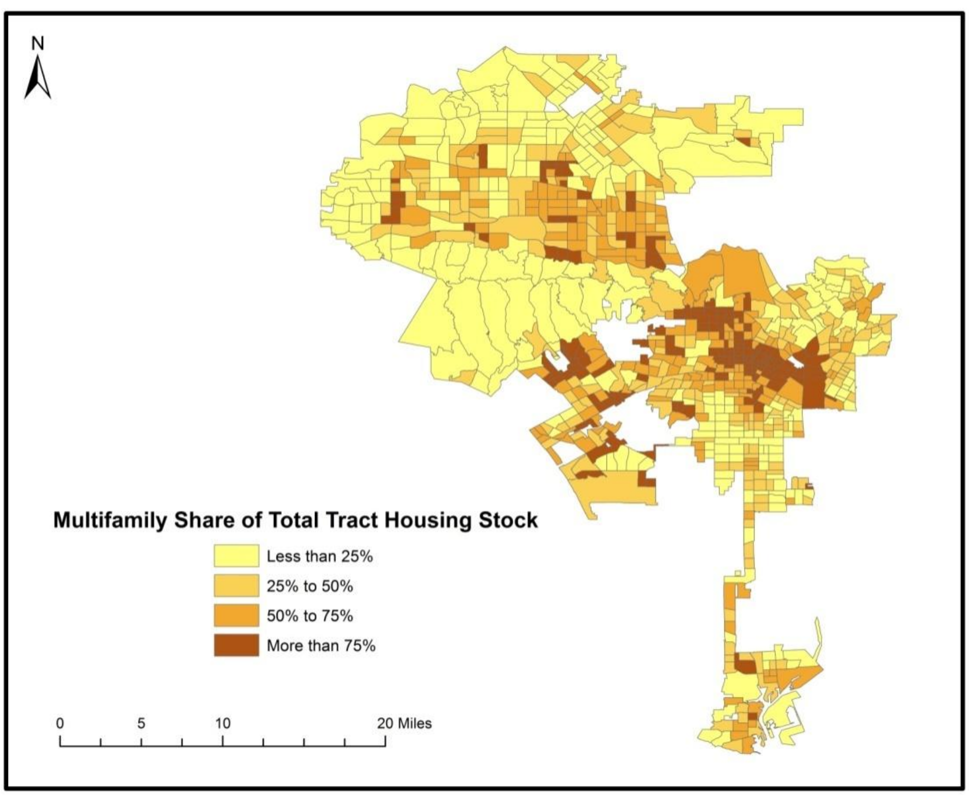
Figure 10. Age of Los Angeles Housing Stock through 2009 (U.S. Census Tracts)



Source: U.S. Census American Community Survey, 2009.

The five periods were selected to correspond with changes made to Los Angeles' parking requirements. For example, 34 percent of Los Angeles' housing supply was built since 1970, indicating compliance with the parking regulations put in place since 1965 and 1970. Since multifamily residential is the focus of this report, Figure 11 displays concentrations of multifamily housing by U.S. Census Tract for 2009.

Figure 11. Concentrations of Multifamily Residential Buildings by U.S. Census Tract, City of Los Angeles



Source: U.S. Census American Community Survey, 2009.

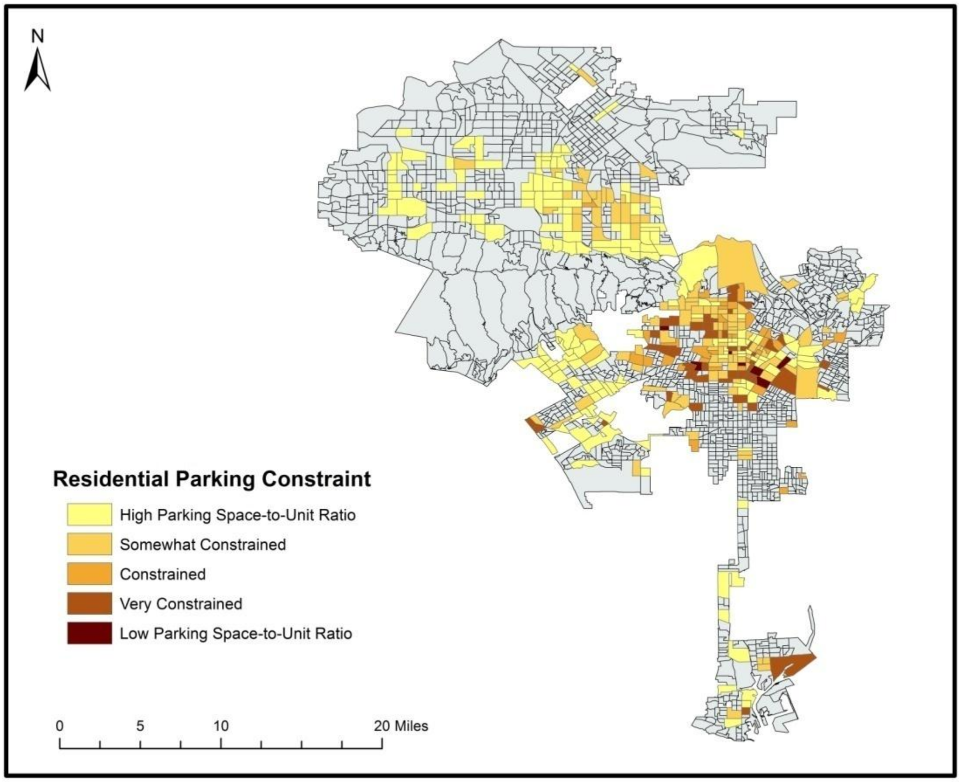
The census tracts were divided into four categories, displaying concentrations of multifamily housing per census tract: less than 25 percent, 25 percent to 50 percent, 50 percent to 75 percent, and above 75 percent. These data were then combined with the housing age data into an index that could predict which census tracts might have a shortage of parking. Only census tracts with 50 percent multifamily housing located within them were selected for the index. The index number for each Census tract is the ratio of the percentage of buildings constructed during periods when parking requirements were less than the number of residential units in the structure, to the percentage of buildings constructed during periods when parking requirements exceeded, or were equal to, the number of residential units in the structure (Equation 1).

Equation 1. Multifamily Parking Shortage Index Number

$$Index\ Number = \frac{(Percent\ built\ 1950\ to\ 1959) + (Percent\ built\ 1939\ or\ earlier)}{(Percent\ built\ 1960\ to\ 2009) + (Percent\ built\ 1940\ to\ 1949)}$$

Due to the limitations of U.S. Census data, the periods of low parking requirements (the numerator in Equation 1) are an approximation of the actual periods as documented by Whittemore (2010) (see Table 3). The period 1950 to 1959 is meant to capture multifamily buildings constructed between 1948 and 1957, and the period capturing all buildings built through 1939 is meant to represent structures built prior to 1934. The resulting map identifies potential Census tracts where parking may be undersupplied, relative to the official regulations (Figure 12).

Figure 12. City of Los Angeles Multifamily Parking Constraint Index



Sources: Whittemore, 2010; U.S. Census American Community Survey, 2009.

The index results suggest potential parking undersupply in the Census tracts surrounding downtown Los Angeles, Hollywood, parts of the Westside, and the eastern portions of the San Fernando Valley. The darker census tracts will typically have an older housing stock and a higher percentage of multifamily buildings as a percentage of the total housing supply within that Census tract. A high percentage of older multifamily buildings indicates limited private parking, and most parking is probably curbside or in off-street lots in those areas.

However useful the index may be in identifying potential multifamily parking undersupply, there are many caveats associated with the analysis. The Census tract is too aggregated to be a useful unit of analysis for making investment or policy decisions, but it does serve as an indicator of potential parking complications. Secondly, a large assumption is made regarding the age and number of parking spaces in multifamily buildings. Since the parking regulations are *minimum* regulations, it could very well be the case that developers provided more parking than was required. Additionally, it is possible that multifamily buildings are the newest housing in a given census tract, and that the oldest structures are single family homes, thereby skewing the results toward the older homes, and thus invalidating the results. A thorough analysis would require compiling parcel data for each building, indicating the building's age, number of parking spaces, and the number of units. Lastly, the analysis assumed every unit would require a parking space, and that fewer parking spaces per unit, as compared to the city's parking regulations, would indicate a shortage. In reality, not everyone in Los Angeles owns a car and requires a parking space. It is possible that a building where only half of the residents own a vehicle, can find adequate curbside parking, and don't have a parking shortage at all.

Parking access is as much a problem as is parking supply when considering charging station installations. Bundled and unbundled parking spaces can affect parking access, depending on whether the unit is a condo (i.e. the unit is for sale or owned) or a rental unit. A bundled parking space is included in the rent or sale price of the unit, and an unbundled space is not, and is paid for separately. Unbundled parking spaces can be assigned on a first-come first-serve basis, or they can be unassigned. In condos, bundled spaces can be deeded to the unit, meaning they are bought and sold along with it. Additionally, the configuration of the parking spaces can affect access. Single, side-by-side, parking spaces offer unobstructed access, but are sometimes an inefficient use of space. Tandem parking spaces, where two cars park, one in front of the other, makes more efficient use of space, but one car will always be obstructed.

Parking access considerations are a crucial determinant of charging station installation costs. Installations are cheaper for parking spaces located a short distance from the electrical panel, and more expensive for parking spaces located farther away. Section 4.1.2 discusses the relationship between parking and electrical upgrades in further detail.

4.1.2 Electrical

Multifamily dwellings face electricity infrastructure challenges when installing charging stations. As most building owners, electricians, and charging station installers will agree, every building is unique and over-arching statements about electrical upgrades are difficult to make. Nevertheless, this report attempts to shed as much light as possible on the main electrical issues.

Supplying Power to the Building

Most transformers that convert electricity from high voltage for transmission to low voltage for residential use, have been upgraded over the years, thus rendering it difficult to make any meaningful inferences about building age and transformer capacity. The introduction of new technology has often been followed by increases in transformer capacity, such as the introduction of air conditioning, and washers and dryers – appliances that consume large amounts of electricity. Large scale adoption of EVs will inevitably require increases in transformer capacity. The most recent city-wide transformer upgrade effort for the City of Los Angeles occurred in the early 2000s.[31]

Transformers supplying multifamily buildings typically have 10% to 15% excess capacity, or overhead, which is enough to sustain a few electric vehicles, but is insufficient to sustain a full conversion of the vehicle fleet to electric power.[32] Transformer size is dictated by the amount of energy required to sustain the building's population with 10% to 15% overhead. For example, in the case of a 450-unit condo called The Azzura (see Section 4.2.3.1 for a case study), the transformer

[31] Interview with Peter Suterko, LADWP, March 2011.
[32] Interview with Peter Suterko, LADWP, March 2011.

supplying the building was at 75% utilization, which allowed for the potential installation of ten Level 2 charging stations (which is determined by assessing the number of EVs that could charge during peak periods), according to a LADWP assessment. Additional EV charging stations would require the installation of a new transformer, but 50% utilization of the new transformer would need to be demonstrated in order to justify its installation.[33] New transformer installations are not a major ordeal from the utility's perspective, and all additional infrastructure costs for supplying power up to the building are absorbed by the LADWP.[34]

Supplying Power to Charging Stations within the Building

Once enough power is being delivered to the building to sustain EV charging stations, the next problem is how to transport that electricity to the EV that needs it. The most common problems associated with this are a lack of electrical panel capacity, small electrical rooms, and the location of the EV parking space.

It isn't uncommon for a building's electrical panel to be fully utilized and not have any room to add new circuits. This problem can be overcome by adding panel capacity, which requires a permit from the Los Angeles Department of Building & Safety (LADBS). Adding more than 400 Amps will trigger a plan review, meaning the applicant will incur higher costs. Each new circuit requires a permit from LADBS at a cost of $100 per circuit.[35]

Adding electrical panel capacity may seem like an easy fix, but electrical room space can be a limiting factor. In apartment buildings, panels are usually located in electrical rooms, which are also where electricity meters can be located, although most are usually located on a building's exterior. Adding another panel could be an issue for some buildings that have small electrical rooms. Additionally, if the building decides to meter a circuit separately (i.e. sub-metering), then a new meter would have to be provided by the LADWP. One could imagine the space limitations of the electrical room when 10, 20 or 30 charging stations are installed, resulting in a corresponding number of electricity meters, essentially placing a limit on the number of charging stations that can be installed.

Running a line from the circuit in the electrical panel to the charging station can be the most difficult step in assuring power delivery to an EV. If the EV parking space, and therefore the charging station, is located close to the electrical panel, costs of running a line should be fairly low. The crux of the problem is whether or not there is an existing conduit from the panel to the parking space. Even if the parking space is three levels below ground, and the electrical panel is located at ground-level, there shouldn't be a problem running a line if a conduit exists. However, if a conduit does not exist, the farther away the charger is from the panel, the more creative, and the more expensive, the solutions become.

Building Code Changes (Green Building Code)

The City of Los Angeles Green Building Code (Chapter IX, Article 9, of the Los Angeles Municipal Code), adopted on December 14, 2010, mandates newly constructed "low-rise" (single family

[33] Interviews with Azzura HOA Board Member, Chuck Fredericks, March 2010.
[34] Interview with Peter Suterko, LADWP, March 2011.
[35] Ladbs.org/permits/feeschedule/electrical permits

residences, duplexes, and townhouses) and "high-rise" residential buildings to be charging station-ready.[36] For low-rise buildings with private parking, either a 208/240 Volt 40 Amp outlet must be installed for each unit, or panel capacity and conduits for future installation of a 208/240 Volt 40 Amp outlet. All outlets must be located "adjacent to the parking area." For low-rise buildings with common parking, the following options are available:

- A minimum number of 208/240 Volt 40 Amp outlets, equal to 5 percent of the total number of parking spaces, to be located within the parking area; or
- Panel capacity for the future installation of 208/240 Volt 40 Amp outlets, equal to a minimum of 5 percent of the total number of parking spaces, with a conduit terminating in the parking area; or
- Additional service capacity, space for future meters, and conduit for future installation of electrical outlets, equal to 5 percent of the total number of parking spaces, with the conduits terminating in the parking area.

High-rise buildings are required to provide 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. The Code also mandates high-rise buildings to provide designated parking for "low-emitting, fuel-efficient, and carpool/van pool vehicles according to a fixed schedule.[37]

The Green Building Code's EV-ready specifications only apply to new construction, and not to building remodels. Peter Suterko, Fleet Services Manager at the LADWP, is developing a proposal to mandate that remodels require a certain percentage of electricity to be set aside for electric transportation, but this is yet to be formalized.[38]

4.1.3 Costs

EV owners living in multifamily dwellings need to overcome a number of hurdles in order to ensure the availability of EV charging in their building's parking spaces. From the tenant's perspective, owning a charging station, even if obtained at subsidized rates through government incentives, doesn't resolve the fact that a new circuit needs to be added to the panel, a new meter installed, and a line run to the charging station. Problems stem from two sources: capital infrastructure costs, and operations and maintenance (O&M) costs.

How much capital infrastructure costs are, and who pays for them, drives the argument in both rental units and condos. Unless the entire building's management is in agreement, the question of who should bear the capital costs of installing charging stations is a contentious issue. Common cost items include the following:

- Level 2 Charging Station
- Permits
- Electrician Assessment

[36] See Appendix 7.1
[37] See Appendix 7.1
[38] Interview with Peter Suterko, LADWP, March 2011.

- Electrical Panel Upgrade
- Electricity Meter
- Installation

Having the user pay for these capital costs seems like an equitable solution, but what if the user is a renter? What if the installation costs are so high that it would be unreasonable for a single EV owner to pay for them? If the EV parking space in question is not located near an electrical panel, then the costs can be very high, depending on the vertical and horizontal distance (and the building materials, or lack thereof, that lie in between). For example, a building that has sufficient panel capacity, and a conduit running from the panel to the EV parking space, will likely only incur charging station, permit, and electrician installation/assessment costs, possibly totaling $5,000. On the other hand, a building without excess panel capacity, no conduit, and a parking space located very far from the electrical panel, will likely incur very high costs, possibly several times the amount of the previous example. In one instance, total costs for installing a charging station in a remote parking space in a Los Angeles apartment building were assessed to be $35,000.[39]

The O&M costs vary depending on how the charging station is managed. O&M cost components are usually only the electricity costs for charging the EV, but other costs, such as a cost for processing bills for multiple users, may exist if the charging station is utilized by more than one user. Charging stations require little maintenance and they are covered by a warranty should they malfunction. Generally, there are two different electricity rate structures: (1) flat rate; and (2) time-of-use (TOU) rate. The flat rate charges a single rate per the amount of electricity consumed. The TOU rate varies with the time of day and the time of year, and the price is directly related to the demand for electricity throughout the day during that time of year. TOU rates are highest during peak periods in the summer (June to September for the LADWP), and lowest during off-peak periods in the fall, winter, and spring (October to May for the LADWP). No matter the season, peak electricity demand usually extends from mid-morning to late afternoon, and off-peak periods are in the evenings, nights and weekends. The LADWP offers the following rates:[40,41]

Table 4. LADWP Standard Residential Electricity Rates (Dollars per kWh)

Zone 1[1]	**Tier 1 <350**	**350<Tier 2<1050**	**Tier 3>1050**
Zone 2	**Tier 1 <500**	**500<Tier 2<1500**	**Tier 3>1500**
June-Sept	$0.132	$0.147	$0.181
Oct-May	$0.132	$0.132	$0.132

[1] *Zone 2 is the San Fernando Valley, and Zone 1 is all other areas.*

Source: Los Angeles Department of Water and Power

[39] Interview with Peter Suterko, LADWP, March 2011.

[40] http://www.ladwpnews.com/external/content/document/1475/952931/1/EV%20Incentive%20and%20Rates%20Final.pdf

[41] The LADWP currently offers an off-peak TOU discount of 2.5 cents per kWh, which equates to a discount ranging from 11 percent to 24 percent of the TOU rate, and it is not shown in the TOU rate schedules.

Table 5. LADWP Time-of-Use (TOU) Rates (Dollars per kWh)

<table>
<tr><th rowspan="2">Time</th><th colspan="12">AM</th><th colspan="12">PM</th></tr>
<tr><th>Midnight</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th></tr>
<tr><td>June-Sept</td><td colspan="10">$0.108</td><td colspan="3">$0.143</td><td colspan="4">$0.222</td><td colspan="3">$0.143</td><td colspan="4">$0.11</td></tr>
<tr><td>Oct-May</td><td colspan="24">$0.127</td></tr>
</table>

Source: Los Angeles Department of Water and Power

These rates may, or may not, be available for the charging stations depending on how electricity is managed in the building. More often than not, electricity provided in parking garages and other common areas is not billed to individual users, and is instead billed to residents through HOA fees (the periodic fees paid for by residents of HOA-managed buildings) or rent. Common areas are typically not subscribed to TOU rates, meaning the price of electricity consumed for EV charging could be high or low, depending on when the EV was charged (e.g. if the TOU rate is less than the flat rate, then the EV owner is needlessly spending more money than necessary).

It is important to consider how capital and O&M costs affect the investor and the end-user of the charging station. Investors in charging station infrastructure seek to recover their investment within a reasonable amount of time. Users, on the other hand, want to access this infrastructure for as little cost as possible. Different investment and user-fee scenarios are analyzed below.

Financing EV Charging Stations

Most charging station installations in multifamily buildings will be financed by some entity representing the building's ownership. For example, an HOA would finance the purchase and installation of a charging station in a condo, and a building owner would finance it in an apartment building. In both cases, the investing entity will pass costs onto users, and some entities might want to earn a profit. EV charging station users can pay a fixed cost to service the loan and pay for taxes. Payment can be made on a monthly basis, similar to the payment cycle for rental apartments and HOA fees, or it can be made incrementally during each EV charging session, with a fee assessed on a time-basis (e.g. by the second, minute or hour the EV is charging). Most HOAs are tax-exempt entities and wouldn't normally seek to earn a profit, but an apartment building managed by a real estate investment trust (REIT) might want a profit. For purposes of estimating a monthly fixed cost paid for by charging station users, I assume the investing entity is tax-exempt, and is not profit-seeking.

Capital costs are presented under high and low cost scenarios, differing on the installation costs. A low cost installation is assumed to be $2,000, the amount typically quoted for installing a Level 2 charging station in the garage of a single family residence. A high cost installation is assumed to be $10,000, and is indicative of what it might cost to install new electrical panel capacity, a new electrical meter, and run a line through a new conduit to a parking space located several hundred feet from the electrical room. There is high variability in costs, and these numbers are only useful as a means of illustrating the two scenarios. The capital cost assumptions are as follows:

- EV Level 2 Charging Station price: $1,500
- Installation Costs:
  - Low Cost: $2,000
  - High Cost: $10,000
- LADBS permit for 1 new circuit and meter: $100
- LADWP Charging Station Rebate: up to $2,000

The financial incentive assumed is the $2,000 LADWP rebate for the charging station. As a tax-exempt entity, the investor does not qualify for the Federal Infrastructure Tax Credit.

O&M costs are assumed to be minimal, except for an $8 monthly fee assessed by the LADWP for TOU billing. Charging station maintenance costs are expected to be negligible, and complications with the unit should be covered by a service warranty.

The principal amounts are $3,600 for the low cost installation and $11,600 for the high cost installation, including the EV charging station price, LADBS permit, and the respective installation cost. The principal amounts are reduced by $2,000 if the LADWP Level 2 charging station rebate is included. It is possible that an investor will not seek external financing, but I assume a loan term and an annual interest rate. Monthly debt service payments are lower with a longer loan term, but for the purposes of estimating a monthly fixed cost, I assume a 7-year loan term. In addition to monthly debt service payments, the fixed cost includes the $8 monthly LADWP TOU fee. Figure 13 and Figure 14 show the break-even monthly fixed cost for the charging station installation for different interest rates. They also show the monthly fixed cost with and without the rebate for both high and low installation cost scenarios.

Figure 13. Monthly Fixed Cost for a Low Cost Installation ($3,600)

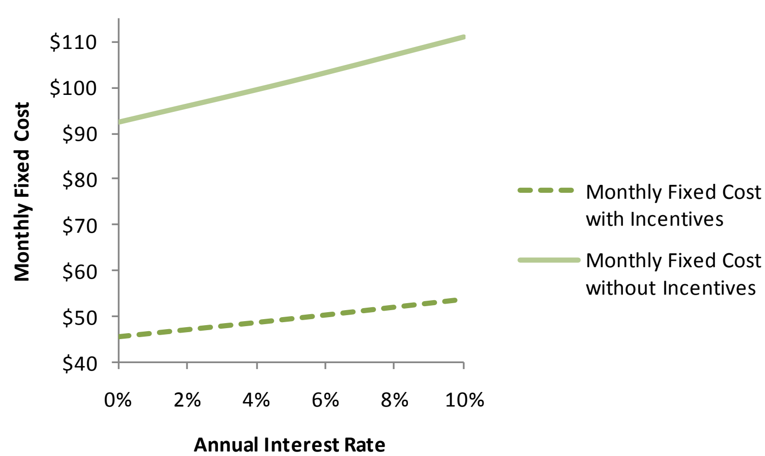
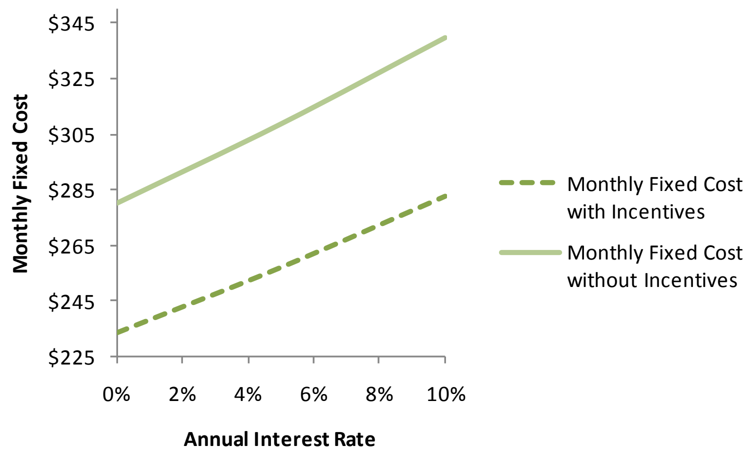


Figure 14. Monthly Fixed Cost for a High Cost Installation ($11,600)



Assuming the interest rate is based on what a financial institution, such as a bank, would presumably charge for a loan to finance the purchase and installation of a charging station, an 8 percent interest rate is a reasonable assumption. The Seven-Year U.S. Treasury Note had an interest rate around 2.5% in the first half of 2011 - the “risk-free” rate for a seven-year investment[42] - and I assume the bank would want to be compensated an additional five to six percent to account for the additional risk associated with EV charging stations.[43] An 8 percent interest rate is probably higher than what a bank would charge for an asset of similar risk, but taking into account EV market uncertainty, a conservative number is appropriate for this analysis. The monthly fixed cost with an 8 percent annual interest rate for the low cost installation is $52 with the rebate and $107 without it. Monthly fixed costs for the high installation cost are $272 and $327, with and without the rebate, respectively.

Financial incentives can significantly reduce capital costs, thereby making EV charging stations more affordable. Financial incentives reduced monthly fixed costs by 51 percent under the low capital cost scenario, and 23 percent under the high capital cost scenario. For a single charging station user, these monthly fixed costs could represent a doubling of their HOA fees, or a large addition to their monthly rent. If the costs are spread among more charging station users, or more tenants, then they can be further reduced. For example, if a 20-unit building spread the fixed cost under the high capital cost scenario among all tenants (EV charging station users and non-users), the cost would be $14 to $16 per month.

Bundling Fixed Costs with Electricity Costs

The monthly fixed cost does not include electricity consumption, which is a marginal cost. EV charging frequency is a function of the distance driven, electricity prices, driving style (e.g. city streets with many stops versus highway), load, and external conditions (e.g. wind resistance), in addition to the vehicle’s body and battery characteristics. Therefore, electricity costs can differ

[42] U.S. Treasury Notes and Bonds are considered “risk-free” because of the low probability of the U.S. government defaulting.
[43] http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/default.aspx

substantially. Daily and monthly electricity costs for a battery and vehicle similar to the Nissan Leaf (24 kWh) are shown in Table 6, and assume three-hour and seven-hour charging sessions during off-peak TOU periods with a Level 2 charger.

Table 6. Nightly and Monthly EV Charging Electricity Costs

Season	Rate ($/kWh)	Averarge Cost per Hour	Monthly Cost[1]	
			3-Hour Nightly Charge[2]	7-Hour Nightly Charge
June to September	$ 0.108	$ 0.37	$ 33.33	$ 77.76
October to May	$ 0.127	$ 0.44	$ 39.19	$ 91.44
June to September with Discount[3]	$ 0.083	$ 0.28	$ 25.61	$ 59.76
October to May with Discount[3]	$ 0.102	$ 0.35	$ 31.47	$ 73.44

[1] *One month is equivalent to 30 nights.*

[2] *The cost is equivalent to 3/7 of the 7-hour charge, and may not reflect the exact cost for a 3-hour charge.*

[3] *Current LADWP EV charging discount of $0.025 per kWh.*

Different cost scenarios are presented based on charging station utilization rates. Two charging station utilization rates are assumed: (1) seven-hour nightly EV charging (29 percent charging station utilization based on 24 hours); and (2) three-hour nightly EV charging (13 percent utilization). Seven hours is the time it takes to fully replenish a depleted Nissan Leaf battery with a Level 2 charging station, and three hours represents a scenario where the driver only needs a few hours to fully charge the battery. Assuming someone drove 30 to 40 miles per day, they could charge nightly (the three hour scenario), or bi-nightly (the seven hour scenario).

Instead of a monthly fixed cost, investors could charge users during an EV charging session on a time basis. For example, fixed costs could be paid during a charging session while the EV simultaneously draws-down electricity, and could be paid by the second, minute, hour, or any other fraction of time. The amount paid would depend on the EV charging station's utilization rate – the more drivers that use the charging station, the lower the fixed cost paid by each driver. This kind of payment method is useful for charging tenants, guests of tenants, and other EV owners who can access the charging station. I assume an hourly fixed cost based on a single EV charging for three or seven hours (similar to the previous examples). Table 7 shows hourly fixed costs, and Table 8, bundles the hourly fixed cost and average hourly electricity cost. The fixed cost assumes an 8 percent interest rate and a 7-year loan term.

Table 7. Hourly Fixed Costs

Capital Cost Scenario	Low Capital Costs		High Capital Costs	
Nightly Charging Station Utilization (hours)	**Three**	**Seven**	**Three**	**Seven**
Fixed Cost without Incentives ($/hour)	$1.19	$0.51	$3.64	$1.56
Fixed Cost with Incentives ($/hour)	$0.58	$0.25	$3.23	$1.30
Change in Fixed Cost ($/hour)	$0.61	$0.26	$0.40	$0.26
Percent Change in Fixed Cost:	51.5%		11.1%	

Table 8. Total Hourly Charging Cost (Fixed Cost + Average Electricity Cost)

		Fixed Cost + Average Electricity Cost ($/hour)			
		Low Capital Cost Scenario		**High Capital Cost Scenario**	
With Incentives	**Average Electricity Cost ($/hour)**	**Three Hours**	**Seven Hours**	**Three Hours**	**Seven Hours**
June to September	$0.37	$0.95	$0.62	$3.60	$1.67
October to May	$0.44	$1.01	$0.68	$3.67	$1.73
June to September with Discount[1]	$0.28	$0.86	$0.53	$3.52	$1.58
October to May with Discount[1]	$0.35	$0.93	$0.60	$3.58	$1.65
Without Incentives					
June to September	$0.37	$1.56	$0.88	$4.01	$1.93
October to May	$0.44	$1.62	$0.94	$4.07	$1.99
June to September with Discount[1]	$0.28	$1.47	$0.79	$3.92	$1.84
October to May with Discount[1]	$0.35	$1.54	$0.86	$3.99	$1.91

[1]*Current LADWP EV charging discount of $0.025 per kWh.*

With such a broad range of costs, one can see the importance of assuring high charging station utilization rates and keeping capital costs as low as possible. Financial incentives help decrease fixed costs, but they can be outweighed by high capital costs and low charging station utilization rates. It should be noted, though, that the majority of fixed costs will only need to be paid for a limited period of time (seven years in this example), or until the charging station needs to be replaced (replacement costs were not considered in this analysis). The simplified payment structure used herein is driven by charging station utilization rates and the type of financing obtained, and doesn't assume any profit. Certainly, more sophisticated payment structures could be developed, but this is beyond the report's scope. Lastly, billing for EV charging station use is possible using a stand-alone computer program, but in many cases the billing is outsourced to an external EV charging station management company. Coulomb Technologies is one such company offering direct billing to EV charging station users, and assesses additional fees for providing this service (see the boxed text on Coulomb's billing services).

Coulomb Technologies, Inc.

Coulomb's EV charging stations use radio frequency identification (RFID) to track charging station users in a voluntary program that bills users for electricity consumption and provides them with reports informing them of their greenhouse gas emissions and charging behavior. If charging station owners opt into this program, users will be charged a fee of $0.50 per session, plus a percentage of the price of the total amount of electricity consumed during that session. Additional fees, such as a fixed cost, can be assessed in this manner as well. Coulomb is not the only company that can provide this service, and many charging service providers are adding this functionality to their charging stations.

Source: Interview with Laura Page, Coulomb Technologies; www.coulombtech.com

4.2 Existing Buildings: Management, Tenancy Status and Costs

Existing multifamily buildings in Los Angeles will undoubtedly encounter difficulties related to the lack of parking, the difficulty of locating a parking space near a 220/240 Volt conduit or outlet, and electrical capacity issues. To complicate matters, building governance practices and tenancy (e.g. owning versus renting) pose an additional set of hurdles that must be overcome. The following section discusses management and tenancy issues, followed by a discussion of incentives to install charging stations or provide EV parking in existing buildings, and concludes by illustrating these issues in the context of three case studies.

4.2.1 Management & Tenancy

The governance status of the building and whether or not the tenant requesting the charging station lives in a condo or rental unit affects the process and the costs of installing a charging station. For simplification purposes, it is assumed that all condo owners are governed by an HOA, and rental apartments are managed by individuals or property management companies. Realistically, different governance structures exist, but most buildings should fall into one of the two aforementioned categories.

HOA's, which fall under the more general category of common interest developments (CIDs), are a type of building governance structure where the tenants own the units and have a percentage interest in the common areas.[44] A governing board is elected from among the HOA members, and the board drafts and implements the rules for the HOA. Common areas often include parking spaces, hallways, and lobbies, among others. Common area maintenance is paid for through HOA fees, which are usually paid on a monthly basis.

[44] Gordon, Tracy M., "Planned Developments in California: Private Communities and Public Life," Public Policy Institute of California, 2004.

Installing charging stations in an HOA-managed building could be difficult for many reasons. First, and foremost, the HOA may simply not allow tenants to charge an EV on the building premises. Discrimination on these grounds is legal, and poses an obstacle to EV adoption. Board resistance is a second potential obstacle. Board members may not understand what a charging station installation entails and are uncertain how to approach the issue. If installed in common areas, the charging station will likely draw on common area electricity, and without the appropriate metering technology, all the HOA members would be paying for the EV's consumption. Secondly, if a costly installation is required, the EV owner will likely be unwilling to bear 100 percent of the costs, and may approach the HOA board for financial support. The HOA might be able to formulate a plan creating a win-win situation for all parties, but getting to that stage in an expedient manner might prove difficult.

Renters and property managers in rental apartments are faced with similar installation constraints as condos, but are possibly more financially constrained. Because the condo unit is owned by someone, that person perceives the charging station installation as a property improvement from which they can benefit, or an improvement that will (hopefully) positively affect the resale value of their unit. In rental apartments, a property manager is less inclined to install charging stations unless current or prospective tenants are willing to pay for the installation costs – an unlikely scenario, even if all the tenants owned an EV, since the electrical upgrades are immobile (i.e. they remain with the building) and would therefore not follow the tenant to their next place of residence. Property managers are faced with the situation of either being a first-mover and installing charging stations with the hopes of differentiating themselves from competing apartments, or to wait until demand for EV charging reaches a critical threshold and makes economic sense to install them.

4.2.2 Incentives for Existing Buildings

Few incentives targeting EV charging in multifamily residential buildings exist, apart from federal and local financial incentives. For existing buildings, the U.S. Green Building Council's (USGBC) building certification program is arguably the single biggest non-monetary incentive for adding charging stations and preferential EV parking to existing buildings.

USGBC LEED Points for EVs

Although there aren't any mandates at the state or city levels for EV charging infrastructure in existing buildings, the U.S. Green Building Council awards points through its Leadership in Energy and Environmental Design (LEED) building certification program. The program certifies environmentally sustainable buildings as Platinum, Gold, Silver or Certified, based on a point system. Installing charging stations can earn points for multifamily buildings in the following categories (for current versions of LEED as of June 2011):[45]

- LEED Existing Buildings, Sustainable Site Credit 4.0: Alternative Commuting Transportation (3-15 points)
- LEED New Construction & Major Renovations, Sustainable Site Credit 4.3: Alternative Transportation: Low Emitting and Fuel Efficient Vehicles (1 point)

[45] www.usgbc.org/LEED/

Additional LEED points can be earned for providing preferential parking for EVs under the following category.

- LEED New Construction & Major Renovations, Sustainable Sites Credit 4.4: Alternative Transportation: Parking Capacity (1 point)

4.2.3 Case Studies

Three case studies attempt to bring to life many of the issues facing existing buildings in Southern California. The Azzura and 211 Spalding are examples of buildings with owner-occupied units. For renter occupied units, anecdotes from the Towbes Group, Inc. highlight the decision-making process behind deciding whether or not to install charging stations in existing buildings. The specific case of the Towbes Group's Ralston Apartments, a building that was designed with charging stations at the outset, is elaborated upon in the section describing new construction.

4.2.3.1 The Azzura

The Azzura is a 450 unit residential apartment in the Del Rey neighborhood of Los Angeles, and the building's HOA is considering installing charging stations. The owner of a Tesla Roadster had previously obtained permission from the HOA to install a 220 Volt outlet in his parking space, but this experience taught the HOA a valuable lesson: its members did not want to periodically record electricity meter readings to determine how much electricity the Tesla Roadster had consumed, and then manually bill the owner. Additionally, they discovered that the Tesla's charging requirements had nearly eliminated the excess panel capacity, thereby increasing the marginal cost of adding new EV chargers. Not long after the Tesla charger was installed, the tenant passed away, and the excess panel capacity was inadvertently restored. Thinking it had rid itself of this problem, the HOA did not have the prescience to anticipate the increasing interest in electric vehicles, and soon found itself confronted with a tenant who recently purchased a Chevrolet Volt, and another tenant with a Nissan Leaf on order.

Building Characteristics

The Azzura is a high-rise residential condo completed in 2003. Each unit is assigned two tandem parking spaces, resulting in 900 tenant spaces and 10 guest spaces. The parking garage is four levels: two above-ground and two below-ground, and there isn't any street parking. Electricity provided in the parking garage, which is designated a "common area", is paid for through HOA fees by all of the building's tenants. Each unit's electricity consumption is individually metered, with the meter located on the same floor as the unit. The LADWP delivers electricity to the building.

Case Study: The Azzura, Los Angeles, California

Building:

- 450 Condo Units
- Year built: 2003

Parking:

- 900 spaces (2 tandem spaces per unit)
- 10 guest spaces (0.01 per unit)
- 2 levels subterranean; 2 levels above-ground
- No street parking

Electrical:

- All original electrical work (2003)
- Constrained by transformer size
- HOA fees pay for common area electricity
- Individually metered units located on each floor

Management: Home-owners association (HOA)

EV Charging Stations

The owner of the Chevrolet Volt is on the HOA's board committee tasked with researching charging station installations, and his first step was to contact the LADWP. The LADWP assessed the building's electrical capacity and determined peak transformer capacity to be 75%, meaning approximately ten Level 2 charging stations could be installed (assuming all of them were in use during peak periods). Additional peak power could be provided, but it would necessitate the installation of a second transformer. To install a second transformer, the HOA would have to demonstrate a 50% utilization rate of the new transformer's capacity during peak periods, in addition to payments for fees and permits. The LADWP representative suggested the individual charging stations be connected to the tenants' respective electrical meter located on the same floor as their units, but this seemed highly impractical given the expensive electrical work required to run a wire to the 17^{th} floor from one of the subterranean parking spaces.

After the LADWP visit, an electrician was invited to provide a cost assessment of installing the 10 chargers, including the electrical work to add new circuits to the panel and run the wire to the parking space. Excluding the capital cost of the charging stations, the electrical work was estimated to be $20,000 for all ten chargers.

After obtaining the estimate for the electrical work, two EV charging station service providers were consulted to provide information about capital and O&M costs. Coulomb Technologies and AeroVironment, Inc. are two of the most popular service providers. AeroVironment is Nissan's preferred EV charging station service provider, and Coulomb's ChargePoint charging stations are being installed in select U.S. cities as part of the federally-backed ChargePoint America program. According to the HOA committee member, capital costs for the charging stations were similar, but he was displeased with the O&M costs. Both companies charge $0.50 per charging session, and assess an additional fee of 7 to 9 percent of the total cost of electricity consumed during the session, adding approximately $30 to each EV owner's monthly electricity bill, above the price of the electricity itself.

Building Management & Decision-Making Process

The opinion of the HOA board is EV charging station users should pay for the capital costs for charging station installations and O&M costs. Additionally, HOA members seek to exert the least amount of effort possible to accommodate tenants who own EVs. The cost for having the convenience of charging in one's place of residence can be expensive, and EV owners are willing to pay for that convenience up to a point – but exactly where that point is unclear. Spreading $20,000 in costs for electricity upgrades among two tenants is a significant burden, and costs could be greater if external financing is sought. Current tenants are not satisfied with paying a charging station management company $30 per month in addition to the capital and electricity costs they will directly incur. Lastly, the HOA board committee member is apprehensive about committing to a long-term contract and being "locked-in" the fixed fee structure offered by the charging station service providers

Parking spaces in the Azzura are deeded to the unit, meaning tenants can only use the spaces that have been assigned to them to park their vehicles. The deeding of parking spaces places limits on the building's flexibility to re-assign spaces since the parking spaces are legally bound to the unit's titles. This makes it difficult to guarantee the lowest possible installation costs. Various forms of parking space swaps have been considered, but none seriously pursued.

Lastly, thus far, residents have been unable to take advantage of financial incentives for charging stations since their installation is dependent upon the HOA's policy vis-à-vis EVs. An additional constraint is the type of incentive offered, which seems to target single family residential homes and commercial operations, leaving multifamily charging unaddressed.

4.2.3.2 211 Spalding

211 Spalding is the Beverly Hills address of an 84-unit apartment building completed in the mid-1970s. The building's HOA and manager have been considering upgrading the apartment complex to accommodate EVs since Fall 2009, but the high cost of electrical upgrades, coupled with the lack of adequate financial incentives and no immediate demand from residents for EV charging, has resulted in no action being taken by the HOA board. The board currently has one EV enthusiast, but he will likely be charging his EV elsewhere if residents' opinions on installing high-speed Internet cable for all units are a predictor of the difficulties that could lie ahead for installing charging stations; a survey found that only 50 percent of the building's residents have computers, with a smaller percentage actually using them, resulting in a majority "against" vote to install high-speed Internet connections in all units. Nevertheless, the building manager understands that high unit

turnover in the near future is likely given the elderly age of most of the building's tenants, and a charging station could be an attractive amenity to attract future prospective owners.

Building Characteristics

The building's parking is subterranean and street parking is unavailable, unless for temporary purposes, in which case a permit must be obtained from the City of Beverly Hills. The 2-level subterranean garage has 168 assigned spaces (2 per unit) and 39 guest spaces. Although the spaces are technically not deeded to the units – they are assigned – they are treated as if they were deeded to the unit's title. Furthermore, the HOA board decided that the parking spaces assigned to units cannot change. The parking spaces on the lower level are tandem. The single spaces on the upper level command a $50,000 premium per space.

Case Study: 211 Spalding, Beverly Hills, California

Building:

- 84 Units to own
- Year built: 1975

Parking:

- 168 spaces (2 per unit)
- 39 guest spaces (0.46 per unit)
- Subterranean (Level 1 is partially underground; Level 2 is fully underground)
- Assigned, but not deeded
- Street parking requires a temporary permit

Electrical:

- All original electrical work (1975)
- Constrained by small electrical room size for additional meters
- Level 2 charging requires major changes to building
- Individually metered units
- HOA fees pay for common area electricity

Management: Home-owners association (HOA)

EV Charging Stations

The primary constraints for installing a charging station at 211 Spalding are the distance from the garage to the electrical room, electrical room capacity, and the reluctance of residents to change parking spaces. The building manager estimates installation costs to be upwards of $6,000, but Southern California Edison, the electric utility servicing the building, has not yet comprehensively ascertained what all the required changes would be. The electrical room is not located near the garage, and running a line from the electrical panel to the garage will be costly (the manager assumes $6,000 to $7,000). Additionally, the electrical room is small, making it very difficult to install more than one new meter for monitoring charging station usage. Lastly, the cost savings between running a line to the parking space closest to the panel and to the parking space farthest from it, easily amounts to several thousand dollars. However, the parking space located close to the electrical room has the most convenient pedestrian access, and the owner of that space will be highly reluctant to relinquish it.

Building Management & Decision-Making Process

The building manager and HOA are considering installing charging stations, but will not act until costs decrease, or demand for EV charging increases. In addition to the capital cost decision, the HOA does not want to be bothered with billing tenants for charging station use, and wants to exert minimal effort for managing charging equipment. Currently, all electricity delivered to the parking garage is paid for by tenants through HOA fees, and ironically, some tenants were “free-riding” by having plugged in 12 industrial-sized freezers in the garage, resulting in $220 per month in electricity payments ($32 per unit per year). Once this was discovered, all outlets in the garage were shut-off, thus saving the entire building $2,640 per year – roughly the capital cost of one commercial charging station.

4.2.3.3 The Towbes Group, Inc.

The Towbes Group, based in Santa Barbara, develops and manages residential properties throughout Southern California, and has begun the process of installing charging stations in its existing residential buildings. With its long-term ownership of buildings, Towbes Group is interested in building improvements that add significant value to its properties, and it sees adding charging stations as an important amenity. Many of its residential buildings are located in Ventura County, and the company’s vice president described the county’s residents as being “green” and “environmentally conscious”, thereby substantiating the community’s high interest in electric vehicles.

However, Towbes is not willing to move beyond the “quick and easy” installations until it sees more demand for EV charging. Towbes made a corporate decision to install charging stations in new residential construction, but did not make the same commitment for its existing buildings because of their comparatively higher installation costs. A 200-unit rental apartment building in Goleta, California, was outfitted with two charging stations, but that was because installing them was easy and relatively inexpensive. The property’s two at-grade parking spaces were located adjacent to a heated swimming pool, and therefore had easy access to 220 Volts for installing Level 2 charging stations. Users pay for electricity use and fixed costs when charging, as well as fees associated with

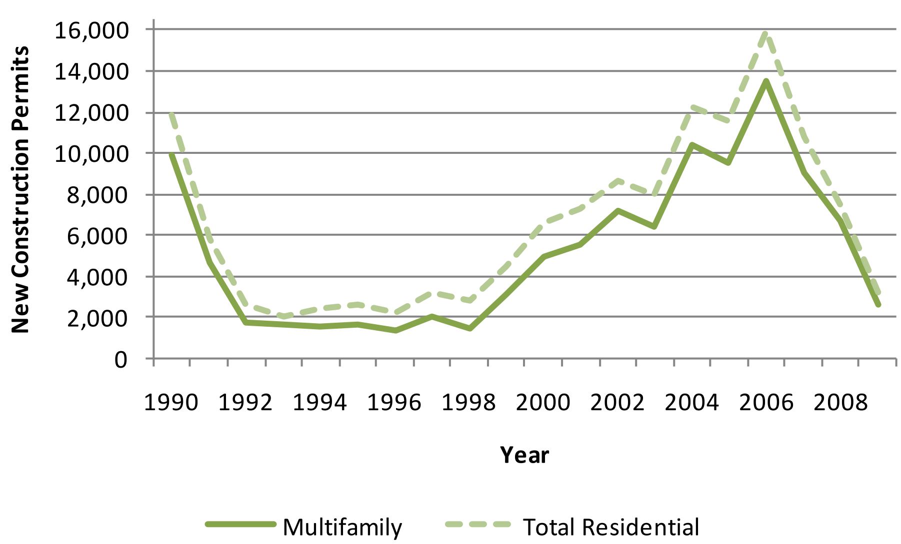
Coulomb's billing services. Additionally, Towbes Group has taken full advantage of the Federal Infrastructure Tax Credit to help pay for its charging stations.

4.3 New Construction

With the adoption of the Los Angeles Green Building Code in December 2010, all new residential structures, both single family and multifamily will have to be EV-ready. Time and money costs for installing EV infrastructure are expected to be minimal in new construction.

New residential construction in the City of Los Angeles will be one of the primary sources of EV-ready buildings due to the construction mandates in the city's Green Building Code. History may not be a perfect indicator, but the graph in Figure 15 displays construction permits for the city between 1990 and 2009. The drop in construction permits from 1990 to 1992 reflects the recession of the early 1990s, and the rapid growth in construction from roughly 1999 to 2007 is the "housing bubble" that burst around the end of 2007 and the beginning of 2008.

Figure 15. New Residential Construction Permits, City of Los Angeles 1990-2009



Source: Construction Industry Research Board

Average annual construction permits for multifamily housing between 1992 and 1998 were roughly 1,600 per year, and between 1999 and 2007 were approximately 9,500 per year. Without delving into the specific details of the real estate market during these periods, and without making any forecasts, if the post-recession period from 1992 to 1998 represents a stable construction rate, then one can infer that approximately 1,600 new EV-ready buildings per year will start construction under stable market conditions. Whether these buildings will have tenants that own or lease EVs will remain to be seen.

4.3.1 New Construction Incentives

Apart from the Los Angeles Green Building Code mandates, and federal and local financial incentives, the USGBC's LEED building certification program awards points for EVs and charging stations in new construction. Developers can earn points in the following categories (current versions of LEED as of June 2011):[46]

- LEED New Construction & Major Renovations, Sustainable Site Credit 4.3: Alternative Transportation: Low Emitting and Fuel Efficient Vehicles (1 point)
- LEED Core and Shell, Sustainable Site Credit 4.3: Low Emitting & Fuel Efficient Vehicles (1 point)
- LEED for Homes Multifamily Mid-Rise, Sustainable Site Credit 7.3: Parking Capacity/Low Emitting and Fuel Efficient Vehicles (1 point)

Additional LEED points can be earned for providing preferential parking for EVs under the following categories:

- LEED New Construction & Major Renovations, Sustainable Sites Credit 4.4: Alternative Transportation: Parking Capacity (1 point)
- LEED Core and Shell, Sustainable Sites Credit 4.4: Alternative Transportation: Parking Capacity (1 point)

4.3.2 Case Study: Ralston Courtyards

The Towbes Group, Inc. made a corporate decision to include at least 2 charging stations in every new residential development. The first of these developments to have installed charging stations is the 108 unit Ralston Courtyards in Ventura, California. According to Towbes Group's vice president, the company sensed "there was a coming" of electric vehicles based on news articles they had read, and felt that providing EV charging was going to be an essential amenity in the Oxnard and Ventura areas, especially due to the paucity of publicly available charging stations. Based on their market research, Towbes Group felt that providing EV charging would be a valuable amenity for the building's target demographic of 25 to 35-year old "echo boomers".

Building Design & Construction

Although local building codes did not mandate EV charging station installations, adding 2 charging stations at a cost of approximately $3,000 per unit was seen as minimal compared to the $18 Million to $20 Million development cost for Ralston Courtyards. The additional resources required to run extra conduit from the electrical panel to the location of the future charging stations was negligible, both in time and out-of-pocket costs.

As a rental property, the residential units do not have deeded parking spaces, but instead have assigned spaces. Each unit is allocated one car port (108 car ports), and the remaining 54 spaces are assigned on a first-come first-serve basis. The charging stations occupy two of the remaining 54

[46] www.usgbc.org/LEED/

spaces. All parking spaces are located at-grade, and the charging stations are in highly visible locations.

The charging stations contributed one point to the building's required minimum of 52 points for its USGBC LEED Silver certification. The contribution to LEED points was an afterthought since its contribution was minimal, and Towbes Group reasoned that it could have earned the point elsewhere. Towbes Group did take advantage of the Federal Infrastructure Tax Credit, but stated that they would have invested in charging stations without the federal discount.

<u>Case Study: Ralston Courtyards, Ventura, California</u>

Building: 108 rental units

Parking:

- 162 spaces (1.5 per unit)
- Parking spaces are not deeded – all units have 1 space; remaining 54 are on a "first come-first serve" basis

EV Charging Station:

- 2 Coulomb chargers installed
- Designed for 10 additional charging stations
- Located at-grade and near swimming pool electrical supply
- TOU Rates

Electrical: Parking spaces designed for Level 2 charging stations

Management: Home-owners association (HOA)

EV Charging Station O&M

The charging stations have been operational since November 2010, and nobody has used them. To encourage their use, and enhance the Ralston Courtyard's marketing, Towbes Group partnered with local Nissan Leaf and Chevrolet Volt dealerships and contacted current and prospective EV owners to notify them of the availability of EV charging at Ralston Courtyards. As of March 2011, this effort has yielded them one prospective tenant specifically looking for a residence where she could charge her EV.

Towbes Group wants the charging stations to pay for themselves and possibly become a future revenue source. To achieve this, Towbes Group partnered with Coulomb Technologies to develop the appropriate pricing structure. Towbes Group charges 10 percent of the total cost of electricity consumed during a charging session based on TOU rates. In addition, Coulomb charges $0.50 per session and a percentage of the session's total electricity cost. Towbes Groups' 10 percent fee was based on a charging station utilization rate of 100 hours per month.

5. Opportunities to Increase EV Charging Station Access

When considering whether or not to install charging stations, all parties need to consider how to increase charging station access given current constraints. As the case studies illustrated, each building faced a unique set of constraints, whether physical, management, or otherwise. Three possible approaches, among many, are discussed here to stimulate discussion around how to effectively provide EV charging for residents of multifamily dwellings.

5.1 Identifying "Fair" EV Parking Access Solutions

Property managers and building owners of rental apartments have the final say as to whether or not charging stations are installed, but installment decisions at condos are made by HOAs and individual EV owners. As illustrated by the case studies, HOAs can restrict installations, and they have the prerogative to do so, but they inadvertently slow EV adoption rates in multifamily buildings. HOAs should foster "fair" parking space access arrangements among residents.

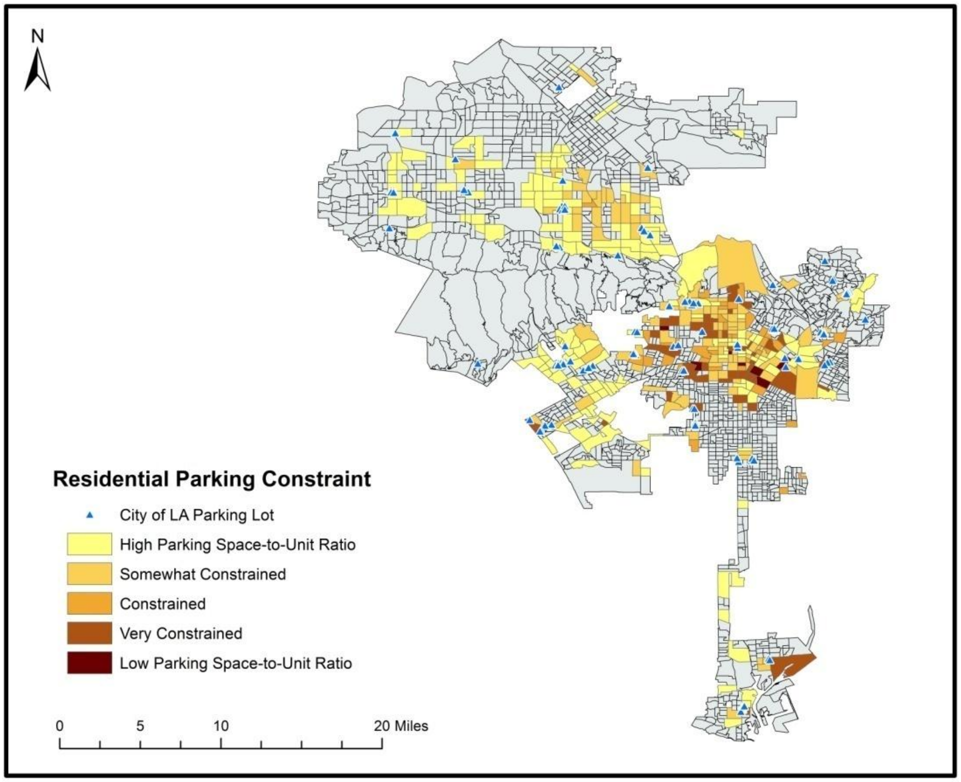
Electrical capacity issues aside, some of the highest costs associated with charging station installations can be avoided by relocating the EV parking space to a location closer to the electrical panel where the new circuit will be installed. As documented in the 211 Spalding case, parking spaces with the highest pedestrian accessibility are often the closest to the electrical room, and are also the most sought after. Should an EV owner own one these sought after parking spaces, then many problematic ownership issues are avoided, and the installation costs are minimized. However, should the EV owner not have access to a lowest possible cost parking space, then all avenues leading to an alternative low-cost option should be explored.

As representatives of a building's common spaces, and as forums for residents to voice private interests, HOAs should facilitate EV parking access solutions to the greatest extent possible. Parking spaces are negotiable and have a price – it is simply a matter of what concessions each party is willing to make, and what prices are deemed acceptable. The transaction could be between individuals, or between the HOA and individuals. For example, EV owners desiring a specific parking space might be willing to pay for it, or swap spaces with the owner of the parking space in question, if acquiring the space lowers the total cost of installing charging stations. If several EV owners are interested in sharing a single space, the HOA, or even a new third party entity, could purchase the space, and recover costs by charging EV charging station users. Opportunities to make "fair" transactions should be explored first in order to minimize EV charging station installation costs.

5.2 Utilizing Public Infrastructure

Apartment renters and owners who own EVs, but who do not have access to a parking space in the building, park curbside, or park in off-street lots, will have to think creatively about where to charge their vehicle. Allowing EV owners to use charging stations installed in public lots, or installed curbside, is one possible solution. The City of Los Angeles' 116 public parking lots could be utilized in the evenings, when most charging would occur, by local residents who own EVs. A map showing the locations of the city's public parking lots is overlaid onto a map displaying Census tracts that have a majority of multifamily buildings. The Census tracts are ranked according to an index indicating tracts with a low parking space to residential unit ratio, to tracts with a high parking space to unit ratio (Figure 16).

Figure 16. City of Los Angeles Parking Lots and Multifamily Parking Constraint Index



Source: Whittemore (2010); U.S. Census Bureau American Community Survey, 2009; City of Los Angeles Department of Transportation.

This proposal can also be applied to private parking lots, such as those belonging to schools, religious institutions, and businesses. The primary limitation to this proposal is the proximity of publicly-owned and privately-owned parking lots to multifamily buildings with a parking shortage, or prohibitively high EV charging installation costs.

The city may want to consider installing curbside infrastructure in cases with severe parking constraints, but there should be sufficient demand to justify installing curbside charging. What that critical number of EV owners will be is unclear for the moment. By providing charging stations in public or private lots, parking lot owners are not only contributing to improving local ambient air quality, but are also creating a new, and presumably reliable, revenue stream.

5.3 *Real Estate Transactions as an Opportunity*

If left to market forces alone – without any monetary or non-monetary incentives – the EV market might never really take-off among residents in multifamily buildings. Many EV owners living in condos could be perceived by HOA boards as anomalies to be resisted – especially in situations with high capital costs. HOAs faced with inexpensive installations will likely go forward with charging station installations because of the available financial incentives and ability to charge users for access. However, many HOA boards will not be receptive to creating a designated parking space close to the electrical room, or making any other kind of change to accommodate EVs that would appear to be unfair to other HOA members.

To incent building owners and HOA boards to consider the most affordable way to accommodate EV's in existing multifamily buildings, the City of Los Angeles could mandate the installation of charging stations when the building, or units in the building, are sold. Shoup (1996) proposes regulating land use when a property is sold as a "pragmatic, low cost method to improve older neighborhoods and stimulate local economic development."[47] Shoup's examples focus on private investments that create neighborhood public improvements. Private investment in charging stations would encourage EV adoption which has public benefits, such as reduced dependence on petroleum fuel sources and improved local air quality. Between 2002 and 2010, multifamily real estate transactions constituted an average of 22 percent of total residential real estate transactions, or roughly 3,000 annual sales (Figure 17).

Figure 17. Annual Residential Real Estate Transactions, Los Angeles, 2002-2010

Source: DataQuick News

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[47] Shoup, Donald. "Regulating Land Use at Sale: Public Improvement from Private Investment," Journal of the American Planning Association, Vol. 62, No. 3, Summer 1996.

Almost 3,000 charging stations could be installed in multifamily buildings annually throughout Los Angeles if EV installations were required in order to sell a property. Financial subsidies could be made available to help with the cost. If installing charging stations in a building was truly cost prohibitive, then it could be considered exempt from the regulation, but assuming the number of EV owners continues to increase, building owners will eventually want to install a charging station, even if costly, because it puts their building in the growing market for potential tenants with EVs.

6. Conclusion

Nearly half of Los Angeles' residents live in some sort of multifamily dwelling, with most residing in rental apartments or condos. Not all multifamily residents own vehicles, but if EVs are going to be adopted among apartment and condo dwellers, safe, convenient and reliable charging access needs to be guaranteed. This report is an attempt to shed light upon the difficult issues facing many key decision-makers, namely building owners, property managers, HOA boards, and prospective and current EV owners, when assessing whether or not to install EV charging stations, and to bring to life many of the related issues by presenting several case studies. Some possible solutions were proposed, but these, and many more, need to be studied in greater detail, assessing the costs, benefits, and political expediency of each. Unfortunately, there isn't a one size fits all solution to EV charging stations, making installation a difficult, and at times very costly, decision.

The primary barrier to EV charging installations is the cost of the installation and the ability to recover those costs. The opposition to installing charging stations from HOAs, and building managers and owners, is based on their unwillingness to pay for them. Depending on how capital costs are financed, and whether or not financial incentives are included, can affect the monthly fixed cost charged to users. High utilization rates can further reduce monthly fixed costs, but high installation costs (attributed to the building's electrical infrastructure or parking space location) can render improvements in utilization rates unimportant, since monthly fixed costs will only be slightly lowered.

Residents and building management must find creative ways to arrive at the lowest cost solution possible. Building management should facilitate parking space agreements and transactions among residents. Individuals can come to mutually agreed upon arrangements in order to secure a low-cost EV parking space. Additionally, building management could devise management tools uniquely tailored to residents' needs, in order to avoid costly installations. Internal negotiations should be the first step in any EV charging station investment.

For residents of multifamily buildings who must park on the street or in off-street parking lots, the barrier to EV access is less about cost, and more about ensuring reliable access to a an EV charging station. Residents in these situations, and owners and managers of buildings with limited on-site parking availability for residents, must look to low-cost alternatives. Utilizing public and private parking lots for night-time EV charging can address the charging needs of drivers who live within close proximity to a public or private lot. However, in cases where such lots are unavailable, installing curbside charging infrastructure could be an option. Publicly accessible charging stations present a revenue opportunity for both public and private parking lot owners, as well serving the needs of residents without access to private charging stations.

Taking into consideration the political support for EV's from the U.S. President and the Los Angeles Mayor, the City of Los Angeles could require the installation of charging stations in multifamily buildings whenever a property (either the building, or units within the building) is sold. [48,49] From 2002 to 2010, approximately 3,000 multifamily real estate transactions took place per year. This kind of policy would encourage HOA's, building managers, building owners and tenants to find low-cost EV charging solutions, and would guarantee the EV-readiness of Los Angeles' multifamily buildings.

The difficulties associated with installing EV charging stations in multifamily residences are not unique to Los Angeles, but are faced by almost every building owner, manager or tenant living in one the world's urban centers. As the world's population continues to grow and urbanize, adopting viable alternatives to petroleum-based transportation is central to ensuring motorized mobility in an increasingly natural resource-constrained world.[50] Electric vehicles offer one such alternative, and enabling their adoption in multifamily buildings increases their potential effectiveness by appealing to a broader user base.

[48] "One Million Electric Vehicles by 2015," U.S. Department of Energy, February 2011
[49] http://mayor.lacity.org/PressRoom/PressReleases/LACITYP_007622
[50] Sperling, Daniel, and Deborah Gordon. "Two Billion Cars," Oxford University Press, 2009.

7. Appendix

7.1 City of Los Angeles Green Building Code - EV Sections

ORDINANCE NO. 181480

An ordinance amending Chapter IX of the Los Angeles Municipal Code by adding a new Article 9 to incorporate various provisions of the 2010 California Green Building Standards Code (CALGreen Code).

THE PEOPLE OF THE CITY OF LOS ANGELES DO ORDAIN AS FOLLOWS:

Section 1. Chapter IX of the Los Angeles Municipal Code is amended by adding a new Article 9, Green Building Code, to read as follows:

ARTICLE 9, DIVISION 4

MANDATORY MEASURES FOR NEWLY CONSTRUCTED LOW-RISE RESIDENTIAL BUILDINGS

99.04.106.6. Electric Vehicle Supply Wiring.

1. For one- or two- family dwellings and townhouses, provide a minimum of:

   a. One 208/240 V 40 amp, grounded AC outlet, for each dwelling unit; or
   b. Panel capacity and conduit for the future installation of a 208/240 V 40 amp, grounded AC outlet, for each dwelling unit.

The electrical outlet or conduit termination shall be located adjacent to the parking area.

2. For other residential occupancies where there is a common parking area, provide one of the following:

   a. A minimum number of 208/240 V 40 amp, grounded AC outlets equal to 5 percent of the total number of parking spaces. The outlets shall be located within the parking area; or
   b. Panel capacity and conduit for future installation of electrical outlets. The panel capacity and conduit size shall be designed to accommodate the future installation, and allow the simultaneous charging, of a minimum number of 208/240 V 40 amp, grounded AC outlets, that is equal to 5 percent of the total number of parking spaces. The conduit shall terminate within the parking area; or
   c. Additional service capacity, space for future meters, and conduit for future installation of electrical outlets. The service capacity and conduit size shall be designed to accommodate the future installation, and allow the simultaneous charging, of a minimum number of 208/240 V 40 amp, grounded AC outlets, that is equal to 5 percent of the total number of parking spaces. The conduit shall terminate within the parking area.

When the application of the 5 percent results in a fractional space, round up to the next whole number.

ARTICLE 9, DIVISION 5

FOR NEWLY CONSTRUCTED NONRESIDENTIAL AND HIGH-RISE RESIDENTIAL BUILDINGS

99.05.106.5.2. Designated Parking. Provide designated parking, by means of permanent marking or a sign, for any combination of low-emitting, fuel- efficient, and carpool/van pool vehicles as follows:

Table 5.106.5.2

Total Number of Parking Spaces	Number of Required Spaces
0-9	0
10-25	1
26-50	3
51-75	6
76-100	8
101-150	11
151-200	16
201 and over	At least 8 percent of total [1]

[1] When the application of this regulation results in the requirement of a fractional space, round up to the next whole number.

99.05.106.5.3.1. Electric Vehicle Supply Wiring. Provide a minimum number of 208/240 V 40 amp, grounded AC outlet(s), that is equal to 5 percent of the total number of parking spaces, rounded up to the next whole number. The outlet(s) shall be located in the parking area.

I hereby certify that this ordinance was passed by the Council of the City of Los Angeles, at its meeting of DEC 14 2010.

JUNE LAGMAY, City Clerk

By ______________________
Deputy

Approved DEC 15 2010

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Mayor

7.2 Charging Station Cash Flow Models

Low Cost Installations with Incentives

Assumptions (Annual)			**Charging**	
EVSE unit price	$ 1,500	Capital	Daily Charging Hours	3
Installation cost	$ 2,000	Capital	Annual Charging Hours	1,095
LADWP Permit	$ 100	Capital	EVSE Utilization Rate Equivalent	13%
LADWP Rebate	$ (2,000)	Capital		
Infrastructure Tax Credit	0%	Capital	**Loan**	
			Principal	$ 1,600
LADWP TOU Admin Fee	$ (96)	O&M	Rate	8%
Discount Rate	0%		Term	7
Effective Tax Rate (Federal + CA State)	0%		Annual Payment	($307.32)
			Monthly Payment	($25.61)

Cost Recovery Payment	$ 0.58	per hour of charging

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cash Flow								
Fee		$ 632	$ 632	$ 632	$ 632	$ 632	$ 632	$ 632
(Finance Payments)		$ (307)	$ (307)	$ (307)	$ (307)	$ (307)	$ (307)	$ (307)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 229	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 228.57	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (1,600)	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229

NPV (Years 0-7)	$ 0

Assumptions (Annual)			**Charging**	
EVSE unit price	$ 1,500	Capital	Daily Charging Hours	7
Installation cost	$ 2,000	Capital	Annual Charging Hours	2,555
LADWP Permit	$ 100	Capital	EVSE Utilization Rate Equivalent	29%
LADWP Rebate	$ (2,000)	Capital		
Infrastructure Tax Credit	0%	Capital	**Loan**	
			Principal	$ 1,600
LADWP TOU Admin Fee	$ (96)	O&M	Rate	8%
Discount Rate	0%		Term	7
Effective Tax Rate (Federal + CA State)	0%		Annual Payment	($307.32)
			Monthly Payment	($25.61)

Cost Recovery Payment	$ 0.25	per hour of charging

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cash Flow								
Fee		$ 632	$ 632	$ 632	$ 632	$ 632	$ 632	$ 632
(Finance Payments)		$ (307)	$ (307)	$ (307)	$ (307)	$ (307)	$ (307)	$ (307)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 229	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 228.57	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (1,600)	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229	$ 229

NPV (Years 0-7)	$ 0

Low Cost Installation without Incentives

Assumptions (Annual)			Charging	
EVSE unit price	$ 1,500	Capital	Daily Charging Hours	3
Installation cost	$ 2,000	Capital	Annual Charging Hours	1,095
LADWP Permit	$ 100	Capital	EVSE Utilization Rate Equivalent	13%
LADWP Rebate	$ -	Capital		
Infrastructure Tax Credit	0%	Capital	**Loan**	
			Principal	$ 3,600
LADWP TOU Admin Fee	$ (96)	O&M	Rate	8%
Discount Rate	0%		Term	7
Effective Tax Rate (Federal + CA State)	0%		Annual Payment	($691.46)
			Monthly Payment	($57.62)

Cost Recovery Payment	$ 1.19	per hour of charging

Year	0	1	2	3	4	5	6	7
Cash Flow								
Fee		$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302
(Finance Payments)		$ (691)	$ (691)	$ (691)	$ (691)	$ (691)	$ (691)	$ (691)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (3,600)	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514

NPV (Years 0-7)	$ (0)

Assumptions (Annual)			Charging	
EVSE unit price	$ 1,500	Capital	Daily Charging Hours	7
Installation cost	$ 2,000	Capital	Annual Charging Hours	2,555
LADWP Permit	$ 100	Capital	EVSE Utilization Rate Equivalent	29%
LADWP Rebate		Capital		
Infrastructure Tax Credit	0%	Capital	**Loan**	
			Principal	$ 3,600
LADWP TOU Admin Fee	$ (96)	O&M	Rate	8%
Discount Rate/IRR	0%		Term	7
Effective Tax Rate (Federal + CA State)	0%		Annual Payment	($691.46)
			Monthly Payment	($57.62)

Cost Recovery Payment	$ 0.51	per hour of charging

Year	0	1	2	3	4	5	6	7
Cash Flow								
Fee		$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302	$ 1,302
(Finance Payments)		$ (691)	$ (691)	$ (691)	$ (691)	$ (691)	$ (691)	$ (691)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (3,600)	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514	$ 514

NPV (Years 0-7)	$ 0

High Cost Installation with Incentives

Assumptions (Annual)				***Charging***	
EVSE unit price	$	1,500	Capital	Daily Charging Hours	3
Installation cost	$	10,000	Capital	Annual Charging Hours	1,095
LADWP Permit	$	100	Capital	EVSE Utilization Rate Equivalent	13%
LADWP Rebate	$	(2,000)	Capital		
Infrastructure Tax Credit		-30%	Capital	**Loan**	
				Principal	$ 9,600
LADWP TOU Admin Fee	$	(96)	O&M	Rate	8%
Discount Rate		0%		Term	7
Effective Tax Rate (Federal + CA State)		0%		Annual Payment	($1,843.90)
				Monthly Payment	($153.66)

Cost Recovery Payment	$	3.23	per hour of charging

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cash Flow								
Fee		$ 3,540	$ 3,540	$ 3,540	$ 3,540	$ 3,540	$ 3,540	$ 3,540
(Finance Payments)		$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600
(Infrastructure Tax Credit)		$ (3,450)						
Taxable Income		$ -	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (9,600)	$ -	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600	$ 1,600

NPV (Years 0-7)	$	0

Assumptions (Annual)				***Charging***	
EVSE unit price	$	1,500	Capital	Daily Charging Hours	7
Installation cost	$	10,000	Capital	Annual Charging Hours	2,555
LADWP Permit	$	100	Capital	EVSE Utilization Rate Equivalent	29%
LADWP Rebate	$	(2,000)	Capital		
Infrastructure Tax Credit		0%	Capital	**Loan**	
				Principal	$ 9,600
LADWP TOU Admin Fee	$	(96)	O&M	Rate	8%
Discount Rate		0%		Term	7
Effective Tax Rate (Federal + CA State)		0%		Annual Payment	($1,843.90)
				Monthly Payment	($153.66)

Cost Recovery Payment	$	1.30	per hour of charging

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cash Flow								
Fee		$ 3,311	$ 3,311	$ 3,311	$ 3,311	$ 3,311	$ 3,311	$ 3,311
(Finance Payments)		$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)	$ (1,844)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 1,371.43	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (9,600)	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371	$ 1,371

NPV (Years 0-7)	$	(0)

High Cost Installation without Incentives

Assumptions (Annual)				Charging	
EVSE unit price	$	1,500	Capital	Daily Charging Hours	3
Installation cost	$	10,000	Capital	Annual Charging Hours	1,095
LADWP Permit	$	100	Capital	EVSE Utilization Rate Equivalent	13%
LADWP Rebate	$	-	Capital		
Infrastructure Tax Credit		0%	Capital	**Loan**	
				Principal	$ 11,600
LADWP TOU Admin Fee	$	(96)	O&M	Rate	8%
Discount Rate		0%		Term	7
Effective Tax Rate (Federal + CA State)		0%		Annual Payment	($2,228.04)
				Monthly Payment	($185.67)

Cost Recovery Payment	$	3.64	per hour of charging

Year	0	1	2	3	4	5	6	7
Cash Flow								
Fee		$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981
(Finance Payments)		$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (11,600)	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657

NPV (Years 0-7)	$	0

Assumptions (Annual)				Charging	
EVSE unit price	$	1,500	Capital	Daily Charging Hours	7
Installation cost	$	10,000	Capital	Annual Charging Hours	2,555
LADWP Permit	$	100	Capital	EVSE Utilization Rate Equivalent	29%
LADWP Rebate	$	-	Capital		
Infrastructure Tax Credit		0%	Capital	**Loan**	
				Principal	$ 11,600
LADWP TOU Admin Fee	$	(96)	O&M	Rate	8%
Discount Rate		0%		Term	7
Effective Tax Rate (Federal + CA State)		0%		Annual Payment	($2,228.04)
				Monthly Payment	($185.67)

Cost Recovery Payment	$	1.56	per hour of charging

Year	0	1	2	3	4	5	6	7
Cash Flow								
Cost Recovery Payment		$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981	$ 3,981
(Finance Payments)		$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)	$ (2,228)
(LADWP TOU Admin Fee)		$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)	$ (96)
Before Tax Cash Flow		$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657
(Infrastructure Tax Credit)		$ -						
Taxable Income		$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657
Tax Payable		$ -	$ -	$ -	$ -	$ -	$ -	$ -
After Tax Cash Flow	$ (11,600)	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657	$ 1,657

NPV (Years 0-7)	$	(0)

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